COMPONENTS OF YIELD FROM A WINTER WHEAT-FERTILIZER STUDY

by

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INTRODUCTION

The fact that fertilizer treatments increase grain yield of winter wheat has been recognized for many years. However, few precise measurements have been made to obtain information on the manner in which the components of yield are related to the yield increases. These components of yield are the number of heads per unit area, the number of kernels per head, and weight per kernel. A study of these components under different treatments of fertilizer should explain which component or components are actually responsible for grain yield differences.

Differences in grain yield of varieties may also be explained on the basis of yield components. The association of each component with yield within and among varieties should be of interest to the plant breeder. These associations not only add general information concerning the varieties, but may also aid him in future breeding programs.

This study was initiated to determine the associations of the yield components of certain varieties of winter wheat and the effect of different nitrogen-phosphorus fertilizer treatments on these components.

REVIEW OF LITERATURE

According to Hobbs (3), Laude (4), Quisenberry (9) and others (5,6,8,11) the major yield components of wheat are the number of heads per unit area, the number of kernels per head and the weight per kernel.

In 1928, Quisenberry (9) reported that the number of heads was the most important factor in determining yield, closely followed by the number of kernels per head. He found that plumpness of grain or weight per 1000 grains was of much less importance. No significant correlations between the number of heads per unit area and the weight per 1000 grains were found. The correlations for the number of heads per unit area and the number of kernels per head were neither high nor consistant. Locke et al. (5) confirmed part of Quisenberry's results in 1942. They found that more than 95% of the variation in yield in Turkey wheat was explained by the number of kernels per area and that the number of heads alone accounted for almost 60% of the variation. In studying F_2 and F_3 lines of a Lemhi x Thatcher spring wheat cross, McNeal (6) reported that the number of kernels per plant accounted for 86.7% and 89.5% respectively, of the variation in yield of grain. He found the number of heads per plant and the number of kernels per head to be more closely associated with yield than kernel weight. Waldron (13) compared the yield components of small-seeded and large-seeded spring wheat varieties. He found that by using average cumulative effects of each component the excess yield of the large-seeded variety was due to 91.2% for kernel weight, 6.6% for number of heads per unit area and 2.2% for the number of kernels per head.

Laude (4) recognized the fact that the ecological conditions surrounding the wheat plant modifies the physiological activity to best meet the conditions. He pointed out that the time the particular condition exists may determine which factor is affected, i.e., early conditions affect the number of tillers while late conditions affect seed size and weight. Sprague (11) also recognized this fact when he reported that more favorable conditions for growth in wheat resulted in a larger number of tillers per unit area or in an increase in the size of heads, depending on the time of the condition. This did not influence greatly the correlation existing between the head characters, i.e., the number of kernels per head and weight per kernel. He found that the number of spikes was never highly correlated with any head character and that these correlations were very unstable.

According to Fajersson (2), Pederson reported that the yield components differed with the time of nitrogen application. Early applied nitrogen was found to raise the yield of wheat by increasing the number of straws per unit area, medium early applied nitrogen caused increase in number of grains per head. Kernel weight was increased in only one case, nitrogen being applied late.

McNeal and Davis (7) applied 50 and 100 pounds of nitrogen to nine varieties of spring wheat at planting. With the exception of two varieties, the increase in culm number was more important than the number of kernels per head and kernel weight combined. Kernel weight was not considered to be of importance since test weight was not affected by the treatments. In a five-year study with winter wheat in Kansas, Hobbs (3) showed a 14% increase in stubble count and a 20% increase in yield from spring application of nitrogen. In only one year did the number of kernels per head show higher increases over the untreated plot than did stubble count. Kernel weight did not add to the increased yield of the fertilized plots. Hobbs also stated that the magnitude of the response to nitrogen topdressing appeared to depend in part at least upon the supply of available phosphorus in the soil.

Another study showing the relation of fertilizers to the yield components was reported by Tucker and Abbott (12). They found that the number of heads per unit area and grain weight per head were significantly affected by nitrogen-phosphorus treatments. The number of heads increased from a nitrogen-phosphorus interaction, primarily. Grain weight per head was increased directly by both nitrogen and phosphorus.

At high nitrogen-phosphorus rates reduced grain size and grain weight per head resulted. All fertilizer treatments increased the number of grains per head.

