EFFECT OF NITROGEN, PLANTING DATE, AND SEEDING RATE ON GRAIN YIELD AND YIELD COMPONENTS OF WINTER WHEAT SOWN IN BERMUDAGRASS SOD

By

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Tripoli, Libya

1971

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
July, 1975

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ACKNOWLEDGMENTS

The author is grateful to the Faculty of Agriculture of the University of Tripoli and the Cultural Section of the Embassy of the Libyan Arab Republic for the financial assistance which made this study possible.

Sincere appreciation is extended to Dr. Lavoy I. Croy, Chairman of the Advisory Committee for the advice, guidance, and counsel throughout the course of this study. Grateful acknowledgments are also extended to Dr. Lewis H. Edwards, Associate Professor of Agronomy, and Dr. Robert M. Reed, Professor of Agronomy, for serving on the advisory committee and for their valuable constructive criticism in the preparation of this thesis. Thanks are extended to Dr. R. D. Morrison, Professor of Mathematics and Statistics, for his assistance in the statistical analysis of the data and to Dr. D. S. Mikkelsen from the University of California, Davis, for helping in the leaf area measurements.

The author is most grateful to his wife, Samira, for her sacrifice of time and understanding throughout the course of this study.

Special thanks to the author's parents and family for their encouragement and patience during his stay in the United States.

The author is thankful to Mrs. Kathy Henslick for typing this thesis.

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CHAPTER I

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the most widely cultivated crop of all cereals in different parts of the world. It is the principal source of food for man and it is used as an animal feed either as grain or forage.

Plant breeders, crop physiologists, soil scientists, and farmers were and are deeply concerned about the best ways and the most economical cultural practices for the production of good wheat crops each year. The main goal is to continue increasing wheat production to meet the food requirements for an increasing world population and to decrease the cost of production to a minimum.

One of the means of reducing production costs is to reduce the operations required for plowing and seed bed preparation by sowing wheat directly in a pre-existing grass crop such as bermudagrass. Previous research indicates that it is possible to produce wheat for grain in a bermudagrass sod by direct sowing wheat in the grass sod without plowing the land. This two-year study was designed to evaluate the use of this principle.

The objectives of this study were (1) to determine the nitrogen fertility level, date and rate of seeding for optimum grain production of a hard red winter wheat variety in a Midland bermudagrass sod, (2) to investigate the interrelationship between grain yield and yield components under the bermudagrass sod system, and (3) to investigate the relation between grain yield and the photosynthetic structures above the flag-leaf node.

CHAPTER II

REVIEW OF LITERATURE

Zero-Tillage Versus Conventional Seedbed Preparation*

In modern agriculture, conventional tillage practices include many time-consuming costly and laborious processes, such as plowing, and this is the dominant and prevailing system of seedbed preparation for farmers in many parts of the world. Farmers still consider that the use of more powerful and sophisticated tractors for plowing is the best way to attain higher yields.

Zero-tillage as a system started in different ways and for different purposes and one of the earliest reports on this concept was reported by Garber as early as 1927 (22). He succeeded in overseeding a legume into a grass sod and to overcome the competition between his main crop and the grass sod. Garber used close grazing, burning, and heavy seeding rates instead of the conventional seedbed preparation system.

Baeumer and Bakermans (4) reported that in the United States zero-tillage started as mulch farming practices in order to provide year-round protection of the soil against erosion and to reduce planting costs.

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*Additional key words: no-tillage, sod-seeding, and direct sowing.

Zero-tillage, when compared with conventional tillage, has many unique advantages. These include water and soil conservation, providing year-round utilization of the land and the climatic conditions, reduction of planting costs, production of forage and grain from the same land, and the most important advantage, which is increased yield. Each of these advantages will be discussed below under a separate topic.

Soil and Water Conservation

Bare soil in the field is exposed to different environmental factors which act to move soil particles from place to place. Among these factors, strong winds and heavy rains, cause the highest soil erosion, which results in the loss of the more fertile surface soil and the exposure of the subsurface, which in general is less fertile. Different parts of the agricultural lands in the world suffer from this problem and contribute to food and feed shortages.

A study was conducted by McWhorter (32) to compare the effect of no-tillage with that of conventional tillage on reducing soil erosion. He found that on a 12% slope soil erosion under no-tillage was 28% of that of conventional tillage from November through March.

The no-tillage system has a great advantage over conventional tillage in soil water conservation under different conditions. One of the major problems in agriculture is water runoff due to heavy rains. Tadmor and Shanan (43) in an experiment in an arid region concluded that eradication of natural vegetation from runoff plots in a 250 mm rainfall isohet region increased the annual runoff threefold from 7% to 21%. They explained their results on the basis of increased infiltration rates of 40-50% for the soil under the vegetative cover.

In another study by Davidson et al. (13) it was found that the improvement which the soil gets from the sod results from a reduction of raindrop impact by the mulch, as well as increased infiltration into the soil. Undisturbed root channels connected to the surface and improved soil aggregation resulting from the growth of the grass sod facilitate more rapid infiltration, and thus reduced runoff.

McWhorter (32) in his 5-year study with sod-seeded and conventionally seeded oats found that runoff water was 27% less for sod-seeded oats than for conventionally seeded oats.

Adams and Barnett (1) reported that both runoff and soil loss were negligible from grass sod and low from row crops following a dense sod on moderate slopes.

In a study on the mechanism of water infiltration in no-till soil, Ehlers (17) found that in conventionally tilled gray brown podzolic soils derived from loess, rapid water infiltration was delayed by a surface seal of silt and a dense traffic pan. During rainstroms, surface water causes soil erosion on sloping land. No-tillage practice induces a reduction in porosity but an increase of aggregate stability in the soil surface. Ehlers also found that the clay-silt segregation was no longer observed and traffic pans were loosened by biologic activity under the no-till practice and as a consequence water infiltration was enhanced. Soil water tension measurements indicated that water can infiltrate into no-till soil against existing hydraulic gradients.

In another study, by Baeumer et al. (5), water infiltration was found to be greater in unplowed plots and under a wheat stand in 1970 than under plowed plots.

In addition to the greater efficiency of water infiltration the no-tillage system of planting, improves the ability of the soil to store moisture under different environmental conditions and reduces water losses that result from evaporation through the periods when the soil is not under a vegetative cover. Keeping the soil under a continuous vegetative cover in no-tillage results in a shading effect from the existing plants on the soil and so produces a microclimate that keeps the temperature relatively low and reduces moisture loss. Many studies were conducted in recent years to investigate the effect of mulch and no-tillage systems on soil moisture conservation and evaporation reduction. In an 8-year study, Black (8) investigated the effect of stubble mulching on soil moisture and found that stubble mulching in a spring wheat fallow system with various wheat straw rates increased stored soil water 0.5 cm per metric ton of surface straw present. Triplett et al. (47) found that mulch from chemically killed bluegrass sod significantly reduced evaporation during the early period of the growing season. High moisture levels were observed near the mulch-soil interface in the early part of the growing season following a rain. Calculation of soil moisture to a depth of 105 cm showed that the no-tillage plots contained 2.5 cm more soil water on July 25 than conventional plots. During the following two weeks of very hot and dry weather the decrease of soil moisture in 0 to 105 cm depth was 5 cm for no-tillage and 3.8 cm for conventional plots. Triplett and his co-workers concluded that no-tillage plots had a larger reserve of water to be utilized during the dry period because the corn plants under the no-tillage system made near-optimum growth while conventional tillage corn was showing visible signs of moisture stress before the end of the two-week dry period.

It has been well documented that in the early part of the growing season under conventional tillage evaporation accounts for a high percentage of water loss. As the aerial parts of the plant grow, a shading effect is produced that decreases evaporation and in case of no-tillage the soil is kept under vegetative cover which reduces this loss from evaporation. Moschler et al. (35) conducted an eleven location-year experiment at four widely separated sites in Virginia to study winter cover crops for sod-planted corn during the 1962-1966 period. They found that in general highest corn yields occurred where the largest amounts of cover crop mulch occurred. Yields of sod-planted corn in rye averaged 44% higher than conventionally tilled corn in 4 of 13 comparisons and were comparable in the remaining nine. Soil moisture measurements indicated that soil moisture was higher under the sod-planted corn than under conventionally tilled corn, especially during the first half of the growing season. These workers concluded that the moisture-conserving aspect of sod planting is most pronounced for droughts of short duration.

Another study which supports the conclusion reached by Moschler and his co-workers was conducted by Blevins and his colleagues (9). In this study the effect of no-tillage versus conventional tillage corn production on soil moisture was compared during the period from 1968 to 1970. Soil moisture at various depths in the soil profile was measured during the growing season. They found that the no-tillage treatments had higher volumetric moisture contents to a depth of 60 cm during most of the growing season. The greatest difference occurred in the upper 0 to 8 cm depth. They concluded that the decrease in evaporation and the greater ability to store moisture under no-tillage produces a greater water reserve that can often carry the crop through periods of short-term drought and avoid the development of detrimental moisture stresses in the plant.

Full Utilization of Land and Climate

Food and feed shortages are presently a major world problem and the existence of this problem can be a result of different factors. Some of them are known and many others are unknown. One of these known factors is the inefficient and incomplete utilization of the land and the existing favorable climatic conditions. Millions of hectares of good agricultural lands are either partially or completely unutilized in different parts of the world that suffer from food and feed shortages. A full and efficient utilization of these lands would insure that human and animal populations would reduce the suffering from shortages of food and feed.

In addition to the production losses from these lands, the fertile surface soil is being lost due to wind and rain when it is left without a vegetative cover. Also soil moisture evaporation is increased when the soil is left exposed.

According to Bertrand (7), under conditions approaching ideal, about 75 to 85% of the net radiation absorbed during the daytime is used to evaporate water, 5 to 10% goes into sensible heat stored in the soil, 5 to 10% goes into sensible heat exchanged with the atmosphere by convective processes, and about 5% goes into photosynthesis. This amount of radiation energy that usually goes to photosynthesis and as a result goes to crop yields is being lost when the land is left without a crop cover.

From the points mentioned above, a system that gives greater utilization of the solar energy, protects the soil from erosion when the land is not under the main crop, and gives a full utilization of the land through the whole year for agricultural production may ultimately help solve the problem of feed and food shortages in the world.

Reduced Production Costs

Labor and machinery are very important inputs in modern agriculture, especially under the conventional tillage system of seedbed preparation. The rising machinery and fuel costs during the last few years hampers the farmer. The farmer, in order to plant his crops and obtain satisfactory yields, has to spend much money for machinery, fuel, labor, and herbicides to control weeds in his field. The farmer needs to go through many tillage operations and most of these require a separate trip over the field.

In contrast to the conventional system of planting, the no-tillage system requires less labor and machinery. One trip is required to plant the seeds and to apply the required fertilizer and one trip to apply herbicides for weed control. This system can save time and money for the farmer and thus reduce the cost of production. According to Moody et al. (33) the comparison of conventional methods and sod planting reveals several advantages in favor of the latter. These include improved soil and water conservation, reduced labor and machinery requirements, and frequently, increased yields of grain and/or stover. Welch et al. (50) concluded that fewer tillage operations are needed for sod-seeded grain crops than for conventional tillage.

Grain and Forage Production

Elder and Tucker (18) concluded that most crop systems in practice include a minor crop with a short growth period. A combination of wheat and bermudagrass would include the two major crops planted in Oklahoma. They reported that in early studies over-seeding wheat, oats, and rye in bermudagrass on the Heavener research station needed forage was produced, and high grain yields were obtained.

Welch et al. (50) reported that satisfactory forage and grain yields were obtained from a 3-year study comparing rye grain and "Coastal" bermudagrass forage yields with cropping systems of Coastal only, rye only (conventional seedbed), and Coastal-rye (rye seeded in Coastal).

In the literature there are many reports of the production of forage and grain from no-tillage systems. Compared to conventional tillage, this system has many applications for the farmer. He can graze the land with animals when the main crop is not in the field and in so doing can reduce the expense of buying animal feed, or the forage can be harvested and sold.

No-Tillage in Relation to Yield Increase

The ultimate goal for any agricultural research program is increasing crop yields to meet the increasing human population and its food requirements. Improving the quantity and quality of agricultural products is the most important aim of plant breeders, crop physiologists, farmers and world governments throughout the history of agriculture on earth. Considerable research has been conducted to evaluate the efficiency of the no-tillage system. Welch et al. (50) found that the grain yields of sod-seeded rye were not significantly different from conventionally seeded rye from either the 1964 or 1965 seasons, but there was a trend in both years toward higher yields of rye grain in sod-seeded culture in response to increased levels of nitrogen. Average grain yields in 1964 were 20.5 and 19.1 quintals per hectare for Coastal-rye and rye only, respectively. In 1965, average yields were 10.4 and 9.7 quintals per hectare for Coastal-rye and rye only, respectively.

Jones et al. (27) reported that in Virginia no-tillage system provided higher corn yields than conventional tillage.

Blevins et al. (9) planted corn in a paraquat-killed bluegrass sod as no-tillage and a plowed seedbed as a conventional system to compare the effect of the two systems on soil moisture. Corn yields were higher in all cases under no-tillage than under conventional tillage.

