THE EFFECT OF SEEDING RATE AND NITROGEN TOP-DRESSING ON THE YIELD, AGRONOMIC CHARACTERS AND QUALITY OF TRITICALE T 131

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CHAPTER I

INTRODUCTION

Rye (Secale cereale) has, for sometime, been a predominant world bread grain (30). Since the 19th Century, however, rye has been replaced more and more by wheat. The lack of winter hardiness in many wheat varieties led to the initiation of research efforts to transfer winter hardiness from winter rye to winter wheat. Many triticale varieties have been produced as a consequence of these efforts but lack of winter hardiness in otherwise acceptable varieties has remained a major problem.

In Oklahoma, T 131 is the most winter hardy triticale available at the moment. This variety has grain and vegetative qualities which make it useful both as a grain and as a forage crop. Like most crop varieties, however, the physiological activities of T 131 may be influenced by particular agronomic practices. Although measurement of the specific effects of a particular agronomic pratice are complex, an understanding of the effects of such a practice on the morphological characters related to yield can simplify the problem. Several investigators have already identified these characters as the number of spikes per unit area, the number of kernels per spike and the average kernel weight (8, 20, 22, 29, 44). This study was initiated to investigate the response of T 131 to several seeding rate and nitrogen top-dressing treatments. The objectives of the study were:

1. to determine the effects of these treatments on yield, yield components and other agronomic characters including grain quality and
2. to determine the relationship between yield and yield components and other characters and the interrelationships among these characters.

CHAPTER II

LITERATURE REVIEW

Yield components have been identified as the number of spikes per unit area, the number of kernels per spike, and the average weight per grain (8, 20, 22, 29, 44). Quisenberry (44) classified these components in that order of importance in wheat. Other investigators have pointed out, however, that the relative importance of the yield components will depend on the variety (25, 28, 42), season of growth and fertilizer practices (29, 42). Pendleton and Dungan (42) showed that variety is the most important single factor affecting grain yield. Several scientists observed that yield may differ among locations (12, 13, 22, 52) and according to the cultural practices employed (14, 21, 23, 24, 28, 29, 30).

Fertilizer studies have indicated that the yield of cereal crops can be increased by a balanced fertilizer program. Several studies have shown that nitrogen is one of the nutrients required for yield increases (13, 15, 30, 34, 42, 52). All these studies indicate, however, that the magnitude of the yield increases will depend on factors such as the amount of nitrogen already present in the soil, the amount of nitrogen applied and other factors such as the relative availability of other nutrients and soil moisture. Gingrich and Smith (12), Hobbs (13), McCalla (34), Miller (41) and Willimas and Smith (52) noted that adequate phosphorus and potassium fertilization will lead to increased response to applied nitrogen. Terman et al. (49) showed that if moisture is excessive, addition of nitrogen will lead to increased grain yield. If moisture is deficient, however, added nitrogen will be incorporated into higher grain protein (9). Nitrogen under intermediate moisture conditions will result in both grain yield and protein increases of intermediate magnitude (44). Hucklesby et al. (15) observed that split applications of nitrogen in the spring resulted in both a grain and protein percent increase if a short, stiff-strawed, variety was grown under the right climatic conditions. They added that such a fertilizer practice would reduce the hazards of environmental pollution by nitrates (15).

Other studies indicated that the amount of nitrogen applied is more important than the time at which it is applied (12). Gingrich and Smith (12) did not find any differences in grain yield between plots which had received all their nitrogen in the fall and those which had their nitrogen split into fall and spring applications. Knowles and Watkins (27) pointed out that, in fact, only about 20% of the nitrogen taken up by winter wheat is absorbed in the fall. The rest is not absorbed until after growth has resumed in the spring. This may suggest that in situations where residual fertilizer from previous crops is enough to support fall growth, delaying nitrogen treatments until late spring will result in a more efficient utilization of nitrogen (15). In other cases where nitrogen supply may be limited at seeding, Gingrich and Smith (12) have proposed that it may be more economical to apply all the nitrogen at seeding. This, of course, will depend on the type of fertilizer (3). Other studies have shown that nitrogen in excess of plant requirement can lead to reductions in grain yield (12, 15, 17).

Seeding rate studies indicated that no benefit will be derived from seeding at very high rates (42, 48). The optimum rate of seeding, however, will depend on the crop and the environmental conditions under which it is grown (1, 43). Optimum seeding rate is usually less under low rainfall conditions than for high rainfall conditions (42). Pendleton and Dungan (42) and Stickler (48) showed that row spacing is even more important than seeding rate. Other studies confirmed that yield was higher in narrow rows than it was at wider row spacings (14, 21, 24). Stickler (48) explained that the reduction in grain yield at wider spacings is due to a decrease in number of spikes per unit area.

An increase in number of spikes will generally bring an increase in yield if the other yield components are not adversely affected to the same extent (2, 4, 6, 8, 11, 13, 25, 35). Hobbs (13), McNeal and Davis (40) and Pendleton and Dungan (42) showed that number of spikes was increased by nitrogen applications. Pendleton and Dungan (42) and Terman _et_ _al_. (49) indicated, however, that the increase in tillering will depend on the variety, the rate of seeding, moisture level and soil fertility. In the presence of adequate moisture, fall nitrogen can promote tiller production on soils where nitrogen is limiting. Stickler (48) observed that tillering at higher seeding rates was restricted by competition within the row, but this was not as important as the reduction of spike number that resulted from an inefficient utilization of space under the wide spacing conditions. Similar observations were made by Ketata (21), Kinra _et_ _al_. (24) and Holliday (14).

The number of kernels per spike is determined prior to spike emergence. Leonard and Martin (30) reported that although the number of florets is fixed at the time of differentiation, kernel number can be greatly influenced by the fertilization and development of the florets. Kernel number, to some extent, is related to the length of the spike (8, 18). Many studies indicate that an increase in the number of kernels per spike will lead to an increase in grain yield (8, 13, 16). McNeal and Davis (40) and Hobbs (13) obtained an increase in the number of kernels per spike by applying nitrogen at seeding. Stickler (48) did not find any effect of seeding rate on this component.

Engledow and Wadham (8) observed that kernel weight varies in a manner similar to kernel development. This may suggest that kernel weight is related to the amount of carbohydrates available at the time the kernel is being filled and to the translocation of the carbohydrates into the grain (5). Any factors that improve the photosynthetic activities of the plant may likely lead to increased kernel weight (5). The relationship between kernel weight and grain yield, however, is obscured by the influence of the environment on this component. Hobbs (13) obtained a positive correlation between kernel weight and grain yield. Correlation coefficients were 0.72 for top-dressed and 0.62 for non-fertilized plots. McNeal and Davis (40) observed that the application of nitrogen slightly increased kernel weight in some varieties. Other studies by Ayoub (3), Locke (16) and Pendleton and Dungan (42) reported a negative relationship between grain yield and kernel weight. Ayoub (3) observed that although yield was increased on the nitrogen plots, kernel weight was simultaneously reduced by as much as 14%. Hobbs (13) also observed that kernel weight was heavier on the untreated than it was on the nitrogen top-dressed areas. Stickler (48) observed a decrease in kernel weight accompanying a high seeding rate but this was not as important as the decrease in number of spikes per unit area.

