TILLERING, FORAGE PRODUCTION, AND GRAIN YIELD
OF WHEAT SODSEEDED INTO BERMUDAGRASS
AND ON CLEAN-TILLED LAND

By

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CHAPTER I

INTRODUCTION

Sodseeding of bermudagrass with small grains offers farmers and ranchers a method of substantially reducing the cash outlay for winter supplementation, and increasing cash sales from grain or livestock production by utilizing land which is normally idle during part of the year. Also, forage production offers one of the best opportunities for agricultural expansion in the United States.

It has been shown by researchers that grain production from wheat sodseeded into bermudagrass compares favorably to that obtained from clean tilled land (Elder and Tucker, 1968). However, it has been observed that forage production from small grains planted in bermudagrass sod is less than from clean-tilled land. If forage yield could be raised to acceptable levels, it would not only benefit farmers and ranchers by reducing winter feed costs, but also would allow them more flexibility in maintaining a profit situation. By having acceptable levels of both grain and forage production, the producer could harvest grain in years of high grain prices or graze out the wheat in years that cattle prices offer the greater profit potential. In addition to the flexibility provided by sodseeding, the producer reduces tillage costs, soil moisture losses, and erosion, and increases the time which the area is productive.

The objectives of these studies were to determine the relationships of certain cultural practices, specifically, nitrogen, paraquat, and spacing, upon tillering, forage production, and grain yield of Osage wheat (Triticum aestivum L. em Thell.) on sodseeded and clean-tilled situations.

CHAPTER II

LITERATURE REVIEW

Importance of Tillering in Grasses

The importance of tillering in the growth of herbage grasses was pointed out by Williams (1970) when he stated that the success of grasses as colonizers and competitors in ecological systems stems from their ability to produce tillers which can develop into new plants independently of the parent plant, thereby, preventing grasses from dying out under intensive management.

Mitchell (1970) pointed out that in grasses, the number of tillers, and growth per tiller determined productivity. He also noted that tiller production and leaf growth were closely related and provided forage crops the ability to survive multiple harvesting and grazing by regenerating a supply of tillers.

Jewiss (1972) named two important roles of tillers in the life cycle of grass plants. First, tillering of the young seedling aids establishment by insuring the production of sufficient leaf area for complete light interception as early as possible in the life of the crop. Second, tillering is essential for the regeneration of the plant following removal of the terminal meristem by cutting or grazing during inflorescence development. This was in agreement with Horrocks and Washko (1970) who stated that tiller formation was the means by which the stand was perpetuated and growth initiated after clipping or after the parent tillers of perennial grasses have reached maturity.

Description of Tillering

Jewiss (1972) attributes the success of the grass plant as a feed for grazing livestock to two features in its morphology and habit of growth. The first was the leaves that are generally produced from basal meristems during the vegetative state of growth, and the second was the mode of branching by basal shoots or tillers. These two factors give forage grasses their advantage over most dicotyledonous species.

Tillers were described by Gardner (1942) as branches that develop within the subtending leaf sheaths. He also noted that maximum tillering capacity is dependent upon the number of bud primordia, a structural characteristic which appears to be heriditary for the species, variety or strain. Gardner pointed out that the number of tillers within the maximum would vary under the influence of the environment.

Langer (1957) reported that the perennial habit of grasses depended directly on the inability of many tillers, particularly those which appear late in the season, to flower. This is in contrast to the cereals such as wheat, in which tillering is a less continuous process, because vegetative tillers play a minor part and normally fail to survive to the time of harvest. He noted, however, that close similarities can be made between cereal grains, annuals, and the tillers which flower in the year of their appearance of perennial and biennial grasses.

A concise description of tillering, or stooling as it is sometimes referred to, was reported by Langer (1963). He stated that grass seedlings emerge as a single shoot consisting of a short stem having at its nodes two leaves of opposite rank. Under suitable conditions, buds are formed in the axil of each leaf. It is from these buds that tillers grow which are similar in structure to the shoot from which they arise. Buds also form from the leaves of tillers forming what is referred to as primary, secondary, tertiary tillers and so on denoting successive orders. Following appearance of a tiller, it develops its own adventitious root system, but remains connected to its parent shoot. These adventitious roots can supply nutrients to the tiller as well as to the parent shoot through the vascular connection.

According to Langer (1963), three types of tillers can be determined on forage plants:

1. Tillers exhibiting an annual life cycle which flower and die in the year they appear.
2. Those showing a biennial life cycle which flower and die in the year following their appearance.
3. And tillers which fail to flower and vary in time of survival from a few weeks to a few years.

A forage plant's longevity is determined by the proportion of these types of tillers the plant possesses. For example, wheat is an annual and exhibits only the first type of tillers.

Factors Affecting Tillering of Grasses

Researchers have observed many factors that affect tillering in grasses. An effective summation of these factors was given by Mitchell (1970) who stated that anything which increased plant growth commonly increased tillering.

Early work by Gregory (1937) established that tiller formation was greatly influenced by mineral nutrition. He concluded that nutrient deficiencies reduced tiller numbers of barley in the order of nitrogen, phosphorus, and potassium respectively. Most early work focused on tillering and grain yield with varying results according to Gardner (1942). However, he pointed out that most researchers agreed that tillering was affected favorably by good soil fertility, adequate moisture, and a wide plant spacing.

The importance of good mineral nutrition on tillering of grasses has been established by several researchers. Whyte et al. (1962) noted that the productivity of a herbage plant was greatly influenced by mineral nutrition. Aspinall (1963), observed increased tillering with increased supply of mineral nutrients. These conclusions gave an indication that productivity and tillering may be closely related.

Aspinall (1961) demonstrated that rate and pattern of tillering was largely controlled by nutrient supply. In the initial phase of tillering, both the rate and number were influenced by the nutrient supply, and tillering ceased earlier where the nutrient supply was low. Langer (1963) stated that primary tillers were better able to compete for nutrients than secondary tillers. Aspinall (1961) attributed the death of developing tiller apices to a shortage of nutrients because no comparable tiller senescence took place when adequate nutrients were supplied.

Of the numerous studies conducted to determine the effect of mineral nutrition on tillering, most have dealt primarly with nitrogen. Whitehead (1970) stated that nitrogen affected herbage yield through its influence on various aspects of the morphology and physiology of the grass plant. One of these factors was tiller production.

Tillering was highly dependent on nitrogen supply, and a shortage caused reduced tillering with a drop in dry matter production (Mitchell, 1970). In order for grass crops to maintain the maximum rate of dry matter production, sufficient leaf area must be present at all times to trap light energy to synthesize the assimilates necessary for the formation of new leaf tissue. Ryle (1964) observed that rate of leaf appearance, number of live leaves, number of active elongating leaves, and leaf length, in addition to tillering, were increased by a high level of nitrogen. Ryle (1970) quantified this conclusion by reporting that high nitrogen caused a three to four-fold increase in total dry weight per unit area by doubling shoot number and increasing shoot weight by sixty percent. Although differing in the response of shoot numbers, Auda et al. (1966) were in agreement with this conclusion. They found that under favorable conditions of light and temperature, the application of nitrogen at the rate of 224 kg/ha increased tiller numbers at least threefold compared to no nitrogen treatment.