The requirements for higher yields under the no-tillage system have been expressed by Moody et al. (34). There are enough water and nutrients to support both crops and to give a chance to the main crop to overcome the competition from the sod in which it is planted. In general, the reason for the higher yields from no-tillage as compared to conventional tillage are the result of the improved soil and water conservation under this system. In addition, the costs of crop production are lowered.

Competition and Nitrogen Effect on Yield Under No-Tillage

One of the important factors that should be considered when applying the no-tillage system of planting is the type of competition which can occur between the main crop and the sod. Harlan (24) reviewed some aspects of competition in grassland agriculture. Competition for light is sometimes very important in grasslands. Some of the low growing forms such as Cynodon dactylon are not shade tolerant. Taller grasses will shade them out if growth is not controlled by grazing, mowing or burning. Harlan concluded that a major factor in the competitive capacity of a species is its ability to become established in competition with other plants.

Van den Bergh and Elberse (48) conducted an experiment to compare the production of two grass-seed mixtures (Dactylis glumerata L. and Agrostis temvis Sibth.) with the production of monocultures of the single species. They found that the mixtures neither outyielded the highest yielding monoculture, nor gave a more regular distribution of the dry matter production throughout the growing season. This was due to the differences in the growth habit and the height between the two species. It appeared that the species with the tallest tillers gains and this is primarily due to competition for light.

Besides the competition for light between the two crops there is a strong root competition for water and soil nutrients or what is called root competition between the main crop and the grass sod. This kind of competition can be detrimental to the expected yields from both the main crop and the grass sod. Eagles (16) studied the type of competition between natural populations of Dactylis glumerata. He included a comparison of monocultures and mixed cultures to provide a sensitive analysis of the effects of competition. From his experiment he concluded that root competition was the important factor in the development of the primary canopies. He summarized three mechanisms involved in root competition: (1) one population may exploit the nutrients in successive horizons in advance of the other, or it may absorb nutrients more efficiently, (2) one of the populations may use more of the available soil moisture than the other, especially in regions where the soil moisture is scarce, and (3) the difference in the amount of nodal root production between the two populations may be due to the ability of one species to withstand more root competition than the other species.

Root competition is detrimental to both the existence of the species in a mixture of species or when planted in grass sod and to the yield of the crop itself under this competition. The detrimental effect comes mainly from the competition for moisture and nutrients, especially nitrogen. Under the no-tillage system, moisture in the form of rain or supplymentary irrigation and nitrogen must be adequate for the sod and the main crop to get high yields or at least maintain yield at the level of conventional tillage. In field trials in 1966-1969, Debruck (14) found that wheat, barley and oats sown directly in ryegrass showed similar or higher yields than when sown after conventional seedbed preparation. Yields of all three cereals decreased with increasing rate of applied nitrogen under conventional cultivation and increased with direct sowing, except winter wheat in 1966, which gave the highest yields at the intermediate rate (70 kg N/ha). Seedling emergence after direct sowing was 74 and 75% in 1966 and 1967 (dry years) and 96 and 98% in 1968 and 1969 (wet years), compared with 64 and 85, 60 and 90%, respectively after conventional cultivation.

Robertson et al. (40) compared no-tillage planting of corn (*Zea mays* L.) in sod and small grain with conventional planting for three years on Lakeland fine sand. They found that corn yielded 3890 kg/ha of grain planted in Pensacola bahiagrass (Paspalum notatum Flugge) sod controlled by paraquat-atrazine at planting while conventionally planted corn yielded 5910 kg/ha. Adding an additional 168 kg/ha of nitrogen to no tillage corn increased grain yields to 6970 kg/ha.

Welch et al. (50) conducted a study to compare rye grain and bermudagrass forage yields with cropping systems of conventional seedbed and no-tillage. Five rates of nitrogen were added for rye (0, 45, 90, 135 and 180 kg/ha) and two levels of N were added to bermudagrass (225 and 450 kg/ha). They found that the grain yields were not significantly different between sod-seeded rye and conventionally seeded rye. There was a trend toward higher grain yields of rye in sod-seeded culture than in conventional culture at the higher N levels. Soil temperatures were recorded at the 5 cm depth. It was found that on plots which received 45 kg/ha of nitrogen the soil temperature was higher than that for plots which received 180 kg/ha of N because of the higher light intensity reaching the ground on the plots which received 45 kg/ha of N. When the soil temperature is high, the dormancy in bermudagrass will be broken earlier in the spring if the level of N is low.

In 1967 on the Muskogee station, Elder and Tucker (18) found that 41 bushels per acre of wheat were obtained from overseeding on sod which had 80 lbs/acre of nitrogen. Where no nitrogen was applied, the yield was 17 bushels per acre. Elder and Tucker conducted their wheat studies at four stations, Muskogee, Perkins, Altus, and Mangum. Rye was included on the Perkins and Mangum stations. Variety tests with wheat, rye and oats were conducted. They found that nitrogen rates of 90-120 pounds per acre increased forage production but lowered grain weights in wheat. Sixty pounds per acre of nitrogen was found to be sufficient for maximum grain yields. Yields were very low on the check plots.

The effects of nitrogen on wheat as a main cereal crop in the world are varied and can be expressed through different stages of the life cycle of the plant up to its main effect on the final stage, which is yield.

Khadr and Kassem (28) studied wheat response to nitrogen. In this study, 0, 20, 40, or 60 kg/acre of N were applied to 4 cultivars and 4 strains of wheat varying in maturity and height. They found that yield per plant, ear yield, ear number, and 100-grain weight were all increased linearly by an increase in applied nitrogen. Application of 20, 40, and 60 kg/acre of nitrogen increased yield per plant by 93, 185 and 197%, respectively, increased ear yield by 79, 135 and 162%, respectively and increased ear number by 36, 71 and 83%, respectively, in comparison with the control.

In an experiment in 1967-68 and 1968-69 Bathkal and Patil (6) studied the response of wheat to nitrogen fertilization. They found that increasing rates of applied nitrogen from 50 to 150 kg/ha increased average grain yields. Grain yield increase was due to an increase in the number of productive tillers per unit area and 1000-grain weight.

The effect of nitrogen application on plant survival is discussed by Cavallero (12) in his experiments of the effect of nitrogen application on wheat and its relation to seeding rates. In his field trials at Vercelli, Italy, in 1966 to 1968, wheat cultivar Argelato was sown at 140, 180 or 220 kg/ha of seed and 0, 60, 90, 120 or 180 kg/ha of nitrogen were applied. Average straw and grain yields were not affected by the seeding rate but increased from 4.25 tons/ha without

N to 6.71 tons/ha with 180 kg/ha of nitrogen applied. Increase in both N and seeding rate increased the number of plants, culms and spikes per square meter and increasing the nitrogen rate increased the number of secondary culms and the weight and number of grains per spike, while these factors decreased with increased seeding rate. Finally he concluded that application of nitrogen increased plant survival and this conclusion is in agreement with that of Mathias et al. (31).

Date and Rate of Seeding Under No-Tillage

Under the no-tillage practice, over-seeding a cereal grain crop in grass sod is a popular practice in Oklahoma and some other states in the United States. The meaning of overseeding in this case is the use of heavy seeding rates of the cereal crop on the sod which is already established in the field. These heavy seeding rates are applied to overcome the interference from the sod with the main crop and to increase the number of plants per unit area since tillering is reduced in the sod.

Combined with heavier seeding rates, the date of seeding of the main cereal crop is very important to give optimum grain yields. The effect of seeding date is clearly noted on the winter survival of the plants, seedling emergence and ultimately flowering time of the plants. Fisher and Kohn (21), investigated the effect of different seeding rates, different seeding dates and 3 nitrogen levels on wheat. They found that heavy seeding rates reduced yields (under conventional tillage) compared to lighter rates. Grain yields were depressed by nitrogen applications due to increased vegetative growth. They noted a significant reduction in spikelets per head in thicker stands.

Each week's delay in the time of seeding, and in turn each corresponding 2-day delay in the time of flowering, resulted in an average grain yield reduction of 2 bushels per acre.

Agarwal et al. (2) found that under the conditions of their experiment a certain date and rate of seeding, combined, gave the highest wheat grain yield.

Ramakrishnan and Kumar (37) conducted an experiment in which wheat and bermudagrass were grown in pure cultures at the rate of 20, 200, 400, 800, 1600 and 3200 plants per square meter. They used mixed cultures at a constant total density of 1000 plants/m^2, but of various proportions of the two species. The mixed cultures at three density levels for wheat and bermudagrass in plot experiments had a low density of 100 plants/m^2, a medium density of 200 plants/m^2 and a high density of 400 plants/m^2, in all possible combinations. In the presence of wheat, bermudagrass was depressed since the cereal assumed partial dominance due to its larger size and different growth habit. At high densities of wheat, bermudagrass remained depauperate, setting very few seeds per plant. The nutrient uptake by the two species was influenced both by intra- and interspecific competition.

From the studies mentioned above and according to Donald (15), the strong competitive ability is advantageous against other species such as weeds, but it will lead to intensified and heavy mutual depression among the crowded plants in a monoculture due to increased competition between the plants of the same species. Borojevic (10) pointed out the importance of planting density in relation to yields. He suggested that the optimum planting density is the one that gives 600-700 tillers per square meter for two spring wheat varieties (Sava and Libellula) grown in Yugoslavia. He also reported a negative correlation between grain yield and planting date.

Elder and Tucker (18) studied the effect of planting date and seeding rate of wheat in bermudagrass sod. They found that 90 pounds per acre seeding rate was sufficient to give high wheat yield. The best date of planting under the conditions of their experiment appeared to be in October.

In general, heavier seeding rates may be required under the no-tillage system of planting compared to the conventional system to obtain good stand uniformity, to withstand the interference of the sod, to give higher seedling emergence and ultimately higher yields because some of the planted seeds do not germinate and can not establish themselves in the sod.

Photosynthetic Area Above the Flag-Leaf Node and Its Contribution to Grain Yield

In wheat, as the plant grows, more of the above-ground parts contribute to the plant and to make its final form. The last developing parts are the above flag-leaf node parts, including the peduncle, the uppermost internode of the stem, the flag-leaf, the uppermost leaf of the plant, and the spike or the floral parts of the plant.

For the grain yield of the crop, the importance of each plant organ is determined by the amount of photosynthate that it contributes to the developing grain and finally its contribution to the total grain yield. The amount of the photosynthate transmitted to the grain from the different green parts of the shoot comes mainly after ear emergence. This contribution depends on many factors, such as the number of leaves, leaf area, leaf area duration, and the position of the leaf in relation to sunlight. In addition to the leaves, many other parts of the shoot system, such as the stem and the spike, contribute considerable amounts of assimilate to the grain.

The cereal plant parts which contribute the most for the grain filling are those parts above the flag-leaf node. In a study to detect the amount of assimilate contributed by the flag leaves and the ears, Thorne (45) used different spring wheat and barley varieties. She measured the gas exchange of the ears and the flag leaves, including the peduncle, between ear emergence and maturity. She found that the gas exchange of these organs during this period accounted for most of the final grain dry weight. The CO_2 fixed by the wheat ear was equivalent to between 17 and 30% of the grain weight. The amount of assimilate contributed by the flag leaf and the peduncle was found to be equivalent to 11-20% of the final grain weight. In barley, Thorne found that photosynthesis in the flag leaf and the net CO_2 uptake by the ear each provided about half of the carbohydrate in the grain.

Evans and Rawson (20) measured the rates of photosynthesis and dark respiration of the ears and flag leaves of three wheat varieties throughout the period of grain development. From this study they found that ear photosynthesis contributed up to 76% to total grain requirements during early growth. Their conclusion was that photosynthesis by the ear and flag leaf blade alone could meet the needs of the ear at all times.

In a detailed study of the movement of carbohydrates during the development of the wheat plant, Rawson and Hofstra (39) supported

Thorne's view.

The importance of the flag leaf area for the grain filling and to the total grain yield arises from the fact that this leaf is generally the last leaf that remains green and healthy as the other leaves are senescing.

Spiertz et al. (42) studied the relation between green area duration and grain yield in some varieties of spring wheat. They found that green area duration for flag leaf and for peduncle were closely correlated with grain yield; the combined value for the two parameters was found to account for 81 and 61% of the variance in grain yield in 1967 and 1968, respectively. Including all the values of the green-area duration in a multiple correlation increased the predictive value to 83 and 74%.

In another report, Thorne (46) reviewed the association between the morphological characters and the yield of cereal crops. She concluded that grain yield of cereals was closely related to the photosynthetic area above the flag leaf node.

Simpson (41) reported high positive correlation coefficients between grain weight and the variables flag leaf lamina area, head area and total photosynthetic area above the flag leaf node of 0.840, 0.911 and 0.928, respectively.

The photosynthetic activity of the ear of the cereal plant comes mainly from the awns, glumes, and lemma. The awns start developing after the other floral parts have been laid down, beginning near the base of the spike. When initiated the awns grow very rapidly. Under arid conditions the awns are advantageous because they can reduce or delay evaporation from around the spikelets making a good microclimate

(33).

Rastogi and Singh (38) conducted an experiment to study the effect of awn clipping on grain development in durum wheat. They found that the removal of awns at 10 and 20 days after ear emergence significantly decreased grain yields and 1000-grain weight. They attributed the yield decrease to a reduction in photosynthesis.

