# RESPONSE OF FIVE WINTER WHEAT CULTIVARS
# TO THREE SEEDING RATES AND
# SIX PLANTING DATES

By

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# CHAPTER I

## INTRODUCTION

Oklahoma is one of the leading states in wheat production, ranking second in the production of hard red winter wheat and fourth in total wheat production. To utilize the land to its maximum efficiency, and to maximize net returns to growers, new and improved production methods are continually being investigated by research scientists.

Three important production factors are: a) the choice of cultivar, b) the date of seeding, and c) the rate of seeding. Farmers are unable to seed their wheat in Oklahoma at the same time every year because of fluctuating weather conditions. So a specific seeding rate cannot be recommended without regard to the date of planting. Seeding rates frequently used in Oklahoma may be unnecessarily high; lower seeding rates will often result in the same yields. Recently, new cultivars of winter wheat have been released. It is necessary to study the effects of planting date and seeding rate on these new cultivars, in order to achieve highest grain yields.

It is important to not only measure grain yield, but to measure the components of yield (tiller number/unit area, kernels/spike, and kernel weight). It has recently been shown that the evaluation of the individual components of yield may provide a better basis for the selection of parents for genetic purposes.

The primary objectives of this study were: (1) to investigate the effect of date and rate of seeding on seven measured agronomic traits of five cultivars of winter wheat, and (2) to study how yield, the components of yield and other characters respond with respect to each other and if there are interactions involving planting date, seeding rate, and genotype.

## CHAPTER II

## REVIEW OF LITERATURE

### Effects of Seeding Rate and Planting Date

Oklahoma is situated in the southeastern part of the nation's hard red winter wheat region. The optimum time for planting and rate of seeding of wheat will fluctuate according to location in the state, weather conditions and also whether the wheat will be used for winter pasture. According to Chaffin (4) the best planting time for most of Oklahoma is the first part of October, although optimum planting dates range from September 15 in the Panhandle to October 15 for the northeastern section of Oklahoma. Earlier seeding is used when wheat is to be used for winter pasture.

Chaffin also stated that seeding rates of winter wheat varied throughout the state. The optimum seeding rate in western Oklahoma or drier regions are 30 lbs/acre and up to 75 lbs/acre in the more moist, eastern sections of the state. When wheat is planted later than optimum times, the seeding rates are usually increased. A seeding rate of 60 lbs/acre is generally used in the Stillwater area because of its fairly high annual rainfall. Jardine (15) stated that a smaller seeding rate is recommended for drier areas and a higher seeding rate in areas with higher rainfall. Chaffin (4) found that a lower seeding rate than that of the optimum rate, generally reduces grain yield, where an increase in the seeding rate, above that of the optimum rate, does not increase yield.

In a two year date and rate of seeding study done by Peck and Croy (25) under irrigated conditions in the Oklahoma Panhandle, mid-October was found to be the best planting date and a seeding rate of 45 lbs/acre was optimum.

In a five year test Martin (22) found that when wheat was planted at the proper time highest yields were obtained from a 60 lb/acre seeding rate near Lawton, Oklahoma. Yield was best when wheat was planted between mid-September and mid-October. After mid-October yield decreased sharply with later planting dates. Martin found that early seedings are at a disadvantage because a heavy fall growth seems to exhaust the available plant nutrients and soil moisture to no apparent benefit, making the spring conditions less favorable for recovery because the moisture supply for spring and summer growth is reduced. Even poorer results are produced by late plantings. If seedings don't emerge until spring they may develop poorly or mature so late the crop is susceptible to drought, hot winds or disease. Also if a plant barely emerges before winter in a later planted stand of wheat, it is more likely to be killed during the winter. Martin (22) stated that the most important factor affecting the results from date of seeding experiments are soil moisture supply and fall rains. But because they are so irregular and undependable from year to year, they cannot be used as a basis for recommending dates of seeding.

In a three-year rate and date of seeding test done in Hays, Kansas, by Jardine (15), yield reached its maximum with the last week of September date and dropped off sharply at later planting dates for all seeding rates (30, 60, 90 and 120 lbs/acre). According to these results, the rate 30 lbs/acre produced yields as large as those of the higher seeding rates, when planted before the last week in September, but after that date heavier seeding rates produced significantly higher yields almost every year of the test.

Woodward (34) agreed with Jardine when he recommended an increase in seeding rates with later planted wheat, but when wheat is planted at the proper time, these high rates are unnecessary. Reasons for this may be given by several researchers (5, 10, 19, and 25) who agree with early studies by Martin (22) where he found that early planted wheat has a greater amount of tillering and therefore can achieve maximum yields at a lower rate of seeding. Later planted wheat tillers less and needs a higher rate of seeding.

In a six year rate by date study done by Leighty and Taylor in Virginia (21), yield was highest when the crop was planted in early October. Seeding dates 25 days before and 25 days after early October gave substantially lower yields. The optimum seeding rates were between 60 and 90 lbs/acre.

Guitard et al. (11) conducted an experiment with six seeding rates at three locations in Canada for three years. They found that a 90 lbs/acre seeding rate produced maximum yields. The number of plants per acre increased with higher seeding rates and yield increased somewhat until a seeding rate of 90 lbs/acre was reached. Higher seeding rates resulted in a decrease in heads per plant, kernels per head and also to lesser extent 1000-kernel weight.

Kiesselbach and Lyness (17) in a long-term seeding trial with 'Turkey' wheat in Nebraska found that yields were very similar from seeding rates of 45, 60, 75, and 90 lb/acre.

Larter et al. (19) stated that of the two cultural factors, planting date has a much greater effect on yield than does the rate of seeding.

Effect of the cultural practices, planting date and seeding rate studies, generally have two things in common. First, an optimum date for planting is found. Wheat planted before that date or after that date is reduced in yield, the latter being reduced more drastically (4, 11, 15, 19, 21, 22, 34). Second, lower seeding rates may be used with early planting dates, but it is necessary to use higher seeding rates with later plantings (10, 15, 19, 21, 22, 25, 34).

## The Relationship of Yield Components to Yield

Recently more attention has been given to the individual components of yield for genetic purposes, so that a superior individual yield component of one variety can be put into another variety which may be lacking in that trait. Also particular attention is given to the individual component of yield so it can be determined specifically what caused an increase or decrease in yield under different circumstances.

Some of the first researchers to divide yield into its individual components were Engledow and Wadham in 1923 (7). These components of yield were the number of plants per area, number of grains per ear and weight per grain. In is generally agreed today that these are the components of yield, although there are many measurements for the different components.

Some researchers (2, 6, 8, 10, 16, 23) conclude that the number of productive tillers or the production spikes is the most important of the yield components, especially under lower seeding rate conditions. Tillering is a varietal characteristic. Wheat varieties ability to tiller can vary widely. Grantham (10) wrote that higher tillering varieties seem to yield better than those lesser tillering varieties, not only under poor conditions but in optimum environments. He found that the amount of tillering is very closely related to yield.

The most important factor affecting tillering is the date of planting. Grantham (10) stated that tiller buds of wheat plants appear to develop mostly in the fall, so the tendency for a plant to tiller is pre-determined by planting date and fall conditions. If seeding is late, the wheat fails to develop the buds from which the rudimentary tillers form, causing the amount of tillering to decrease sharply. The optimum planting date for tillering and yield correspond very closely.

The rate of seeding also strongly affects the amount of tillering. Grantham (10) found that at lower seeding rates, much more tillering occurs than at higher seeding rates. His reason for this was that the space in which a plant has to grow largely determines the amount of tillering. Wheat tends to tiller more freely when given a greater area to grow because it has access to more nutrients and moisture.

Denisov (16) studied the correlation coefficients for grain yield with respect to the individual yield components for the different cereal grains. The correlation coefficient for the number of productive tillers per plant was 0.64 in wheat, which made it the most important factor affecting yield. Correlation between yield and the number of kernels per ear was 0.41 for wheat. For all other cereal grains, kernels per ear was the most important factor in yield. Kernel weight was found to be of relatively small importance (2, 6, 23).

The components of yield are greatly influenced by the environment and often there is found a negative correlation between these components.

Adams (1) stated that because of this negative association, genetic selection for an individual component may not be successful.

In a selection experiment in barley by Rasmusson and Cannell (26), it was found that selection for yield through components can be effective when selecting for a specific component. Selection for kernel weight was effective in producing an increase in yield, where selection for kernels per head actually decreased yield. The reason for this, according to Rasmusson and Cannell, is that kernel weight is not as affected by the environment as are the other components of yield. Because of this its genetic potential is more near its maximum under varying environmental conditions. Therefore to increase kernel weights genetic potential should increase yield.

A study by Knott and Talujdar (18) was done to transfer the character kernel weight from a variety of wheat ('Selkirk') which had a heavy kernel weight to another variety ('Thatcher') which produced good yields but lacked that character. This could be done easily by back-crossing because kernel weight is a simply inherited qualitative character. The variety which resulted had a higher kernel weight that Thatcher but the other two components of yield, kernels/spike and number of spikes decreased. This decrease did not totally counteract the increase in kernel weight, because the yield of the new cultivar did go up slightly. This finding was in agreement with Adams (10), in that yield components compensate for one another. In this instance compensation was not entirely complete, the genetic increase of one component did increase yield.

In a three-year experiment conducted in Northwest Mexico by Fisher et al. (8), several treatments (crowding, thinning, shading and carbon dioxide fertilization) were carried on before anthesis on a wheat crop. Grain numbers ranged from 4,000 to 34,000 per $m^2$ and in every case the relationship between grain yield and kernel weight was the same. Grain yield was highly associated with grain number. As grain number increased, the kernel weight fell. High yields were associated with low kernel weight. Despite the reduction in kernel weight, yield increased as grain number increased.

In an experiment conducted by Austenson and Walton (2), varieties with different seed sizes were compared with respect to yield and the components of yield. They found that kernel weight accounted for less than 5% of the yield variation. Kernel size was correlated with heads per plant and yield but not with kernels per head. Bingham (3) also found that kernel weight increases when the number of kernels/spike decreased. Hsu and Walton (14) found a negative correlation between ear number and 1000-kernel weight.

Devison (6) found that late plantings of wheat produced a higher number of kernels/spike than earlier plantings. A reason for this may be given by Rawson (27), where he found that an increase in kernels/spike was associated with longer development. An increase in kernels/spike will occur by an extension of the growing season.

## Other Characters of Wheat and Their Relation to Yield

In an experiment by McNeal et al. (23), it was noted that plant height had a negative relation to yield. This may be the reason semi-dwarfs often produce higher yields. Height was also negatively associated to kernels/spike and number of heads. Height was positively related to kernel weight.

Test weight is an important grading factor in wheat. The environment profoundly affects this character. Unfavorable environmental conditions may cause kernels not to fill properly, reducing the test weight by shriveling of the kernels (9).

# CHAPTER III

# MATERIALS AND METHODS

## Materials

In this experiment the performance of five adapted winter wheat cultivars was studied at three seeding rates and six planting dates. The study was conducted on the Stillwater Agronomy Research Station, Stillwater, Oklahoma, during the 1977-78 crop year. The soil was a Port clay loam. Is is deep, reddish brown alluvial soil which is well drained and easily worked.

The five winter wheat cultivars adapted to the state were 'Triumph 64', 'Osage', 'Vona', 'Newton', and 'Payne'. Triumph 64 was released in 1964 and since its release has been a popular cultivar with growers in Oklahoma (28). It is a standard height cultivar and is early in maturity. Triumph 64 was used in this study as a control for comparison with the four newer cultivars. Osage was released in 1974 jointly by the Oklahoma and Texas Agricultural Experiment Stations. This cultivar is of standard height, medium to medium late in maturity, and has good resistance to leaf rust and powdery mildew. It is a good grazing wheat and produces good grain yields (30). Vona was released by Colorado State University in 1976. It is an early maturing, semidwarf cultivar, and produces good grain yields (33). Newton was released by Kansas State University in 1977. It is a semidwarf wheat, medium in maturity, resistant to soil born mosaic virus. It is moderately resistant to leaf rust and stem rust and produces above average grain yields (12). Payne was released in 1978 by Oklahoma State University. It is a semidwarf, medium in maturity, resistant to leaf rust and produces good yields (29). In 26 performance trials in Oklahoma in 1977-78, Vona, Newton, Payne, Triumph 64, and Osage ranked 1st, 3rd, 4th, 9th and 10th respectively out of 16 cultivars tested (20).

The source of seed for planting of all cultivars was 1977 Foundation Seed. The seeding rates used in this study were equivalent to 34 kg/ha (30 lbs/A), 67 kg/ha (60 lbs/A) and 101 kg/ha (90 lbs/A). These three seeding rates represent the range normally used by farmers in the state. A seed sample of each cultivar was counted and weighed in order to insure that equal number of seeds of each cultivar were planted. The rates of seeding were made on basis of seed count.