Anslow (1966) summarized the importance of nitrogen to tillering by pointing out that when nitrogen was deficient tiller formation would cease. He also found that level of nitrogen had no effect on the rate of leaf appearance. The relationship of tillering and leaf appearance to forage yield was explained by Langer (1959). He observed that leaf numbers per tiller vary within narrow limits, and, therefore, attributed the increase in leaves per plant to a greater number of tillers. There was no increase in the rate at which new leaves appeared on a tiller when the nitrogen rate was increased from 30 to 50 ppm, but an increase in leaf area was obtained from increased leaf size and more tillers per plant. He concluded that dry matter production was controlled largely by the amount of leaf surface area per plant. Langer is supported by work of Sampaio and Beaty (1976) who found that nitrogen rate had little effect on number of leaves per tiller produced, but the total number of leaves per unit area increased with nitrogen, due to the increased number of tillers.

Langer (1963) stated that one of the most important effects of nitrogen was on the duration of tillering. This was based on his findings that low levels of nitrogen had less effect on the number and dry weight of primary tillers than on secondary tillers, meaning that primary tillers occupy a preferential position in competing for nitrogen. Evidence of this was observed earlier by Langer (1959) when tiller production was not limited until 8 to 10 tillers had appeared at low nitrogen, but further branching was restricted by a shortage of nitrogen.

Ishag and Taha (1974) noted that in wheat and other cereal crops the number of fertile tillers at harvest was determined by production and death of tillers, a large proportion of tillers are unreproductive, and early-formed tillers have a greater chance of surviving and producing grain. From his experiment he found that the application of nitrogen increased tillering efficiency, or the ratio of fertile tillers to total tillers produced.

From reviewing the previous studies, it becomes obvious that nitrogen does affect tillering of herbage grasses. However, the extent of this effect is highly dependent on interactions with many other factors such as time of nitrogen application, available moisture, plant spacing, temperature, light intensity, species, and interval between harvests.

Lewis (1968) discovered that date of nitrogen application had a marked effect on fertile tiller production. He suggested that in order to encourage head production, it was important to apply nitrogen before the onset of seed development and it might be possible to manipulate crop production by timing nitrogen applications.

Continuing his studies of timing nitrogen applications, Lewis (1969) found that the major difference between early and late applications of nitrogen was the rate of conversion of wintering fescue (Festuca arundinacea Schreb.) tillers to inflorescence bearing shoots. This supplemented his previous suggestion by showing there was a possibility of manipulating tiller function by nutritional means. The ratio of overwintering shoots which became fertile was higher with an early nitrogen application than with a late application.

Khalifa (1973) demonstrated the importance of time of nitrogen application on wheat using three easily described times. The times were prior to sowing, at tillering, and at ear emergence. He found that early application either at sowing or tillering, or split application of the two, increased grain yield, but application at ear emergence did not.

Nitrogen and water supply interact in their effects on tillering as shown with regularly cut swards of Italian ryegrass (Lolium multiflorum L.) (Whitehead, 1970). Under low moisture conditions during the dry part of the season, the number of tillers per unit area was substantially higher with an application rate of 246 kg/ha of nitrogen than with 123 kg, but the number with 492 kg was similar to that with 246 kg. With irrigation to prevent a soil moisture deficit, there was no difference between 123 and 246 kg nitrogen treatments, but tiller number with 492 kg of nitrogen was noticeably higher.

Increased tillering brought about by nitrogen application causes an increase in leaf area index which has created early moisture stress and finally a yield reduction in dryland conditions. Luebs and Laay (1969) found that 45 kg/ha and 90 kg/ha of nitrogen increased LAI of wheat 44 and 109 percent respectively and that evapotranspiration was 14 and 43 percent higher, respectively. The results of Singh et al. (1975) summarized observations of other workers in that maximum response to nitrogen application increased with increasing water supply. Nitrogen increased yield, water use, and water use efficiency (Singh et al., 1975).

Most studies involving changes of morphology and physiology have been done on individual plants grown separately either in greenhouse or field studies. There is evidence, however, that the effects of nitrogen are different under sward conditions where competition between plants is important. Under sward conditions, the effect of nitrogen on tiller number is generally smaller than for single plants due to the effects of competition. Langer (1963) expounded on the interaction between plant spacing and nitrogen, stating that it has been demonstrated that the effect of nitrogen on the number of tillers per plant was greater in widely spaced than in closely spaced prairie grass.

Temperature affects the response of grasses to nitrogen. Smith and Jewiss (1966) studied timothy (Phleum pratense L.) in growth chambers under cool or warm conditions. Ammonium nitrate applied at the rate of 336 kg/ha of nitrogen per year increased tiller number per unit area by up to 50 percent after several weeks of cool conditions, but the increase was much smaller under warm conditions. Light intensity interacted with nitrogen in perennial ryegrass (Lolium perenne L.) with nitrogen causing greater increases in tiller numbers in bright than in reduced light (Langer, 1963). O'Brien (1960) found significant interactions between species and nitrogen using perennial ryegrass and cocksfoot (Dactylis glomerata L.). The perennial ryegrass had a greater potential than cocksfoot at higher nitrogen levels.

Since nitrogen tends to promote tillering of forage grasses, there appears to be a problem of earlier lodging in grasses receiving high rates of nitrogen due to a higher tiller population, longer stems, and larger leaves (Wilman et al., 1976). This relationship was demonstrated by Wilman et al. (1975) using six harvest intervals and two nitrogen fertilization rates. They found a negative interaction between level of nitrogen and interval between harvest with the number of tillers being increased by nitrogen applications and short harvest intervals, and decreased with nitrogen application and the longer harvest intervals.

In addition to the effect of harvest interval on tiller number, they found that nitrogen at the rate of 263 kg/ha increased weight per tiller by an average of 46 percent. This was partially attributed to a 20 percent increase obtained in number of leaves per tiller. Weight per leaf increased by 16 percent at the 263 kg rate and 8 percent at the 525 kg/ha nitrogen rate. However, at the longest harvest interval, dry matter yields were reduced due to fewer tiller numbers. Wilman's conclusions were that increasing the levels of nitrogen at three-to six-week harvest intervals increased the number of tillers, number of green leaves per tiller, and weight per leaf, which all contributed to an increase in dry matter yield. He also stated that these factors point out the importance of more intense management practices at higher rates of nitrogen application than at low nitrogen levels.

The preceding discussions verify the conclusion of Gregory (1937), that nitrogen was the most important single plant nutrient affecting tiller development in herbage grasses. Furthermore, tillering is affected by a complexity of many other factors, often with significant interactions.

Two other factors affecting the extent of tillering in grasses, and with which less research has been conducted, are seeding rates and dates. Where plant density has varied over a wide range of densities, grain yield of barley (Hordeum vulgare L.) changed relatively little (Kirby and Faris, 1972). The tillering habit of the temperate cereals was an important feature of their development enabling the plant to exploit the environment to the fullest, particularly where the seeding rate was low or establishment poor. This ability of grasses to compensate for differences in plant density was demonstrated by Thorne and Blacklock (1971). Using two varieties of wheat, they found no difference in grain yield from plant densities of 75 or 105 to 298 plants per square meter.

Donald (1951) conducted experiments to determine the influence of density, stage of growth, and fertility level on competition among annual pasture grasses. His results demonstrated that, while stands of moderate density may give satisfactory or even maximum final yields for the environment, only stands of high density can give satisfactory early yields of forage. This could be important in areas, such as Oklahoma, where the winter period is normally the time of greatest livestock feed shortage.

In later studies using subterranean clover (Trifolium subterraneum L.) and Wimmera ryegrass (Lolium rigidum Gaud.), Donald (1954) determined that the optimum stand density varied depending on the primary use of the crop, such as grazing or seed production. In his experiments he concluded that for both species a dense stand would give maximum final yield, maximum winter yield, and satisfactory seed production, all of which were important factors for grazing. If the emphasis was on seed production, he found that moderate densities would give maximum yields per unit area while very low densities produced maximum yield per plant.