MATERIALS AND METHODS

Data for this study were obtained from a long term wheat-fertilizer test at the Agronomy Research Farm, Perkins, Oklahoma. Each plot area contained the same variety and treatment for eight years.

The five varieties of hard red winter wheat used included Comanche (C.I. 11673), Concho (C.I. 12517), Pawnee (C.I. 11669), Ponca (C.I. 12128) and Triumph (C.I. 12132)[1]. All are adapted varieties and have been included on the so-called "Recommended List" for Oklahoma at some time. They are medium in maturity, except Triumph which is an early maturing variety. Concho has bronze chaff, while the other four varieties have white chaff; all are awned.

Seven treatments of nitrogen-phosphorus fertilizers were used. They included:

Treatments	Pounds per Acre		
	N	P_2O_5	(P)[2]
1	0	0	(0.0)
2	0	40	(17.6)
3	40	0	(0.0)
4	20	40	(17.6)
5	40	40	(17.6)
6	40	80	(35.2)
7	80	40	(17.6)

[1]Varietal abbreviations used in tables are: Comanche = Cmn, Concho = Cch, Pawnee = Pn, Ponca = Pnc, Triumph = Tmp.

[2]Pounds of P_2O_5 per acre was converted to pounds of P by multiplying by 0.44.

The phosphorus was applied in the form of concentrated superphosphate prior to seeding, while the nitrogen as ammonium nitrate was topdressed on March 7, 1961.

The experimental design was a split-plot with four replications where the whole plots were fertilizer treatments and the subplots were wheat varieties. The subplot size was a drill strip composed of 13 rows spaced seven inches apart and 40 feet in length. The seeding date was November 23, 1960, at the rate of one bushel per acre.

For the study of yield components the lengths of the subplots were divided into four equal sections. From the center nine rows of each section one 2-foot row was selected at random and harvested by hand at maturity. These samples were taken to the laboratory for measurements of the yield factors.

The number of heads per unit area was determined by counting the seed-bearing heads from the 2-foot sample.

Twenty heads were selected at random from each 2-foot sample and hand-threshed. The number of kernels from 20 heads was determined and converted to the average number of kernels per head.

In deriving the average kernel weight the kernels from the 20 hand-threshed heads were weighed and divided by the number of kernels from the same 20 heads.

To determine the yield for each 2-foot sample the remaining heads of the sample were threshed with a head thresher and weighed. This weight was added to the weight of the kernels from the 20 selected heads and was converted to bushels per acre. This yield determination was used for comparing yields and calculating correlation coefficients.

The subplots were harvested with a combine and weight of grain per plot was obtained. After adding the weights of the four 2-foot samples taken from each subplot to the subplot weights, the grain yield in bushels per acre was calculated. This determination was used only as a check in sampling procedure for yield.

An IBM 650 Electronic Computer was used for computations. The correlation coefficients and analyses of variance were determined by the method described by Snedecor (10). The multiple range tests used were those proposed by Duncan (1).

EXPERIMENTAL RESULTS

Components of Yield

The average number of heads per 2-foot sample, the average number of kernels per head and the average kernel weight by treatment and by variety are presented in tables I, II and III, respectively. Highly significant differences were found among varieties and treatments for each component as shown in the analysis of variance summary (Table IV). The component, average kernel weight, had the only significant variety x treatment interaction, being significant at the 5% level of confidence.

Yields

The average yields from the 2-foot samples and subplots by treatment, by variety are presented in tables V and VI, respectively. Highly significant differences were found in varieties and treatments for both yield determinations as shown in table IV. A significant variety x treatment interaction was obtained for subplot yield at the 5% level of confidence.

Triumph and Concho were the highest yielding varieties and were not significantly different in either determination. In the smaller plots, the three lower yielding varieties were

TABLE I.

THE AVERAGE NUMBER OF HEADS PER 2-FOOT PLOT FOR FIVE VARIETIES OF WINTER WHEAT PRODUCED WITH SEVEN TREATMENTS OF FERTILIZER AND THE STATISTICAL ANALYSIS.