Walpole and Morgan (49) in order to test for the amount of assimilate that the awn contributes to the barley grain used $^{14}CO_2$ either for the flag leaves or individual awns of barley ears at different times after anthesis. They followed the distribution of labeled assimilate to the individual grain. Substantial quantities of $^{14}CO_2$ assimilated by the awns did not become generally distributed within the ear but virtually all the labeled material was retained in the grain subtended by the treated awn. The results for the awn and the flag leaf were the same: $^{14}CO_2$ was transmitted to the grains. Their conclusion was that the size, duration, and photosynthetic efficiency of the awns are very important criteria for increasing grain yields.

The effect of awn photosynthesis was found in many studies to affect seed size. Teare et al. (44) measured net photosynthesis, respiration and transpiration in ears and flag leaves of awned and awnless isogenic lines of wheat by measuring the difference in CO_2 and water vapor concentrations between the incoming and outgoing air streams of an open cuvett system. They found that the amount of photosynthesis per ear was greater for awned than for the awnless isogenic lines. Net photosynthetic rates of ears were 20-26% of the flag leaves. Respiration rates were nearly two-fold greater in awnless and de-awned ears than in awned ears. Awn length was found to be positively related to seed size and total grain yield.

Under different experimental conditions the amount of photosynthate contributed by the ear, the awn, the flag leaf and the peduncle to the grain may take different values according to the procedure followed to measure this amount of assimilate. But the general conclusion that can be safely stated is that photosynthesis by these organs contributes the major part of the grain.

The Relation Between Grain Yield and Its Components

Grain yield in cereals is a result of a complex interaction between three factors, the number of spikes per unit area, number of grains per spike, and weight per grain. The interaction between these three components is so complex that an increase in one of them may result in a decrease in one or the two other components. The effect of these three components is mainly due to genetic factors but can be affected to a lesser degree by seeding rates, fertilizer application, and the environmental conditions prevailing in the area. Different varieties may produce all high yields but due to different yield components.

As early as 1923, Engledow and Wadham (19) divided yield into its component parts. Characters such as the number of plants per unit area, number of spikes per plant, number of grains per ear, and weight per grain were considered as the units from which high yield might be developed. But the problem with this suggestion is that selection for all of these component parts is nearly impossible and research indicated that selection for these characters did not result in higher yields. Donald (15) reviewed the effect of the number of plants per unit area as a yield component and concluded that in a field crop each plant suffers intense competition from its neighbors. Its yield is 10-20% less than the yield of an isolated plant. He considered the yield per plant as one of the factors for a genotype to yield well in a community.

The importance of the components of yield differs from one variety to another and from one environment to another. Austenson and Walton (3) and Jain et al. (26) considered ear number per plant as the most important component of grain yield in cereals.

Nass (36) conducted a 2-year study on 22 cultivars of spring wheat to investigate the contribution of the yield components. He found that yield per ear and number of ears per plant reduced yield variance the most in stepwise regression analysis. In this study kernels per ear and yield per ear were associated with yield per plot.

Hsu and Walton (25), in an extensive study using five spring wheat varieties with the F_1, F_2, and backcross progenies of a complete diallel set of crosses between them, studied the relationship of grain yield with its components and the morphological structures above the flag leaf node under both field and greenhouse conditions. They found that the simple correlation between yield per plant and three primary components (number of ears per plant, number of kernels per ear, and 1000-kernel weight) were consistent for the trials in the greenhouse. The correlation between yield per plant and 1000-kernel weight was found to be not significant. There was a negative correlation between ear number and 1000-kernel weight. They concluded that ear number per plant was the most important component of grain yield.

Fischer and Kohn (21) found a correlation coefficient between grain yield and grain number per spike of 0.966.

Lupton and Ali (30) reported that the 1000-grain weight increased significantly with the increase in the number of grains per ear or spikelets per ear.

In general, the contribution made by each of the yield components to the total grain yield differs from one variety to another and a balanced interaction between these components is an important criterion for selection for higher yields. It is also the factor that determines the seeding rate and fertilizer application rate. Donald (15) in his essay about the wheat idiotype reached a conclusion that the capacity of a genotype to yield well in a community can be analyzed in terms of two parameters, namely (a) the yield per plant in the absence of competition from neighbors, and (b) its response to crowding among other plants of like genotype. In a crowded field of a cereal crop, an interplant competition for nutrients, moisture and sunlight will cause a low number of tillers per plant. In this case, logically, the number of spikes per plant will be reduced but the number of spikes per unit area will be increased. In contrast with low seeding rates, the number of plants per unit area will be lower but the tillering per plant will increase because of the elimination of the interplant competition.

Similar competition happens between the florets of a cereal spike. In a spike with large number of florets and accordingly high number of kernels, a competition between these kernels for the photosynthate will take place which might result in lower grain weight but a large number of seeds per spike.

In consideration of these points, a compensation or balance between grain yield components, optimum seeding rates, and optimun fertility levels combined with the genetic yield potential of the plant will give the grain yields expected from a cereal crop.

CHAPTER III

MATERIALS AND METHODS

This study was conducted at the Agronomy Research Station, Stillwater, Oklahoma, in 1972-73 and 1973-74 seasons. The wheat variety was Danne, a hard red winter wheat variety developed by the Oklahoma Agricultural Experiment Station and named for the late Mr. Joseph Danne, a private wheat breeder.

The grass sod was Midland bermudagrass which is characterized by a low competitive ability when grown in mixture with other grass species.

In the 1972-73 season two dates of planting were used: September 15 and October 1. In the 1973-74 season three dates of planting were used: October 19, October 26 and November 2. The four nitrogen rates in both seasons were 34, 68, 102 and 136 kg/ha of actual nitrogen in the form of ammonium nitrate applied as a topdressing. The three seeding rates used were 68, 102 and 136 kg/ha of wheat seeds.

Precipitation during both seasons at Stillwater was above normal.

Design and Field Layout

The experimental design used for this study was a randomized complete block design with four replications. Each replication contained 24 plots in the 1972-73 season and 36 plots for the 1973-74 season. The plots were each 12 m long and 3 m wide. Ten rows per plot were planted with a distance of 30 cm between rows.

All plots were planted with a drill used for planting wheat where stubble mulching is practiced.* The seeds were placed 2.5 cm deep in the soil in the established bermudagrass sod.

Nitrogen in the form of ammonium nitrate was applied December 28, 1972, for the 1972-73 season and January 29, 1974, for the 1973-74 season.

Characters Evaluated and Sampling Procedures

Grain yield, number of tillers per unit area, flag leaf blade area, peduncle length, peduncle weight, chaff weight, percent grain protein, total protein production, number of kernels per spike, and weight per 200 kernels were the ten primary variables investigated in this study.

Grain yield was determined by harvesting each plot separately with a standard farm combine and weighing the grain yield per plot. Harvesting was done the same day for all plots in the experiment. The date of harvesting was June 5, 1973, for the first season and June 8, 1974, for the second season.

Number of tillers was determined on the basis of tillers bearing spikes. Three square meter areas were assigned at random in each plot and the number of fertile tillers was counted in each of these three meter areas. The average number of tillers per square meter was determined from the average of the three samples.

Flag leaf blade area was calculated from 10 flag leaf samples taken at random from each plot and the average of these ten leaves was expressed in square centimeters and taken as flag leaf area. The flag

*John Deere L. Z-B hoe type drill, equipped with spear points.

leaf samples were taken on April 27, 1973, for the first season and on May 1, 1974, for the second season. The area of the samples was measured for each plot separately on the "Automatic Area Meter"* which is a photoelectric apparatus that measures the total area of the test object by means of detecting how much the test object shades the scanning light beam.

Peduncle length and weight were determined from a sample of 10 stems per plot taken at random when the peduncle turned completely yellow. The 10 stem samples were cut from the base of the last internode (flag leaf node), measured for length, dried in the oven for 48 hours under a temperature of 40°C and then the weights were taken and expressed in mgs/stem.

Number of kernels per spike was obtained from the average of 10 spikes per plot. The spikes were taken at random five days before harvesting, threshed by hand and the number of kernels from the ten spikes was counted and the average was taken as the number of kernels per spike.

Chaff weight was obtained from the spike samples taken for determining number of kernels per spike. After threshing the ten spike samples from each plot the chaff was separated from the kernels by hand and weighed. Chaff weight consisted of the glumes, lemma, palea, and awns. The rachis was excluded. The average weight of chaff per spike was determined and expressed in mgs/spike.

Weight per 200 kernels was determined after harvesting the plots. Samples of 200 normal unbroken kernels were taken at random from each

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*Manufactured by Yen Enterprises, Inc., Japan.

plot and the weights were taken and expressed in grams/200 kernels.

Grain protein content was expressed in the Oklahoma State University Wheat Quality Laboratory. A one gram sample of grain from each plot was taken randomly. These grain samples were then cleaned to remove any foreign materials. To determine the percent grain protein, the whole grains were used instead of grinding the samples. The macro Kjeldahl method with Winkler modification was used to determine percent grain protein.

Total grain protein production was determined as the product of grain yield in kg/ha x percent grain divided by 100 and expressed in kg protein per hectare.

Statistical Analysis

The statistical analysis was run separately for each of the two seasons in the Oklahoma State University Computer Center on the IBM 360/65 Computer. Analysis of variance and cross product analysis were conducted to determine the correlations between each of the ten variables. The coefficient of correlation between two variables X and Y is determined from the formula:

$$r_{XY} = \frac{\Sigma xy}{\sqrt{\Sigma x^2 \Sigma y^2}}$$

where Σx^2 is the error sum of squares of the deviations of the variable x, Σy^2 is the error sum of squares of the deviations of the variable Y, and Σxy is the error sum of products of the deviations of X and Y.

CHAPTER IV

GENERAL RESULTS AND DISCUSSION

In the 1972-73 season, a large scale weed infestation resulted in nonuniform stands of the wheat plants and high coefficients of variability. Some of the plots gave zero yield due to the high competition from both the bermudagrass sod and the weed population.

In both seasons during which this study was carried out the wheat plants were infected by leaf rust, but the infection during the 1972-73 season was more severe than that in the 1973-74 season. This infection was uniform, and the effect of the rust was not considered as a major factor in the high coefficients of variability for grain yield and the other evaluated variables.

Effect of Nitrogen, Planting Date and Seeding Rate

The analysis of variance (Table I) shows that in the 1972-73 season the nitrogen levels used did not significantly influence yield. This may have been due to the heavy rainfall during that season, resulting in nitrogen loss by leaching. However, flag leaf blade area (Table II) was significant at the 0.05 level of probability. On the other variables measured, nitrogen had no significant effect.

Grain yield along with its three components, tiller count, number of kernels per spike and the 200-kernel weight were influenced by

TABLE I

MEAN SQUARES FOR GRAIN YIELD, YIELD COMPONENTS, GRAIN PROTEIN AND TOTAL PROTEIN PRODUCTION OF A HARD RED WINTER WHEAT VARIETY (1972-73 SEASON)

Source of Variation	d.f.	Grain Yield	Tiller Count	Kernels per Spike	Kernel Weight	Grain Protein	Protein Production
				Mean Squares			
Replications	3	3754080.0**	634213.15**	74.25	5.47	12.97	30882.98**
Nitrogen Level	3	320256.1	89468.17**	33.08	2.37	1.57	2781.20
Date of Planting	1	11188975.3**	4092004.17**	345.04**	7.14*	3.30	77654.23**
Rate of Seeding	2	229217.6	210020.57	11.20	0.37	0.33	2306.90
Nitrogen X Date	3	509923.5	59628.08	40.01	2.44	1.09	3353.48
Nitrogen X Rate	6	125830.1	36996.81	48.45	1.77	4.04	1489.18
Date X Rate	2	90084.8	5675.64	11.32	0.73	1.64	877.79
Nitrogen X Date X Rate	6	410614.5	68952.43	74.96	1.94	3.15	3203.86
Error	69	286413.3	87130.63	40.88	1.60	3.52	2438.72
C.V.%		61.80	52.70	26.55	20.94	14.46	65.89

*Significant at the 0.05 level of probability
**Significant at the 0.01 level of probability

TABLE II

MEAN SQUARES FOR THE PHOTOSYNTHETIC STRUCTURES ABOVE THE FLAG-LEAF NODE OF A HARD RED WINTER WHEAT VARIETY (1972-73 SEASON)

Source of Variation	d.f.	Flag-leaf Blade Area	Peduncle Length	Peduncle Weight	Chaff Weight
		Mean Squares			
Replications	3	93.58**	75.85*	12.55*	88.09
Nitrogen	3	24.46*	30.61	6.08	28.94
Date of Planting	1	38.93*	100.45*	10.52	167.98*
Rate of Seeding	2	1.64	0.77	0.88	13.76
Nitrogen X Date	3	10.41	22.94	7.38	27.06
Nitrogen X Rate	6	14.11	13.81	4.15	36.58
Date X Rate	2	18.29	6.01	2.00	5.14
Nitrogen X Date X Rate	6	12.54	25.12	5.23	53.23
Error	69	8.40	14.95	3.06	34.14
C.V.%		31.25	21.38	24.91	27.74

*Significant at the 0.05 level of probability

**Significant at the 0.01 level of probability planting dates (Table I). A highly significant difference also was found in total protein production due to planting dates. The effect of planting date was also observed on the photosynthetic area above the flag leaf node including flag leaf blade area, peduncle length, and chaff weight (Table II).