Sodseeding Small Grains Into Bermudagrass

Seeding wheat into bermudagrass (Cynodon dactylon L. Pers.) sod combines two of the major crops grown in Oklahoma as a very desirable cropping system from the standpoint of soil and water conservation (Elder and Tucker, 1968). Commonly, double cropping systems require additional cultivation, but sodseeding wheat into bermudagrass required no cultivation. Other benefits of this double-cropping system were, reduced soil erosion, increased water uptake due to the grass cover, and longer growing season. May was the only month that the crops would compete for light, nutrients, and moisture, but this would be prevented by grazing out the wheat rather than harvesting for grain.

Information on sodseeding small grains into bermudagrass is limited, and most of the work deals with grain production. Alhagi (1975) commented that high seeding rates are very important for the establishment of a uniform stand of wheat plants when grown in bermudagrass sod. He attributed this to tiller production per plant being reduced in bermudagrass sod. In his studies, Alhagi found that, by increasing the seeding rate of wheat in bermudagrass sod from 68 to 136 kg/ha, grain production increased from 778 to 947 kg/ha. He attributed this to a compensation for non-germinating seeds and reduced competition from increased shading of the wheat plants on the grass sod.

In an experiment using four different seeding rates, Nightengale (1977) obtained optimum grain production at seeding rates between 101 and 168 kg/ha.

Sodseeding for grazing purposes usually provides little forage until late spring because seeding cannot be done in early fall due to competition from bermudagrass, a summer perennial (Welch, et al., 1967). This suggests that by using paraquat this source of competition might be removed. This was demonstrated by Triplett, et al. (1975) who reported that 280 to 560 g/ha of paraquat allowed cool season annual grasses to be planted 4-6 weeks earlier than dormancy normally occurs in swards of bermudagrass and other warm season perennial grasses. He also pointed out that early seeding allowed some fall grazing and provided fall forage production increases of 50 percent over conventional overseeding methods. Farnworth and Williams (1977) revealed that applying paraquat before planting also gave increased grain yields, especially with early sowings.

The effect of nitrogen on tillering of small grains planted in bermudagrass is the same as on cultivated lands. Alhagi (1975) substantiated this by reporting that the application of his highest level of nitrogen, 136 kg/ha, resulted in the greatest number of tillers per square meter. He concluded that this increase in tiller density was due to reduced competition for nitrogen between the crop and the bermudagrass.

Alton and Rogers (1976) determined that high rates of nitrogen with 40 to 60 percent of the nitrogen applied at sowing produced the highest forage yields. Nitrogen applied between January and March increased small grain forage yields, but all of the nitrogen was not utilized by the cereals as the bermudagrass responded to residual nitrogen.

With a cropping system of small grains in bermudagrass sod, summer production of the bermudagrass was depressed, but forage production per year on a given area was greater (Fribourg and Overton, 1973).

Welch et al. (1967) found that rye for grain planted in bermudagrass reduced the first bermudagrass harvest due to a reduction in light intensity, soil moisture, and soil temperature. With rye grain production this unfavorable effect on first cutting bermudagrass yield would remain as long as the rye stayed on the plots until grain maturity. However, modifications in the bermudagrass-rye system whereby the rye is removed as haylage rather than grain had potential for increasing first cutting bermudagrass yields and total forage production from land areas.

CHAPTER III

MATERIALS AND METHODS

This project consisted of two studies conducted at the Oklahoma State University Agronomy Research Station at Perkins, Oklahoma. These studies were Osage wheat (*Triticum aestivum* L. em. Thell.) planted in bermudagrass sod and in clean-tilled cropland.

No statistical comparisons were made between the two studies due to soil differences and previous management practices on the two locations. Data presented in Results and Discussion focus only upon significant differences (P=0.05) among treatments and their interactions.

Both studies were planted on October 19, 1978. Planting was done with drill rows running widthwise across the plots. The drill used was a 3.66 m John Deere with a 25.4 cm row spacing. The seeding rate was 77 kg/ha.

Sodseeded Study

The experimental design was a randomized complete block with a factorial arrangement of 2 paraquat treatments, 2 spacing treatments, and 3 nitrogen treatments in 4 replications.

The 2 paraquat (1,1' - dimethyl - 4,4' - bipyridinium) treatments were 280 g/ha versus no paraquat. Paraquat treatment was applied October 18, 1978, using a CO_2 hand plot sprayer with a 1.83 m boom. Weather conditions at the time of spraying were 24^{o}C and no wind.

The spacing treatments were normal drill placement and a 24.5 cm plant spacing accomplished by hand thinning.

Nitrogen treatments were 44, 88, and 176 kg/ha of actual N using ammonium nitrate. Fertilization was split into 2 equal applications, with the first application on October 24, 1978, and the second on March 2, 1979. Fertilizer was applied using a 0.92 m Gandy fertilizer spreader.

Plots were 11.0 m long and 2.1 m wide. Only 9.2 m was used for data collection and the remaining 1.8 m was left at each end for borders.

Data collected included tiller counts, forage production, and grain yield. Tiller counts in the spaced plots were made on 3 plants which were flagged and the same plant counted each time. Tiller counts in the drill row plots were taken on a 0.92 m row length which was also flagged for repeated counting. Forage was harvested when plants reached a height of 20 cm and clipping was at a 5 cm height. Forage production and grain yield were determined by harvesting a 102 x 91 cm quadrat within each plot. In each plot 4.6 m was used for collecting forage data and another 4.6 m for determining grain yield which was harvested at the end of the growing season.

The soil is a Konawa loam (Ultic Haplustalf). A soil sample collected on October 10, 1978 revealed a pH of 5.8, 10 kg/ha nitrate nitrogen, a phosphorus reading of 87, and a potassium level of 239. Phosphorus and potassium levels were sufficiently high without additional fertilization.

Clean-tilled Study

The experimental design was a split plot in time (Steel and Torrie, 1960) with a factorial arrangement of 2 spacing treatments, 2 levels of nitrogen, and 2 clipping treatments in 4 replications.

The spacing treatments were normal drill placement and a 24.5 cm plant spacing accomplished by thinning. Nitrogen treatments were 66 and 132 kg/ha of actual nitrogen using ammonium nitrate. Fertilization was split into 2 applications with 66 kg/ha being applied to all plots on August 24, 1978, and a second application of 66 kg/ha to the plots receiving the high nitrogen treatment on March 2, 1979. Forage was harvested when the plants reached a height of 20 cm and clipping was at a height of 5 cm. The grain plots were not clipped except to harvest grain at the end of the growing season.

Data collected included tiller counts, forage production, and grain yield. Tiller counts were made on 3 plants in the spaced plots and on a 0.92 m row in the drill-row plots. In each case the plant or row was flagged for repeated counting. Forage production and grain yield were determined by harvesting a 102 x 91 cm quadrat within the plot.

The soil was a Teller loam (Udic Arguistoll). A soil test revealed a pH of 5.5, 25 kg/ha surface nitrate nitrogen, a phosphorus reading of 52, and a potassium reading of 240. This pH was acceptable for growing wheat and potassium was sufficiently high so as not to require additional fertilization. The plots were fertilized with 90 kg/ha P_2O_5 as concentrated super phosphate (0-46-0) on August 24, 1978.

CHAPTER IV

RESULTS AND DISCUSSION

SODSEEDED EXPERIMENT

Grain Study

The dry weather conditions were the reason for the late planting date, and this wheat made very little growth until late March of 1979. Therefore, the first tiller count was made on April 17, 1979.