Treatments (Pounds per Acre)			Varieties					
N	P_2O_5	(P)	Comanche	Concho	Pawnee	Ponca	Triumph	Average
0	0	(0.0)	29.8	38.1	32.6	40.4	33.1	34.8
0	40	(17.6)	33.9	32.1	33.9	35.8	36.4	34.4
40	0	(0.0)	31.1	39.9	34.2	38.5	33.1	35.4
20	40	(17.6)	40.2	42.3	37.4	41.3	43.7	41.0
40	40	(17.6)	42.5	42.8	40.9	45.8	42.4	42.8
40	80	(35.2)	44.5	44.8	45.7	51.1	45.3	46.3
80	40	(17.6)	43.3	49.4	47.3	45.3	42.8	45.6
Average			37.9	41.3	38.8	42.6	39.5	

S.E.M.= 0.252 for varieties, C.V.= 21.1%; S.E.M.= 1.215 for treatments, C.V.= 27.1%.

5% Multiple range on variety means

Cmn	Pn	Tmp	Cch	Pnc
37.9	38.8	39.5	41.3	42.6

5% Multiple range on treatment means

0-17.6	0-0	40-0	20-17.6	40-17.6	80-17.6	40-35.2
34.4	34.8	35.4	41.0	42.8	45.6	46.3

Any two means not underlined by the same line are significantly different.

TABLE II.

THE AVERAGE NUMBER OF KERNELS PER HEAD FOR FIVE VARIETIES OF WINTER WHEAT PRODUCED WITH SEVEN TREATMENTS OF FERTILIZER AND THE STATISTICAL ANALYSIS.

Treatments (Pounds per Acre)			Varieties					
N	P_2O_5	(P)	Comanche	Concho	Pawnee	Ponca	Triumph	Average
0	0	(0.0)	19.7	21.8	19.9	19.2	19.0	19.9
0	40	(17.6)	18.9	18.7	18.6	17.0	18.3	18.3
40	0	(0.0)	23.0	23.5	22.1	21.8	20.9	22.3
20	40	(17.6)	20.4	20.0	20.9	17.7	18.7	19.5
40	40	(17.6)	21.4	21.9	21.1	19.3	19.0	20.5
40	80	(35.2)	19.7	21.8	20.9	19.0	19.4	20.1
80	40	(17.6)	22.4	23.0	23.5	21.2	19.2	21.9
Average			20.8	21.5	21.0	19.3	19.2	

S.E.M. = 0.228 for varieties, C.V. = 11.9%; S.E.M. = 0.346 for treatments, C.V. = 15.2%.

5% Multiple range on variety means

Tmp	Pnc	Cmn	Pn	Cch
19.2	19.3	20.8	21.0	21.5

5% Multiple range on treatment means

0-17.6	20-17.6	0-0	40-35.2	40-17.6	80-17.6	40-0
18.3	19.5	19.9	20.1	20.5	21.9	22.3

Any 2 means not underlined by the same line are significantly different.

TABLE III.

THE AVERAGE WEIGHT PER KERNEL IN MILLIGRAMS FOR FIVE VARIETIES OF WINTER WHEAT PRODUCED WITH SEVEN TREATMENTS OF FERTILIZER AND THE STATISTICAL ANALYSIS.

Treatments (Pounds per Acre)			Varieties					
N	P_2O_5	(P)	Comanche	Concho	Pawnee	Ponca	Triumph	Average
0	0	(0.0)	31.0	29.9	28.5	29.3	36.0	31.0
0	40	(17.6)	33.3	31.4	30.4	32.2	36.2	32.7
40	0	(0.0)	29.1	30.0	24.8	28.3	36.1	29.7
20	40	(17.6)	30.7	31.0	28.1	29.3	35.8	31.0
40	40	(17.6)	28.4	28.9	26.7	28.1	35.3	29.5
40	80	(35.2)	29.6	30.4	28.2	28.5	36.1	30.5
80	40	(17.6)	26.4	27.6	23.5	25.3	35.9	27.8
Average			29.8	29.9	27.2	28.7	35.9	

S.E.M =0.266 for varieties, C.V.= 9.3%; S.E.M.= 0.324 for treatments, C.V.= 9.6%.

5% Multiple range on variety means

Pn	Pnc	Cmn	Cch	Tmp
27.2	28.7	29.8	29.9	35.9

5% Multiple range on treatment means

80-17.6	40-17.6	40-0	40-35.2	0-0	20-17.6	0-17.6
27.8	29.5	29.7	30.5	31.0	31.0	32.7

Any 2 means not underlined by the same line are significantly different.