The rates of seeding used in this study did not influence grain yield or any of the other variables measured in 1972-73 and no significant interaction between any of the factors used was observed.

In the 1973-74 season, nitrogen was found to have a significant effect on tiller count, kernels per spike, kernel weight, and grain protein at the 0.01 level of probability (Table III).

The three dates of planting for the 1973-74 season were found to have no significant effect on grain yield and its components. Table IV shows that there was no significant effect from date of planting on the photosynthetic structures above the flag leaf node.

The three levels of seeding rates used in the 1973-74 season were found to have significant effects on grain yield, tiller count, protein production (Table III), and chaff weight (Table IV).

Also for the 1973-74 season there was no significant interaction between the three major factors used in this study (nitrogen, planting date and rate of seeding).

1972-73 Season

Grain Yield

The overall mean for grain yield was 865.9 kg/ha with a low value of 565.3 for 68 kg/ha nitrogen, planted September 15 at a seeding rate of 68 kg/ha. The highest grain yield was 1596.8 kg/ha from the treat-

TABLE III

MEAN SQUARES FOR GRAIN YIELD, YIELD COMPONENTS, GRAIN PROTEIN AND TOTAL PROTEIN PRODUCTION OF A HARD RED WINTER WHEAT VARIETY (1973-74 SEASON)

Source of Variation	d.f.	Grain Yield	Tiller Count	Kernels per Spike	Kernel Weight	Grain Protein	Protein Production
Replications	3	1187612.4**	663378.70**	123.56**	0.14	0.38	14322.24**
Nitrogen Level	3	351706.6	543966.80**	60.54**	0.63	2.59	5439.01
Date of Planting	2	176970.1	165542.80	0.33	0.23	0.30	2047.87
Rate of Seeding	2	865395.8*	492636.30**	22.33	0.29	1.03	9885.29*
Nitrogen X Date	6	253234.1	62814.90	14.31	0.23	0.21	2817.35
Nitrogen X Rate	6	131390.0	118381.20	4.51	0.10	0.62	1441.77
Date X Rate	4	59225.3	59456.80	7.85	0.07	0.74	940.87
Nitrogen X Date X Rate	12	112062.7	75592.10	11.86	0.09	0.20	1316.19
Error	105	249143.7	98480.70	11.29	0.11	0.47	2566.76
C.V.%		44.51	43.73	16.11	6.84	6.73	44.23

*Significant at the 0.05 level of probability.

**Significant at the 0.01 level of probability.

TABLE IV

MEAN SQUARES FOR PHOTOSYNTHETIC STRUCTURES ABOVE THE FLAG-LEAF NODE OF A HARD RED WINTER WHEAT VARIETY (1973-74 SEASON)

Source of Variation	d.f.	Flag-leaf Blade Area	Peduncle Length	Peduncle Weight	Chaff Weight
		Mean Squares			
Replications	3	148.35**	577.87**	115.81	117.42**
Nitrogen Level	3	14.51	30.60	6.11	22.02
Date of Planting	2	6.89	4.33	3.44	20.21
Rate of Seeding	2	0.48	1.77	17.25	71.46**
Nitrogen X Date	6	7.35	25.87	7.86	21.52
Nitrogen X Rate	6	9.02	40.01	11.80	13.06
Date X Rate	4	15.65	11.59	1.74	7.30
Nitrogen X Date X Rate	12	3.88	21.72	6.16	13.27
Error	105	7.16	21.46	63.22	11.59
C.V.%		26.42	17.02	28.07	21.08

**Significant at the 0.01 level of probability.

ment combination of 34 kg/ha nitrogen, planted September 15 at 68 kg/ha of seed (Appendix Table IX).

The effect of planting date is shown in Figure I. Average grain yield was 1207.3 kg/ha in the first planting date and declined to 524.5 kg/ha due to the second planting date (Table V). These results were in agreement with the strong negative correlation found by Borojevic (10) between grain yield and planting date in spring wheat. The effect of date of planting and seeding rate are shown in Figure 2-A. Although there was no significant interaction between the effects of the two factors on grain yield it is clear that the first date of planting (Sept. 15) gave higher grain yields with all three seeding rates when compared with the second planting date (Oct. 1).

From the analysis of variance, Table I, it can be observed that there was no significant interaction between the three nitrogen levels used in this study and planting date. But Figure 2-C shows that the first date was superior to the second date on all levels of nitrogen used. Grain yields were decreased due to the second date of planting with increasing nitrogen level. Yield increased from the first level of nitrogen to the second level and then declined with increasing nitrogen levels for the first date of planting. This may have resulted from the early breaking of the dormancy of the bermudagrass sod during the spring under the higher nitrogen levels: thus, increasing competition between the bermudagrass and wheat plants (Elder and Tucker, 18). With the first date of planting the results of this study indicated that 68 kg/ha of nitrogen is sufficient for maximum grain yields.

Increasing seeding rate under the conditions of this study

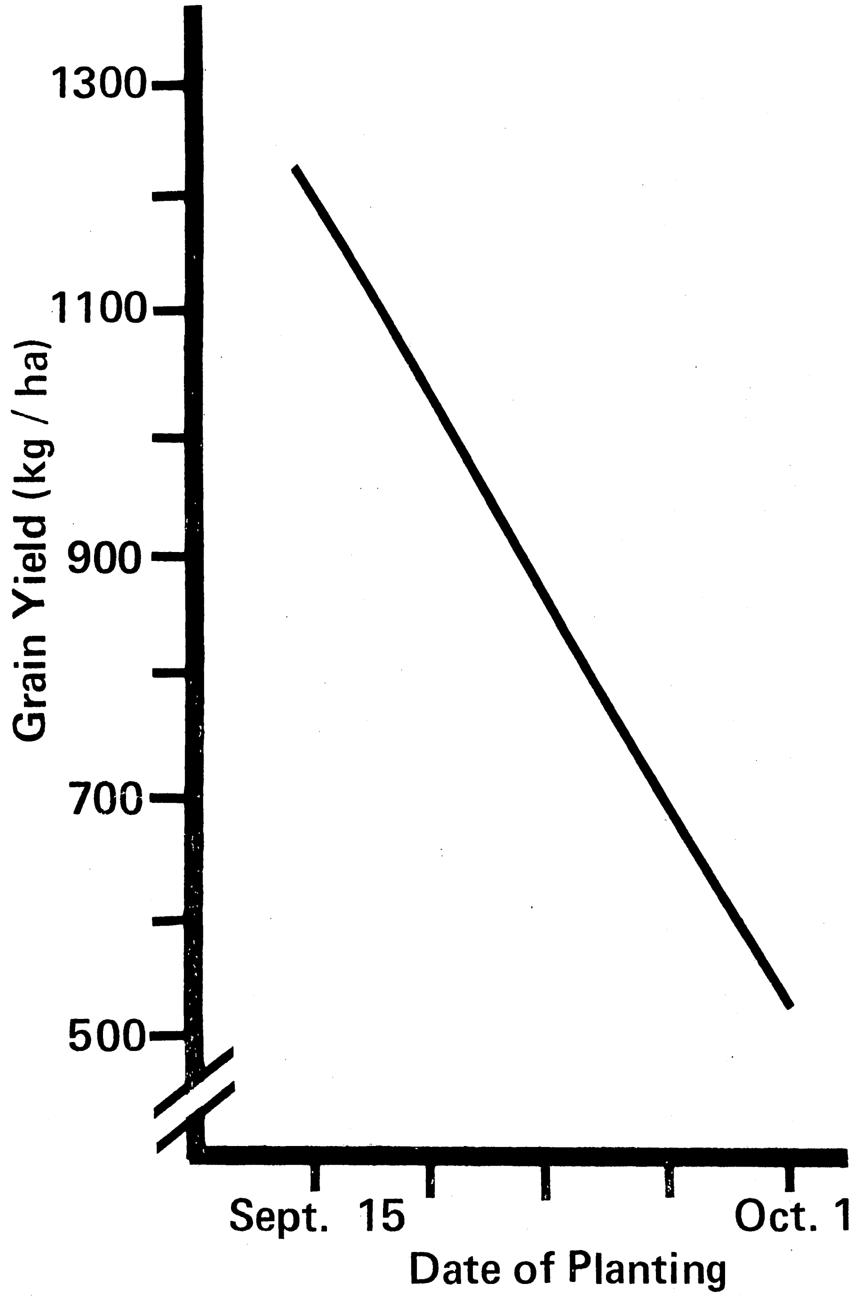

Figure 1. Response of Grain Yield to Planting Date (1972-73 Season).

TABLE V

MEANS* FOR GRAIN YIELD AND SOME OTHER CHARACTERS OF A HARD RED WINTER WHEAT VARIETY AS AFFECTED BY PLANTING DATE (1972-73 SEASON)

Date of Planting	Grain Yield (kg/ha)	Tiller Count (Til/m^2)	Kernels per Spike	Kernel Weight (gm)	Protein Production (kg/ha)	Flag-Leaf Blade Area (cm^2)	Peduncle Length (cm)	Chaff Weight (mg)
	Means							
Sept. 15	1207.3	766.6	25.97	6.32	103.38	9.91	19.11	22.39
Oct. 1	524.5	353.7	22.19	5.77	46.50	8.64	17.07	19.74

*Based on means of 48 observations each.

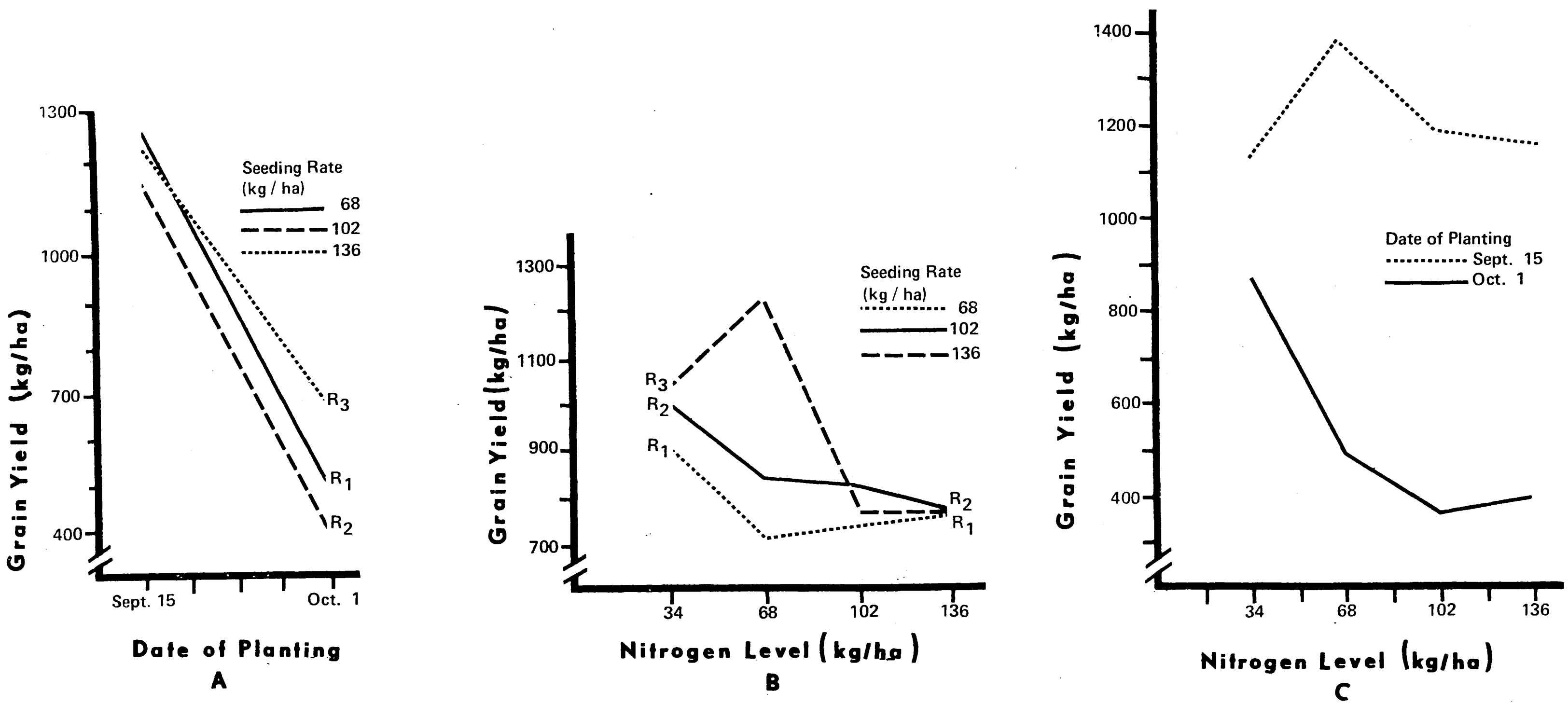

Figure 2. Response of Grain Yield to Planting Date and Seeding Rate, Nitrogen and Seeding Rate, and Nitrogen and Planting Date (1972-73 Season).

increased grain yield from 778.1 kg/ha with 68 kg/ha seeding rate to 947.1 kg/ha with the highest seeding rate (136 kg/ha). In general, increasing seeding rate increased grain yields. This can be attributed to a compensation for the loss that occurs due to nongerminating seeds and reduced competition from increased shading of the wheat plants on the grass sod. The effect of number of tillers/m^2 may be excluded in this case due to the absence of significant effect of seeding rate on this factor.