There was a significant effect on tiller numbers due to spacing with the spaced plots having 228 tillers and the solid row plots 956 tillers/m^2 in April. This trend continued and the spacing effect was also significant at maturity on tiller numbers and grain production (Table 1). The number of fertile tillers at maturity, 153/m^2 in the spaced plots and 480/m^2 in the solid row plots, represent 67 and 50 percent, respectively, of tillers counted in April. It was apparent that many tillers developed early in the growth of the plant were not fertile. The spaced plots had substantially fewer tillers than did the solid row plots and also produced significantly less grain (1848 kg/ha as opposed to 3292 kg/ha for the solid row plots).

Triplett et al. (1975) suggested that when planted early, paraquat helped reduce competition between rye and bermudagrass and led to increased grain yields. The present study was considered a late planting, October 19, 1978, because the fall of 1978 was unusually dry. However, the bermudagrass did not go dormant until mid-November. The use of

Table 1. Sodseeded grain study, mean tiller number and grain yield as affected by spacing, paraquat, and nitrogen.

Treatment	Level	Tillers/m^2 April 1/	Tillers/m^2 Mature fertile 1/	grain production kg/ha 1/
Spacing	spaced	228b	153b	1848b
	solid row	956a	480a	3292a
Paraquat in g/ha	0	539b	281b	2203b
	280	645a	353a	2937a
Nitrogen in kg/ha	44	518b	276b	2161c
	88	661a	335a	2546b
	176	598a	339a	3003a
	CV%	23	17	21

1. Means within a treatment followed by the same letter are not significantly different at P=0.05.

paraquat significantly increased the number of tillers in both dates as well as grain production. The results in Table 1 lend support to Triplett's (1975) findings by showing that the application of 280 g/ha of paraquat caused an increase of 106 tillers/m^2 in April, 72 tillers/m^2 at maturity, and an increase in grain yield of 734 kg/ha over the untreated plots.

Nitrogen applications significantly affected tiller numbers at both dates but only up to the 88 kg/ha rate. This suggests that at the 44 kg/ha rate tiller production was limited by nitrogen deficiency, but at 88 kg/ha the plant's needs were provided. However, there was an increase in grain yield with each increase in nitrogen and maximum grain yields may not have been obtained at the 176 kg/ha rate.

A significant effect on tiller numbers at maturity was found due to a spacing x paraquat interaction (Figure 1). The application of paraquat afforded the solid row plots to have a greater increase in tiller numbers than it allowed the spaced plots. There also was a significant spacing x paraquat x nitrogen interaction on grain production shown in Table 2. In the solid row, or plots having a dense plant number and receiving no paraquat treatment, there was no effect due to nitrogen. However, where paraquat was applied to the solid row plots there was a good response to nitrogen. In the spaced plots the opposite was true, as the no-paraquat treatment responded to the addition of nitrogen and the paraquat treated plots did not.

Forage Study

In the forage production study from wheat planted in bermudagrass sod, an increased wheat response was obtained from a denser plant spac-

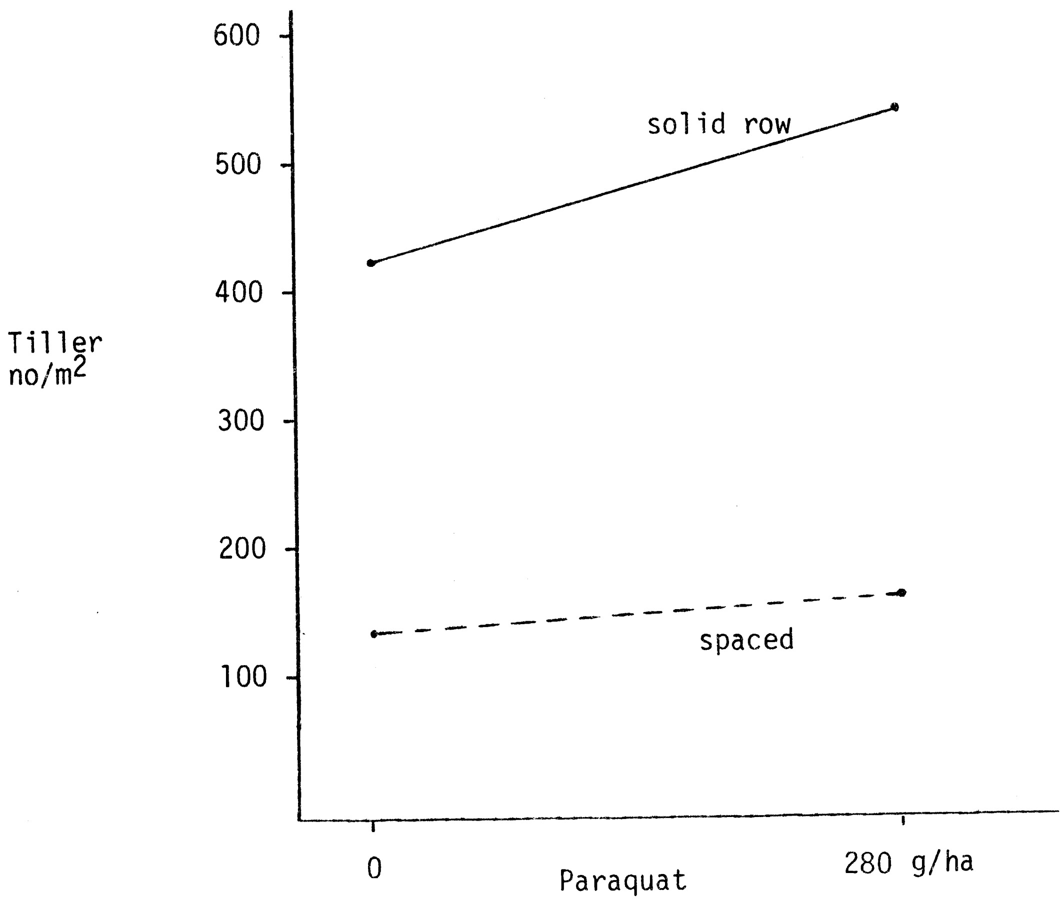

Figure 1. Sodseeded grain study, effect of paraquat x spacing interaction on tiller numbers at maturity.

Table 2. Sodseeded grain production (kg/ha), significant nitrogen x paraquat x spacing interaction.

Paraquat 1/	Spacing 1/	Nitrogen kg/ha 1/ 44	88	176
0	solid row	2809	2632	3035
	spaced	924	1695	2122
280g/ha	solid row	3060	3749	4470
	spaced	1850	2109	2386

1. LSD 764, P=0.05.

ing, use of paraquat, and the addition of nitrogen (Table 3).

The results obtained due to spacing varied throughout the course of the study, particularly in relation to forage yields. The solid row plots with greater plant density had a substantially greater number of tillers at each harvest than the spaced plots. Tiller numbers decreased at each harvest in the solid row plots (Table 3), due to the removal of many growing points at each harvest. However, in the spaced plots there was no reduction in tiller numbers following the first harvest. This can be explained by the difference in growth patterns between the spaced and solid row plots. In the solid rows, plants grew upright allowing many of the apical meristems of the tillers to be removed by harvesting, but spaced plants grew prostrate during the early part of the season, thus leaving growing points below the clipping height at the first harvest. By growing prostrate the spaced plants were left with a greater leaf area following the first harvest, allowing the spaced plots a faster rate of regrowth than the solid row plots between the first and second harvest. As a result, forage yields at the May harvest were not significantly different between spacing treatments. At the June harvest, even though forage production was very low for both spacings, the solid row plots again produced more forage. Overall, solid rows produced 2358 kg/ha of forage as opposed to 947 kg/ha in the spaced plots.

Paraquat was the only factor that independently increased both tiller numbers and forage yield at all harvest dates, as well as total forage production. Paraquat gave an increase of 680 kg/ha in total forage produced (Table 3).