TABLE IV.

A SUMMARY OF THE ANALYSIS OF VARIANCE FOR CHARACTERS ANALYZED IN FIVE VARIETIES OF WINTER WHEAT PRODUCED WITH SEVEN TREATMENTS OF FERTILIZER.

Source of Variation	Heads per Unit Area	Kernels per Head	Kernel Weight	2-Foot Yield	Subplot Yield
Replications	--	--	**	*	**
Treatments	**	**	**	**	**
Varieties	**	**	**	**	**
Var. x Treat.	--	--	*	--	*
Sections	--	**	**	**	
Sect. x Treat.	--	--	--	--	
Sect. x Var.	--	--	--	--	
Sect. x Treat. x Var.	--	--	--	--	

* Significant at the 5% level.
** Significant at the 1% level.
-- No significant difference.

TABLE V.

THE AVERAGE GRAIN YIELD IN BUSHELS PER ACRE FOR FIVE VARIETIES OF WINTER WHEAT PRODUCED WITH SEVEN TREATMENTS OF FERTILIZER AND THE STATISTICAL ANALYSIS. (2-FOOT PLOTS)

Treatments (Pounds per Acre)			Varieties					
N	P_2O_5	(P)	Comanche	Concho	Pawnee	Ponca	Triumph	Average
0	0	(0.0)	24.7	34.3	25.6	30.9	31.0	29.3
0	40	(17.6)	28.9	26.3	26.8	26.5	31.9	28.1
40	0	(0.0)	29.1	36.9	25.5	32.7	34.0	31.6
20	40	(17.6)	36.1	36.1	29.6	30.4	39.4	34.3
40	40	(17.6)	35.0	36.8	31.8	33.1	37.8	34.9
40	80	(35.2)	36.4	39.6	36.9	38.8	42.0	38.7
80	40	(17.6)	35.7	42.3	37.1	33.6	41.9	38.1
Average			32.3	36.0	30.5	32.3	36.8	

S.E.M.= 0.703 for varieties, C.V.= 22.1%; S.E.M.= 0.954 for treatments, C. V.= 25.4%.

5% Multiple range on variety means

Pn	Pnc	Cmn	Cch	Tmp
30.5	32.3	32.3	36.0	36.8

5% Multiple range on treatment means

0-17.6	0-0	40-0	20-17.6	40-17.6	80-17.6	40-35.2
28.1	29.3	31.6	34.3	34.9	38.1	38.7

Any 2 means not underlined by the same line are significantly different.

TABLE VI.

THE AVERAGE GRAIN YIELD IN BUSHELS PER ACRE FOR FIVE VARIETIES OF WINTER WHEAT PRODUCED WITH SEVEN TREATMENTS OF FERTILIZER AND THE STATISTICAL ANALYSIS. (Subplots)

Treatments (Pounds per Acre)			Varieties					
N	P_2O_5	(P)	Comanche	Concho	Pawnee	Ponca	Triumph	Average
0	0	(0.0)	28.6	32.4	25.9	28.4	32.3	29.5
0	40	(17.6)	31.2	31.1	28.2	27.1	31.4	29.8
40	0	(0.0)	30.8	34.3	25.4	30.5	33.5	30.9
20	40	(17.6)	35.3	35.7	29.2	33.5	37.9	34.3
40	40	(17.6)	34.2	37.9	31.9	33.6	38.5	35.2
40	80	(35.2)	35.7	39.0	33.0	35.7	42.0	37.1
80	40	(17.6)	34.2	38.9	31.7	34.2	39.1	35.6
Average			32.9	35.6	29.3	31.9	36.4	

S.E.M. = 0.311 for varieties, C.V. = 5.0%; S.E.M. = 0.208 for treatments, C.V. = 8.9%.

5% Multiple range for variety means

Pn	Pnc	Cmn	Cch	Tmp
29.3	31.9	32.9	35.6	36.4

5% Multiple range on treatment means

0-0	0-17.6	40-0	20-17.6	40-17.6	80-17.6	40-35.2
29.5	29.8	30.9	34.3	35.2	35.6	37.1

Any 2 means not underlined by the same line are significantly different.

not significantly different, whereas all were different in the larger plots. Treatments 40-35.2 and 80-17.6 produced the highest yields in both determinations; they were not significantly different in the small plots, but were in the larger plots.