There were six planting dates. These were September 20, October 4, October 18, November 1, November 15, and December 1. These six dates cover the range of times wheat is usually planted in Oklahoma. For an average year the optimum planting date in the Stillwater area is early October. That time was October 4, in this study. The land area used in this study had been clean-tilled during the preceeding summer. The plots were planted with a tractor-mounted 4-row cone planter.

The field layout was a split-plot factorial. Each main plot represented one planting date and the five cultivars and three seeding rates (15 treatments) were arranged factorially in each of three replications. The individual plots were four 3.0 m rows with 30 cm spacing between rows. TAM W-103, at a 67 kg/ha rate, was used as a guard around the main plots. At maturity all four rows of each plot were harvested with a Hege plot combine.

An 18-46-0 fertilizer was applied to all plots before planting on September 1 at the rate of 112 kg/ha. An additional top dressing of 135 kg/ha of amonium nitrate (45 kg/ha of N) was applied on February 27 to all plots.

The growing season at Stillwater was characterized by normal precipitation, with a near normal monthly distribution. There was an extended cold period with snow cover during January and February (24).

## Characters Evaluated

Seven characters were evaluated. They were heading date, plant height, number of tillers per unit area, average number of kernels/spike, average kernel weight, grain yield, and test weight.

### Heading Date

Heading date was described as the number of days from March 31 until approximately 75% of the plants in the plot were headed.

### Plant Height

A meter stick was held in the middle of the plot and the average height of the plants, excluding the awns, was recorded in cm. Some of the wheat stems that were leaning at the time of measurement were held upright against the meter stick.

### Tiller Number

The number of seed-bearing tillers was determined by counting the number of fertile tillers in two different randomly selected 30 cm sections in each of two rows in each plot. The average of the two counts was determined. This character was expressed as tillers per 30 $cm^2$.

Kernels/Spike

The average number of kernels/spike was obtained by taking six random upper story spikes from each plot, threshing the spikes and then counting the kernels. This trait was expressed as the average number of kernels/spike.

Kernel Weight

Kernel weight was determined by weighing to the nearest 1/10 of a gram, the grain from the six spikes that were counted to obtain the kernels/spike measurement. The weight was then divided by the number of kernels. This data gives the average individual kernel weight, which was multiplied by 1,000 and then expressed as grains per 1,000 kernels.

Grain Yield

Yield was determined by weighing the threshed grain from the four 3.0 m rows which comprised a plot. Yield was first determined in grams per plot, then converted to kg/ha.

Test Weight

Test weight was measured in pounds per bushel by using a small-scale test weight apparatus, then converted to kg/hl.

## Statistical Analysis

An analysis of variance was conducted for all seven measured characters for each planting date and seeding rate. A combined statistical analysis was also used to detect any significant genotype by rate, genotype by date, rate by date or genotype by rate by date interaction for all seven characters.

The results of the analysis as shown in Tables I and II, are expressed in mean squares. A single asterisk (*) denotes a .1 level of significance, a double asterisk (**) denotes a .01 level of significance and a triple asterisk (***) denotes a .001 level of significance.

Least significant difference (LSD) values were calculated for testing ten different treatment comparisons at the .05 level of probability for all seven characters. For the following equations used in determining the LSD values:

r is the number of replications (3),

p is the number of planting dates (6),

g is the number of genotypes (5),

s is the number of seeding rates (3),

E(a) is error a with 12 df and a "t" value of 2.17, and

E(b) is error b with 168 df and a "t" value of 1.96.

1) LSD for comparison between two planting dates averaged over all other factors:

$$\text{LSD} = t\sqrt{\frac{2[E(a)]}{rsg}} = 2.17\sqrt{\frac{2[E(a)]}{(3)(3)(5)}}$$

2) LSD for comparison between two genotypes averaged over all other factors:

$$\text{LSD} = t\sqrt{\frac{2[E(b)]}{rps}} = 1.96\sqrt{\frac{2[E(b)]}{(3)(6)(3)}}$$

3) LSD for comparison between two seeding rates averaged over all other factors:

$$LSD = t\sqrt{\frac{2[E(b)]}{rpg}} = 1.96\sqrt{\frac{2[E(b)]}{(3)(6)(5)}}$$

4) LSD for comparison between two genotypes by seeding rate averaged over all other factors:

$$LSD = t\sqrt{\frac{2[E(b)]}{rp}} = 1.96\sqrt{\frac{2[E(b)]}{(3)(6)}}$$

5) LSD for comparison between two genotypes for a given planting date:

$$LSD = t\sqrt{\frac{2[E(b)]}{rs}} = 1.96\sqrt{\frac{2[E(b)]}{(3)(3)}}$$

6) LSD for comparison between two seeding rates for a given planting date:

$$LSD = t\sqrt{\frac{2[E(b)]}{rg}} = 1.96\sqrt{\frac{2[E(b)]}{(3)(5)}}$$

7) LSD for comparison between two genotypes by seeding rate for a given planting date:

$$LSD = t\sqrt{\frac{2[E(b)]}{r}} = 1.96\sqrt{\frac{2[E(b)]}{3}}$$

8) LSD for comparison between two planting dates for a given genotype:

$$LSD = t'\sqrt{\frac{2[(g-1)E(b) + E(a)}{rsg}} = t'\sqrt{\frac{2[(4)E(b) + E(a)]}{(3)(3)(5)}}$$

$$t' = \frac{(v-1)[t_{df\ for\ E(b)}]\ E(b) + [t_{df\ for\ E(a)}]\ E(a)}{(g-1)E(b) + E(a)}$$

$$= \frac{(4)(1.96)[E(b)] + (2.17)[E(a)]}{(4)E(b) + E(a)}$$

9) LSD for comparison between two planting dates for a given seeding rate:

$$LSD = t'' \sqrt{\frac{2[(s-1)E(b) + E(a)]}{rsg}} = t'' \sqrt{\frac{2[(2)E(b) + E(a)}{(3)(3)(5)}}$$

$$t'' = \frac{(s-1)[t_{df\ for\ E(b)}][E(b)] + [t_{df\ for\ E(a)}][E(a)]}{(g-1)E(b) + E(a)}$$

$$= \frac{(2)(1.96)[E(b)] + (2.17)[E(a)]}{(2)E(b) + E(a)}$$

10) LSD for comparison between two planting dates for a given genotype by seeding rate:

$$LSD = t''' \sqrt{\frac{2[(sv-1)E(b) + E(a)]}{rsg}} = t''' \sqrt{\frac{2[(14)E(b) + E(a)}{(3)(3)(5)}}$$

$$t''' = \frac{(sg-1)[t_{df\ for\ E(b)}][E(b)] + [t_{df\ for\ E(a)}][E(a)]}{(sg-1)E(b) + E(a)}$$

$$= \frac{(14)(1.96)[E(b)] + (2.17)[E(a)]}{14[E(b)] + [E(a)]}$$

# CHAPTER IV

## RESULTS AND DISCUSSION

This study was designed to determine the effect of date and rate of seeding on the performance of seven measured agronomic traits of five winter wheat cultivars. The study was also designed to detect interactions involving planting dates, seeding rates and genotypes. To achieve these goals, five adapted wheat cultivars were planted at three seeding rates on six separate planting dates. Grain yield, the three components of yield, including tillers, kernels/spike and 1000-kernel weight along with days to head, test weight and plant height, were measured in order to determine agronomic performance and to calculate effects and interactions of planting date, seeding rate and genotype.

During the course of this study, conducted on the Agronomy Research Station at Stillwater, there were no unusual stress factors involved. There were no serious problems with insects, diseases or lodging. However, there was somewhat of a weed problem on Dates 4, 5, and 6.

Generally the growing season was typical for wheat and the highest yields were obtained from an early October planting. As an indication of the general level of productivity of the test, mean grain yields were 2174, 2445, 2003, 1731, 1699, 1436 kg/ha (32.4, 36.4, 29.8, 25.8, 25.3, 21.4 bu/acre) respectively for Planting Dates 1 through 6. This compares favorably with yield trial average at Stillwater on a Norge loam soil the same year, where 30 wheat cultivars were tested at a seeding rate of

67 kg/ha and planted on October 27. The average grain yield was 1907 kg/ha and grain yields ranged from 2458 kg/ha for 'Rocky' to 1209 kg/ha for 'Hutch' (24).

## Combined Analysis of Variance

The combined analysis of variance (Table I) indicated that each of the seven characters measured was significantly affected by planting date. There was also a significant variance among cultivars for all seven characters. Although seeding rate did not significantly affect heading date, plant height or test weight, it did affect grain yield and the components of yield (tiller number, kernels/spike and kernel weight). The genotype by seeding rate interaction was not statistically significant, however the genotype by date interaction was significant for all characters except tiller number, demonstrating that the cultivars responded differently, relative to each other, at different planting dates. A significant seeding rate by planting date interaction was found for kernels/spike and heading date and a significant second order interaction was found for genotype by seeding rate by planting date for plant height.

## Grain Yield

The analysis of variance for grain yield (Table II) showed significant differences among cultivars for grain yield at Planting Dates 2, 4, and 6 but not at Dates 1, 3, and 5. Significant differences among seeding rates were observed at Planting Dates 3 and 4. There were no significant genotype by seeding rate interactions at any of the six planting dates for grain yield. Generally, as indicated by Table II, yield response was not greatly affected by seeding rate differences. This is in agreement with studies on Turkey wheat reported by Kiesselbach and Lyness (17).

Mean grain yield performance in kg/ha is presented in Table III for genotypes, seeding rates and planting dates. Grain yield relationships among cultivars and seeding rates are shown in Figure 1. Averaged across genotype and seeding rates, grain yields for Dates 1 through 5 respectively were 2174, 2445, 2003, 1731, 1699, 1436 kg/ha. The highest average yield was obtained at Date 2 (October 4). The second highest grain yield was observed at Date 1 (September 20). Grain yields declined markedly at Dates 3 through 6.

Averaged across genotypes and planting dates, grain yields were 1835, 1930, 1979 kg/ha for seeding rates of 34, 67 and 101 kg/ha, respectively. Average grain yields were similar for the three seeding rates in four of the planting dates. Figure 1b illustrates that on Dates 3 and 4 the yields from seeding rate 34 kg/ha were noticeably lower than those of the two higher seeding rates. All three seeding rates had similar patterns of yields response although the 34 kg/ha seeding rate deviated somewhat from that pattern on Dates 3 and 4 as mentioned above.

The cultivar Vona had the highest average grain yield followed by Osage, Newton, Triumph and Payne with yields of 2094, 1963, 1973, 1861, and 1783 kg/ha respectively.

The lowest seeding rate gave the lowest average grain yield for four of the five cultivars. The exception, Vona, had its lowest average yield at 67 kg/ha seeding rate. In all but one case the highest average yield was produced by the highest seeding rate. Newton had the highest grain yield at Date 1, Vona the highest at Date 2, Osage at Date 3, Vona the highest at Dates 4 and 5, and Triumph 64 the highest at Date 6.

As shown on Figure 1a, the yield performance of Triumph 64 changed relatively little with respect to the other cultivars across the six planting dates, demonstrating the stability of this cultivar in varying environments.

## Tiller Number

Each of the five wheat cultivars tested varied considerable in their ability to tiller and, consequently, there were significant differences among genotypes for this trait (Table II) in five of the six planting dates.

Differences among seeding rates as shown in Table II, significantly affected the tillering at Planting Dates 3, 4, and 6. Tillering at the 34 kg/ha seeding rate was somewhat lower on these dates, than the higher seeding rates (Table IV). Seeding rate appeared to be more directly involved in the amount of tillering than is indicated by Table II and III because the 34 kg/ha seeding rate plots would have had to produce three times the amount of tillering per plant to equal the tiller level of the 101 kg/ha seeding rate. Individual plants at the lower seeding rate had more moisture and nutrients than the denser plants in plots with higher seeding rates and consequently were capable of producing a higher number of tillers. As the season progressed the individual plants had less time to tiller. The results showed that the lower seeding rates were at a disadvantage at later planting dates. This is in agreement with studies by Croy (5). In his rate by date studies he found that later-planted wheat produced fewer tillers. Where earlier planted wheat does about the same at all seeding rates, later-planted wheat produced higher yields at higher seeding rates. There was no significant genotype by rate interaction for this trait (Table II).