Johnson (20) recognized that a yield increase would not be achieved if an increase in one component was offset by a decrease in one or both of the other components. In a thorough investigation, Fonseca and Patterson (10) showed that negative correlations existed between the yield components. The correlation between number of spikes and kernels per spike was highly significant and greater than the correlation between kernels per spike and kernel weight. The correlation between number of spikes and kernel weight was least important in that study. Hsu and Walton (18), Walton (50) and McNeal (35) observed similar interactions between yield components and morphological structures such as flag leaf area.

Test weight is related to the distribution of kernel weight on the spike more than to the average kernel weight. Engledow and Wadham (8) showed that although two spikes may have the same number of kernels and the same average weight for a single grain, they may differ in the distribution of kernel weight among the individual grains. A spike with a high proportion of plump kernels will show a higher test weight than the one with a smaller proportion of such kernels. They (8) concluded that test weight depended on the variety. Williams and Smith (52) observed, however, that test weight varied among locations with respect to nitrogen treatments. Pendleton and Dungan (42) obtained an adverse effect of nitrogen treatments on test weight. In his top-dressing study, Hobbs (13), on the other hand, did not find any difference in test weight between the nitrogen and the non-nitrogen plots. Stickler (48) and Pendleton (42) also did not find any effect of seeding rate on test weight.

Plant height is affected to a greater extent by the genetic constitution of the plant, but moisture level, sunlight distribution and soil nitrogen content can influence height to a limited extent (13, 30). Hobbs (13) obtained a significant effect of spring nitrogen on plant height. Pendleton and Dungan (42) similarly observed increased plant height when 30 pounds of nitrogen was applied. They noted that plant height was reduced at seeding rates above six pecks per acre (42). Bingham (4) reported that the carbohydrate stored in the grain was synthesized after the straw had reached its final length. He argued that less carbohydrate was required to furnish the needs of a short straw; consequently, more carbohydrate would be available for storage in the grain of shorter varieties (4, 25, 33). Yield in the taller types could also be reduced by lodging which might prevail when moisture, wind, and soil nitrogen are in excess (30).

The protein content of the grain is positively related to the amount of nitrogen absorbed by the plant (7). Schlehuber and Tucker (45) concluded, however, that climate, soil and variety also play important roles in determining the protein content of wheat. McNeal et al. (35, 36, 37, 38) and Gasser et al. (11) proposed that conditions favorable for general plant growth resulted in a lowered protein content. Similar studies showed a negative correlation between grain yield and grain protein percent (39, 49). McNeal et al. (35) concluded that the high protein content observed in their study was the result of the distribution of a similar amount of nitrogen (as that in the low protein composites) over a smaller amount of kernels (in the high protein composites).

Results obtained by Hucklesby _et al_. (15) are, however, contradictory to the conclusions of McNeal _et al_. (35). Hucklesby _et al_. (15) suggested that the negative correlation observed by McNeal _et al_. (35) and others (16) is due to the use of varieties susceptible to lodging and also due to the relatively small amounts of fertilizer applied in the fall or spring. Other studies suggested that high protein content was negatively related to the length of the period of grain filling (47). Terman _et al_. (49) noted that an intermediate level of available moisture was important for realizing high grain yield with high protein.

CHAPTER III

MATERIALS AND METHODS

The effects of seeding rate and nitrogen top-dressing on triticale T 131 were investigated in the 1974-1975 growing season, on a Kirkland Silt Loam soil, at the Agronomy Research Station in Stillwater. T 131 is a fairly tall, late maturing winter hardy variety with fairly good tillering characteristics. This variety is the most winter hardy type available in Oklahoma and it also has grain and vegetative qualities that suggest its suitability to grain and forage production. This variety was planted at three seeding rates by means of a tractor mounted seeder on October 12, 1974. There were four nitrogen top-dressing rates in this study.

Seeding Rates

The seeding rates were 30 lbs/A (33.6 kg/ha), 60 lbs/A (67.2 kg/ha) and 90 lbs/A (100.8 kg/ha) planted in rows of width 12 inches (30 cm) on October 12, 1974. The current seeding rate in Oklahoma is 60 lbs/A (67.2 kg/ha).

Fertilizer Treatments

A preplant application of 100 lbs/A (112.0 kg/ha) of 18-46-0 ($N-P_2O_5-K_2O$) was made on September 9, 1974. Top-dressing rates were 0 lbs/A (0 kg/ha), 20 lbs/A (22.4 kg/ha), 40 lbs/A (44.8 kg/ha) and 80 lbs/A (89.6 kg/ha) of nitrogen as ammonium nitrate applied on

March 6, 1975. The top-dressing rates were selected to reflect current fertilizer rates in Oklahoma.

Experimental Design

The experiment consisted of a single variety of triticale, T 131, planted at three seeding rates and four top-dressing levels. The experimental design was a split plot arranged in a randomized complete block with four replicates. Seeding rates formed the main plots and the top-dressing sub-plots were randomized within each main plot. Each sub-plot consisted of eight rows of width 1 ft. (30 cm) and length 10 ft. (3.0 meters). Sixteen square feet (1.44 sq. meters) from the two center rows of each sub-plot was harvested for yield measurements.

Characters Investigated

The characters investigated include grain yield, number of spikes, number of kernels per spike, kernel weight, plant height, test weight and protein content. Measurements were taken from the two center rows of all plots.

Yield

Grain yield was estimated by the weight of the threshed and cleaned grain, in grams, harvested from 16 sq. ft. (1.44 sq. meters) of the two center rows. One foot (30 cm) of row was discarded at each end of the row to eliminate border effects.

Number of Spikes Per Unit Area

Spikes per 0.18 sq m was determined from the total number of spike bearing tillers in a distance of 1 ft. (30 cm) taken from each of the two center rows. Two samples were taken per plot. In order to facilitate measuring under full stand conditions, tiller counts were restricted to row portions in which no stand deficiencies existed.

Number of Kernels Per Spike

The number of kernels per spike was determined from the number of kernels in a random sample of 10 spikes per plot. To eliminate bias, the bundle of each plot was opened prior to threshing and the 10 straws were drawn. A straw was rejected only if its spike was broken or otherwise damaged to the extent that some of the grain was missing.

Kernel Weight

Kernel weight was determined from the weight of 100 kernels, in grams, in a random sample drawn from the 10 spikes selected for kernel count. A grain was rejected only if it was malformed to the extent that it was useless for all practical purposes.

Plant Height

Plant height was recorded as the distance in centimeters from the soil surface to the tip of the spike. One plant height was measured per plot. Measurements, at maturity, were taken to reflect the mean height of the plants in each sub-plot.

Test Weight

Test weight, in pounds per bushel, was taken from one sample taken from the cleaned grain of each sub-plot.

Protein Percentage

The protein percentage was determined from 1 gram of ground sample per sub-plot. The Kjeldahl procedure was adopted for its simplicity.

Statistical Analysis

The statistical analysis was carried out on grain yield and other characters using one sample per plot. The two tiller counts for each sub-plot were added together to give one reading for the analysis. The analyses of variance were computed by the Statistical Analysis System (SAS) at the Oklahoma State University Computer Center. The effects of seeding rate, nitrogen and seeding rate by nitrogen interaction were broken down into their respective linear, quadratic, and cubic components and interactions between these contrasts were also examined. Simple correlation analysis between yield and the other characters investigated were made to evaluate possible relationships. Correlations among the other characters (other than yield) were also examined but none of the coefficients reached the required significant value at the 0.05 level of probability.