Much more variation was found in the 2-foot plots than in the larger subplots as shown by the coefficients of variation. As a result smaller significant differences were detected in the subplots.

The average values for the two yield determinations varied as much as 5.4 bushels by treatment, by variety. However, the overall means were very similar being 33.2 for subplots and 33.6 for 2-foot plots.

Correlation Coefficients

A highly significant correlation coefficient of 0.752 was found between the average of the four 2-foot plot yields from each subplot and the subplot yields.

Correlation coefficients within each variety (disregarding treatments) and within each treatment (disregarding varieties) for the three yield components and yield are presented in tables VII and VIII. The overall correlation coefficients (Appendix table IX) and the by treatment, by variety correlation coefficients (Appendix tables X-XV) are not included in the discussion.

TABLE VII.

CORRELATION COEFFICIENTS (r) BETWEEN FOUR CHARACTERS IN FIVE VARIETIES OF WINTER WHEAT.

	Number of Kernels per Head		Average Weight per Kernel		Yield from 2-Ft. Plots	
Number of Heads per Unit Area	Cmn	-0.014	Cmn	-0.247**	Cmn	0.860**
	Cch	0.210*	Cch	-0.264**	Cch	0.919**
	Pn	0.123	Pn	-0.199 *	Pn	0.860**
	Pnc	0.135	Pnc	-0.188 *	Pnc	0.848**
	Tmp	-0.087	Tmp	-0.186	Tmp	0.912**
Number of Kernels per Head			Cmn	-0.192 *	Cmn	0.276**
			Cch	-0.215 *	Cch	0.447**
			Pn	-0.267**	Pn	0.368**
			Pnc	-0.319**	Pnc	0.409**
			Tmp	0.021	Tmp	0.131
Average Weight per Kernel					Cmn	0.022
					Cch	-0.055
					Pn	0.104
					Pnc	0.097
					Tmp	0.012

* Significant at the 5% level of confidence. (110 D.F.)
** Significant at the 1% level of confidence.

TABLE VIII.

CORRELATION COEFFICIENTS (r) BETWEEN FOUR CHARACTERS FOR SEVEN TREATMENTS OF FERTILIZER.

	Number of Kernels per Head		Average Weight per Kernel		Yield from 2-Ft. Plots	
Number of Heads per Unit Area	0-0	0.082	0-0	-0.137	0-0	0.842**
	0-17.6	0.286 *	0-17.6	0.043	0-17.6	0.888**
	40-0	-0.131	40-0	-0.112	40-0	0.776**
	20-17.6	-0.021	20-17.6	0.100	20-17.6	0.835**
	40-17.6	-0.065	40-17.6	-0.112	40-17.6	0.839**
	40-35.2	-0.090	40-35.2	-0.089	40-35.2	0.828**
	80-17.6	-0.072	80-17.6	-0.177	80-17.6	0.747**
Number of Kernels per Head			0-0	-0.080	0-0	0.419**
			0-17.6	0.133	0-17.6	0.600**
			40-0	-0.105	40-0	0.142
			20-17.6	-0.230 *	20-17.6	0.255 *
			40-17.6	-0.311**	40-17.6	0.142
			40-35.2	-0.070	40-35.2	0.210
			80-17.6	-0.267 *	80-17.6	0.052
Average Weight per Kernel					0-0	0.210
					0-17.6	0.293**
					40-0	0.407**
					20-17.6	0.394**
					40-17.6	0.260 *
					40-35.2	0.295**
					80-17.6	0.376**

* Significant at the 5% level of confidence. (78 D.F.)
** Significant at the 1% level of confidence.

DISCUSSION

Number of Heads Per Unit Area

Varieties

The varietal means for the number of heads per 2-foot plot ranged from 37.9 to 42.6 heads. Of the five varieties only Triumph and Pawnee were not significantly different; however, these two varieties ranked first and last in yields, respectively. Ponca produced the highest number of heads although it had the same yield as Comanche, which produced the lowest number of heads.

The above data seem to contradict previous reports (5,6,9) in that there appeared to be little association between the number of heads per unit area and yield. However, the associations reported by these workers were overall associations or associations within varieties rather than among varieties. Extermely high r values ranging from 0.848 to 0.919 (Table VII) were found in this study within varieties. With these relationships, the higher yielding plots could be determined by the component, number of heads per unit area, within each variety but not among varieties.