In this study several factors were affected by a paraquat x spac-

Table 3. Sodseeded forage study, tiller numbers and forage production as affected by spacing, paraquat, and nitrogen.

		April 17		May 8		June 3		Forage 1/
Treatment	Level	tiller 1/ no./m^2	Forage 1/ kg/ha	tiller 1/ no./m^2	Forage 1/ kg/ha	tiller 1/ no./m^2	Forage 1/ kg/ha	Total kg/hg
Spacing	Spaced	256b	374b	250b	475a	128b	98b	947b
	Solid Row	929a	1711a	628a	441a	263a	206a	2358a
Paraquat in g/ha	0	515b	827b	390b	388b	159b	97b	1312b
	280	670a	1259a	489a	526a	232a	207a	1992a
Nitrogen in kg/ha	44	562a	820b	398a	327b	163a	94a	1241b
	88	624a	1153a	434a	505a	195a	142a	1800a
	176	591a	1155a	485a	540a	229a	221a	1916a
	CV%	25	34	29	21	44	117	10

1. Means within a treatment, in the same column, followed by the same letter are not significantly different at P=0.05.

ing interaction. These interactions also assist in giving a better understanding of the results obtained from the May forage harvest.

The solid row plots had a greater increase in tillers/m^2 from the application of paraquat than did the spaced plots (Figure 2). This increase, when expressed as a percentage increase due to paraquat, were both 130. Therefore, the greater increase from solid row plots was directly related to the greater plant density. The paraquat treatment reduced competition from bermudagrass and cool season annuals, thus enabling wheat to produce more tillers and more forage (Figure 3).

However, the trend previously discussed was reversed in its effect on forage yield at the May harvest. Figure 4 illustrates that at this point the spaced plots had a greater increase than the solid row plots due to the application of paraquat. Yet, this response is explained by considering that at the April harvest the spaced plants were growing prostrate which allowed fewer tillers to be killed by harvesting. Also, the spaced plants were left with a greater leaf area following the April harvest which allowed these plots to make a faster regrowth than the solid row plots.

At the June tiller count, the paraquat x spacing interaction had returned to a situation similar to the April count in that paraquat gave a greater response to tillers/m^2 in the solid row plots than the spaced plots (Figure 5).

With respect to nitrogen, the number of tillers appeared to be determined early in the life of the plant since there was no difference in tiller numbers at any of the three nitrogen rates (Table 3). This suggests that nitrogen, even at the lowest rate, was available in adequate amounts for tillering, considering the dry Fall of 1978 and unu-

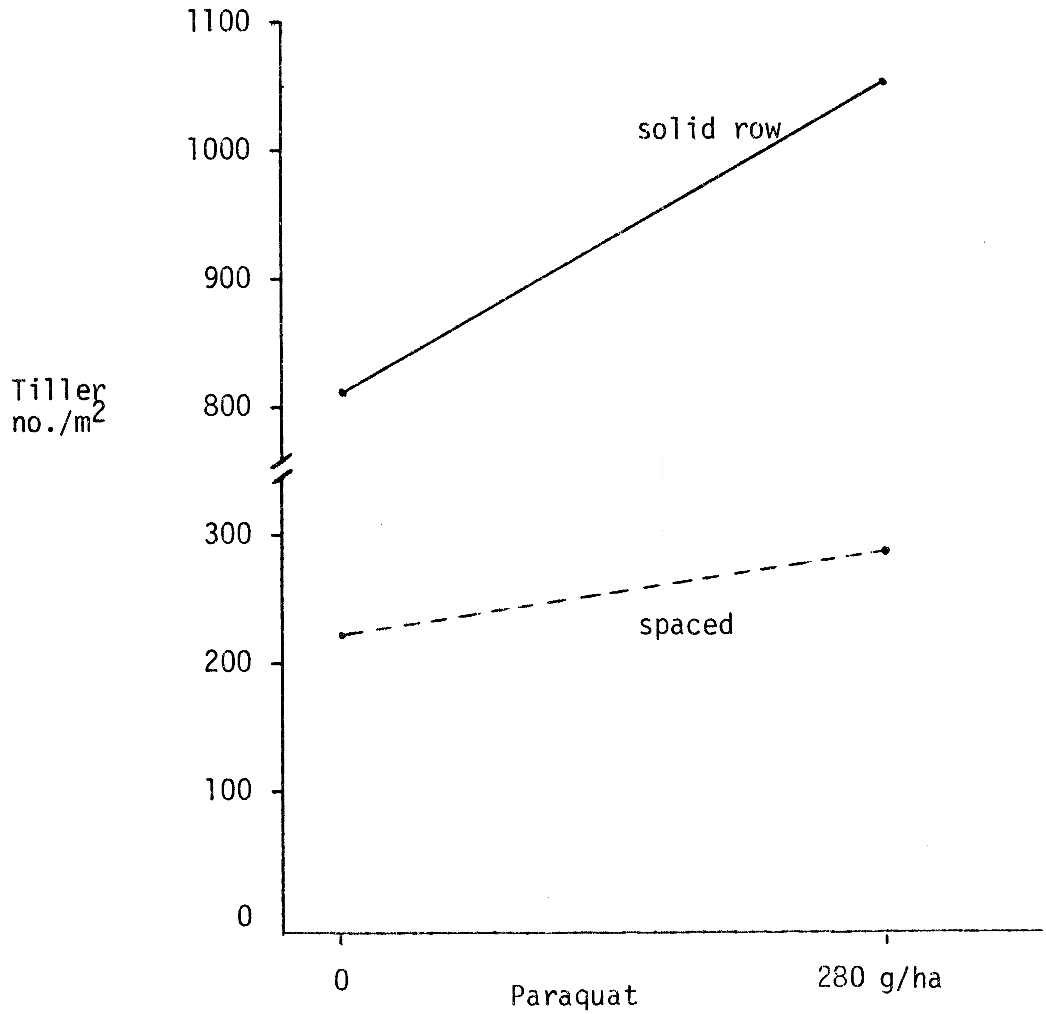

Figure 2. Sodseeded forage study, effect of paraquat x spacing interaction on tiller numbers at April harvest.