CHAPTER IV

RESULTS AND DISCUSSION

Grain Yield

Grain yield was not significantly affected by either the seeding rate or the top-dressing treatments (Table I). The highest grain yield of 289.06 grams was given by the 67.2 kg/ha seeding rate (Table II). The lowest grain yield was recorded from the 33.6 kg/ha seeding rate. The highest seeding rate of 100.8 kg/ha gave an average grain yield of 268.75 grams per 1.44 square meter.

The differences in yield between the nitrogen top-dressed plots were not statistically significant. The yield of the 0 kg nitrogen and the 22.4 kg nitrogen rates were 263.75 grams each. The 44.8 kg and the 89.6 kg nitrogen rates gave the same average grain yields of 280.83 grams per 1.44 square meter each.

There was, however, a significant seeding rate quadratic by nitrogen linear interaction (Table I). Yield response to nitrogen applications were identical at the lowest and at the highest seeding rates (Figure 1). At the 33.6 kg/ha seeding rate, yield was significantly increased as the top-dressing rate increased from 0 kg to 44.8 kg/ha. Increase of top-dressing rates to levels above 44.8 kg/ha did not influence grain yield statistically (Table II, Figure 1). A similar trend was followed at the 100.8 kg/ha seeding rate. Yield was significantly increased as the nitrogen level was increased from

TABLE I

MEAN SQUARES FOR GRAIN YIELD AND YIELD COMPONENTS OF T 131 AT THREE SEEDING RATES X FOUR NITROGEN TOP-DRESSING RATES

Source	d.f.	Grain Yield	Tiller Count	Kernels per 10 Spikes	100 Kernel Weight
Replication (R)	3	920.14	189.58	1026.81	0.14
Seeding Rate (S)	2	3750.52	20.58	858.27	0.05
Seeding Rate Linear (S_1)	1	750.78	24.50	840.04	0.07
Seeding Rate Quadratic (S_2)	1	6750.26	16.67	876.04	0.02
Main Plot Error	6	4045.83	20.47	192.24	0.14
Nitrogen (N)	3	1167.36	4.30	1394.92*	0.08
Nitrogen Linear (N_1)	1	2501.49	3.35	2580.19*	0.02
Nitrogen Quadratic (N_2)	1	204.67	1.20	1151.88	0.08
Nitrogen Cubic (N_3)	1	795.93	8.35	452.67	0.13
Nitrogen x Seeding Rate (NXS)	6	1955.38	54.44	823.19	0.08
S_1N_1	1	295.20	48.06	1064.70	0.03
S_1N_2	1	4275.18	70.64	980.36	0.06
S_1N_3	1	0.71	24.56	1699.69	0.00
S_2N_1	1	6013.40*	170.10	6.70	0.01
S_2N_2	1	184.15	7.01	150.17	0.03
S_2N_3	1	963.65	6.03	1037.51	0.03
Sub-Plot Error	27	1124.19	42.41	413.32	0.14

*Significant at the 0.05 level of probability.

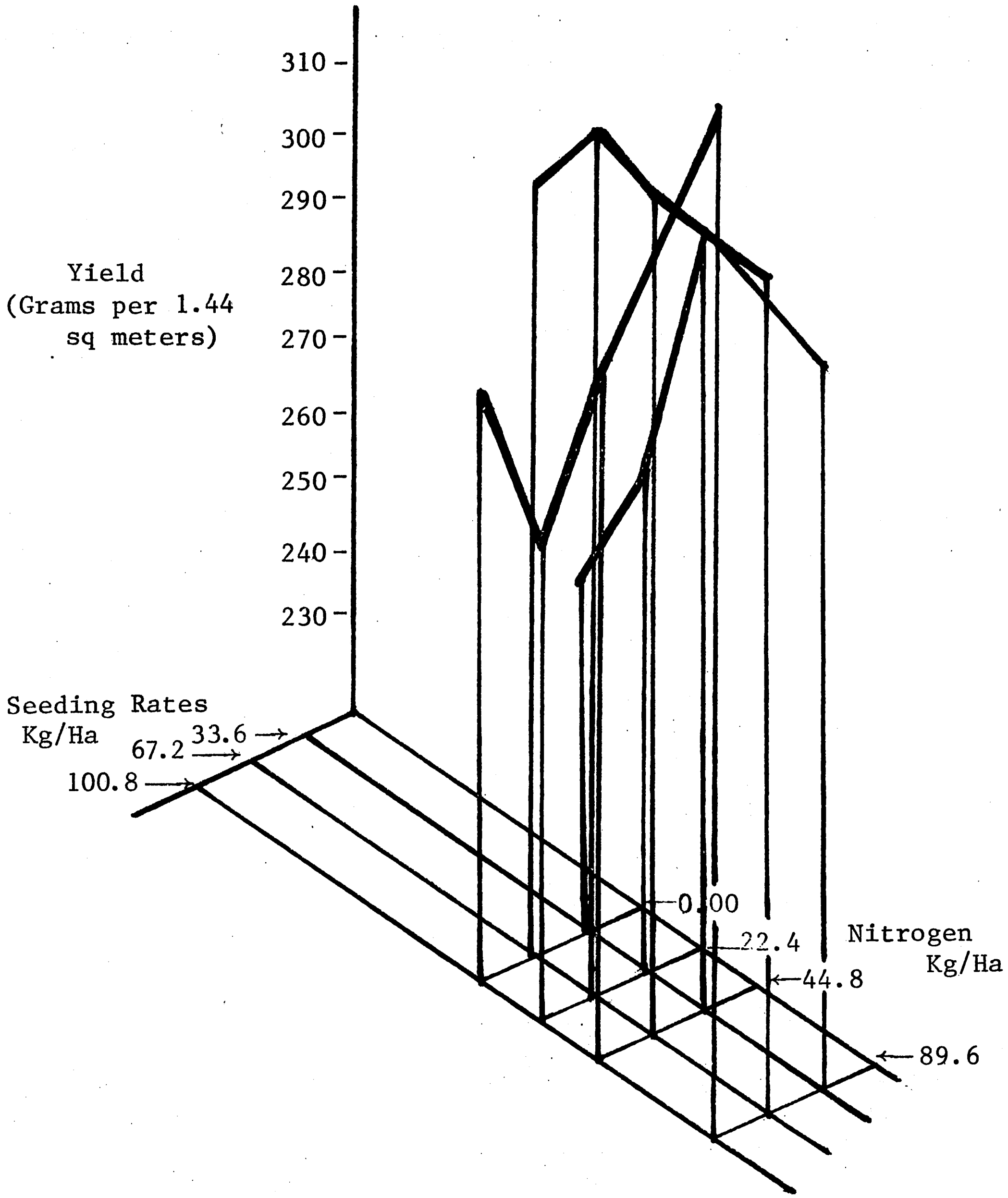

Figure 1. Yield in Response to Nitrogen Top-dressing

TABLE II

AVERAGE EFFECT OF SEEDING RATE AND NITROGEN TOP-DRESSING ON GRAIN YIELD IN GRAMS PER 1.44 SQ METERS

Seeding Rate kg/ha	Nitrogen kg/ha				Mean Yield (g)
	0	22.4	44.8	89.6	
33.6	235.00	250.00	285.00	266.25	259.06
67.2	292.00	300.00	291.25	272.50	289.06
100.8	263.75	241.25	266.25	303.75	268.75
Mean Yield	263.75	263.75	280.83	280.83	

$LSD_{.05}$ for nitrogen levels within the same seeding rate = 48.65 grams

22.4 kg/ha to 89.6 kg/ha. Other differences within this seeding rate did not reach the required Least Significant Difference (Table II). There was no statistically significant difference in yield at the various nitrogen levels within the 67.2 kg/ha seeding rate. The nitrogen by seeding rate interaction was not strong enough to cause significant differences in grain yield. Yields for seeding rates at the same nitrogen level were not significantly different (Table II, Figure 2).