The components, number of heads per unit area and number of kernels per head, did not appear to be associated within or among varieties.

The number of heads per unit area and kernel weight were negatively correlated within varieties as shown by r values of -0.186 to -0.264 (Table VII). Over all varieties no association of the two factors was apparent.

Treatments

The number of heads was increased with both nitrogen and phosphorus (Figures 1A, 1B). Consequently, treatments that were high in both elements (40-35.2, 80-17.6 and 40-17.6) produced the highest values. No significant increases occurred in the number of heads when either element was added alone.

The rankings of the treatment means for the number of heads per unit area and yield were identical. Because there was a high association between these factors (Figure 1C), the number of heads per unit area appeared to be the component responsible for most of the yield increases. These findings are similar to those reported by McNeal and Davis (7) and Hobbs(3) who attributed a large part of increased yields of fertilized plots over unfertilized plots to the number of culms per unit area.

This high association of the number of heads per unit area and yield was also found within each treatment as shown by the correlation coefficients of 0.747 to 0.888 (Table VIII).

There were no significant correlations between the number of heads per unit area and the number of kernels per head within or among treatments. However, the association of these components for treatments having an increase of

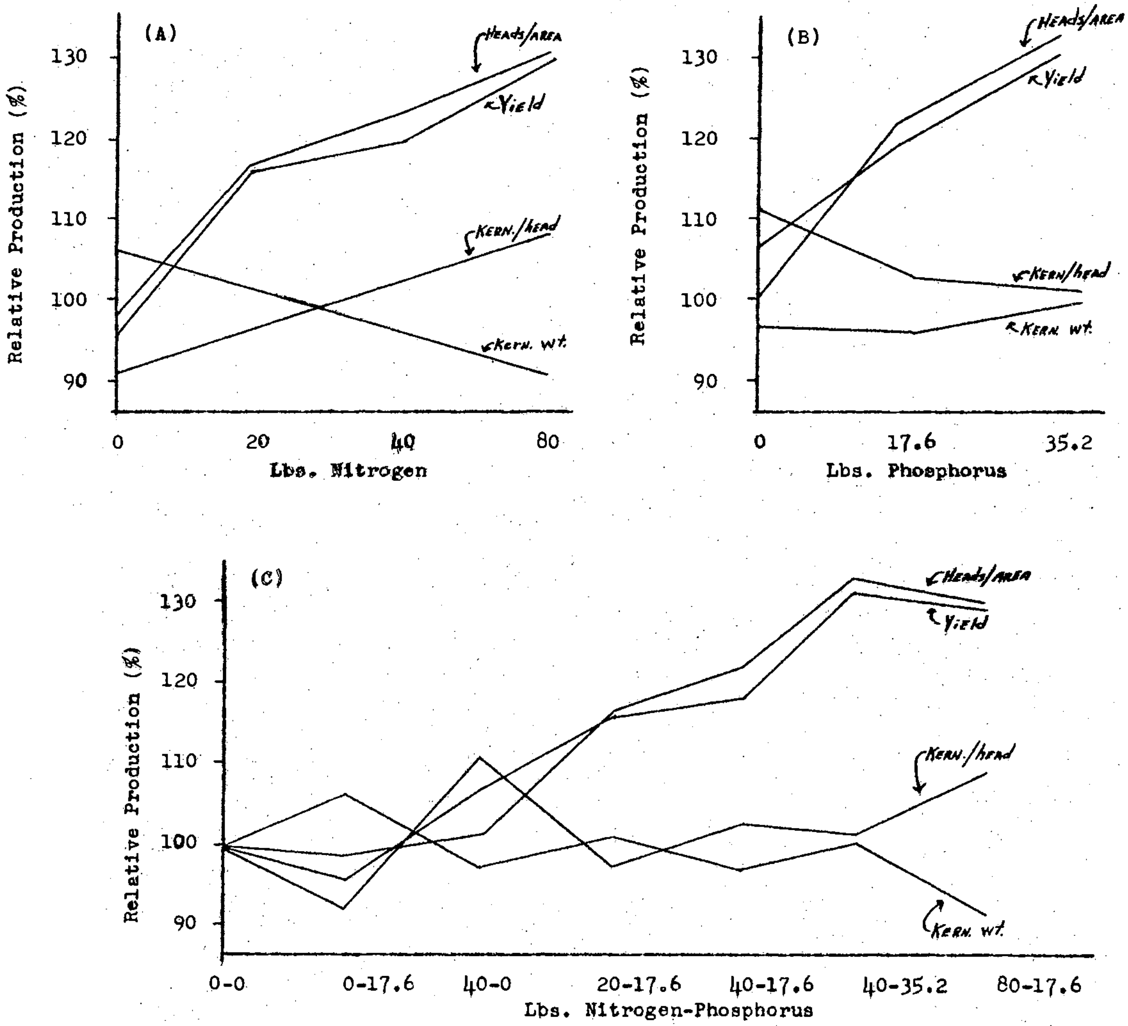

Figure 1. The relative production of the components of yield and yield by treatments using treatment 0-0 as a base of 100 per cent. (A) Treatments increasing in nitrogen with 17.6 lbs. of phorphorus, (B) treatments increasing in phosphorus with 40 lbs. of nitrogen, (C) all treatments.

of nitrogen alone at a 17.6 pound phosphorus level appeared highly positive, while a highly negative relationship seemed to exist when phosphorus alone was increased at a 40 pound nitrogen level (Figures 1A, 1B).

Except for the 0-17.6 treatment there were no significant correlations between the number of heads per unit area and kernel weight. There appeared to be a low negative association over all treatments although this relationship was not statistically determined. When nitrogen was increased while holding phosphorus at 17.6 pounds a more pronounced negative relationship seemed to exist (Figure 1A).

Number of Kernels per Head

Varieties

A range of only 2.3 kernels was obtained between varieties for this component with Concho and Pawnee producing the highest values. Although these two varieties were not significantly different in number of kernels per head, they ranked second and last in yields. Triumph and Concho were not significantly different in yield, yet ranked last and first, respectively, in the number of kernels per head.