The tillering pattern (Figure 2) closely paralleled that of yield (Figure 1). The cultivars that tillered the most produced the highest yields. As shown in Figure 2b, tiller number was lower for the 34 kg/ha rate on Dates 2 through 6 but there did not appear to be much difference between the 67 and 101 kg/ha rates on the effect of tiller number (Table IV, Figure 2b).

Averaged across rates, the tiller number increased from Planting Date 1 to Date 2 and then decreased sharply with the later planting dates. This decrease in the amount of tillering would account for a large portion of the decrease in grain yield that occurred with the later planting dates. Vona and Osage had the highest number of tillers. The tiller number of Triumph 64 decreased below that of the other cultivars in Planting Dates 4 through 6.

## Kernels/Spike

The analysis of variance (Table II) showed that there were significant differences among cultivars for kernels/spike at all six planting dates. It is noteworthy that seeding rates had a significant effect on kernels/spike at all six planting dates (Table II). This was the only trait that showed significant mean squares for seeding rates at all six planting dates. The lowest seeding rate (34 kg/ha) consistently produced the highest number of kernels/spike (Table V). This larger number of kernels/spike, along with higher tillering, would help to reduce the decrease in grain yield one might expect at lower seeding rates. There were no appreciable differences in the number of kernels/spike between the 67 and 101 kg/ha seeding rates (Table V, Figure 3b). There was only one date (Date 5) in which a significant genotype by rate interaction occurred for kernels/spike (Table II).

In contrast to the response patterns of tiller number and grain yield, the values for kernels/spike were lowest at Planting Date 2 and then increased with later planting dates (Figure 3).

Triumph 64 was conspicuously low in number of kernels/spike at all six planting dates. Vona had the highest number of kernels/spike at Planting Dates 1, 2, and 3 while Newton had the highest values for this trait at Planting Dates 4, 5, and 6.

## Kernel Weight

There were significant differences among genotypes for kernel weight at all six planting dates (Table II). Dates 1 and 6 showed significant differences among seeding rates for this trait. As shown in Figure 4b, all three seeding rates followed the same general pattern with regard to kernel weight response. That is, each was high on the first planting date and decreased with subsequent plantings. All three rates gave approximately the same average kernel weight value, with the exception of Dates 1 and 6, where the seeding rate of 34 kg/ha produced somewhat higher average kernel weight values than did the higher seeding rates.

There was also a significant genotype by seeding rate interaction for Planting Dates 1 and 6. A partial explanation, as shown in Figure 4 and Table VI, is that Newton had a relatively high value for this trait at Date 1, but a low value at Date 6. Conversely, Payne had a low value at Date 1 and a relatively high value at Date 6.

It is interesting to note that Triumph 64 had much higher average kernel weight values for all six planting dates than did any of the other cultivars. Triumph 64 also had the lowest number of kernels/spike for all planting dates (Figure 3a). The high kernel weight of this cultivar apparently compensated for the low number of kernels/spike. Adams (1) discussed the compensation of certain yield components for each other. When one component that is initiated early in the development cycle of the plant decreases, another, later developing component, tends to increase. Triumph 64 maintained high kernel weight for all planting dates which further demonstrates the stability of this cultivar across different environments and helps to explain why it did not decrease as drastically in grain yield as did the other four wheat cultivars with later planting dates.

Newton and Osage both had relatively high kernel weight values at Date 1, but both dropped off drastically with later plantings. On the other hand, Vona and Payne had the lowest average kernel weights, but exceeded Newton and Osage for this trait at Planting Dates 5 and 6 (Figure 4).

In regard to the major yield components of wheat (tiller number, kernels/spike, and kernel weight), the data from Table II indicated that in the six planting dates (environments) studied, seeding rates had little effect on kernel weight, some effect on tiller number and a more marked effect on kernels/spike. These data suggest that of the three major components of yield, kernels/spike was the most variable and would be the least stable under stress conditions.

## Heading Date

There were significant differences among genotypes for heading date at all six planting dates (Table II). Newton and Osage were late, Payne was medium and Triumph 64 and Vona were early in maturity in this study (Table VII and Figure 5). This information is consistent with the general descriptions of these varieties (12, 28, 29, 30, and 33).

All five cultivars followed the same pattern across planting dates for this trait (Figure 5). Earlier-planted plots require fewer days to head. Later planted wheat took longer (Table VII, Figure 5a). Averaged across genotypes and seeding rates, earliest date of planting (September 20) matured 10 days before the latest planting date (December 1).

The analysis of variance (Table II) showed that heading date was significantly affected by the seeding rate of Planting Dates 2 and 3. As shown in Figure 5 the seeding rate of 34 kg/ha took about one day longer to head on Planting Dates 2 and 3 than did the 67 and 101 kg/ha seeding rates. The effect of seeding rate on heading date was considered to be of little consequence. There was only one instance (Date 3) of a significant genotype by seeding rate interaction for heading date.

## Plant Height

Significant differences among cultivars at all six planting dates were observed for plant height (Table II). Triumph 64 and Osage had the highest values for this trait while Newton, Vona, and Payne had lower values and appeared to be of similar height (Table VIII, Figure 6a). These findings are consistent with the general description of the cultivars (12, 28, 29, 30, 33). Triumph 64 and Osage are standard height and

Newton, Vona and Payne are all semi-dwarf cultivars. Plant height followed the same response pattern as yield. Plant height reached its maximum on Planting Date 2 and declined with later planting dates (Figure 6). Neither seeding rates nor genotype by seeding rate interaction were significant with respect to plant height.

## Test Weight

There were significant differences among genotypes at all six planting dates for test weight (Table II). All five cultivars reached their highest test weight on Planting Date 2 and generally values for this trait declined gradually with later planting dates (Table IX, Figure 7). However, this decline was less pronounced for Triumph 64 and Osage than for the other three cultivars.

Triumph 64 had the highest test weight at all six plantings and did not fluctuate as much as the other cultivars. Osage also remained relatively stable for this trait whereas Payne, Newton, and Vona decreased rather sharply with later plantings.

The analysis of variance for test weight showed that there were significant differences among seeding rates at Planting Dates 1 and 5. Except for these two deviations the response pattern was the same for the three seeding rates. Accordingly, seeding rate had very little effect on test weight.

## Interrelationships Among Characters

In order to examine the response patterns of the seven characters across the six planting dates, each trait was plotted by relative units and presented in Figure 8. In this figure, the distance of the lines above the starting point have no meaning. It is the relative response curve of one trait to another across the six dates that is important.

Grain yield, tiller number and plant height showed similar response patterns as demonstrated in Figure 8. They all hit a peak on Date 2, then dropped off sharply at later planting dates. Apparently these three traits responded in a similar fashion to the environmental stresses that the plants encountered at each of the six planting dates.

Grantham (10) also found this to be true. The fact that tillering decreases with later planted wheat is probably the major factor contributing to the decrease in grain yield for later planted stands of wheat. Kernel weight also declined with later plantings, further causing a decrease in grain yield. Kernels/spike showed an inverse relationship to tiller number across the planting dates. It was lowest on Date 2 and continually rose with each sucessive planting date. This increase to some degree compensated for the decrease in the other two yield components (tillering and kernel weight). Test weight generally remained relatively stable throughout the study, but did peak slightly on Planting Date 2 and then gradually declined with later planting dates. It should also be noted (Figure 1) that the later the planting date, the later the heading date in the spring.

# CHAPTER V

## SUMMARY AND CONCLUSIONS

This study was conducted on the Agronomy Research Station, Stillwater, Oklahoma, during the 1977-78 crop year. The purpose of the study was to determine the response of five adapted winter wheat cultivars with respect to different planting dates, and seeding rates and also to study possible interactions between cultivar, seeding rate and planting date. Of the five wheat cultivars used, four were relatively new cultivars (Payne, Newton, Osage, and Vona) and one, Triumph 64, a cultivar which has been widely grown in the state for many years, was used as a control. Six planting dates were used. They were chosen to cover the range of dates wheat is usually planted in Oklahoma. The dates were September 20, October 4, October 18, November 1, November 15, and December 1. Three seeding rates were used. They were 34, 67, and 101 kg/ha. A split plot factorial design was used in which planting dates comprised the main plots. Seeding rates by cultivar combinations were arranged factorially with three replications. Individual plots consisted of four 3.0 m rows spaced 30 cm apart. Characters evaluated were grain yield, tillers per unit area, kernels/spike, kernel weight, days to head, plant height, and test weight.

All characters were statistically analyzed. A combined analysis of variance showed (1) that planting date significantly affected all seven characters, (2) there were differences among cultivars for all characters,

(3) seeding rate did not appear to have much effect on cultivar performance, except for the character kernels/spike, (4) there was no cultivar by rate interaction, and (5) there was a cultivar by date interaction for all characters with the exception of tiller number.

Grain yield, tiller number, and plant height showed similar response patterns for the six planting dates, with values for these traits being the highest at Date 2 and then dropping off sharply at later planting dates. Kernel weight values also declined with later planting dates, no doubt contributing to the reduction in grain yield with later planted wheat. Kernels/spike demonstrated an inverse relationship to the grain yield pattern with respect to the planting dates. Kernels/spike values increased with each successive planting after Date 2. Test weight was generally stable across the planting dates although there was a slight peak on Planting Date 2 and then a gradual decline with later planting dates.

Triumph 64 appeared to be the most stable cultivar across the planting dates (environments) in relation to the newer cultivars. Triumph 64 was lower in yield at earlier planting dates but did not drop off as drastically as the other cultivars on later planting dates. The stability of Triumph 64 was also demonstrated by the kernel response pattern in which its kernel weight remained relatively constant across the six planting dates. This type of stability response is consistent with observations that Triumph 64 performs well under various stress conditions. On the other hand, for a year with average growing conditions, the newer cultivars, especially Vona and Newton, gave much higher yields when planted at the optimum time, which in this study was early October.

Newton had the highest grain yield at Date 1, Vona the highest at Dates 2, 4, and 5, Osage at Date 3 and Triumph 64 the highest at Date 6.

The three seeding rates had similar patterns of yield response, although the 34 kg/ha seeding rate was somewhat lower than the two higher seeding rates at Dates 3 and 4. It appears that the lower seeding rates are at a disadvantage at later planting dates because wheat tillers less at later planting dates.

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# APPENDIXES

# APPENDIX A

# TABLES

TABLE I

MEAN SQUARES FROM THE COMBINED ANALYSIS OF VARIANCE FOR SEVEN CHARACTERS

| Source of Variation | df | Grain Yield | Tiller Number | Kernels per Spike | Kernel Weight | Heading Date | Plant Height | Test Weight |
|---|---|---|---|---|---|---|---|---|
| Date | 5 | 1323.16** | 2345.95*** | 844.95*** | 414.26*** | 698.25*** | 2836.74*** | 29.44*** |
| E(a) | 12 | 245.80 | 237.44 | 19.75 | 13.09 | 7.82 | 189.92 | 3.08 |
| Genotype | 4 | 168.31*** | 939.66*** | 846.96*** | 924.23*** | 761.28*** | 2497.04*** | 148.96*** |
| Rate | 2 | 106.97** | 459.06*** | 403.70*** | 18.20* | 1.20 | 0.81 | 1.69 |
| G x R | 8 | 12.49 | 29.41 | 13.04 | 9.06 | 0.90 | 51.19 | 1.27 |
| G x D | 20 | 37.96* | 77.62 | 35.23*** | 46.59*** | 2.54*** | 85.88** | 6.63*** |
| R x D | 10 | 17.53 | 49.30 | 16.59* | 6.68 | 1.53* | 33.71 | 2.17 |
| G x R x D | 40 | 16.27 | 43.39 | 7.96 | 7.47 | 0.79 | 52.39* | 1.22 |
| E(b) | 168 | 19.20 | 56.79 | 9.39 | 6.18 | 0.64 | 38.48 | 1.48 |

*Significant at the .1 probability level
**Significant at the .01 probability level
***Significant at the .001 probability level