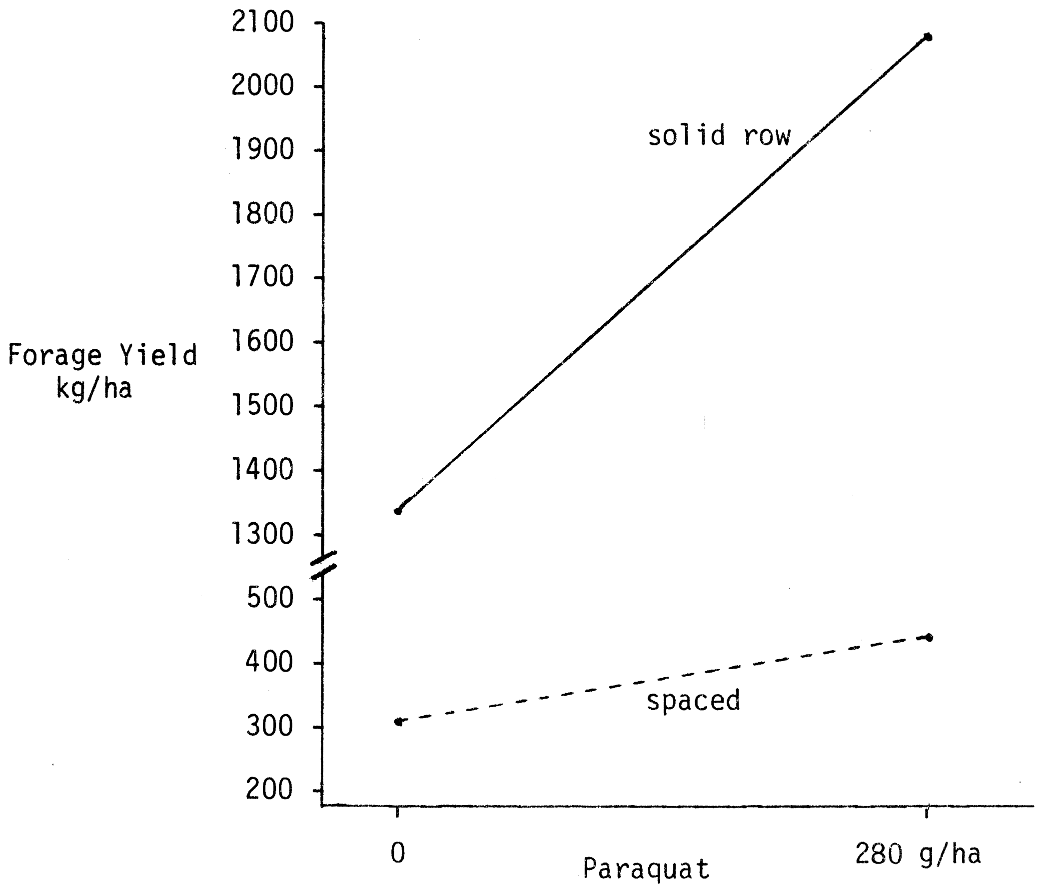

Figure 3. Sodseeded forage study, effect of paraquat x spacing interaction on forage yield at April harvest.

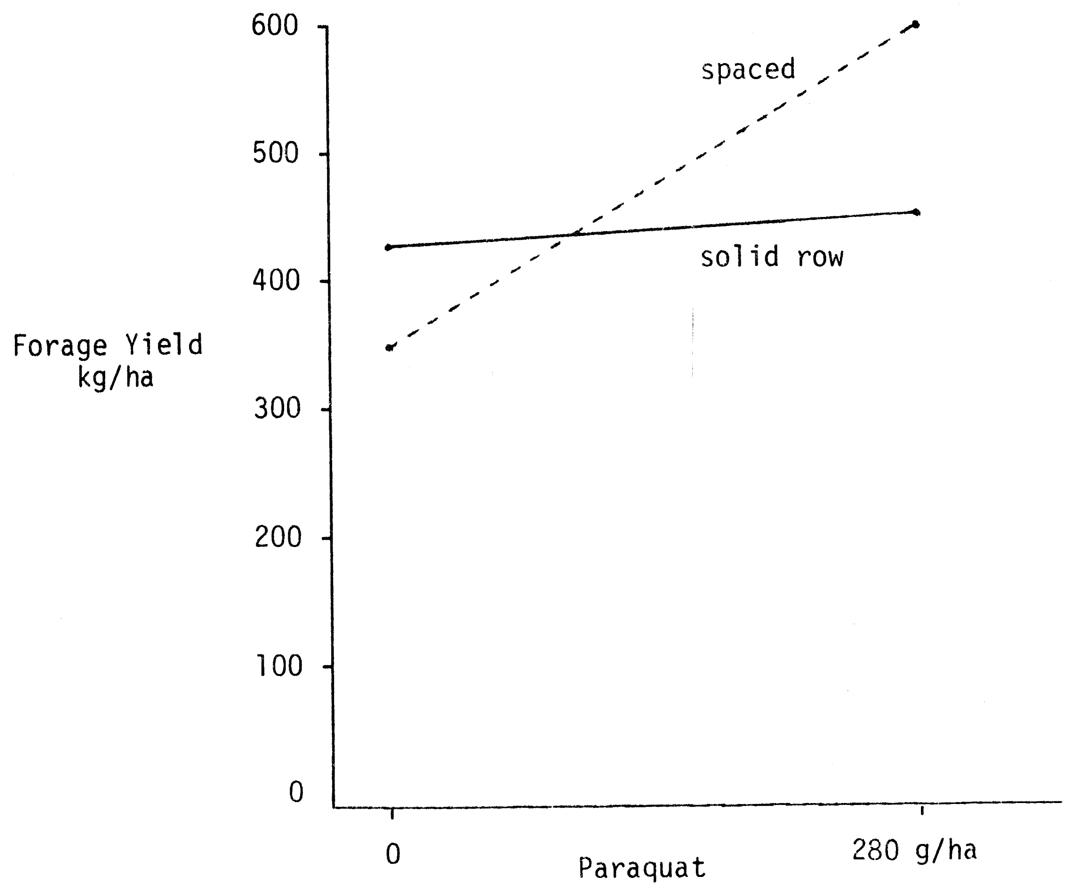

Figure 4. Sodseeded forage study, effect of paraquat x spacing interaction on forage yield at May harvest.

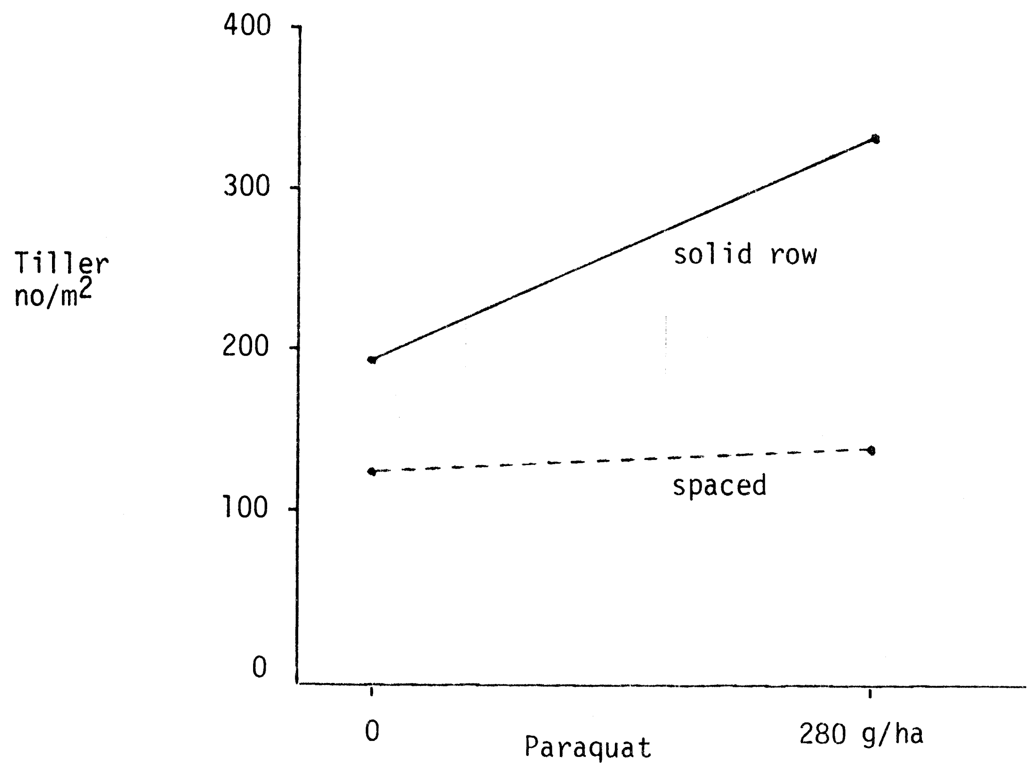

Figure 5. Sodseeded forage study, effect of paraquat x spacing interaction on tiller numbers at June harvest

sually cold winter of 1979.