Gingrich and Smith (12), Stanford and Hunter (17) and Williams and Smith (52) observed that yield response to applied nitrogen depends on the amount of nitrogen already present in the soil. Gingrich and Smith (12) and Hobbs (13) observed also that response to top-dressing treatments was insignificant (12) or small (13) when enough nitrogen was applied in the fall. It appears that residual nitrogen and the basal treatments were adequate for the realization of optimum yield on all plots in this experiment.

Seeding rate studies by Ali Khan (1) and by Stickler (48) gave results similar to those obtained in this study. Both studies reported that seeding rate did not have a significant effect on grain yield. Stickler (48) observed also that row spacing was even more important than was seeding rate. The return per bushel of seed was, however, highest at the lowest seeding rate. A similar result was obtained in this experiment. Grain yield per kilogram of seed planted at the 67.2 kg seeding rate and at the 100.8 kg seedng rate were 55.79% and 34.58%, respectively, of the return per kilogram of seed planted at the lowest seeding rate (Table X). This indicates that a low seeding rate will be desirable for a maximum increase from a given amount of seed.

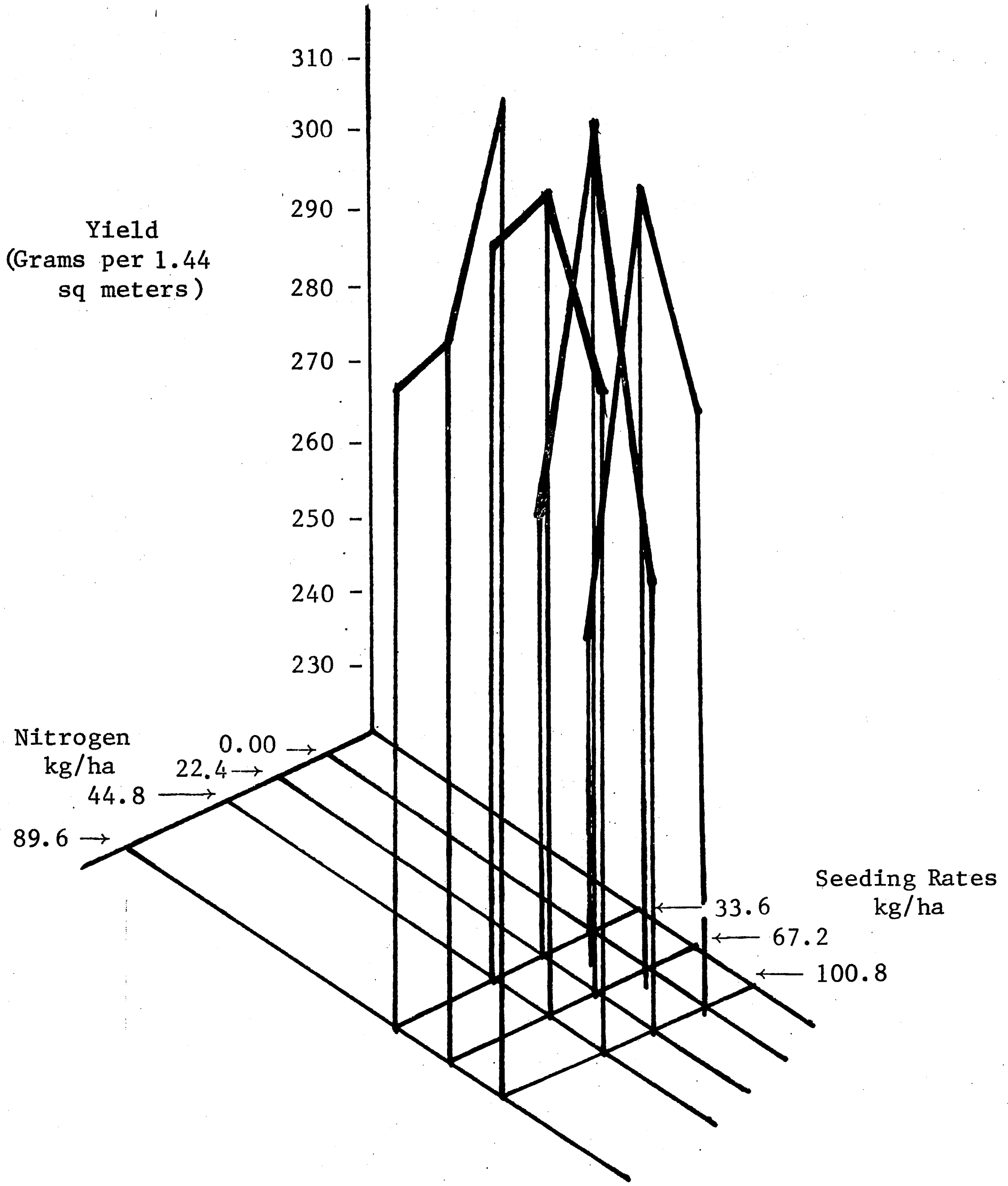

Figure 2. Yield in Response to Seeding Rate

Yield Components

Number of Spikes Per Unit Area

The number of spikes per 0.18 sq m did not show any significant response to either the seeding rate or to the top-dressing treatments (Table I). The number of spikes were 68.06 and 68.44 at the 33.6 kg and at the 67.2 kg seeding rates, respectively. The 100.8 kg/ha seeding rate gave the lowest spike number of 66.31 (Table III). Spike number for the top-dressing treatments were almost identical. Spike number on the untreated areas averaged 68.33 per 0.18 sq m. The nitrogen treated areas produced an average of 67.0 spikes per 0.18 sq m. The nitrogen by seeding rate interaction was not significant.

The studies by Hobbs (13), Gingrich and Smith (12), Williams and Smith (52) and Hunter and Stanford (17) reported that the increase in yield was at least partly accounted for by an increased number of spikes per unit area. Invariably all these studies reported that the response of spike number to nitrogen application also depended on the fertility status of the soil. Residual nitrogen and fall treatments were probably enough to realize a maximum spike number on all plots under the conditions of this study. Consequently, spring nitrogen was undesirable for obtaining a maximum spike number per unit area.