TABLE II

MEAN SQUARES FROM THE ANALYSIS OF VARIANCE FOR GRAIN YIELD, TILLER NUMBER, KERNELS/SPIKE, KERNEL WEIGHT, HEADING DATE, PLANT HEIGHT AND TEST WEIGHT

| Source of Variation | df | Dates | | | | | |
|---|---|---|---|---|---|---|---|
| | | D 1 | D 2 | D 3 | D 4 | D 5 | D 6 |
| | | | | Grain Yield | | | |
| Genotype | 4 | 26.57 | 83.76** | 60.10 | 117.03** | 36.50 | 34.15* |
| Seeding Rate | 2 | 19.28 | 18.64 | 74.81* | 77.18* | 4.30 | 0.41 |
| G x R | 8 | 8.97 | 15.36 | 23.33 | 24.33 | 12.84 | 9.01 |
| Error | 28 | 14.38 | 19.28 | 28.74 | 18.93 | 18.18 | 15.68 |
| | | | | Tiller Number | | | |
| Genotype | 4 | 137.44* | 360.77** | 328.29** | 283.43* | 106.91 | 110.90** |
| Seeding Rate | 2 | 1.52 | 117.95 | 190.21* | 311.09* | 14.57 | 70.21* |
| G x R | 8 | 36.45 | 31.10 | 41.72 | 69.63 | 45.37 | 22.08 |
| Error | 28 | 59.11 | 61.54 | 59.94 | 71.93 | 62.93 | 25.30 |
| | | | | Kernels/Spike | | | |
| Genotype | 4 | 90.51*** | 98.99*** | 97.39*** | 121.58*** | 310.88*** | 303.75*** |
| Seeding Rate | 2 | 29.17* | 12.71* | 50.60** | 98.23*** | 214.09*** | 81.83* |
| G x R | 8 | 4.93 | 4.32 | 12.42 | 2.01 | 20.01* | 9.14 |
| Error | 28 | 7.05 | 3.74 | 8.49 | 5.66 | 7.09 | 24.28 |
| | | | | Kernel Weight | | | |
| Genotype | 4 | 92.03*** | 94.85*** | 144.65*** | 171.93*** | 275.68*** | 378.03*** |
| Seeding Rate | 2 | 13.28* | 0.45 | 3.02 | 4.79 | 11.08 | 18.96* |
| G x R | 8 | 8.20* | 2.27 | 1.45 | 8.04 | 12.93 | 13.51* |
| Error | 28 | 3.55 | 3.19 | 3.87 | 5.86 | 14.44 | 6.15 |
| | | | | Heading Date | | | |
| Genotype | 4 | 96.94*** | 117.41*** | 114.39*** | 150.58*** | 149.63*** | 145.06*** |
| Seeding Rate | 2 | 0.02 | 4.02* | 2.87** | 1.09 | 0.56 | 0.29 |
| G x R | 8 | 0.33 | 1.58 | 1.17* | 0.73 | 0.58 | 0.46 |
| Error | 28 | 0.71 | 0.87 | 0.49 | 0.78 | 0.36 | 0.64 |
| | | | | Plant Height | | | |
| Genotype | 4 | 588.14*** | 419.11*** | 462.94** | 336.83*** | 483.97*** | 635.48*** |
| Seeding Rate | 2 | 20.69 | 40.62 | 46.67 | 44.82 | 6.96 | 9.62 |
| G x R | 8 | 24.91 | 20.18 | 144.28 | 75.10 | 34.07 | 14.59 |
| Error | 28 | 34.02 | 26.84 | 87.45 | 39.60 | 20.61 | 22.36 |
| | | | | Test Weight | | | |
| Genotype | 4 | 22.41*** | 13.69*** | 29.14*** | 37.24*** | 42.81*** | 36.81*** |
| Seeding Rate | 2 | 6.47* | 0.16 | 0.16 | 0.29 | 5.27* | 0.20 |
| G x R | 8 | 0.91 | 1.07 | 0.79 | 1.18 | 1.96 | 1.48 |
| Error | 28 | 1.30 | 0.81 | 1.18 | 1.98 | 1.56 | 2.06 |

*Significant at the .1 probablility level
**Significant at the .01 probability level
***Significant at the .001 probability level

# TABLE III

## MEANS AND LSD VALUES FOR GRAIN YIELD (kg/ha) BY CULTIVAR, SEEDING RATE AND PLANTING DATE

| Genotype | Seeding Rate Kg/ha | Date D 1 | D 2 | D 3 | D 4 | D 5 | D 6 | Avg. |
|---|---|---|---|---|---|---|---|---|
| Newton | 34 | 2301 | 2720 | 1832 | 1094 | 1508 | 1434 | 1815 |
| Newton | 67 | 2259 | 2428 | 1745 | 1508 | 1588 | 1453 | 1830 |
| Newton | 101 | 2387 | 2556 | 2198 | 1718 | 1663 | 1328 | 1975 |
| Average | | 2316 | 2568 | 1925 | 1440 | 1586 | 1405 | 1873 |
| Osage | 34 | 2323 | 2420 | 2163 | 1682 | 1600 | 1258 | 1908 |
| Osage | 67 | 2112 | 2379 | 2179 | 1849 | 1859 | 1500 | 1980 |
| Osage | 101 | 2056 | 2407 | 2284 | 2205 | 1619 | 1445 | 2003 |
| Average | | 2164 | 2402 | 2209 | 1912 | 1692 | 1401 | 1963 |
| Payne | 34 | 2099 | 2172 | 1335 | 1509 | 1438 | 1274 | 1638 |
| Payne | 67 | 2150 | 2342 | 2017 | 1745 | 1632 | 1352 | 1873 |
| Payne | 101 | 2351 | 2464 | 1956 | 1454 | 1680 | 1125 | 1839 |
| Average | | 2201 | 2326 | 1769 | 1569 | 1583 | 1250 | 1783 |
| Triumph | 34 | 1884 | 2035 | 1847 | 1453 | 1672 | 1590 | 1747 |
| Triumph | 67 | 1954 | 2277 | 2157 | 1922 | 1743 | 1437 | 1915 |
| Triumph | 101 | 2146 | 2297 | 1933 | 1730 | 1743 | 1668 | 1920 |
| Average | | 1995 | 2203 | 1979 | 1702 | 1720 | 1565 | 1861 |
| Vona | 34 | 2234 | 2459 | 2034 | 2039 | 2088 | 1562 | 2068 |
| Vona | 67 | 2029 | 2911 | 2069 | 2136 | 1700 | 1474 | 2053 |
| Vona | 101 | 2324 | 2805 | 2309 | 1921 | 1958 | 1645 | 2160 |
| Average | | 2195 | 2725 | 2134 | 2032 | 1915 | 1560 | 2094 |
| Average Rate | | | | | | | | |
| | 34 | 2168 | 2361 | 1840 | 1556 | 1661 | 1424 | 1835 |
| | 67 | 2101 | 2467 | 2033 | 1832 | 1705 | 1443 | 1930 |
| | 101 | 2253 | 2506 | 2136 | 1806 | 1733 | 1442 | 1979 |
| Average Date | | | | | | | | |
| | | 2174 | 2445 | 2003 | 1731 | 1699 | 1436 | 1915 |

LSD (.05) for comparison between two planting dates averaged over all other factors = 484.31

LSD (.05) for comparison between two genotypes averaged over all other factors = 274.23

LSD (.05) for comparison between two seeding rates averaged over all other factors = 212.42

LSD (.15) for comparison between two genotypes by seeding rate averaged over all other factors = 474.98

LSD (.05) for comparison between two genotypes for a given planting date = 111.95

LSD (.05) for comparison between two seeding rates for a given planting date = 86.72

LSD (.05) for comparison between two genotypes by seeding rate for a given planting date = 193.91

LSD (.05) for comparison between two planting dates for a given genotype = 542.71

LSD (.05) for comparison between two planting dates for a given seeding rate = 513.79

LSD (.05) for comparison between two planting dates for a given genotype by seeding rate = 662.41

TABLE IV

MEANS AND LSD VALUES FOR TILLER NUMBER (NO./30cm$^2$) BY CULTIVAR, SEEDING RATE AND PLANTING DATE

| Genotype | Seeding Rate Kg/ha | Date D 1 | D 2 | D 3 | D 4 | D 5 | D 6 | Avg. |
|---|---|---|---|---|---|---|---|---|
| Newton | 34 | 45.0 | 52.7 | 48.2 | 39.3 | 40.0 | 35.7 | 43.5 |
| Newton | 67 | 48.5 | 52.8 | 42.5 | 45.3 | 36.8 | 37.2 | 43.9 |
| Newton | 101 | 41.8 | 57.5 | 49.2 | 46.0 | 44.5 | 43.2 | 47.0 |
| Average | | 45.1 | 54.3 | 46.6 | 43.6 | 40.4 | 38.7 | 44.8 |
| Osage | 34 | 46.7 | 63.3 | 50.7 | 48.3 | 46.5 | 33.3 | 48.1 |
| Osage | 67 | 52.2 | 62.3 | 60.7 | 53.5 | 51.5 | 43.3 | 53.9 |
| Osage | 101 | 48.3 | 64.2 | 66.3 | 67.0 | 41.8 | 41.8 | 54.9 |
| Average | | 49.1 | 63.3 | 59.2 | 56.3 | 46.6 | 39.5 | 52.3 |
| Payne | 34 | 53.0 | 46.2 | 41.2 | 44.3 | 41.5 | 34.0 | 43.4 |
| Payne | 67 | 47.5 | 55.3 | 48.3 | 48.8 | 40.7 | 35.8 | 46.1 |
| Payne | 101 | 48.2 | 50.7 | 48.3 | 40.7 | 49.8 | 33.7 | 45.2 |
| Average | | 49.6 | 50.7 | 45.9 | 44.6 | 44.0 | 34.5 | 44.9 |
| Triumph | 34 | 46.2 | 53.2 | 43.7 | 37.0 | 38.8 | 32.2 | 41.8 |
| Triumph | 67 | 46.2 | 64.2 | 51.8 | 46.5 | 40.3 | 31.0 | 46.7 |
| Triumph | 101 | 53.3 | 57.5 | 49.5 | 46.5 | 39.3 | 34.8 | 46.8 |
| Average | | 48.6 | 58.3 | 48.3 | 43.3 | 39.5 | 32.7 | 45.1 |
| Vona | 34 | 58.2 | 61.3 | 53.7 | 42.8 | 46.0 | 39.6 | 50.3 |
| Vona | 67 | 54.8 | 67.0 | 55.5 | 55.3 | 47.8 | 40.3 | 53.5 |
| Vona | 101 | 54.7 | 70.3 | 59.3 | 52.7 | 47.2 | 42.8 | 54.5 |
| Average | | 55.9 | 66.2 | 56.2 | 50.3 | 47.0 | 40.9 | 52.7 |
| Average Rate | | | | | | | | |
| | 34 | 49.8 | 55.3 | 47.5 | 42.4 | 42.6 | 35.0 | 45.4 |
| | 67 | 49.8 | 60.3 | 51.8 | 49.9 | 43.4 | 37.5 | 48.8 |
| | 101 | 49.3 | 60.0 | 54.5 | 50.6 | 44.5 | 39.3 | 49.7 |
| Average Date | | | | | | | | |
| | | 49.6 | 58.6 | 51.3 | 47.6 | 43.5 | 37.3 | 48.0 |

LSD (.05) for comparison between two planting dates averaged over all other factors = 7.37

LSD (.05) for comparison between two genotypes averaged over all other factors = 7.01

LSD (.05) for comparison between two seeding rates averaged over all other factors = 5.43

LSD (.05) for comparison between two genotype by seeding rates averaged over all other factors = 12.15

LSD (.05) for comparison between two genotypes for a given planting date = 2.86

LSD (.05) for comparison between two seeding rates for a given planting date = 2.22

LSD (.05) for comparison between two genotypes by seeding rate for a given planting date = 4.96

LSD (.05) for comparison between two planting dates for a given genotype = 9.61

LSD (.05) for comparison between the planting dates for a given seeding rate = 8.55

LSD (.05) for comparison between two planting dates for a given genotype by seeding rate = 13.76