Nitrogen did, however, increase forage production at the April and May harvests, but only up to the 88 kg/ha rate. Applying 176 kg/ha gave no response in forage yield above the 88 kg rate. This was also true for total forage production, as the optimum rate of nitrogen appears to be 88 kg/ha. This suggests that nitrogen was not the limiting factor to production. Other limiting factors could be late planting date, extremely dry fall, unusually cold winter, and other factors.

The bermudagrass plots were harvested in September 1979 to determine the effect of residual nitrogen (Table 4). However, much of the bermudagrass had winterkilled and the plots were dominated by crabgrass (Digitaria sanguinalis L. Scop.). This winterkilling of bermudagrass was a common situation throughout Northern Oklahoma in the spring of 1979.

The solid row plots produced less forage in September (Table 4). Thus, it appears that less residual nitrogen remained for warm season grasses in the solid row plots. This was expected because the solid row plots had produced more wheat forage. These results add support to work by Fribourg and Overton (1973) who found that when overseeding bermudagrass sod with cool season annuals, summer production of bermudagrass was depressed.

Paraquat had no effect on forage production in September. These results were somewhat unexpected because paraquat increased wheat forage production and theoretically this might require more nitrogen for the wheat.

There was an effect on residual nitrogen due to the rate of fertilization, but was apparent only between the 44 kg/ha and 88 kg/ha rates.

Table 4. Sodseeded forage study, mean forage production from September, 1979 harvest, to determine residual nitrogen effects.

Treatment	Level	Forage 1/ production kg/ha
Spacing	spaced	6453b
	solid row	4563a
Paraquat in g/ha	0	5502a
	280	5496a
Nitrogen in kg/ha	44	4740b
	88	5909a
	176	5849a
	CV%	17

1. Means within a treatment followed by the same letter are not significantly different at P=0.05.

The higher rates of nitrogen fertilizer did contribute to some residual nitrogen. However, production at 88 and 176 kg/ha were similar.

CHAPTER V

RESULTS AND DISCUSSION

CLEAN-TILLED EXPERIMENT

Grain Study

In the clean-tilled study for grain production, spacing significantly affected tiller numbers, but not grain production (Table 5). These results support the research of Thorne and Blacklock (1970) who demonstrated the ability of grasses to compensate for differences in density. In the solid row plots, the seeding rate was 77 kg/ha and in the spaced plots after thinning, the plant density was estimated to be equivalent to a seeding rate of 5 kg/ha. Kirby et al. (1972), had commented that over a wide range of densities, grain yield changed relatively little. This suggests that tiller numbers are of minor importance in grain production.

Forage Study

Tiller numbers appear to be of greater importance to forage production than grain production (Table 6). At the first harvest, both tiller number and forage production were much greater in the solid row plots than in the spaced plots. Tiller number on April 26 was much greater in the solid row plots, but due to the prostrate growth of the spaced plants, as described in the previous chapter, there was no difference in forage production. When harvested on May 14 the solid row

Table 5. Clean-tilled grain study, mean tiller numbers and grain yield as affected by spacing.

Treatment	Level	Tillers/m² April 4 1/	Tillers/m² Mature 1/	Grain 1/ production kg/ha
	spaced	467b	345b	3951a
Spacing	solid row	1514a	706a	4230a
	CV%	13	16	11

1. Means within a treatment followed by the same letter are not significantly differently at P=0.05.

Table 6. Clean-tilled forage study, effect of spacing on the tiller number and forage production by harvest, and on mean tiller numbers and total forage yield.

	April 4		April 26		May 14		June 5		Mean 1/	Total 1/
Treatment	Tiller 1/ no/m^2	Forage 1/ kg/ha	Tiller 1/ no/m^2	Forage 1/ kg/ha	Tiller 1/ no/m^2	Forage 1/ kg/ha	Tiller 1/ no/m^2	Forage 1/ kg/ha	Tiller no/m^2	Forage kg/ha
spaced	480b	389b	645b	1453a	413b	851a	220a	551a	445b	3244b
solid row	1607a	2038b	1088a	1335a	551a	627b	168a	435a	863a	4435a
CV%	23	16	18	13	20	15	29	26	19	17

1. Means within a column followed by the same letter are not significantly different at P=0.05.

plots were again greater in tiller number but spaced plots produced significantly more forage. There was no difference in either tiller numbers or forage yield at the last harvest. This lack of significant difference in tiller numbers can be explained by the early prostrate growth of the spaced plants which allowed a greater number of growing points to escape the 5 cm clipping height during harvesting. There was no difference in forage production at the June 5 harvest because wheat growth essentially ceased in all plots shortly after the May 14 harvest date. However, the importance of tiller numbers to forage production is best shown by the mean tiller number and total forage production which are both significantly higher for the solid row plots.

For the forage production study the pattern of tillers and forage yield by harvest is shown in Table 7. The number of tillers/m^2 declined at each harvest except for the April 26 harvest of the spaced plots, which was also the pattern for forage yields. The exception at the April 26 harvest is perhaps better explained by looking at the signigicant spacing x harvest date interactions shown in Figures 6 and 7. In the solid row plots, the number of tillers/m^2 decreased following each harvest, but such is not the case in the spaced plots (Figure 6). The spaced plants had a much lower plant population and with the prostrate growth tiller development continued after the first harvest. However, the spaced plots also decreased in tiller numbers at each of the last harvests. This would indicate that the number of potential tillers was determined and growth initiated early in the growth of the wheat, since the number of tillers declined at each harvest in the solid row plots and after the second harvest in the spaced plots. Forage production followed the same trend as tiller numbers (Figure 7).

Table 7. Clean-tilled forage study, mean tiller number and forage yield by harvest averaged over spacing.

	Means	
Harvest date	tiller 1/ no./m^2	Forage 1/ kg/ha
April 4	1044a	1214b
April 26	866b	1394a
May 14	482c	739c
June 5	194d	493d
CV%	19	17