Although there was no significant interaction between nitrogen and seeding rate (Table I), the third level of seeding rate (136 kg/ha) gave the highest grain yield (Figure 2-B) when combined with 68 kg/ha of nitrogen and the lowest grain yields were obtained from the lowest seeding rate (68 kg/ha). A grain yield of 1218.2 kg/ha was obtained from the treatment combination of 68 kg/ha of nitrogen and 136 kg/ha seeding rate.

Yield Components

The effect of planting date on number of tillers per square meter is shown in Figure 3-A where the highest value of 766.6 tillers per square meter was obtained (Table V) with the first planting date and 353.7 tillers per square meter with the second planting date. The effect of planting date on number of kernels and the 200-kernel weight can be seen from Figure 3 (B and C) and from Table V where delaying planting date from September 15 to October 1 reduced the number of kernels per spike from 25.97 to 22.19 and reduced the 200-kernel weight from 6.32 gm to 5.77 gm. Under the conditions of the 1972-73 season, it is clear that delaying planting date reduced grain yield

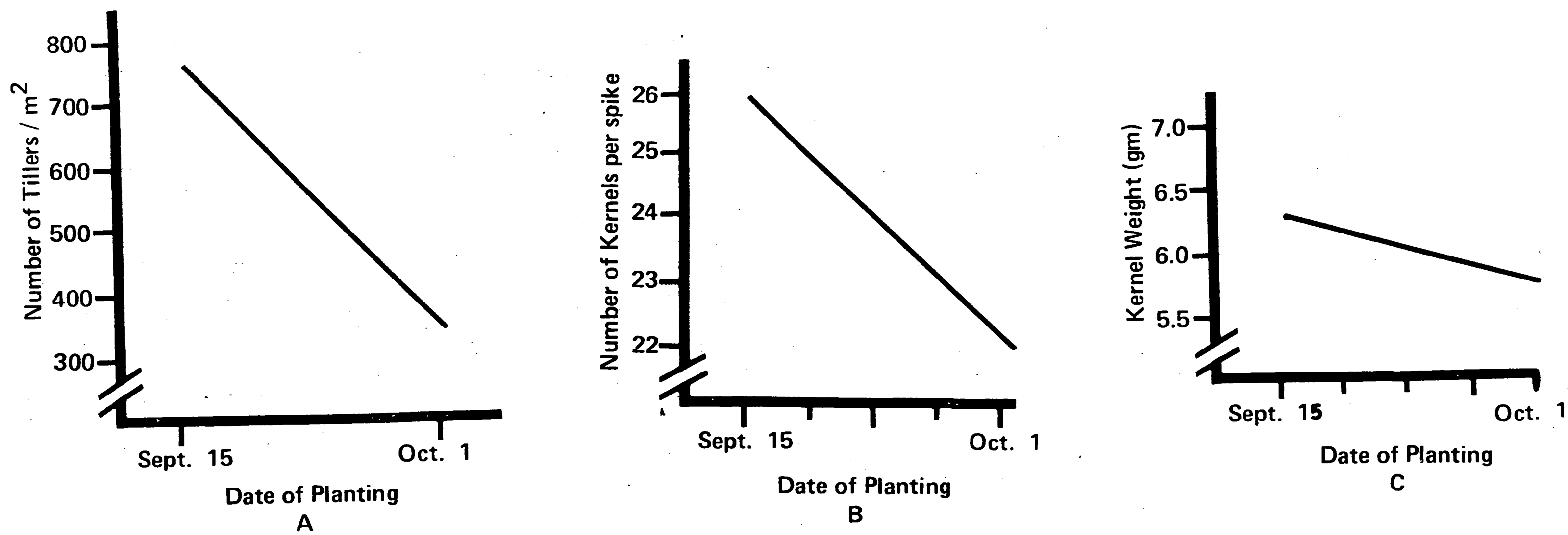

Figure 3. Response of Grain Yield Components to Planting Date (1972-73 Season).

through the effect on all yield components.

The correlation coefficients of grain yield and yield components are presented in Table VI. The correlation coefficient between grain yield and number of tillers per square meter was positive and highly significant (0.782) indicating the importance of the contribution of this component to grain yield. Because the number of tillers counted per square meter was on the basis of tillers bearing fertile spikes, the results of this study are in agreement with Borojevic (10) who found a positive correlation between grain yield and number of spikes per square meter. Austenson and Walton (3), Hsu and Walton (25), Jain et al. (26), and Simpson (41) found nearly the same results as that obtained from this study.

A positive and highly significant correlation was found between grain yield and number of kernels per spike (0.512) indicating the importance of this factor and its contribution to grain yield.

The correlation coefficient between grain yield and the 200-kernel weight was found to be positive and significant at the 0.05 level of probability. The importance of kernel weight for grain yield was reported by Nass (36) who found that kernel weight was closely related to yield per ear.

From the magnitude of the correlation coefficients between grain yield and each of its components the number of tillers per unit area can be classified as the most important component of the three, followed by number of kernels per spike, and kernel weight.

TABLE VI

SIMPLE CORRELATION COEFFICIENTS FOR GRAIN YIELD AND SOME OTHER CHARACTERS FOR A HARD RED WINTER WHEAT VARIETY (1972-73 SEASON)

Plant Character	Plant Character									
	1	2	3	4	5	6	7	8	9	10
1. Grain Yield	1	0.782**	0.512**	0.293*	-0.033	0.357**	0.380**	0.387**	-0.010	0.986**
2. Tiller Count		1	0.545**	0.416**	0.060	0.520**	0.491**	0.467**	0.438**	0.794**
3. Kernels per Spike			1	0.814**	0.305**	0.787**	0.873**	0.946**	0.808**	0.521**
4. Kernel Weight				1	.546**	0.885**	0.846**	0.848**	0.882**	0.285*
5. Flag-leaf Blade Area					1	0.435**	0.308**	0.311**	0.465**	-0.044
6. Peduncle Length						1	0.856**	0.788**	0.890**	0.356**
7. Peduncle Weight							1	0.883**	0.799**	0.375**
8. Chaff Weight								1	0.812**	0.394**
9. Protein Content									1	0.326**
10. Protein Content										1

*Significant at the 0.05 level of probability.

**Significant at the 0.01 level of probability.

Photosynthetic Structures Above the Flag-
Leaf Node

The analysis of variance, Table II, shows that nitrogen levels were significantly different in their effect on flag-leaf blade area. This was expected since increasing nitrogen levels usually increases vegetative growth of the plant. The results of this study indicated that flag-leaf blade area decreased from 9.4 cm^2 with the second and third nitrogen levels, respectively. With the highest level of nitrogen (136 kg/ha) the area of the flag-leaf blade increased to 10.6 cm^2 per single leaf. This fluctuation from the lowest to the highest levels of nitrogen may have resulted from the heavy leaf rust infection on the wheat plants late in the growing period. Also, a negative correlation coefficient (-0.033) was obtained between grain yield and flag-leaf blade area (Table VI). The destruction of the flag leaves late in the season would result in the inability of the flag leaves to produce the required photosynthate for grain filling. They would become parasites on the other photosynthetic structures, such as the head and the peduncle. Also, leaf size may be reduced as a result of increased plant population or the number of tillers.

Nitrogen levels used in this study during the 1972-73 season were not significantly different in their effect on the other photosynthetic structures evaluated in this study (peduncle length, peduncle weight and chaff weight). Table VI indicates that the correlation between grain yield and peduncle length was highly significant (r = +0.357); between grain yield and peduncle weight was also highly significant (r = +0.380); and between grain yield and chaff weight was +0.387 and highly significant. This indicates that spike photosynthesis and peduncle photosynthesis contribute to grain yield. These results were in agreement with the results obtained by Carr and Wardlaw (11), Evans and Rawson (20), Kriedmann (29) and Thorne (45).

Rate of seeding was found not to have any significant effect on the structures above the flag-leaf node (Table II).

A significant effect was obtained due to the difference between the two planting dates on flag leaf blade area, peduncle length and chaff weight (Table II). Figure 4 (A, B. and C) shows the effect of planting date on these three components. The second planting date resulted in a decrease of 1.27 cm^2 in the leaf area, a reduction of 2.04 cm in peduncle length, and a reduction of 2.65 mg of chaff weight when compared with the earlier date of planting (Table V).

Grain Protein and Total Protein Production

Percent grain protein was found not to be affected by nitrogen, planting date or seeding rate. No significant interaction was observed between any of these factors with percent grain protein.

The difference between the two dates of planting was found to be significant at the 0.05 level of probability on total protein production per hectare, and this can be attributed to the effect of planting date on grain yield.

1973-74 Season

Grain Yield

Grain yield for the 1973-74 experiment ranged from a high value of 1596.8 kg/ha to a low value of 565.3 kg/ha with an overall mean of

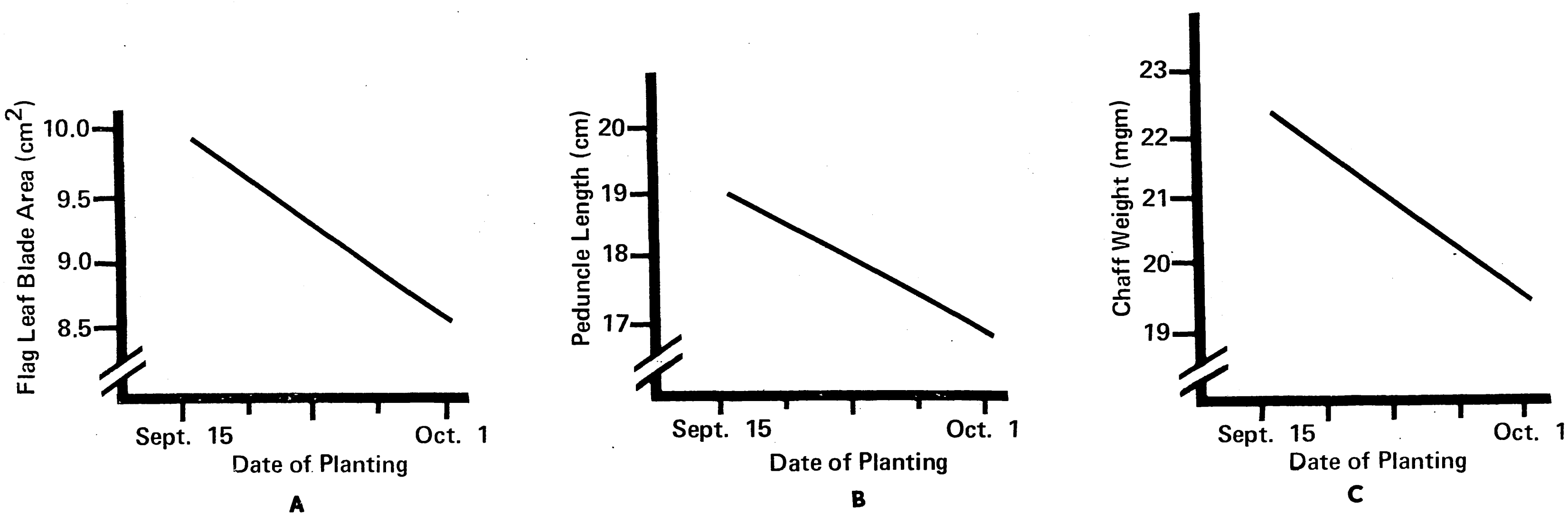

Figure 4. Response of Photosynthetic Structures Above the Flag-Leaf Node to Planting Date (1973-74 Season).

1121.4 kg/ha (Appendix Table XI). Analysis of variance, Table III, showed no significant effect of nitrogen on grain yield. The reduction in grain yield that was observed due to the second nitrogen level may be explained by the fact that a large number of plots having this treatment were located in unfavorable plot areas. The third and the fourth nitrogen levels did increase grain yields when compared to the first and second levels. These results were in agreement with those reported by Cavallero (12), Fischer and Khon (21), Khadr and Kassem (28) and Welch et al. (50).

Date of planting had no significant effect on grain yield as it can be seen from the analysis of variance, Table III. This result may be due to the relatively short intervals between plantings and the late planting dates used during this season compared to those used in the 1972-73 season. A seven day interval is not a large difference among the planting dates.