# TABLE V

## MEANS AND LSD VALUES FOR KERNELS/SPIKE (NO./SPIKE) BY CULTIVAR, SEEDING RATE AND PLANTING DATE

| Genotype | Seeding Rate Kg/ha | Date D 1 | D 2 | D 3 | D 4 | D 5 | D 6 | Avg. |
|---|---|---|---|---|---|---|---|---|
| Newton | 34 | 36.7 | 31.3 | 36.3 | 37.3 | 45.7 | 47.5 | 39.2 |
| Newton | 67 | 32.9 | 28.6 | 27.8 | 33.2 | 42.2 | 45.5 | 35.0 |
| Newton | 101 | 33.6 | 29.7 | 30.3 | 32.4 | 39.6 | 44.0 | 34.9 |
| Average | | 34.4 | 29.9 | 31.5 | 34.3 | 42.5 | 45.7 | 36.4 |
| Osage | 34 | 32.1 | 30.0 | 31.7 | 32.4 | 45.2 | 46.1 | 36.3 |
| Osage | 67 | 32.2 | 29.3 | 27.4 | 30.1 | 37.5 | 41.1 | 32.9 |
| Osage | 101 | 31.9 | 27.0 | 26.5 | 29.9 | 31.4 | 40.4 | 31.2 |
| Average | | 32.1 | 28.8 | 28.5 | 30.8 | 38.0 | 42.5 | 33.5 |
| Payne | 34 | 31.2 | 27.6 | 28.7 | 36.3 | 37.8 | 41.4 | 33.8 |
| Payne | 67 | 31.1 | 29.4 | 29.8 | 32.3 | 36.5 | 38.7 | 33.0 |
| Payne | 101 | 29.6 | 28.9 | 27.4 | 31.7 | 33.2 | 36.7 | 31.3 |
| Average | | 30.6 | 28.6 | 28.7 | 33.5 | 35.8 | 38.9 | 32.7 |
| Triumph | 34 | 30.9 | 24.3 | 23.9 | 28.4 | 29.3 | 33.7 | 28.4 |
| Triumph | 67 | 27.0 | 23.1 | 23.6 | 24.2 | 25.7 | 31.2 | 25.8 |
| Triumph | 101 | 24.8 | 22.1 | 23.0 | 23.1 | 24.3 | 26.3 | 23.9 |
| Average | | 27.6 | 23.2 | 23.5 | 25.2 | 26.4 | 30.4 | 26.1 |
| Vona | 34 | 37.0 | 34.0 | 33.8 | 36.9 | 40.6 | 43.7 | 37.7 |
| Vona | 67 | 35.7 | 32.2 | 29.4 | 32.5 | 30.1 | 38.8 | 33.1 |
| Vona | 101 | 34.3 | 30.3 | 31.9 | 30.0 | 33.6 | 42.8 | 33.8 |
| Average | | 35.6 | 32.2 | 31.7 | 33.1 | 34.7 | 41.8 | 34.9 |
| Average Rate | | | | | | | | |
| | 34 | 33.6 | 29.5 | 30.9 | 34.3 | 39.7 | 42.5 | 35.1 |
| | 67 | 31.8 | 28.5 | 27.6 | 30.5 | 34.4 | 39.0 | 32.0 |
| | 101 | 30.8 | 27.6 | 27.8 | 29.4 | 32.4 | 38.0 | 31.0 |
| Average Date | | | | | | | | |
| | | 32.1 | 28.5 | 28.8 | 31.4 | 35.5 | 39.8 | 32.7 |

LSD (.05) for comparison between two planting dates averaged over all other factors = 2.04

LSD (.05) for comparison between two genotypes averaged over all other factors = 2.85

LSD (.05) for comparison between two seeding rates averaged over all other factors = 2.21

LSD (.05) for comparison between two genotypes by seeding rates averaged over all other factors = 4.94

LSD (.05) for comparison between two genotypes for a given planting date = 1.16

LSD (.05) for comparison between two seeding rates for a given planting date = 0.90

LSD (.05) for comparison between two genotypes by seeding rate for a given planting date = 2.02

LSD (.05) for comparison between two planting dates for a given genotype = 3.24

LSD (.05) for comparison between the planting dates for a given seeding rate = 2.71

LSD (.05) for comparison between two planting dates for a given genotype by seeding rate = 5.16

TABLE VI

MEANS AND LSD VALUES FOR KERNEL WEIGHT (g/1000) BY CULTIVAR, SEEDING RATE AND PLANTING DATE

| Genotype | Seeding Rate Kg/ha | Date D 1 | D 2 | D 3 | D 4 | D 5 | D 6 | Avg. |
|---|---|---|---|---|---|---|---|---|
| Newton | 34 | 36.1 | 35.6 | 31.4 | 25.9 | 26.4 | 23.1 | 29.8 |
| Newton | 67 | 38.5 | 35.7 | 30.7 | 31.4 | 24.8 | 22.7 | 30.6 |
| Newton | 101 | 37.1 | 33.8 | 29.9 | 28.0 | 25.5 | 23.0 | 29.6 |
| Average | | 37.2 | 35.0 | 30.7 | 28.4 | 25.6 | 22.9 | 30.0 |
| Osage | 34 | 38.7 | 33.6 | 31.2 | 30.4 | 26.4 | 25.4 | 31.0 |
| Osage | 67 | 32.8 | 32.8 | 30.8 | 28.8 | 25.8 | 21.5 | 28.7 |
| Osage | 101 | 33.8 | 33.4 | 31.6 | 31.0 | 28.1 | 19.1 | 29.5 |
| Average | | 35.1 | 33.3 | 31.2 | 30.1 | 26.7 | 22.0 | 29.7 |
| Payne | 34 | 34.5 | 30.1 | 27.3 | 27.6 | 27.4 | 27.7 | 29.1 |
| Payne | 67 | 32.5 | 31.8 | 27.5 | 27.5 | 28.6 | 27.3 | 29.2 |
| Payne | 101 | 30.9 | 31.6 | 26.4 | 27.9 | 25.9 | 29.1 | 28.6 |
| Average | | 32.6 | 31.2 | 27.1 | 27.7 | 27.3 | 28.0 | 29.0 |
| Triumph | 34 | 40.9 | 39.7 | 38.7 | 38.6 | 38.0 | 37.4 | 38.9 |
| Triumph | 67 | 40.1 | 38.2 | 37.0 | 39.9 | 40.2 | 37.6 | 38.8 |
| Triumph | 101 | 40.6 | 38.9 | 36.9 | 37.1 | 39.5 | 39.1 | 38.7 |
| Average | | 40.6 | 38.9 | 37.5 | 38.5 | 39.2 | 38.0 | 38.8 |
| Vona | 34 | 34.2 | 31.4 | 28.4 | 30.7 | 29.2 | 29.1 | 30.5 |
| Vona | 67 | 32.8 | 30.4 | 29.7 | 30.1 | 34.4 | 23.9 | 30.2 |
| Vona | 101 | 33.4 | 31.5 | 27.8 | 28.5 | 26.7 | 22.4 | 28.4 |
| Average | | 33.4 | 31.1 | 28.6 | 29.8 | 30.1 | 25.1 | 29.7 |
| Average Rate | | | | | | | | |
| | 34 | 36.9 | 34.1 | 31.4 | 30.6 | 29.5 | 28.5 | 31.8 |
| | 67 | 35.3 | 33.8 | 31.1 | 31.5 | 30.8 | 26.6 | 31.5 |
| | 101 | 35.2 | 33.9 | 30.5 | 30.5 | 29.1 | 26.5 | 30.9 |
| Average Date | | | | | | | | |
| | | 35.8 | 33.9 | 31.0 | 30.9 | 29.8 | 27.2 | 31.4 |

LSD (.05) for comparsion between two planting dates averaged over all other factors = 1.66

LSD (.05) for comparison between two genotypes averaged over all other factors = 2.31

LSD (.05) for comparison between two seeding rates averaged over all other factors = 1.79

LSD (.05) for comparison between two genotypes by seeding rates averaged over all other factors = 4.01

LSD (.05) for comparison between two genotypes for a given planting date = 0.94

LSD (.05) for comparison between two seeding rates for a given planting date = 0.73

LSD (.05) for comparison between two seeding rates for a given planting date = 1.64

LSD (.05) for comparison between two planting dates for a given genotype = 2.63

LSD (.05) for comparison between the planting dates for a given seeding rate = 2.20

LSD (.05) for comparison between two planting dates for a given genotype by seeding rate = 4.18

TABLE VII

MEANS AND LSD VALUES FOR HEADING DATE (DAYS AFTER MARCH 31) BY CULTIVAR, SEEDING RATE AND PLANTING DATE

| Genotype | Seeding Rate Kg/ha | Date D 1 | D 2 | D 3 | D 4 | D 5 | D 6 | Avg. |
|---|---|---|---|---|---|---|---|---|
| Newton | 34 | 36.7 | 37.0 | 38.0 | 40.0 | 46.0 | 47.0 | 40.8 |
| Newton | 67 | 36.7 | 38.0 | 37.3 | 39.3 | 45.3 | 46.7 | 40.6 |
| Newton | 101 | 36.7 | 38.0 | 38.7 | 39.7 | 45.3 | 47.0 | 40.9 |
| Average | | 36.7 | 37.7 | 38.0 | 39.7 | 45.6 | 46.9 | 40.7 |
| Osage | 34 | 36.7 | 38.3 | 38.0 | 40.3 | 46.0 | 47.3 | 41.1 |
| Osage | 67 | 37.0 | 38.7 | 38.7 | 40.7 | 45.3 | 46.3 | 41.1 |
| Osage | 101 | 37.0 | 38.0 | 38.3 | 40.7 | 45.3 | 47.0 | 41.1 |
| Average | | 36.9 | 38.3 | 38.3 | 40.6 | 45.6 | 46.9 | 41.1 |
| Payne | 34 | 33.3 | 32.0 | 33.7 | 37.7 | 39.7 | 42.0 | 36.4 |
| Payne | 67 | 32.7 | 33.3 | 36.0 | 36.7 | 40.3 | 42.7 | 36.9 |
| Payne | 101 | 33.7 | 35.3 | 35.0 | 36.7 | 40.3 | 42.3 | 37.2 |
| Average | | 33.2 | 33.6 | 34.9 | 37.0 | 40.1 | 42.3 | 36.9 |
| Triumph | 34 | 30.0 | 30.7 | 30.3 | 32.3 | 38.3 | 39.7 | 33.6 |
| Triumph | 67 | 30.3 | 31.0 | 30.7 | 31.3 | 37.0 | 39.3 | 33.3 |
| Triumph | 101 | 30.0 | 31.0 | 31.3 | 32.0 | 37.3 | 38.7 | 33.4 |
| Average | | 30.1 | 30.9 | 30.8 | 31.9 | 37.6 | 39.2 | 33.4 |
| Vona | 34 | 30.3 | 30.3 | 31.0 | 31.7 | 37.3 | 38.7 | 33.2 |
| Vona | 67 | 30.7 | 31.0 | 31.0 | 31.7 | 37.7 | 38.7 | 33.4 |
| Vona | 101 | 30.0 | 31.0 | 32.0 | 33.0 | 37.3 | 38.3 | 33.6 |
| Average | | 30.3 | 30.8 | 31.3 | 32.1 | 37.4 | 38.6 | 33.4 |
| Average Rate | | | | | | | | |
| | 34 | 33.4 | 33.7 | 34.2 | 36.4 | 41.5 | 42.9 | 37.0 |
| | 67 | 33.5 | 34.4 | 34.7 | 35.9 | 41.1 | 42.7 | 37.1 |
| | 101 | 33.5 | 34.7 | 35.1 | 36.4 | 41.1 | 42.7 | 37.2 |
| Average Date | | | | | | | | |
| | | 33.4 | 34.2 | 34.7 | 36.2 | 41.2 | 42.8 | 37.1 |

LSD (.05) is comparison between two planting dates averaged over all other factors = 0.77

LSD (.05) is comparison between two genotypes averaged over all other factors = 0.74

LSD (.05) for comparison between two seeding rates averaged over all other factors = 0.58

LSD (.15) for comparison between two genotypes by seeding rate averaged over all other factors = 1.29

LSD (.05) for comparison between two genotypes for a given planting date = 0.30

LSD (.05) for comparison between two seeding rates for a given planting date = 0.24

LSD (.05) for comparison between two genotypes by seeding rate for a given planting date = 0.53

LSD (.05) for comparison between two planting dates for a given genotype = 1.01

LSD (.05) is comparison between two planting dates for a given seeding rate = 0.90

LSD (.05) for comparison between two planting dates for a given genotype by seeding rate = 1.45