Holliday (14), Kinra _et al_. (24) and Stickler (48) have indicated that competition at increased plant populations within the row can lead to a reduction in the number of tillers per plant. The data obtained from the present study suggest that more spikes were produced per plant at the lower seeding rates than at the higher

TABLE III

AVERAGE EFFECT OF SEEDING RATE AND NITROGEN TOP-DRESSING ON NUMBER OF SPIKES PER 0.18 SQ METER

Seeding Rate kg/ha	Nitrogen kg/ha				Mean Number of Spikes
	0	22.4	44.8	89.6	
33.6	64.75	66.00	71.00	70.50	68.06
67.2	72.00	68.75	69.50	63.50	68.44
100.8	68.25	66.25	63.00	67.75	66.31
Mean Number of Spikes	68.33	67.00	67.83	67.25	

seeding rates. This may have been due to the increased competition observed by Stickler (48).

Number of Kernels per Spike

The number of kernels per spike showed a significant linear decrease to top-dressing treatments (Table I). Spring nitrogen treatments reduced the number of kernels per 10 spikes below the mean kernel number for the untreated plots by 20.09, 20.0 and 23.75 kernels when 22.4 kg, 44.8 kg, and 89.6 kg of nitrogen per hectare was applied respectively (Table IV, Figure 3). There was no significant difference in kernel number among the spring nitrogen treatment plots. Seeding rates had no effect on the number of kernels per 10 spikes. The highest average kernel number of 270.94 was recorded on plots which were seeded at 33.6 kg/ha. The highest seeding rate gave a kernel number intermediate between the other two seeding rates. The lowest kernel number was produced by the 67.2 kg seeding rate plots. The nitrogen by seeding rate interaction was not significant for this component.

Nitrogen studies by Hobbs (13) and McNeal and Davis (40) did not show any effects of this element on kernel number. Ishizuka (19), however, has observed increased grain sterility due to very heavy nitrogen dressings in rice. This was attributed to the inadequate light intensity conditions that prevailed on such plots. The number of sterile grains were not counted in this study, but the reduction in kernel number observed on the spring treated plots may have been due to excess nitrogen conditions. Some studies have, in fact, shown that excess nitrogen can lead to reductions in grain yield (12, 15, 17).

TABLE IV

AVERAGE EFFECT OF SEEDING RATE AND NITROGEN TOP-DRESSING ON NUMBER OF KERNELS PER 10 SPIKES

Seeding Rate kg/ha	Nitrogen kg/ha				Mean Kernel Number
	0	22.4	44.8	89.6	
33.6	285.75	265.75	254.50	277.75	270.94
67.2	265.50	264.00	248.50	249.00	256.75
100.8	285.50	246.25	273.25	238.25	260.69
Mean Kernel Number	278.75	258.66	258.75	255.00	

$LSD_{.05}$ for nitrogen levels = 17.03

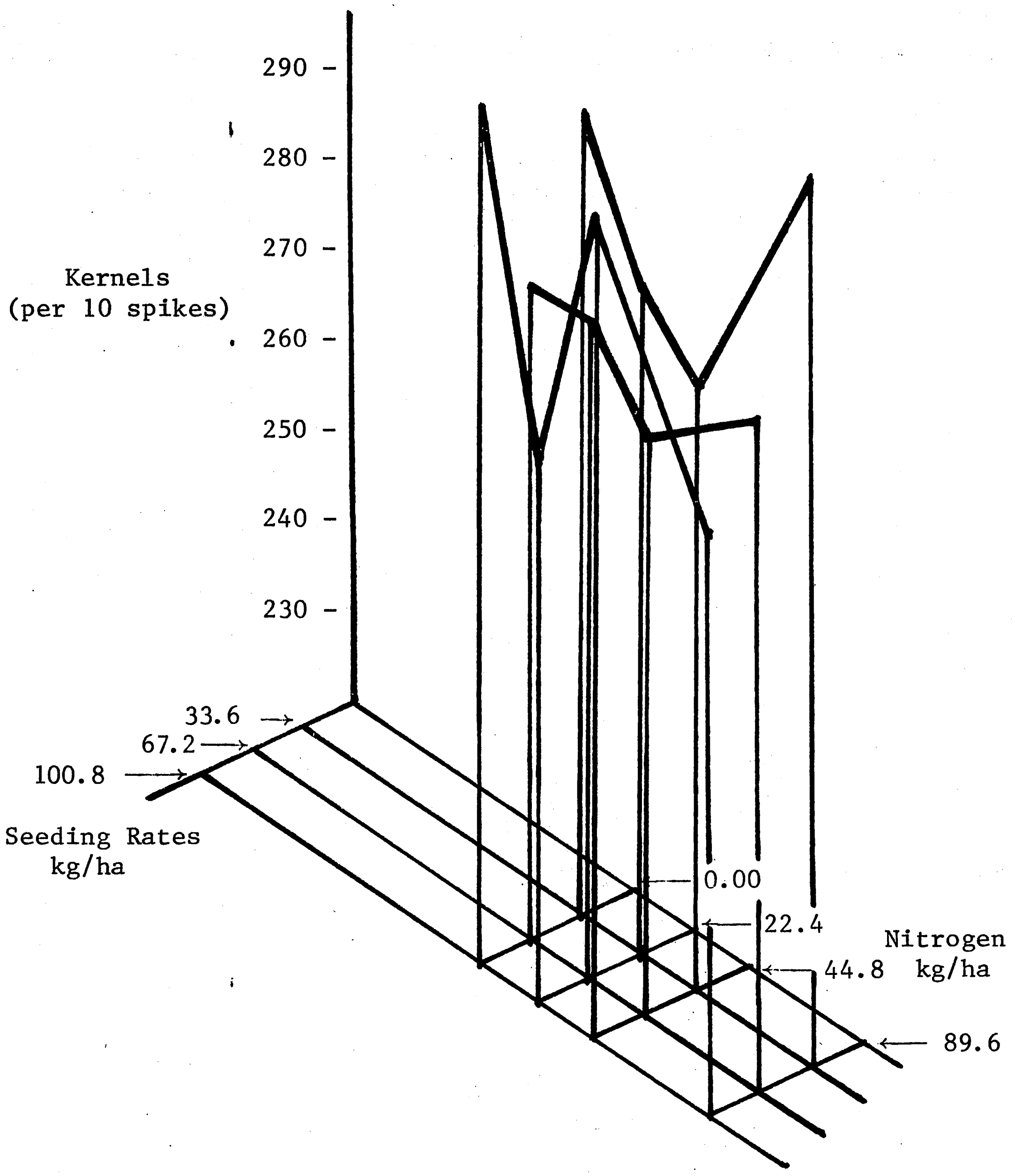

Figure 3. Kernel Number in Response to Nitrogen Top-dressing

Leonard and Martin (30) indicated that the number of kernels per spike will depend on environmental factors. Ketata (21) observed that the 12 inch spaced rows gave consistently higher number of kernels per spike than did the narrower spaced rows. Pendleton _et al_. (42) and Stickler (48), in fact, suggested that the influence of seeding rate on kernel number is secondary to that on spike number.

Kernel Weight

The effect of seeding rates and nitrogen top-dressing were insignificant on kernel weight (Table I). Average kernel weight was fairly constant over all seeding rate and nitrogen top-dressing treatments (Table V). The average kernel weight per 100 kernels was 3.0 grams. The nitrogen by seeding rate interaction was not significant for kernel weight.