A significant difference was observed between the effects of the three seeding rates on grain yield (Table III). From Figure 5 it can be seen that increasing seeding rate increased grain yield for the three levels of seeding rate used for this study. An average grain yield of 968.7 kg/ha was obtained from 68 kg/ha of seed, 1174.7 kg/ha of grain from 102 kg/ha of seed, and 1220.9 kg/ha of grain yield was produced from a seeding rate of 136 kg/ha. Under the conditions of this study, increasing the seeding rate was important in compensating for late plant effects and for reducing the effect of the sod competition with the wheat plants. Donald (15) concluded that the individual plant within the community will express its potential for yield most fully if it suffers minimum interference from its neighbors. This minimum

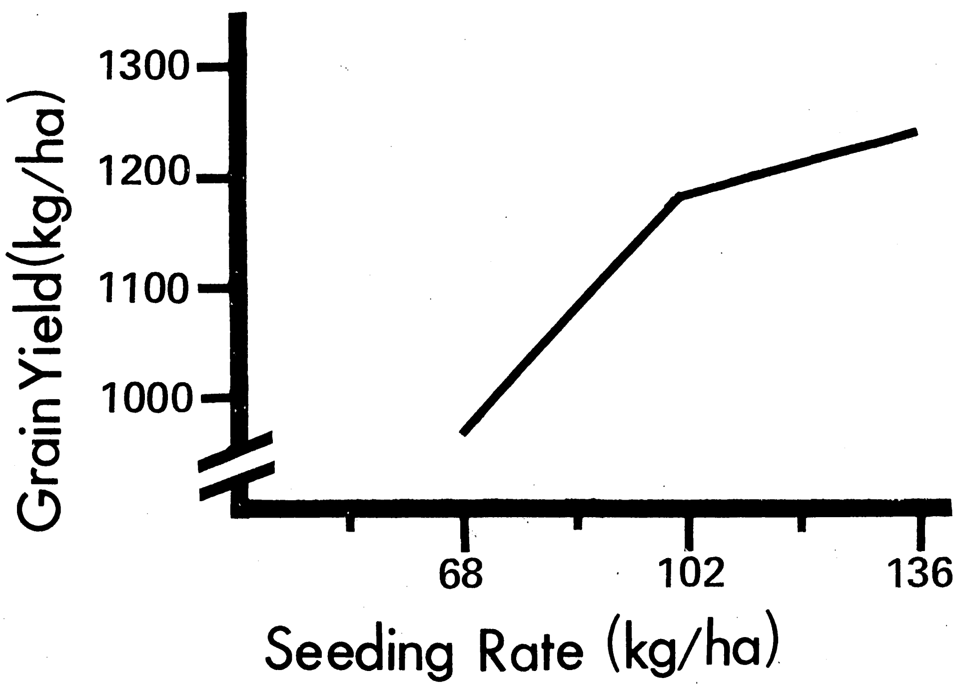

Figure 5. Response of Grain Yield to Seeding Rate (1973-74 Season).

interference should come from neighbors that are weak competitors. In other words, increasing seeding rates might result in increasing grain yields up to a limit where the competition between the plants of the same species will increase and cause yield depression. Under the limits of this study, the seeding rates did increase grain yields from the lowest to the highest rates. This may have been due to the effects of the high seeding rates on increasing the number of tillers per unit area, as will be discussed later.

No significant interaction was found among any of the factors used in this study (nitrogen, date of planting and seeding rate). But as can be seen from Figure 6-A, the highest grain yield was 1332.3 kg/ha from combining 136 kg/ha of nitrogen with the first date of planting. The lowest grain yield obtained was 832.6 kg/ha from 68 kg/ha of nitrogen and October 19 planting date. Figure 6-B shows the pattern of grain yield fluctuation due to nitrogen levels combined with seeding rates.

Figure 6-C shows the effect of date of planting and seeding rate on grain yield. The highest grain yield obtained due to the effect of these two factors was 1286.4 kg/ha from October 26 seeding date and the second level of seeding rate (102 kg/ha) and the lowest grain yield (882.6 kg/ha) was the result of the third date (November 2) and the first rate of seeding (68 kg/ha). The third rate of seeding (136 kg/ha) produced higher average grain yield than the other two rates on two of the dates, October 19 and November 2.

In general, when compared with the 1972-73 season, the 1973-74 season produced higher grain yields. An average grain yield of 1121.4 kg/ha was obtained from the 1973-74 season; whereas, the 1972-73 season produced an average grain yield of 865.9 kg/ha, a difference of 255.5

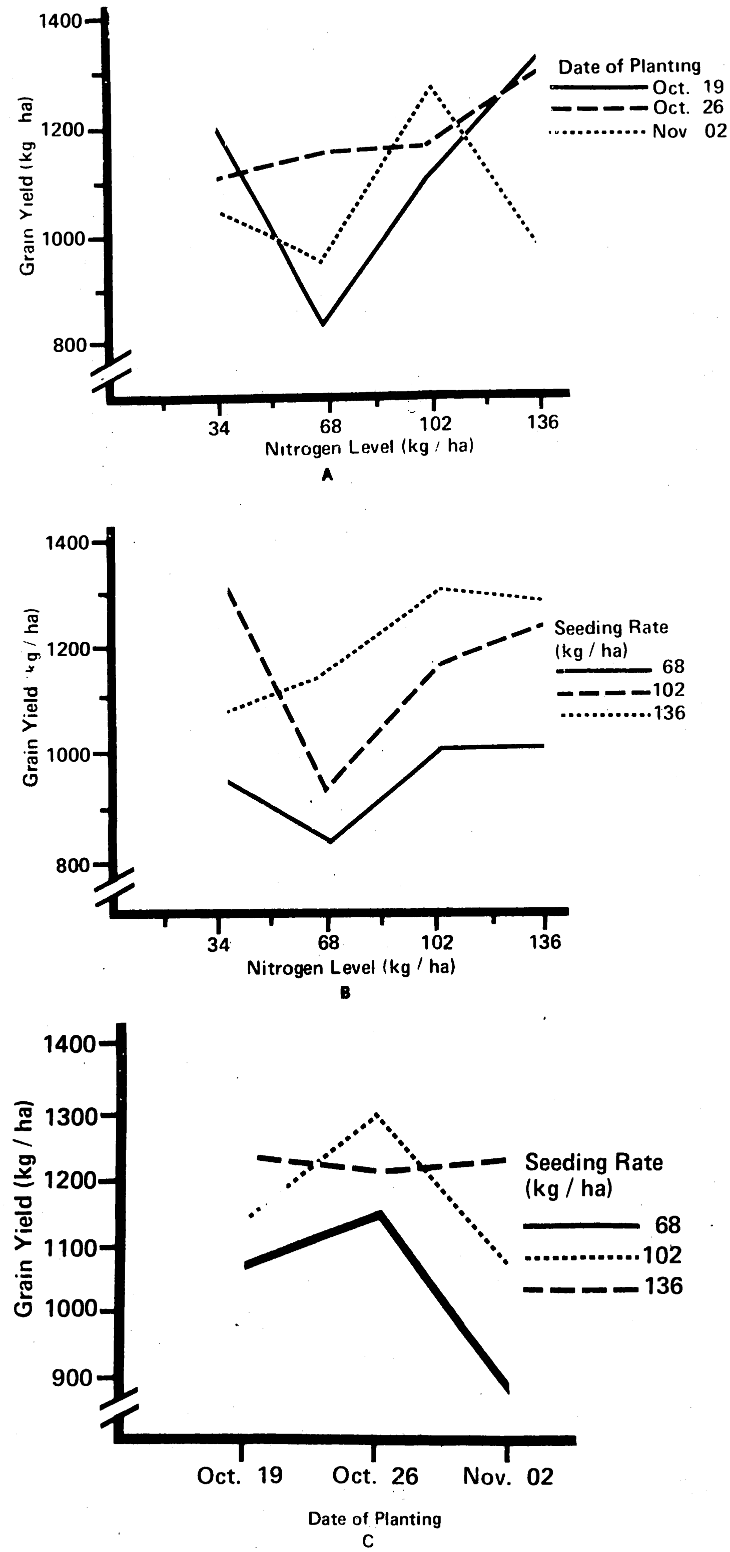

Figure 6. Response of Grain Yield to Nitrogen and Date of Planting, Nitrogen and Rate of Seeding, and Date of Planting and Rate of Seeding (1973-74 Season).

kg/ha. This difference in grain yield production may be attributed to two effects -- the heavy leaf rust infection observed on the wheat plants during the first season and some plots from the 1972-73 experiment produced zero grain yield which reduced the overall season mean.

Yield Components

A highly significant effect was found for nitrogen on all three major yield components (Table III). Table VII shows the average responses of the yield components to the three levels of nitrogen used in this study. The highest value of number of tillers per square meter obtained was 861.44 for 136 kg/ha of nitrogen, and the lowest value was 583.36 tillers per square meter obtained from 68 kg/ha of nitrogen. There was a trend for increased number of tillers per square meter due to increasing nitrogen levels if the second level of nitrogen is excluded (Figure 7-A). The effect of nitrogen on increasing number of tillers per unit area was also observed by Bathkal and Patil (6), Cavallero (12) and Khadr and Kassem (28). This effect may be explained on the basis of a decreased competition for nitrogen between wheat plants and the bermudagrass sod.

The effect of nitrogen on number of kernels per spike followed the same pattern as number of tillers per unit area (Figure 7-B). But in case of kernel weight the trend was reversed (Figure 7-C). Kernel weight decreased with increases in nitrogen level.

Date of planting had no significant effect on any of the grain yield components. But a highly significant effect of seeding rate on tiller count was found (Table III). These results reported herein support the view of Borojevic (10) who concluded that number of

TABLE VII

MEANS* FOR SOME CHARACTERS OF A HARD RED WINTER WHEAT VARIETY AS AFFECTED BY NITROGEN LEVEL (1973-74 SEASON)

Nitrogen Level (kg/ha)	Tiller Count (Til/m^2)	Kernels per Spike	Kernel Weight (gm)	Grain Protein (%)
	Means			
34	655.42	20.72	5.05	10.00
68	583.36	19.28	4.87	10.04
102	770.06	20.97	4.96	10.11
136	861.44	22.44	4.74	10.58

*Based on Means of 36 observations each.

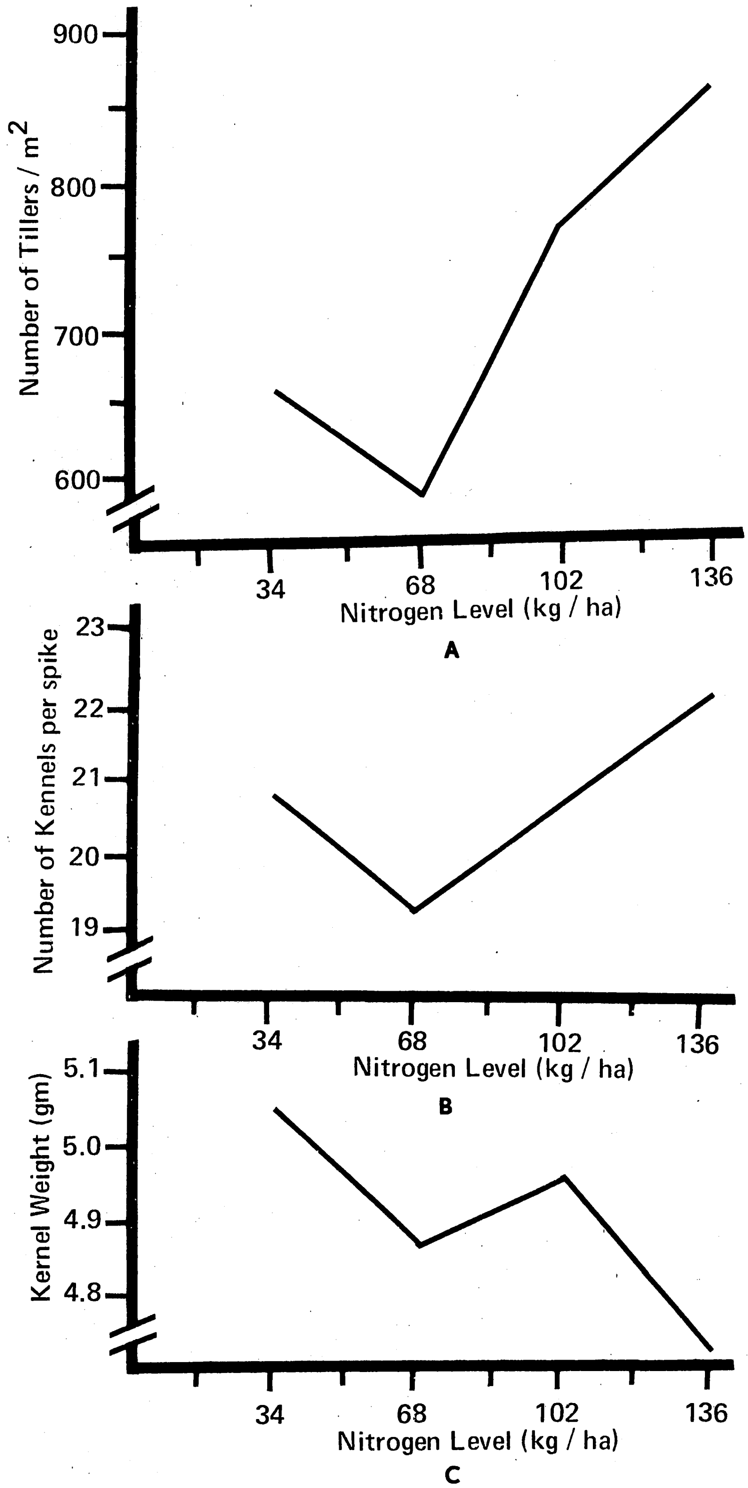

Figure 7. Response of Grain Yield Components to Different Nitrogen Levels (1973-74 Season).

tillers per unit area is a very important yield component. Figure 8 illustrates the effect of seeding rate on number of tillers per square meter. High seeding rates are very important for the establishment of a uniform stand of wheat plants when grown with other species such as bermudagrass. Also, tiller production per plant is reduced in the bermuda sod. Seeding rate was found to have no significant effect on any of the other two yield components.