# TABLE VIII

## MEANS AND LSD VALUES FOR PLANT HEIGHT (cm) BY CULTIVAR, SEEDING RATE AND PLANTING DATE

| Genotype | Seeding Rate Kg/ha | Date D 1 | D 2 | D 3 | D 4 | D 5 | D 6 | Avg. |
|---|---|---|---|---|---|---|---|---|
| Newton | 34 | 88.0 | 99.3 | 92.0 | 78.7 | 76.7 | 71.0 | 84.3 |
| Newton | 67 | 87.7 | 99.0 | 81.3 | 90.3 | 74.0 | 74.3 | 84.4 |
| Newton | 101 | 85.7 | 99.7 | 99.3 | 87.3 | 80.0 | 77.7 | 88.3 |
| Average | | 87.1 | 99.3 | 90.1 | 85.4 | 76.9 | 74.3 | 85.7 |
| Osage | 34 | 102.3 | 110.3 | 109.7 | 89.0 | 86.3 | 79.7 | 96.2 |
| Osage | 67 | 100.3 | 109.3 | 105.7 | 88.7 | 90.0 | 82.7 | 96.1 |
| Osage | 101 | 96.7 | 101.7 | 99.0 | 93.7 | 86.3 | 81.3 | 93.1 |
| Average | | 99.8 | 107.1 | 104.8 | 90.4 | 87.6 | 81.2 | 95.1 |
| Payne | 34 | 94.0 | 94.3 | 83.0 | 86.7 | 72.7 | 69.7 | 83.4 |
| Payne | 67 | 93.3 | 94.7 | 96.7 | 80.7 | 79.3 | 69.7 | 85.7 |
| Payne | 101 | 90.7 | 96.3 | 88.3 | 84.3 | 80.0 | 74.0 | 85.6 |
| Average | | 92.7 | 95.1 | 89.3 | 83.9 | 77.3 | 71.1 | 84.9 |
| Triumph | 34 | 99.0 | 109.0 | 94.0 | 91.7 | 98.3 | 72.3 | 97.4 |
| Triumph | 67 | 99.0 | 108.0 | 97.7 | 99.0 | 90.6 | 91.7 | 97.7 |
| Triumph | 101 | 105.7 | 102.0 | 98.0 | 92.7 | 92.0 | 90.0 | 96.7 |
| Average | | 101.2 | 106.3 | 96.6 | 94.4 | 93.7 | 91.3 | 97.3 |
| Vona | 34 | 86.0 | 93.3 | 86.3 | 80.7 | 78.7 | 73.7 | 83.1 |
| Vona | 67 | 82.0 | 90.7 | 80.3 | 84.0 | 79.7 | 71.7 | 81.4 |
| Vona | 101 | 79.0 | 90.7 | 93.7 | 71.0 | 80.7 | 71.3 | 81.1 |
| Average | | 82.3 | 91.6 | 86.8 | 78.6 | 79.7 | 72.2 | 81.9 |
| Average Rate | | | | | | | | |
| | 34 | 93.9 | 101.3 | 93.0 | 85.3 | 82.5 | 77.3 | 88.9 |
| | 67 | 92.5 | 100.3 | 92.3 | 88.5 | 82.7 | 78.0 | 89.1 |
| | 101 | 91.5 | 98.1 | 95.7 | 85.8 | 83.8 | 78.9 | 89.0 |
| Average Date | | | | | | | | |
| | | 92.6 | 99.9 | 93.7 | 86.6 | 83.0 | 78.0 | 89.0 |

LSD (.05) for comparison between two planting dates averaged over all other factors = 6.33

LSD (.05) for comparison between two genotypes averaged over all other factors = 5.77

LSD (.05) for comparison between two seeding rates averaged over all other factors = 4.47

LSD (.15) for comparison between two genotypes by seeding rate averaged over all other factors = 10.00

LSD (.05) for comparison between two genotypes for a given planting date = 2.36

LSD (.05) for comparison between two seeding rates for a given planting date = 1.83

LSD (.05) for comparison between two genotypes by seeding rate for a given planting date = 4.08

LSD (.05) for comparison between two planting dates for a given genotype = 8.12

LSD (.05) for comparison between two planting dates for a given seeding rate = 7.27

LSD (.05) for comparison between two planting dates for a given genotype by seeding rate = 11.47

# TABLE IX

## MEANS AND LSD VALUES FOR TEST WEIGHT (kg/hl) BY CULTIVAR, SEEDING RATE AND PLANTING DATE

| Genotype | Seeding Rate Kg/ha | Date D 1 | D 2 | D 3 | D 4 | D 5 | D 6 | Avg. |
|---|---|---|---|---|---|---|---|---|
| Newton | 34 | 67.3 | 69.6 | 66.6 | 63.1 | 62.2 | 63.5 | 65.5 |
| Newton | 67 | 67.9 | 67.3 | 66.6 | 64.8 | 66.1 | 64.0 | 66.1 |
| Newton | 101 | 68.7 | 67.3 | 64.8 | 63.1 | 65.7 | 63.1 | 65.5 |
| Average | | 68.0 | 68.1 | 65.9 | 63.6 | 64.7 | 63.5 | 65.7 |
| Osage | 34 | 66.1 | 68.7 | 68.7 | 67.9 | 67.9 | 67.9 | 67.9 |
| Osage | 67 | 66.1 | 68.2 | 68.2 | 67.0 | 67.9 | 68.2 | 67.6 |
| Osage | 101 | 67.0 | 69.2 | 68.7 | 67.0 | 68.2 | 67.0 | 67.9 |
| Average | | 66.5 | 68.7 | 68.5 | 67.2 | 68.0 | 66.7 | 67.7 |
| Payne | 34 | 63.5 | 67.9 | 65.3 | 65.7 | 65.7 | 65.7 | 65.6 |
| Payne | 67 | 65.3 | 67.9 | 65.3 | 64.8 | 65.7 | 65.3 | 65.7 |
| Payne | 101 | 65.3 | 67.0 | 66.6 | 66.6 | 65.3 | 64.0 | 65.8 |
| Average | | 64.7 | 67.5 | 65.7 | 65.7 | 65.6 | 64.9 | 65.7 |
| Triumph | 34 | 68.7 | 70.8 | 71.2 | 70.8 | 70.5 | 69.6 | 70.3 |
| Triumph | 67 | 69.9 | 72.1 | 71.2 | 71.7 | 71.2 | 68.7 | 70.8 |
| Triumph | 101 | 71.7 | 71.7 | 71.2 | 69.9 | 69.9 | 69.6 | 70.7 |
| Average | | 70.1 | 71.6 | 71.2 | 70.8 | 70.6 | 69.3 | 70.6 |
| Vona | 34 | 66.6 | 67.9 | 67.0 | 66.6 | 61.8 | 63.1 | 65.5 |
| Vona | 67 | 65.3 | 68.2 | 66.1 | 67.0 | 64.4 | 62.2 | 65.6 |
| Vona | 101 | 67.9 | 68.2 | 67.0 | 67.0 | 64.4 | 64.8 | 66.6 |
| Average | | 66.7 | 68.1 | 66.7 | 66.8 | 63.5 | 63.3 | 65.8 |
| Average Rate | | | | | | | | |
| | 34 | 66.5 | 68.9 | 67.7 | 66.8 | 65.6 | 65.9 | 67.0 |
| | 67 | 66.8 | 68.8 | 67.5 | 67.1 | 67.1 | 65.7 | 67.1 |
| | 101 | 68.1 | 68.7 | 67.6 | 66.7 | 66.7 | 65.7 | 67.2 |
| Average Date | | | | | | | | |
| | | 67.1 | 68.8 | 67.6 | 66.8 | 66.5 | 65.8 | 67.1 |

LSD (.05) for comparison between two planting dates averaged over all other factors = 1.04

LSD (.05) for comparison between two genotypes averaged over all other factors = 1.46

LSD (.05) for comparison between two seeding rates averaged over all other factors = 1.13

LSD (.15) for comparison between two genotypes by seeding rate averaged over all other factors = 2.52

LSD (.05) for comparison between two genotypes for a given planting date = 0.59

LSD (.05) for comparison between two seeding rates for a given planting date = 0.46

LSD (.05) for comparison between two genotypes by seeding rate for a given planting date = 1.03

LSD (.05) for comparison between two planting dates for a given genotype = 1.66

LSD (.05) for comparison between two planting dates for a given seeding rate = 1.37

LSD (.05) for comparison between two planting dates for a given genotype by seeding rate = 2.64

APPENDIX B

FIGURES

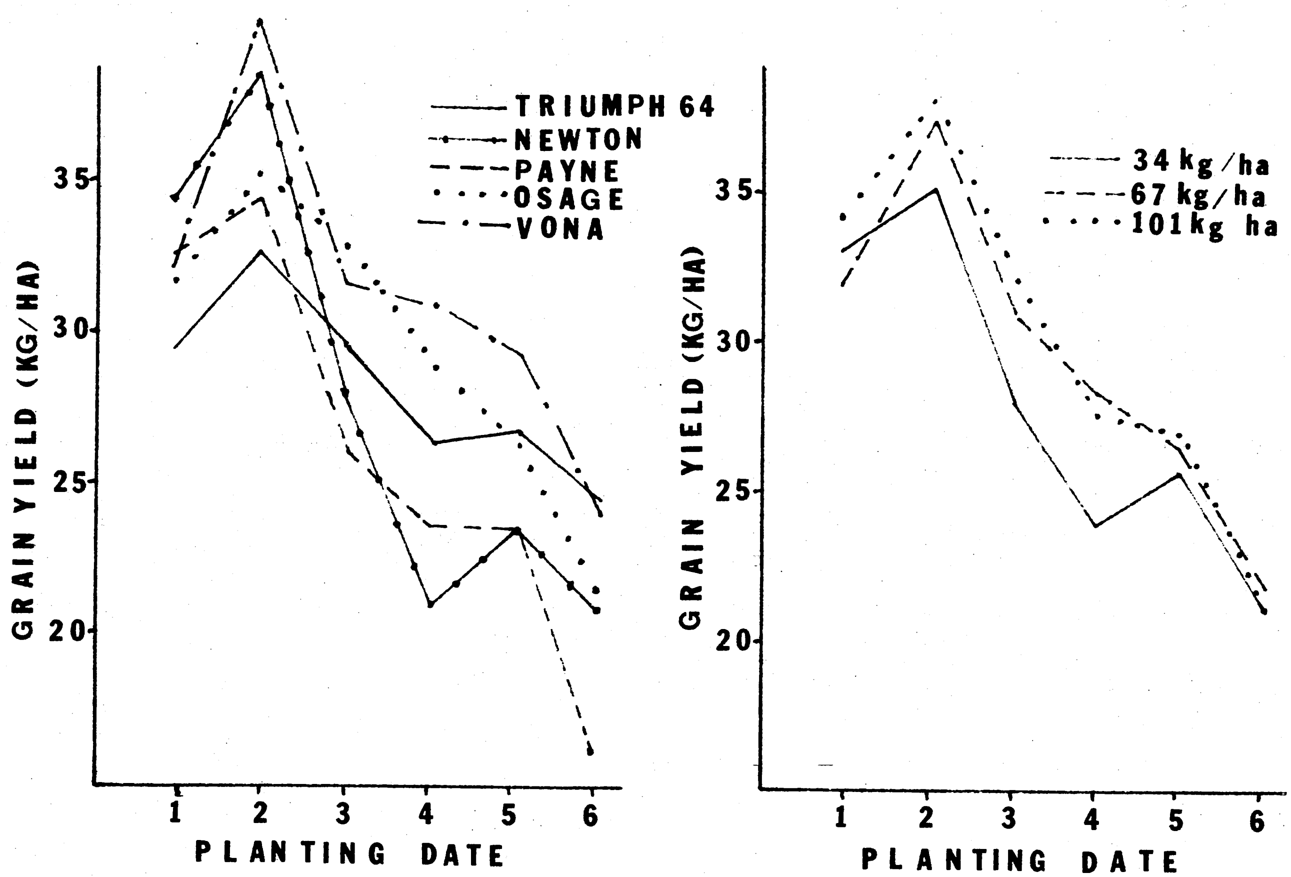


Figure 1. Grain Yield Relationships at Six Planting Dates:
(1a) Among Five Wheat Cultivars;
(1b) Among Three Seeding Rates.