1. Means within a treatment followed by the same letter are not significantly different at P=0.05.

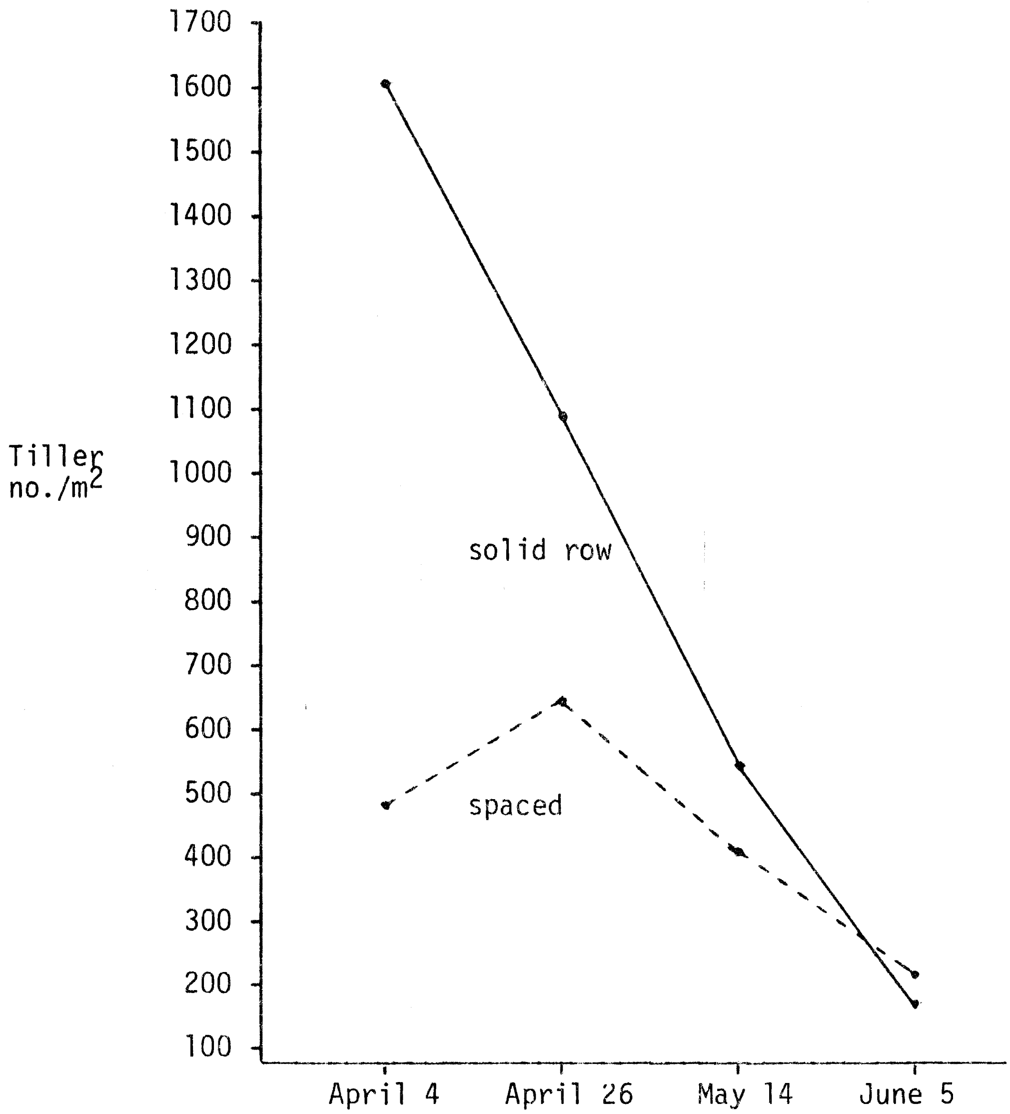

Figure 6. Clean-tilled forage study, effect of spacing x harvest interaction on tiller number.

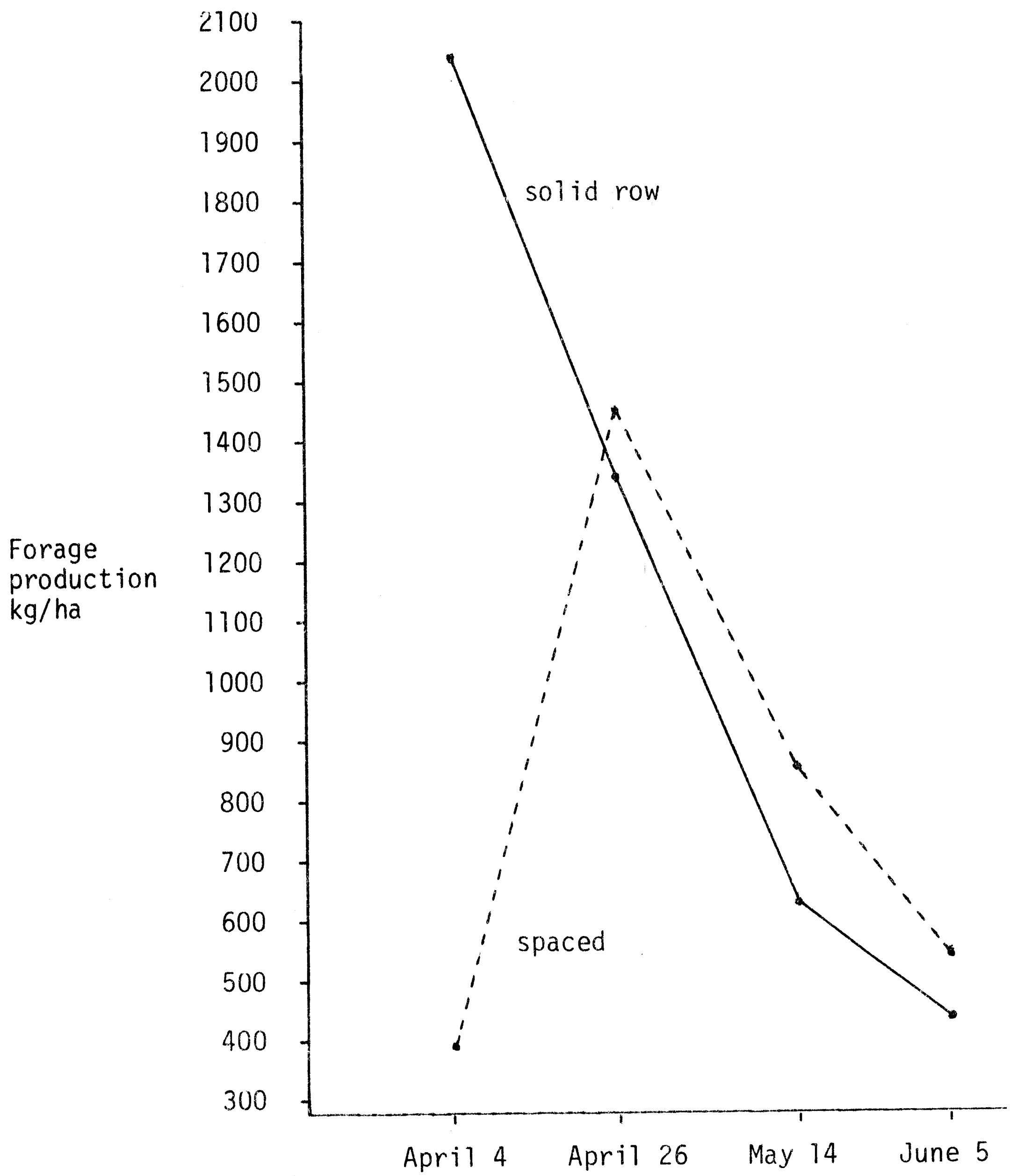

Figure 7. Clean-tilled forage study, effect of spacing x harvest interaction on forage production.

Forage yield at the first harvest was much greater on the solid row plots and this would cause a greater shading effect on developing tillers. Thus, the spaced plots had two advantages accounting for the increase in forage production at the second harvest, the retention of a greater number of growing points, and more light reaching the undeveloped tiller buds.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The experiment consisted of two studies, one planted in bermudagrass sod and the other in clean-tilled land on October 19, 1978. The purpose was to determine the effect of certain cultural factors on tiller numbers, forage production, and grain yield of wheat. These practices were spacing, paraquat, and nitrogen.

From the clean-tilled study, it appeared that tiller numbers were more important to forage production than to grain production. This study demonstrated the ability of wheat to compensate in grain yield for a wide range in plant densities. However, this was not the case for forage production and it appeared that a high plant density may be an important consideration in maximizing forage yields.

In the sodseeded study, a dense plant population significantly increased grain and forage production. The use of paraquat contributed to a higher tiller number, grain yield, and total forage production. Tiller numbers in the grain production plots increased with nitrogen application up to 88 kg/ha, but grain production increased with each increment of nitrogen fertilization up to 176 kg/ha. In the forage plots, nitrogen had no effect on tiller numbers throughout the study, but did increase forage yield over the low nitrogen treatment.

Results from both studies indicated that tiller numbers are determined early in the life of the wheat plant. It appears that dense stands are important to maximize tiller numbers and, consequently, improve forage yields. Paraquat was important in improving forage production from wheat planted in bermudagrass sod.

It appears that additional work is needed to determine the value of increased seeding rates and perhaps planting in narrower rows for increasing tiller numbers and forage production. Seeding dates earlier than mid-October should be evaluated.

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