No significant interaction existed between any of the three factors used on any of the three yield components.

The correlation coefficients between grain yield, grain yield components and some other characters are presented in Table VIII. Grain yield was found to be highly correlated with number of tillers per unit area (0.820), number of kernels per spike (0.363) and 200-kernel weight (0.284). These values of correlation coefficients and their magnitude indicate the importance of each component and its contribution to the total grain yield.

Tiller count was found to be highly correlated with number of kernels per spike with a correlation coefficient of +0.345. A positive but not significant correlation was found between tiller count and 200-kernel weight (+0.053). Another positive but not significant correlation was found between number of kernels per spike and 200-kernel weight. These results were in agreement with that reported by Borojevic (10), Fischer and Khon (21), Jain et al. (26), and Nass (36).

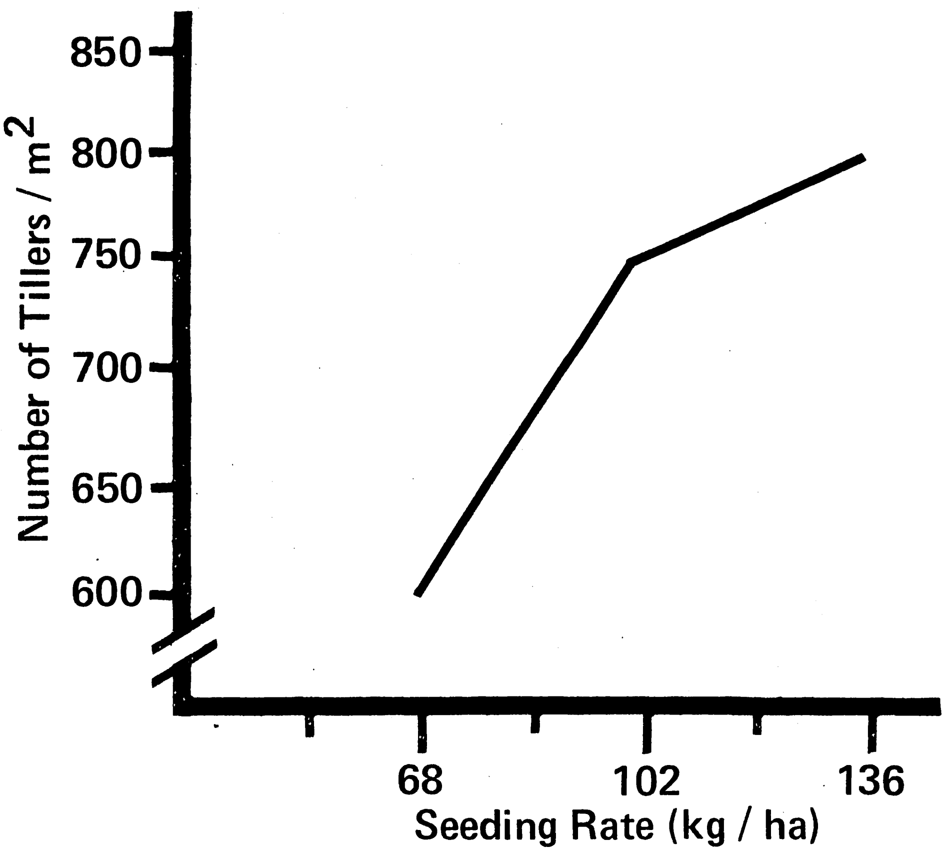

Figure 8. Response of Tiller Count to Seeding Rate (1973-74 Season).

TABLE VIII

SIMPLE CORRELATION COEFFICIENTS FOR GRAIN YIELD AND SOME OTHER CHARACTERS OF A HARD RED WINTER WHEAT VARIETY (1973-74 SEASON)

Plant Character	Plant Character									
	1	2	3	4	5	6	7	8	9	10
1. Grain Yield	1	0.820**	0.363**	0.284**	0.436**	0.560**	0.370**	0.194*	-0.027	0.987**
2. Tiller Count		1	0.345**	0.053	0.470**	0.509**	0.296**	0.145	0.151	0.837**
3. Kernels per Spike			1	0.163	0.446**	0.592**	0.732**	0.870**	0.166	0.367**
4. Kernel Weight				1	.179	0.216*	0.215*	0.204*	-0.284**	0.231*
5. Flag Leaf Blade Area					1	0.639**	0.593**	0.457**	0.129	0.447**
6. Peduncle Length						1	0.891**	0.622**	-0.137	0.527**
7. Peduncle Weight							1	0.844**	-0.085	0.345**
8. Chaff Weight								1	0.045	0.186
9. Protein Content									1	0.124
10. Protein Production										1

*Significant at the 0.05 level of probability.

**Significant at the 0.01 level of probability.

Photosynthetic Structures Above the Flag-Leaf Node

The three factors included in this study were found not to have any significant effect, when considered singly, on any of the photosynthetic structures evaluated except in the case of rate of seeding on chaff weight where it was found to be highly significant (Table IV).

Flag-leaf blade area ranged from a high value of 13.6 square centimeters to a low value of 5.9 square centimeters and the overall mean for the 1973-74 experiment was 10.13 square centimeters per leaf (Appendix Table XII). The effect of leaf rust was not as severe during this season as that observed for the 1972-73 experiment.

Date of planting did not affect flag-leaf blade area to any extent because the average values of this character were relatively constant from the lowest seeding rate to the highest level.

No interaction between any of the three factors used was found to be significant on flag-leaf blade area.

Peduncle length and peduncle weight were not affected significantly by any of the three factors. Peduncle length, relatively, was not affected to any extent by increasing nitrogen levels but decreased by late planting and was not affected by seeding rate.

Chaff weight was not significantly affected by increasing nitrogen level but an increasing pattern was observed from the low nitrogen levels to the higher levels. Date of planting, relatively, affected chaff weight. Late planting decreased chaff weight under the conditions of this season. Seeding rate was found to have a significant effect on chaff weight (Table IV). Figure 9 shows the decreasing pattern of chaff weight due to increasing seeding rate. Chaff weight

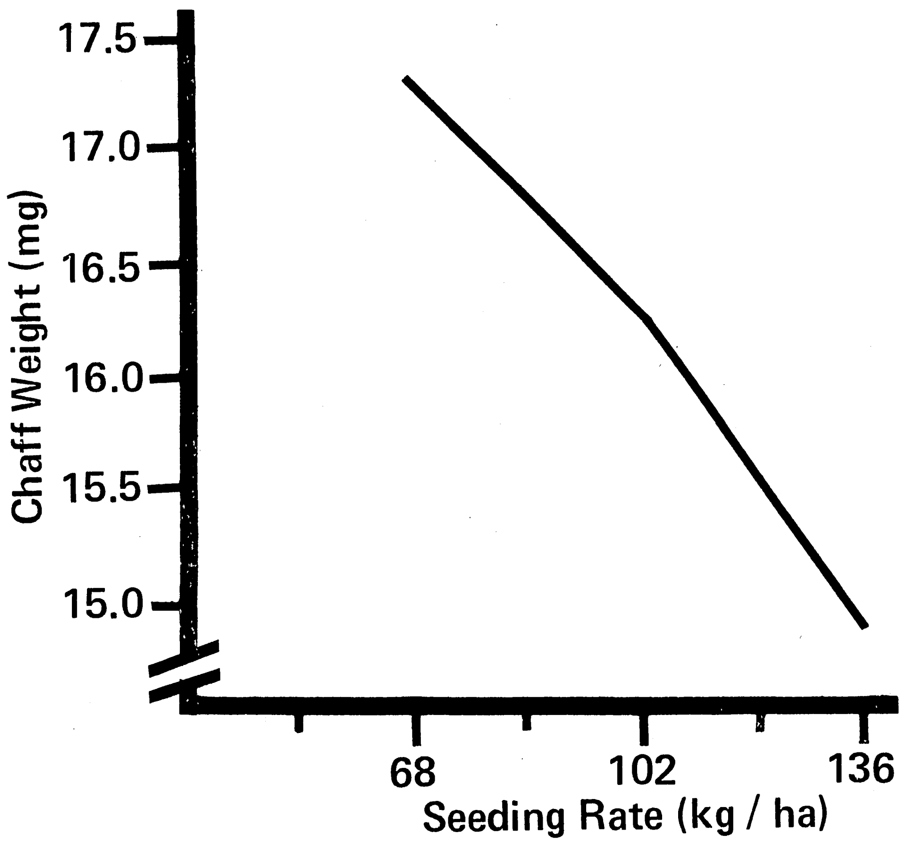

Figure 9. Response of Chaff Weight to Rate of Seeding (1973-74 Season).

ranged from 17.3 mg per spike for the lowest seeding rate to a value of 14.9 mg per spike with the highest level of seeding rate.

Table VIII presented the correlation coefficients of the characters evaluated during the course of this study. Flag-leaf blade area, peduncle length and peduncle weight were found to be highly associated with grain yield with correlation coefficients +0.436, +0.560, and +0.370 for each character, respectively. Chaff weight was found to be significantly (>0.05) correlated with grain yield with a correlation coefficient of +0.194. The magnitude of these correlation coefficients indicated that the amount of the photosynthate contributed by the peduncle was higher than any of the other structures above the flag-leaf node followed by flag-leaf blade and chaff weight in that order. The results reported herein agreed with those reported by Thorne (46).

Flag-leaf blade area was found to be associated with number of kernels per spike, with a positive and highly significant correlation coefficient (r = 0.446). According to this result, it appears that flag-leaf photosynthetic contribution was in support of the number of kernels per spike. Number of kernels per spike was also found to be closely associated with peduncle length (0.592) and weight (0.870). A significant positive correlation was found between kernel weight and peduncle length and weight and chaff weight.

Number of tillers per unit area was found to be highly correlated with flag-leaf blade area, peduncle length and peduncle weight.

From these results one can conclude that the flag-leaf blade contributes more photosynthate to the developmental structures of number of kernels per spike than it contributes to kernel filling, and kernel weight was more dependent on peduncle and head photosynthesis.

These results indicated the importance of all photosynthetic structures above the flag-leaf node to grain yield.

Grain Protein and Total Protein Production

Percent grain protein ranged from an average of 9.3% to 11% with an overall mean of 10.18%.

Nitrogen levels had a highly significant effect on percent grain protein. A value of 10.00% was obtained as a result of using 102 kg/ha of nitrogen, and an average of 10.58% was obtained from the highest nitrogen level used (136 kg/ha).

No significant effect was found from either date of planting or rate of seeding, and there was no interaction between any of these factors and percent grain protein. Averages of percent grain protein and total protein production were presented in Appendix Table XI.

Grain yield was found to be negatively associated with percent grain protein. A negative and highly significant correlation was observed between 200-kernel weight and percent grain protein. A positive but non-significant correlation was found between percent grain protein and number of tillers per unit area and between number of kernels per spike and percent grain protein.

Protein production per hectare ranged from 56.3 kg/ha to 161.6 kg/ha and the overall mean was 114.6 kg/ha. Total protein production depended mainly on the factors that affected grain yield and/or percent grain protein. Rate of seeding was the only factor that significantly affected total protein production per unit area where it was increased from 98.5 kg/ha due to the lowest rate of seeding to 119.1 kg/ha from the second seeding rate (102 kg/ha), and the third seeding rate produced an average of 126.0 kg/ha of total protein. In this case the effect of seeding rate on total protein production was the result of this factor on grain yield increase. No other applied factors, singly or combined, significantly affected total protein production. Protein production was closely related to grain yield, tiller count, kernels per spike, flag-leaf blade area, peduncle length and peduncle weight. Kernel weight was significantly correlated to protein production.

CHAPTER V

SUMMARY AND CONCLUSIONS

A two-year study was conducted on a hard red winter wheat variety to determine the effect of nitrogen fertilizer, planting date and seeding rate on grain yield, yield components, percent grain protein, protein production per unit area, and photosynthetic structures above the flag-leaf node of this variety when sown directly in bermudagrass sod. The two-year study was accomplished through the period 1972-73 and 1973-74 at the Agronomy Research Station, Stillwater, Oklahoma.

The treatments were all combinations of four nitrogen levels (34, 68, 102, and 136 kg/ha), applied as a topdressing, two planting dates for the 1972-73 season (September 15 and October 1), and three planting dates for the 1973-74 season (October 19, October 26 and November 2) and three seeding rates (68, 102 and 136 kg/ha).

According to the results obtained from this study the following conclusions appeared to be justifiable:

1. Grain yield was not affected to a large extent by any combination of the three factors used during both seasons. A higher nitrogen level combined with higher seeding rates level may result in higher grain yield when seeding Danne variety in a bermudagrass sod.