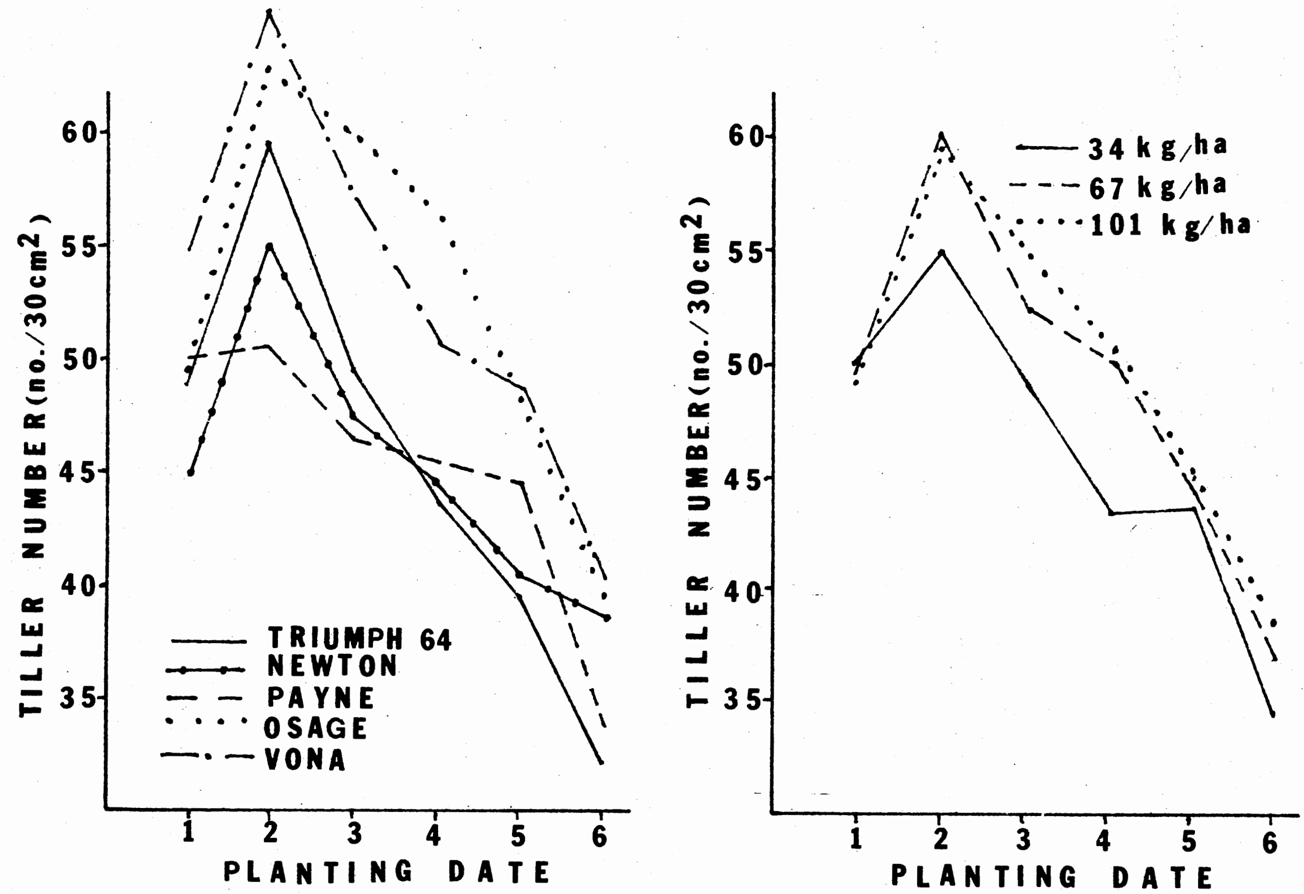


Figure 2. Tiller Number Relationships at Six Planting Dates:
(2a) Among Five Wheat Cultivars;
(2b) Among Three Seeding Rates.

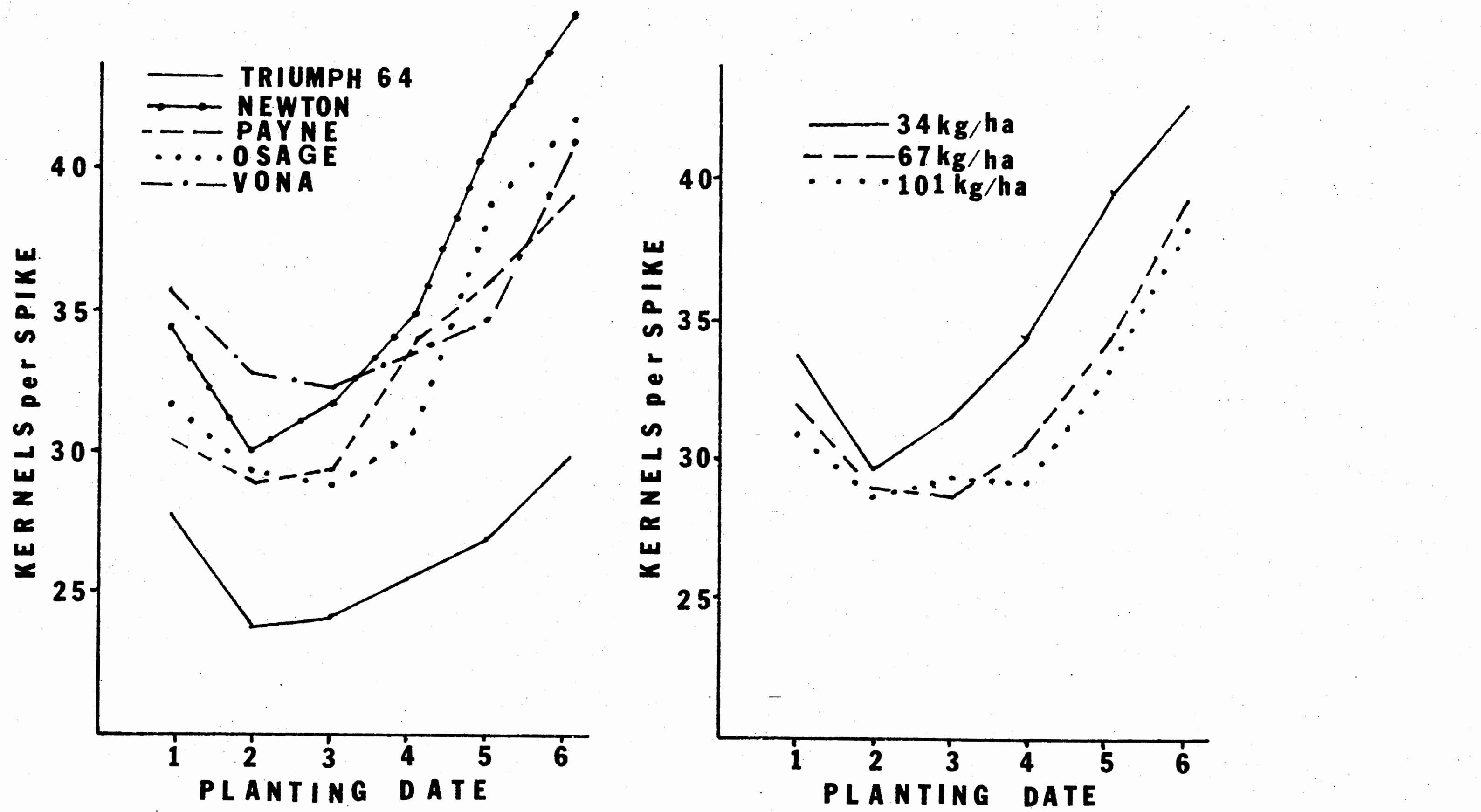


Figure 3. Kernels/Spike Relationships at Six Planting Dates:
(3a) Among Five Wheat Cultivars;
(3b) Among Three Seeding Rates.

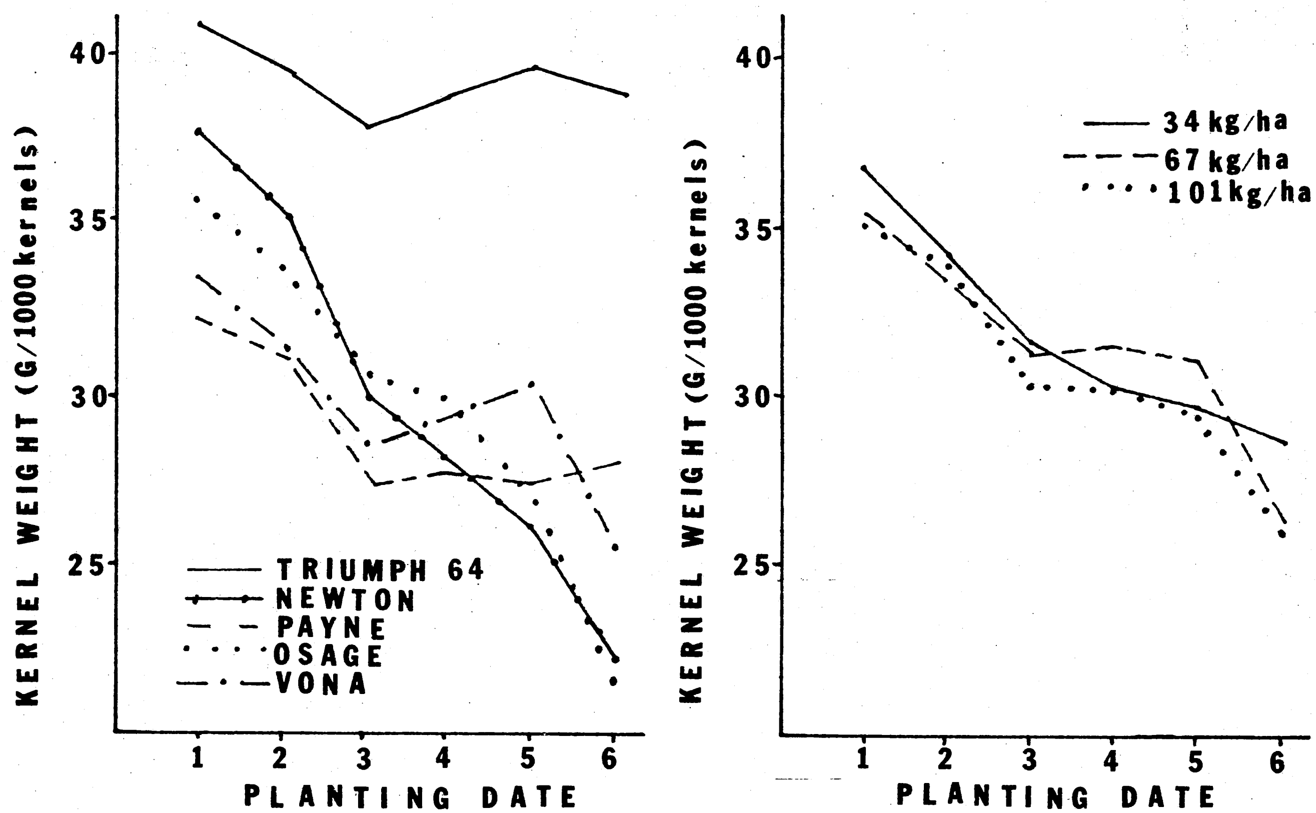


Figure 4. Kernel Weight Relationships at Six Planting Dates:
(4a) Among Five Wheat Cultivars;
(4b) Among Three Seeding Rates.

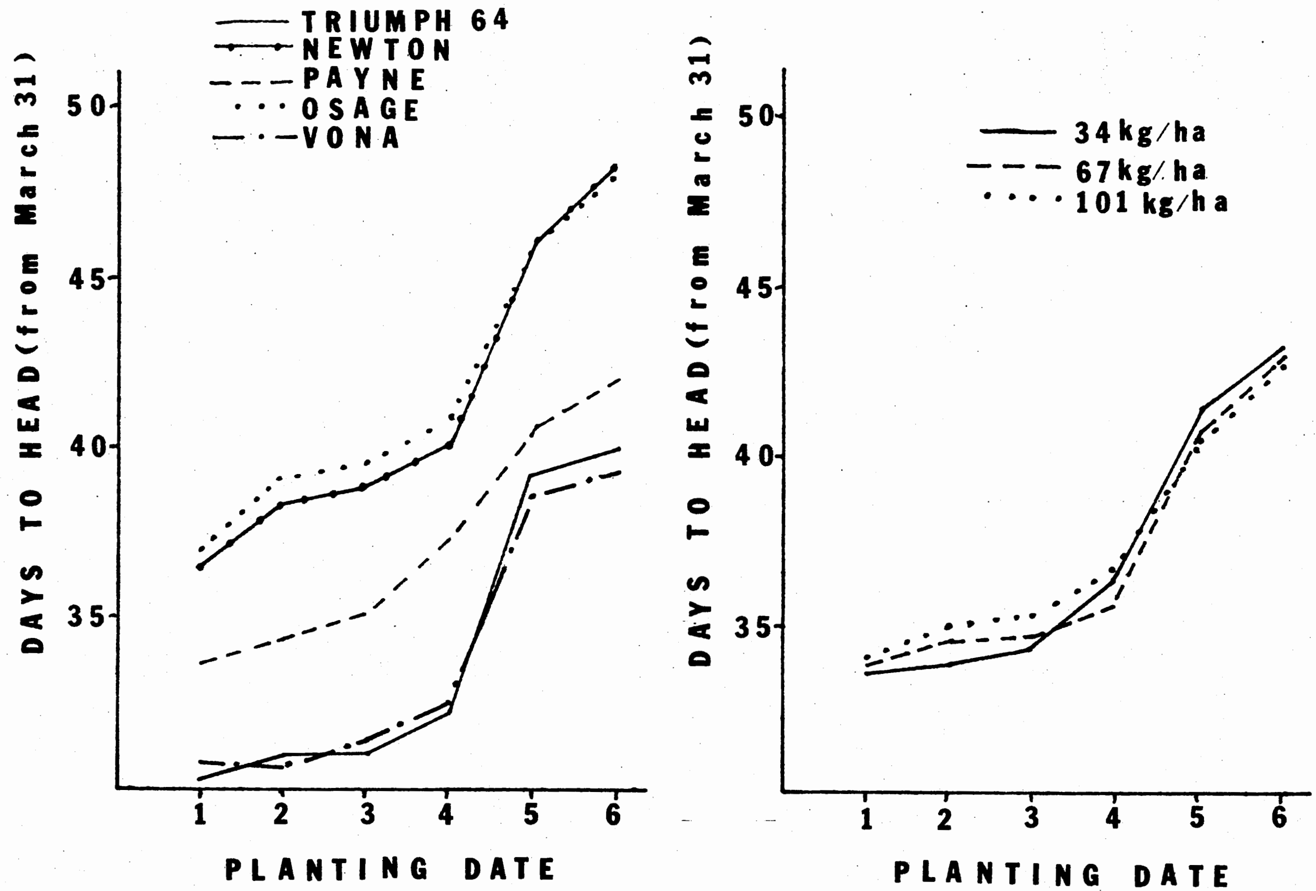


Figure 5. Heading Date Relationships at Six Planting Dates:
(5a) Among Five Wheat Cultivars;
(5b) Among Three Seeding Rates.