Several investigators have reported a negative relationship between kernel weight and nitrogen treatments (3, 13, 20, 32, 42). The number of spikes per unit area, however, was also increased without exception. This may suggest that the response of kernel weight to the nitrogen treatments depended more on the interaction between this component and the other yield components. Fonseca and Patterson (10) found that the negative correlation between the number of kernels per spike and kernel weight was greater than the negative correlation between this component and spike number. The failure of kernel weight to respond to the decrease in kernel number observed in this study may indicate, however, that the kernel weight by kernel number interaction, at least, did not have any significant influence on grain yield.

TABLE V

AVERAGE EFFECT OF SEEDING RATE AND NITROGEN TOP-DRESSING ON KERNEL WEIGHT PER 100 KERNELS (IN GRAMS)

Seeding Rate kg/ha	Nitrogen kg/ha				Mean Kernel Weight
	0	22.4	44.8	89.6	
33.6	3.25	2.88	3.00	3.25	3.09
67.2	2.85	3.00	3.13	3.00	3.00
100.8	3.13	2.88	3.00	3.00	3.00
Mean Kernel Weight	3.08	2.92	3.04	3.08	

Stickler (48) and Pendleton _et_ _al_. (42) similarly observed that kernel weight was not significantly affected by seeding rate.

Test Weight

Like kernel weight, test weight was not affected by either the seeding rate or the top-dressing treatments (Table VI). A test weight of 45 lbs/bu was fairly constant over the range of treatments (Table VII). The nitrogen by seeding rate interaction was not significant for test weight.

Leonard and Martin (30) reported that test weight is related more to the distribution of kernel weight on the spike than it is related to the average kernel weight per se. Pendleton (42) observed a decrease in test weight at very high nitrogen rates. An increase in protein percent and a simultaneous decrease in kernel weight were, however, also associated with the nitrogen treatments.

Plant Height

Average plant height was affected neither by the seeding rate nor by the nitrogen top-dressing treatments (Table VI). The highest seeding rate gave an average plant height of 121.44 cm (Table VIII). The lowest plant height of 119.94 cm was given by the lowest seeding rate. The 67.2 kg seeding rate produced an average plant height of 121.19 cm. The average plant height was not influenced by the top-dressing treatments (Table VI). The lowest plant height of 119.75 cm was given by the 44.8 kg/ha top-dressing level. At the 22.4 kg and the 88.6 kg top-dressing rates, observed plant heights were 121.75 and 121.92 cm, respectively. These were not significantly different from

TABLE VI

MEAN SQUARE FOR PLANT HEIGHT, PROTEIN CONTENT, AND TEST WEIGHT OF T 131 AT THREE SEEDING RATES X FOUR NITROGEN TOP-DRESSING RATES

Source	d.f.	Plant Height	Protein Percent	Test Weight
Replication (R)	3	51.41	6.90	1.23
Seeding Rate (S)	2	10.33	2.91	0.33
Seeding Rate Linear (S_1)	1	18.00	4.65	0.28
Seeding Rate Quadratic (S_2)	1	2.67	1.17	0.38
Main Plot Error	6	53.06	6.52	1.38
Nitrogen (N)	3	15.52	0.48	1.56
Nitrogen Linear (N_1)	1	11.83	0.01	0.45
Nitrogen Quadratic (N_2)	1	1.64	0.22	0.52
Nitrogen Cubic (N_3)	1	33.09	1.22	3.71
Nitrogen x Seeding Rate (NXS)	6	30.67	0.57	1.07
S_1N_1	1	0.01	0.07	0.04
S_1N_2	1	0.47	0.10	0.99
S_1N_3	1	14.77	1.78	0.37
S_2N_1	1	22.67	0.02	4.01
S_2N_2	1	29.82	1.43	0.94
S_2N_3	1	116.26*	0.03	0.07
Sub-Plot Error	27	17.79	1.35	0.98

*Significant at the 0.05 level of probability.

TABLE VII

AVERAGE EFFECT OF SEEDING RATE AND NITROGEN TOP-DRESSING ON TEST WEIGHT (IN LBS/BU)

Seeding Rate kg/ha	Nitrogen kg/ha 0	22.4	44.8	89.6	Mean Test Weight
33.6	45.00	44.75	46.00	45.50	45.31
67.2	45.25	44.88	45.75	44.25	45.03
100.8	45.00	44.63	45.13	45.75	45.13
Mean Test Weight	45.08	44.75	45.63	45.17	

TABLE VIII

AVERAGE EFFECT OF SEEDING RATE AND NITROGEN TOP-DRESSING ON PLANT HEIGHT (IN CENTIMETERS)

Seeding Rate kg/ha	Nitrogen kg/ha				Mean Plant Height
	0	22.4	44.8	89.6	
33.6	117.75	121.50	119.00	121.50	119.94
67.2	124.00	118.50	121.00	121.50	121.19
100.8	118.25	125.25	119.25	123.00	121.44
Mean Plant Height	120.00	121.75	119.75	121.92	

$LSD_{.05}$ for nitrogen levels within the same seeding rate = 6.12 cm the 120.0 cm average plant height given by the 0 kg/ha nitrogen level.

The seeding rate quadratic and the nitrogen cubic interaction however, was significant at the 0.05 level of probability. Nitrogen treatments did not affect plant height at seeding rates lower than 100.8 kg/ha (Table VIII). At this seeding rate, spring application of 22.4 kg of nitrogen increased plant height by 7 cm. Nitrogen above 22.4 kg/ha tended to decrease plant height (Figure 4). The highest plant height was 125.25 cm, given by the 22.4 kg/ha nitrogen level. The 0 kg nitrogen rate gave the lowest plant height of 118.25 cm. Nitrogen above 22.4 kg/ha gave plant height values intermediate between 118.25 cm and 125.25 cm. The variations in plant height were not strong enough to indicate a general significant interaction between nitrogen treatments and seeding rates. Effects of varying seeding rates at a uniform level of nitrogen were not significant on plant height (Table VIII, Figure 5).

Hobbs (13) and Leonard and Martin (30) proposed that plant height was influenced by environmental conditions. Pendleton (42) similarly reported that plant height was increased as the nitrogen level was changed from 0 lbs/A to 30 lbs/A. Increasing nitrogen above 30 lbs/A did not show any further significant changes in plant height even when as much as 90 lbs of nitrogen was applied per acre. The slight increase in plant height observed in this study may have been influenced by mutual shading and increased vegetative growth which might have prevailed at the highest seeding rate. Vegetative growth was promoted by applying 22.4 kg of nitrogen in the spring. Further changes in plant height were inhibited by competition at nitrogen levels higher than 22.4 kg/ha.