2. Grain yield was affected significantly by planting date in the 1972-73 season and to a lesser extent in the 1973-74 season. Planting late in September or very early in October may result in

higher grain yields when optimum moisture is available for wheat growth.

3. Rate of seeding significantly affected grain yield. An increase in grain yield by increasing seeding rate was observed from the 1973-74 data and vice versa in the 1972-73 season. A seeding rate of 68-102 kg/ha seems optimum under the conditions of sod seeding wheat in bermudagrass.

4. All three yield components were found to be correlated with grain yield but the most important component was the number of fertile tillers per unit area.

5. Photosynthetic structures above flag-leaf node were found to have high correlations with grain yield but in general peduncle contribution to grain yield was very important followed by flag-leaf blade area and spike photosynthesis. In a breeding program for higher grain yields these photosynthetic structures should strongly be considered.

6. Percent grain protein was affected by nitrogen. An increase in grain protein was observed as a result of increasing applied nitrogen levels in the 1973-74 seasons.

7. Total protein production per unit area was affected mainly by the factors that affected grain yield and/or percent grain protein. Increased nitrogen rates also increased total protein production per unit area.

8. To improve wheat grain yield in quantity and quality under the conditions of double cropping, nitrogen and seeding rates may be considered as important factors for the wheat crop.

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APPENDIX

TABLE IX

GRAIN YIELD, YIELD COMPONENTS, PERCENT GRAIN PROTEIN AND TOTAL PROTEIN PRODUCTION AS AFFECTED BY NITROGEN AND DATE AND RATE OF SEEDING (1972-73 SEASON)

Nitrogen Level (kg/ha)	Date of Planting	Rate of Seeding (kg/ha)	Grain Yield (kg/ha)*	Tiller Count*	Kernels per Spike*	200-Kernel Weight* (gm)	Grain Protein* (%)	Protein Production* (kg/ha)
34	Sept. 15	68	1135.7	674.5	26.0	6.2	8.2	96.2
34	Sept. 15	102	1054.6	741.8	26.0	6.3	8.5	90.6
34	Sept. 15	136	1181.3	897.5	23.8	6.	8.6	104.1
34	Oct. 1	68	681.8	368.5	21.3	6.4	8.2	58.1
34	Oct. 1	102	1050.8	544.5	28.5	6.7	8.3	89.9
34	Oct. 1	136	883.1	605.3	23.8	6.4	9.0	78.4
68	Sept. 15	68	1182.3	648.5	25.0	6.3	8.0	99.0
68	Sept. 15	102	1590.5	929.5	28.8	6.4	8.7	139.3
68	Sept. 15	136	1341.3	862.0	25.0	6.2	8.7	120.9
68	Oct. 1	68	253.3	218.0	26.3	6.3	8.5	20.2
68	Oct. 1	102	104.4	257.3	17.5	4.6	6.7	9.7
68	Oct. 1	136	1095.1	542.0	26.5	6.1	9.2	103.4
102	Sept. 15	68	1204.8	720.3	26.8	6.3	8.1	100.2
102	Sept. 15	102	1328.5	750.8	16.5	6.4	8.8	118.2
102	Sept. 15	136	1021.7	774.3	24.0	6.1	8.1	84.0
102	Oct. 1	68	242.6	182.0	15.5	4.7	6.4	20.3
102	Oct. 1	102	311.7	280.8	18.8	4.2	7.2	29.4
102	Oct. 1	136	519.9	451.0	22.8	6.1	8.5	44.6
136	Sept. 15	68	1041.3	783.8	28.0	6.5	8.4	87.8
136	Sept. 15	102	1038.2	563.3	26.0	6.4	8.5	87.9
136	Sept. 15	136	1367.9	863.3	26.0	6.3	8.1	112.5
136	Oct. 1	68	483.6	282.8	27.3	6.6	9.2	45.5
136	Oct. 1	102	502.0	348.0	22.0	6.5	8.8	44.7
136	Oct. 1	136	166.3	164.3	15.5	4.7	6.4	14.0

*Each value is an average of 4 replications.

TABLE X

PHOTOSYNTHETIC STRUCTURES ABOVE THE FLAG-LEAF NODE AS AFFECTED BY NITROGEN AND DATE AND RATE OF SEEDING (1972-73 SEASON)

Nitrogen Level (kg/ha)	Planting	Rate of Seeding (kg/ha)	Flag-leaf Blade Area* (cm^2)	Peduncle Length* (cm)	Peduncle Weight (mg)	Chaff Weight* (mg)
34	Sept. 15	68	11.4	18.7	7.0	22.0
34	Sept. 15	102	9.8	19.3	7.1	22.0
34	Sept. 15	136	9.1	19.6	7.8	21.4
34	Oct. 1	68	7.0	19.0	7.3	19.5
34	Oct. 1	102	10.9	19.8	7.9	23.4
34	Oct. 1	136	8.3	20.1	8.0	21.7
68	Sept. 15	68	8.6	19.4	7.2	21.0
68	Sept. 15	102	8.6	20.6	7.9	24.8
68	Sept. 15	136	8.7	18.6	6.7	21.3
68	Oct. 1	68	8.3	18.9	9.0	22.8
68	Oct. 1	102	6.7	13.3	5.7	15.9
68	Oct. 1	136	11.2	19.6	7.9	21.9
102	Sept. 15	68	9.8	19.0	7.7	23.3
102	Sept. 15	102	8.7	19.6	7.4	22.5
102	Sept. 15	136	11.1	18.1	7.0	20.6
102	Oct. 1	68	6.8	12.5	4.5	13.6
102	Oct. 1	102	5.9	13.8	4.6	16.8
102	Oct. 1	136	7.9	17.2	6.6	19.9
136	Sept. 15	68	13.6	19.5	7.6	24.2
136	Sept. 15	102	9.8	18.2	7.7	23.7
136	Sept. 15	136	9.8	19.0	7.2	21.9
136	Oct. 1	68	9.2	18.8	8.4	24.9
136	Oct. 1	102	13.2	18.9	6.9	22.8
136	Oct. 1	136	8.2	13.2	4.5	13.7

TABLE XI

GRAIN YIELD, YIELD COMPONENTS, PERCENT GRAIN PROTEIN AND TOTAL PROTEIN PRODUCTION AS AFFECTED BY NITROGEN AND DATE AND RATE OF SEEDING (1973-74 SEASON)

Nitrogen Level (kg/ha)	Date of Planting	Rate of Seeding (kg/ha)	Grain Yield* (kg/ha)	Tiller Count*	Kernels per Spike*	Kernel Weight* (gm)	Grain Protein* (%)	Protein Production* (kg/ha)
34	Oct. 19	68	1238.3	638.0	22.3	4.9	10.2	127.2
34	Oct. 19	102	1239.8	815.3	23.3	5.0	10.4	126.2
34	Oct. 19	136	1153.0	592.3	19.5	5.1	10.1	112.6
34	Oct. 26	68	854.8	535.5	22.0	5.4	9.8	83.6
34	Oct. 26	102	1596.8	928.3	21.5	5.2	9.8	156.7
34	Oct. 26	136	883.3	616.0	17,8	4.9	10.1	88.7
34	Nov. 2	68	788.3	430.8	19.8	5.0	9.7	74.9
34	Nov. 2	102	1133.3	656.5	19.8	5.1	9.3	108.7
34	Nov. 2	136	1221.3	686.3	20.8	4.8	10.7	130.9
68	Oct. 19	68	565.3	277.0	18.3	4.9	10.1	56.3
68	Oct. 19	102	885.3	702.5	19.3	5.0	10.1	89.0
68	Oct. 19	136	1047.3	737.3	20.5	4.9	10.2	105.1
68	Oct. 26	68	1110.0	654.0	20.3	4.8	10.1	112.6
68	Oct. 26	102	989.5	543.5	19.0	4.8	10.0	97.9
68	Oct. 26	136	1366.5	708.0	19.0	4.8	10.5	143.0
68	Nov. 2	68	874.0	530.0	19.8	5.1	9.7	86.2
68	Nov. 2	102	895.3	594.8	19.5	4.8	9.9	88.5
68	Nov. 2	136	1104.8	502.2	18.0	4.8	9.9	110.2
102	Oct. 19	68	1016.0	724.0	19.0	5.0	10.1	103.8
102	Oct. 19	102	1126.3	559.8	19.8	5.0	10.0	110.0
102	Oct. 19	136	1184.8	772.5	19.5	5.1	10.0	118.0
102	Oct. 26	68	1079.5	761.8	23.3	4.7	10.4	115.2
102	Oct. 26	102	1181.8	772.5	20.5	4.7	10.1	117.8
102	Oct. 26	136	1238.3	928.5	19.5	4.9	10.1	124.8
102	Nov. 2	68	1000.3	619.0	22.0	5.2	10.3	102.6
102	Nov. 2	102	1257.3	659.5	22.3	5.3	9.6	122.1
102	Nov. 2	136	1537.5	1133.0	23.0	4.8	10.6	161.6

TABLE XI "CONTINUED"

Nitrogen Level (kg/ha)	Date of Planting	Rate of Seeding (kg/ha)	Grain Yield* (kg/ha)	Tiller Count*	Kernels per Spike*	Kernel Weight* (gm)	Grain Protein* (%)	Protein Production* (kg/ha)
136	Oct. 19	68	1066.3	747.0	26.3	5.2	10.4	109.8
136	Oct. 19	102	1393.8	1030.5	21.5	4.9	11.0	150.9
136	Oct. 19	136	1536.8	966.3	22.3	4.7	10.5	160.5
136	Oct. 26	68	1163.8	753.8	21.3	4.9	10.3	120.6
136	Oct. 26	102	1377.8	1149.0	25.0	4.5	10.9	151.4
136	Oct. 26	136	1346.3	987.5	20.3	4.5	10.7	143.0
136	Nov. 2	68	878.0	570.5	23.3	4.8	10.0	88.7
136	Nov. 2	102	1020.0	613.8	21.0	4.5	10.6	110.5
136	Nov. 2	136	1030.8	934.0	21.3	4.6	10.9	114.1

*Each value is an average of 4 replications.

TABLE XII

PHOTOSYNTHETIC STRUCTURES ABOVE THE FLAG-LEAF NODE AS AFFECTED BY NITROGEN AND DATE AND RATE OF SEEDING (1973-74 SEASON)

Nitrogen Level (kg/ha)	Date of Planting	Rate of Seeding (kg/ha)	Flag-leaf Blade Area* (cm^2)	Peduncle Length* (cm)	Peduncle Weight* (mg)	Chaff Weight* (mg)
34	Oct. 19	68	11.8	31.6	11.5	18.6
34	Oct. 19	102	10.7	30.5	10.9	19.1
34	Oct. 19	136	10.5	28.2	8.8	15.1
34	Oct. 26	68	7.3	20.0	9.9	17.6
34	Oct. 26	102	11.8	30.1	10.1	16.6
34	Oct. 26	136	9.1	25.1	7.8	13.1
34	Nov. 2	68	8.9	25.3	8.2	15.4
34	Nov. 2	102	11.3	30.3	9.6	15.1
34	Nov. 2	136	8.1	26.7	8.1	14.7
68	Oct. 19	68	9.4	24.5	7.7	15.9
68	Oct. 19	102	7.9	25.7	8.9	14.8
68	Oct. 19	136	9.7	27.7	9.1	16.6
68	Oct. 26	68	8.4	28.3	9.4	15.0
68	Oct. 26	102	10.9	26.8	8.5	14.9
68	Oct. 26	136	10.8	26.9	8.4	14.4
68	Nov. 2	68	10.3	24.5	8.0	15.2
68	Nov. 2	102	8.5	26.9	8.9	15.9
68	Nov. 2	136	9.6	24.9	7.3	13.3
102	Oct. 19	68	10.2	23.2	7.5	15.3
102	Oct. 19	102	9.4	27.2	9.2	16.1
102	Oct. 19	136	11.7	27.4	7.8	14.4
102	Oct. 26	68	9.8	26.1	9.2	17.7
102	Oct. 26	102	9.8	26.0	8.3	15.5
102	Oct. 26	136	8.9	26.1	7.8	14.3
102	Nov. 2	68	9.4	27.5	9.8	17.8

TABLE XII "CONTINUED"

Nitrogen Level (kg/ha)	Date of Planting	Rate of Seeding (kg/ha)	Flag-leaf Blade Area* (cm^2)	Peduncle Length* (cm)	Peduncle Weight* (mg)	Chaff Weight* (cm)
102	Nov. 2	102	9.5	25.7	8.4	18.2
102	Nov. 2	136	11.8	32.9	11.2	17.6
136	Oct. 19	68	13.5	31.3	12.9	24.4
136	Oct. 19	102	10.6	23.9	7.0	15.2
136	Oct. 19	136	10.7	28.6	9.4	17.1
136	Oct. 26	68	10.9	27.9	10.2	17.1
136	Oct. 26	102	13.1	30.1	9.8	19.1
136	Oct. 26	136	10.9	26.3	7.8	13.8
136	Nov. 2	68	10.4	29.7	10.4	17.6
136	Nov. 2	102	9.0	25.1	7.7	14.8
136	Nov. 2	136	10.0	23.4	6.9	13.9

*Each value is an average of 4 replications.

VITA

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