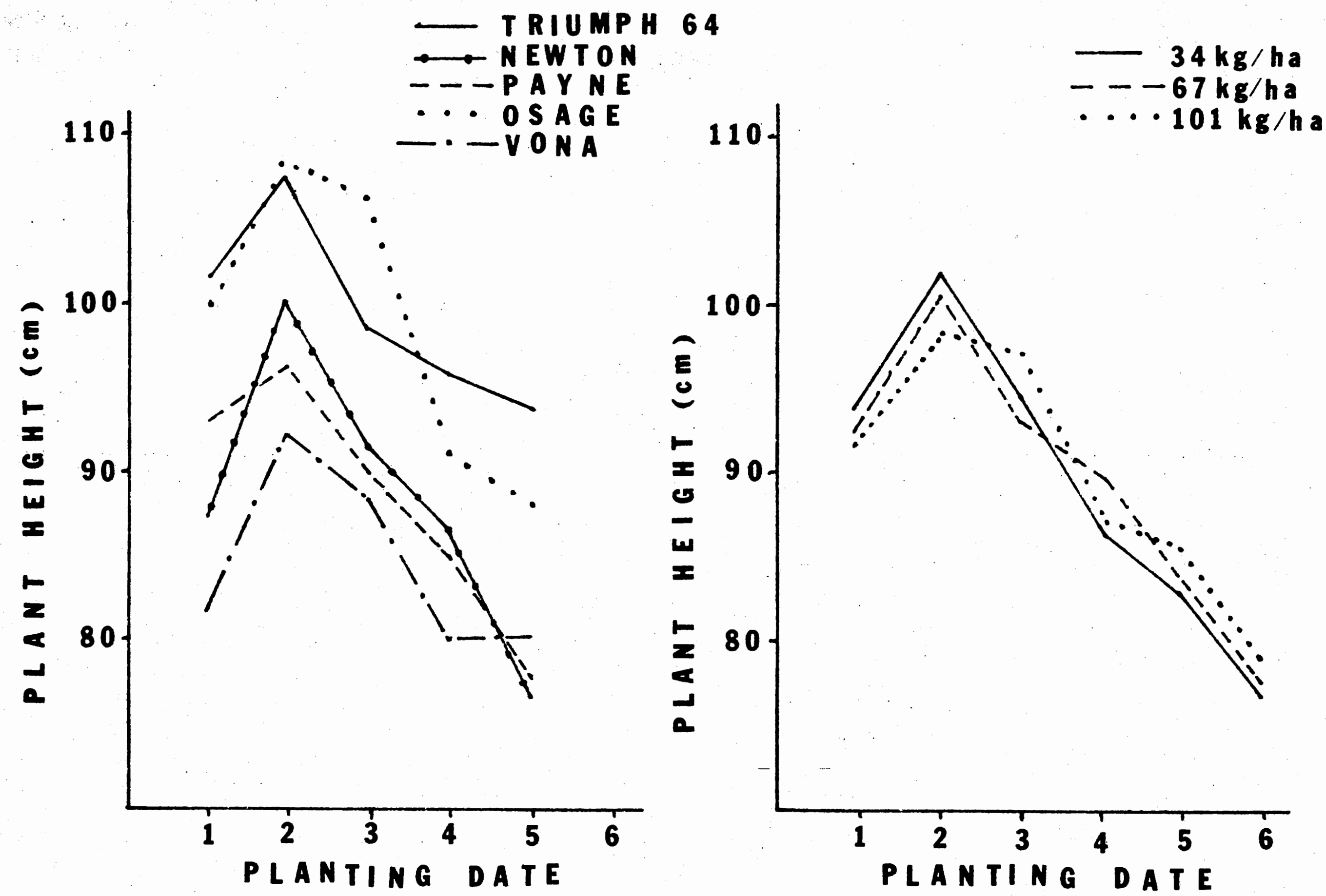


Figure 6. Plant Height Relationships at Six Planting Dates:
(6a) Among Five Wheat Cultivars;
(6b) Among Three Seeding Rates.

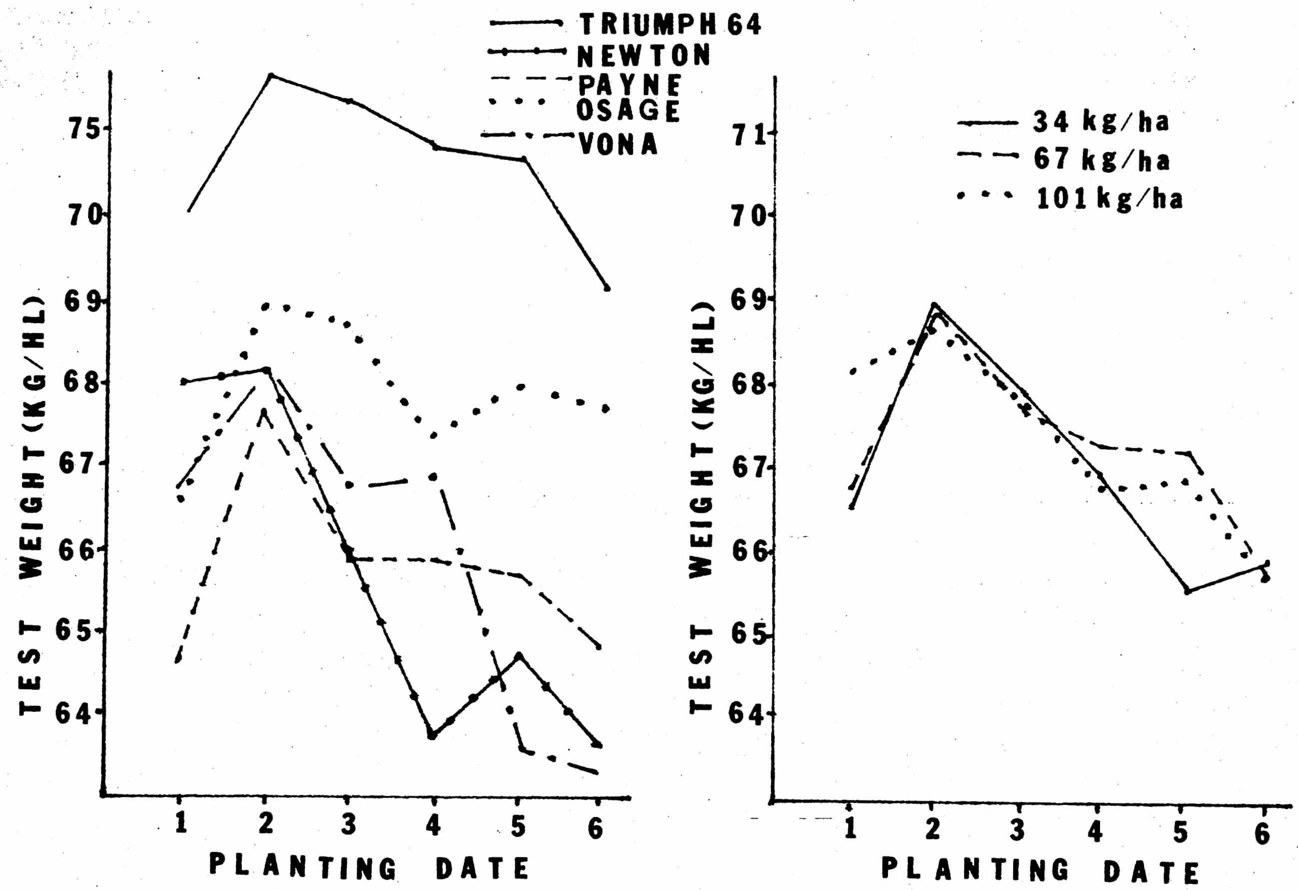


Figure 7. Test Weight Relationships at Six Planting Dates:
(7a) Among Five Wheat Cultivars;
(7b) Among Three Seeding Rates.

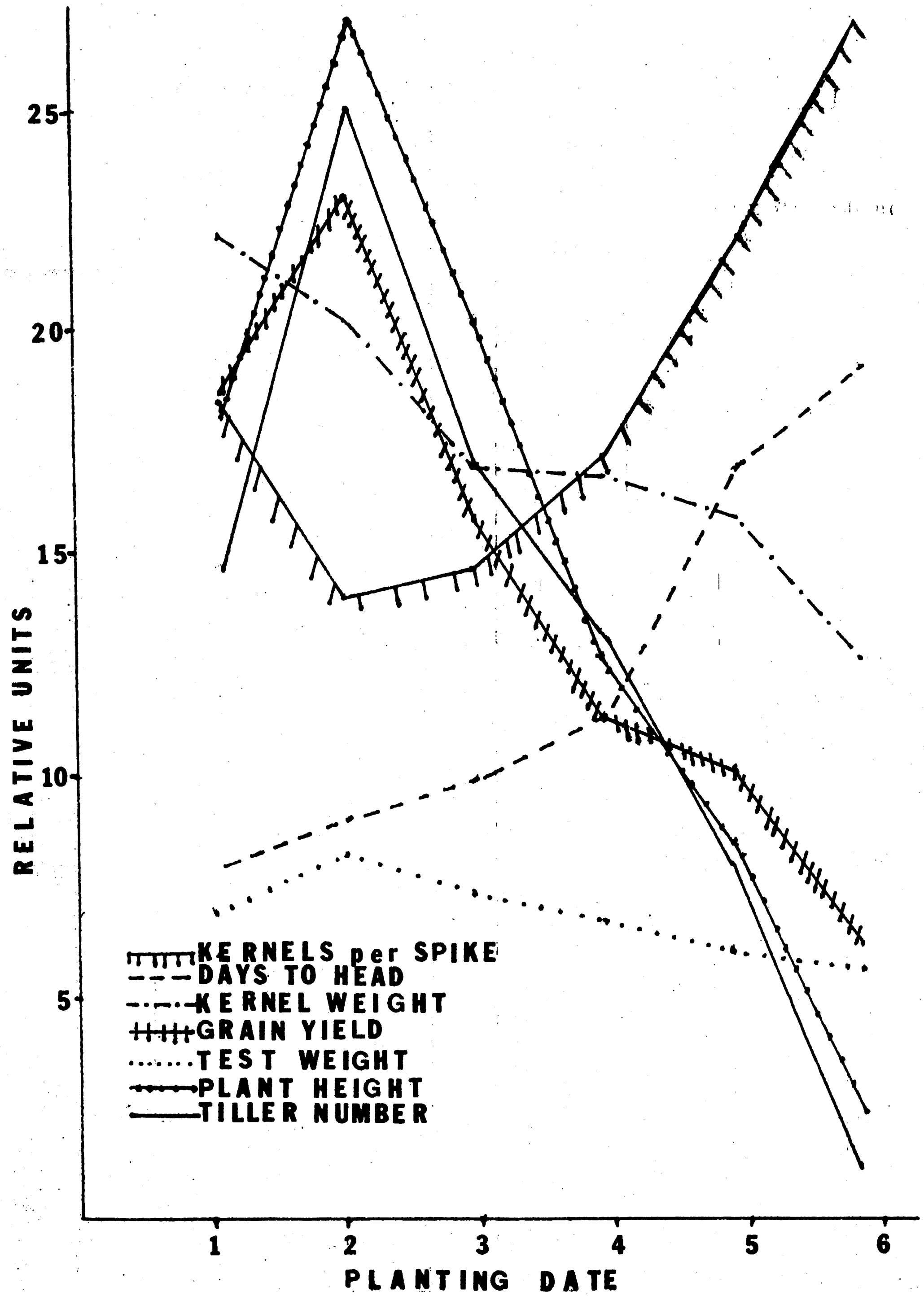


Figure 8. Interrelationships Among Seven Characters (Averaged Over Cultivar and Seeding Rates) at Six Planting Dates.

VITA

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