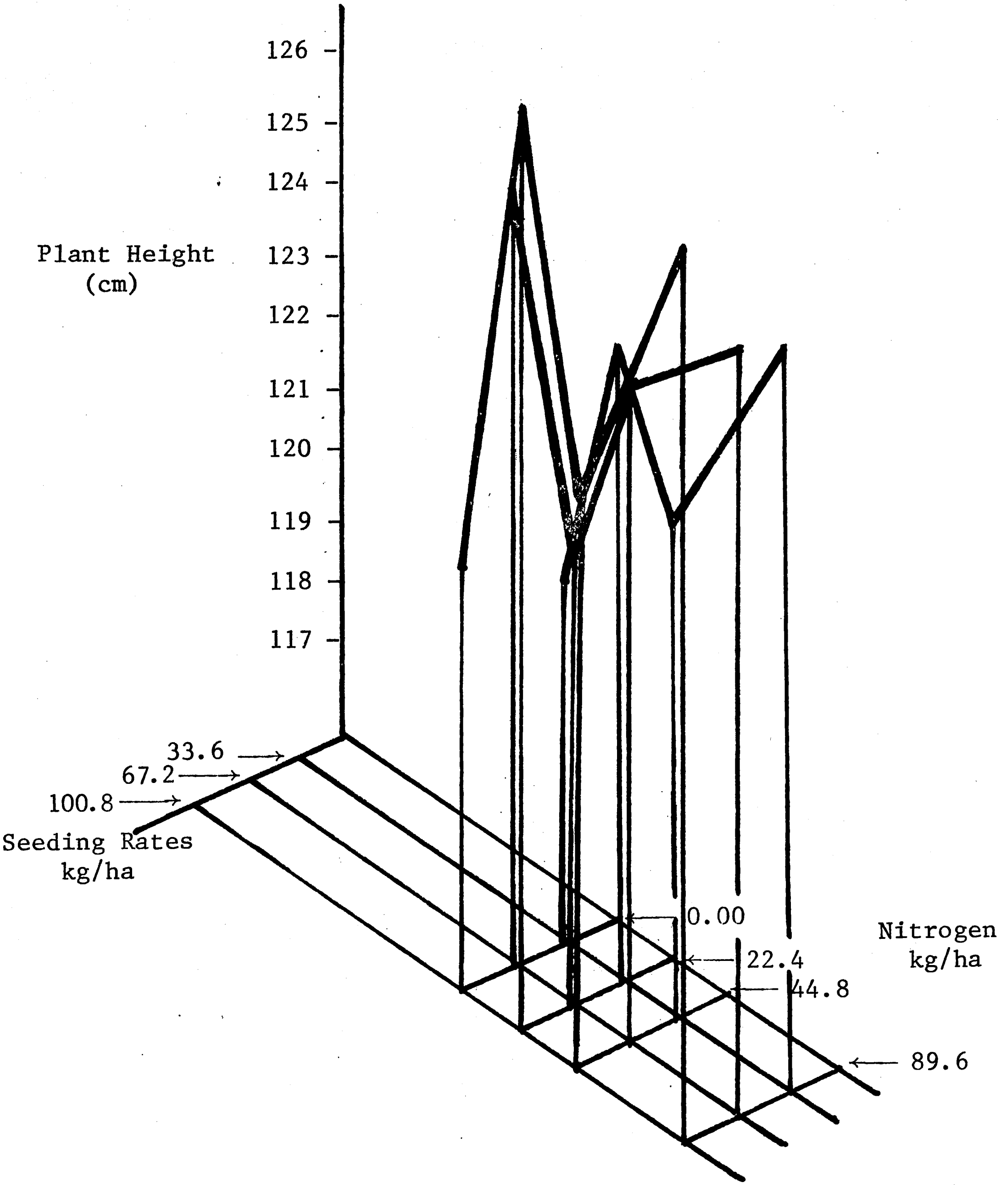

Figure 4. Plant Height in Response to Nitrogen Top-dressing

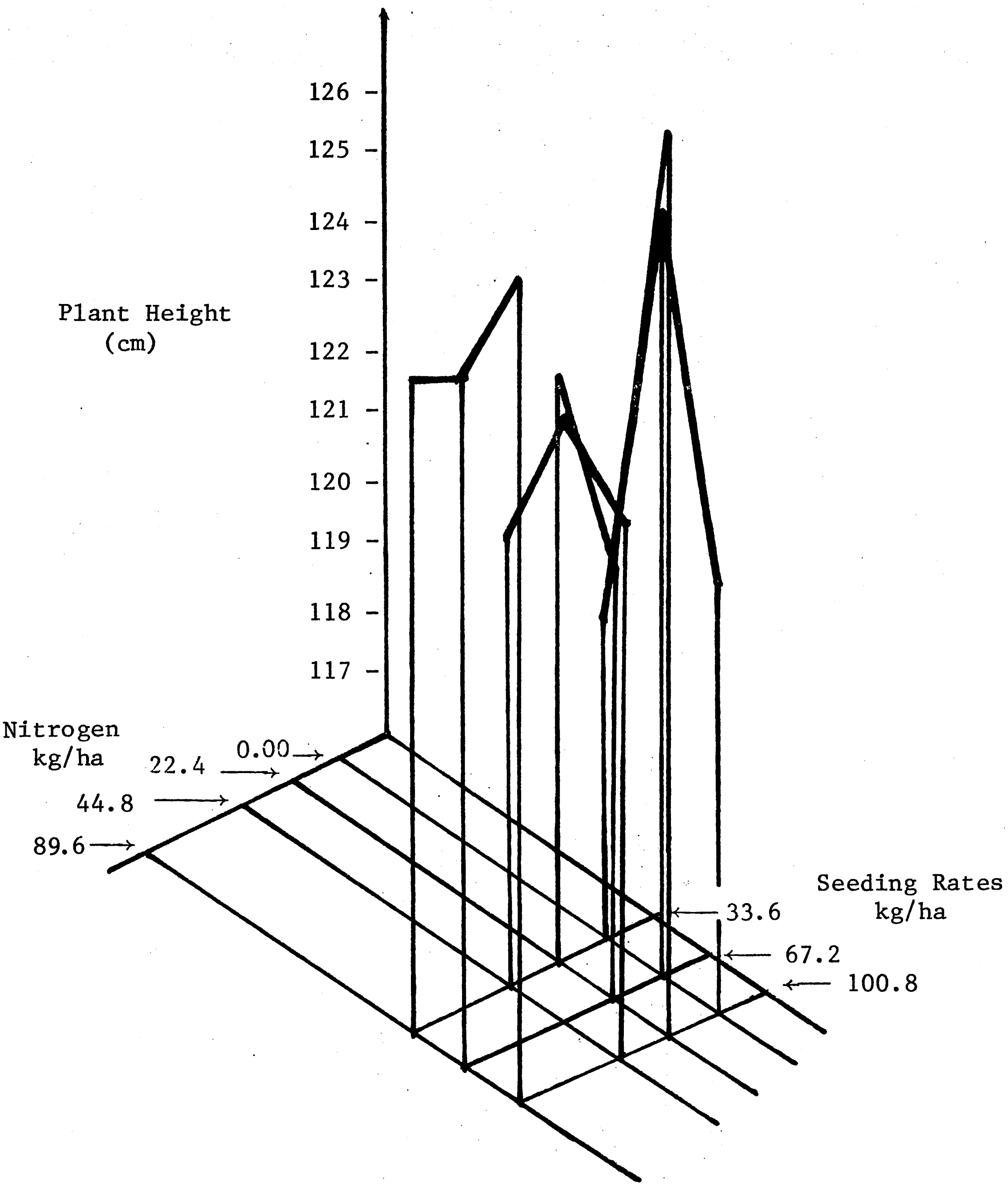

Figure 5. Plant Height in Response to Seeding Rate

Protein Percent

Protein percent was not significantly affected by either the top-dressing or the seeding rate treatments (Table VI). The highest protein percent of 12.53 was recorded from the 33.6 kg/ha seeding rate (Table IX). The 67.2 kg/ha and the 100.8 kg/ha seeding rates gave protein percentages of 11.81 and 11.76, respectively. Among the nitrogen treatments, the lowest protein percent of 11.77 was observed at the 44.8 kg/ha top-dressing rate. The 0 kg/ha, the 22.4 kg/ha and the 89.6 kg/ha top-dressing rates gave the average protein percents of 12.0, 12.23, and 12.14, respectively. The interaction between seeding rate and top-dressing levels was not significant for protein percent (Table VI).

McNeal and Davis (40) showed that when available nitrogen is limiting, the addition of nitrogen will increase grain yield. Nitrogen above the needs for grain production will be elaborated into grain protein. Other investigators observed a negative relationship between grain protein content and grain yield (7, 11, 35, 36, 37, 38, 39, 49). Hucklesby *et al*. (15) and Terman *et al*. (49), however, obtained a simultaneous increase in grain yield and grain protein percent. The failure of both grain yield and grain protein percent to respond to the nitrogen applications may suggest that residual nitrogen and fall treatments were enough to furnish the nitrogen requirements of the crop both for grain yield and for protein percent. It appears that much of the spring nitrogen was not required either for grain production or for grain protein increase.

TABLE IX

AVERAGE EFFECT OF SEEDING RATE AND NITROGEN TOP-DRESSING ON GRAIN PROTEIN PERCENT

Seeding Rate kg/ha	Nitrogen kg/ha				Mean Protein Percent
	0	22.4	44.8	89.6	
33.6	12.80	12.20	12.33	12.78	12.53
67.2	11.45	12.20	11.83	11.78	11.81
100.8	11.75	12.28	11.15	11.88	11.76
Mean Protein Percent	12.00	12.23	11.77	12.14	

TABLE X

INFLUENCE OF SEEDING RATE ON THE RETURN FROM 1 KG OF SEED PLANTED

Seeding Rate	Yield	Yield per kg of Seed Planted
33.6 kg/ha	1799.05 kg/ha	53.55 kg
67.2 kg/ha	2007.38 kg/ha	29.87 kg
100.8 kg/ha	1866.32 kg/ha	18.52 kg

Correlations

Correlation describes the relative variation of a component in response to variations in another. Due to the relative stability of the characters in this study, correlation coefficients computed were essentially null (Table XI). There was, however, an indication that yield will be positively related to the yield components. Johnson *et al*. (20) argued that in efforts to obtain new levels of productivity, all the yield components assume importance. "Any increase in a single yield component offset by decrease in one or both of the other components would produce no gain to total yield (p.440)." Other investigators noted that the relative importance of a particular yield component will depend on the variety (25, 28, 42) and the season (29). The failure of the decrease in kernel number to cause a corresponding decrease in grain yield may indicate that this component was of minor importance relative to the others under the conditions of this study. Although essentially null, the negative correlation between kernel number and number of spikes may indicate that an increased number of spikes per unit area may have compensated for the decrease in kernel number (Table XI). Fonseca and Patterson (10) reported similar relationships between the yield components.

TABLE XI

COEFFICIENTS OF SIMPLE CORRELATIONS BETWEEN YIELD AND OTHER CHARACTERS

	Yield
Spike Number	0.13
Kernel Number	0.24
Kernel Weight	0.12
Test Weight	-0.02
Plant Height	-0.05
Protein Percent	0.05

TABLE XII

COEFFICIENTS OF SIMPLE CORRELATION AMONG YIELD COMPONENTS AND OTHER CHARACTERS

	Spike No.	Kernel No.	Kernel Wt.	Test Wt.	Plant Ht.	Protein %
Spike Number	---	-0.02	-0.20	-0.32	0.29	0.17
Kernel Number		---	0.23	0.33	0.14	0.15
Kernel Weight			---	0.29	0.01	0.18
Test Weight				---	-0.23	-0.27
Plant Height					---	-0.03
Protein Percent						---

CHAPTER V

SUMMARY AND CONCLUSIONS

A single variety of triticale, T 131, was planted at seeding rates of 33.6 kg/ha 67.2 kg/ha and 100.8 kg/ha on the Agronomy Research Farm in Stillwater on October 12, 1974. A preplant application of 112.0 kg/ha of 18-46-0 ($N-P_2O_5-K_2O$) was made to all plots on September 9, 1974. Nitrogen top-dressing treatments at the rates of 0 kg/ha, 22.4 kg/ha, and 89.6 kg/ha were given on March 6, 1975. The plots were arranged in a split-plot fashion with seeding rates as main plots and nitrogen top-dressing rates as sub-plots. The experiment was laid in a Randomized Complete Block design with four replicates.

Characters analyzed were grain yield, number of spikes, kernel number, kernel weight, test weight, plant height and grain protein percent. An analysis of variance was conducted for each character to provide information on the effects of seeding rate and nitrogen top-dressing treatments on these characters. Correlation studies were also done to evaluate the importance of the relationship between yield and these characters and the interrelationship between the characters investigated.

Seeding rates did not have significant effects on grain yield or any of the other characters investigated. When averaged over all nitrogen levels, grain yield was 1796.04 kg/ha, 2007.38 kg/ha and 1866.32 kg/ha for the seeding rates of 33.6 kg/ha, 67.2 kg/ha and

100.8 kg/ha, respectively. The corresponding protein percentages were 12.53, 11.81 and 11.76 in that order. Test weight, yield, protein percent, kernel weight, kernel number, spike number and plant height were not significantly different at the various seeding rates.

Nitrogen treatments significantly decreased the number of kernels per spike. Number of kernels per 10 spikes was 278.75 on the untreated plots and 255 to 258 on the top-dressed plots. The number of kernels per spike was not significantly different among plots which had received spring nitrogen applications. The nitrogen treatments did not significantly affect grain yield and other characters, including protein percent. There was a tendency for seeding rate and nitrogen treatments to interact for grain yield and plant height but these interactions were not great enough to cause significant differences in these characters at the various treatment combination levels.

Relationships between yield and yield components were not statistically significant but the correlation coeficients indicated that these relationships were positive. The failure of the reduction in kernel number to adversely affect grain yield may indicate that this component is of minor importance for grain yield of T 131. Correlation between grain yield and protein percent was positive while that between yield and test weight, and between yield and plant height was negative. None of these coefficients, however, was statistically significant. Relationships between spike number and each of the other yield components including test weight was negative. Protein percent indicated a negative relationship with kernel weight, test weight and plant height. Plant height indicated a negative relationship with test weight. All other relationships were positive but none of the correlation coefficients was significant. This was due to the stability of characters, other than kernel number, investigated in this study.

The data of this one year study suggest that no advantage could be gained by planting triticale T 131 at seeding rates above 67.2 kg/ha. In the event of seed shortage, the seeding rate could be reduced to 33.6 kg/ha without serious reductions in grain yield. In fact, when the return in grain yield is of major concern, lower seeding rates could be more advantageous. The failure of grain yield and grain protein percent to respond to nitrogen treatments suggests that residual nitrogen and the basal treatment were sufficient for the realization of maximum yields with maximum protein levels under the conditions of this study. Under such a situation of adequate residual nitrogen, spring applications were ineffective and uneconomical for increased grain yield and grain protein percent of T 131.

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