From these observations it is obvious that there was little association between the number of kernels per head and yield over all varieties, i.e., the highest yielding varieties could not be determined by the number of kernels per head. However, within each variety (except Triumph) the r values were highly significant (a range of

0.276 to 0.447) but were much lower than those obtained for the number of heads per unit area and yield.

The fact that the number of kernels per head and the number of heads per unit area appeared to have little association has been previously discussed.

The r values for the number of kernels per head and kernel weight were significantly negative within all varieties except Triumph. Comanche and Concho were significant only at the 5% level of confidence. When considering the data over all varieties, the association appeared to be slightly negative, although this value was not calculated.

Treatments

Treatments that were higher in nitrogen than phosphorus, i.e., treatments 40-0 and 80-17.6 produced the highest number of kernels per head. With phosphorus at a constant rate (17.6 lbs.) and increasing the amount of nitrogen (0,20,40 and 80 lbs.), a consistant increase in this component resulted (Figure 1A). Conversely, when the rate of nitrogen was held constant (40 lbs.) and phosphorus was increased (0, 17.6 and 35.2 lbs.), the number of kernels decreased at a similar rate (Figure 1B).

In considering all treatments, there appeared to be little association between the number of kernels per head and yield. When nitrogen alone was increased, a highly positive relationship seemed to exist; when phosphorus alone was increased, the association seemed highly negative

(Figures 1A, 1B). From these data it would appear that the number of kernels per head contributed to increased yields when nitrogen alone was increased. However, it is doubtful that this component ever added appreciably to increased yields since it tended to increase at the expense of kernel weight. This relationship will be considered later.

The associations of the number of kernels per head and yield were highly variable within treatments. Only the two lowest yielding treatments, 0-0 and 0-17.6 had highly significant r values while treatment 20-17.6 was significant at the 5% level of confidence.

The relationship of the number of kernels per head and the number of heads per unit area has been previously discussed.

Treatments 20-17.6, 40-17.6 and 80-17.6 had significant negative r values for the number of kernels per head and kernel weight. Over all treatments, the values appeared to be negative, i.e., treatments that produced high number of kernels per head usually produced low kernel weights and vice-versa. When only nitrogen was increased an extremely high negative relationship existed, whereas, no relationship seemed to be present when phosphorous only was increased (Figure 1A, 1B).

Kernel Weight

Varieties

Triumph produced by far the highest average kernel weight as it exceeded the next highest variety, Concho, by 6 milligrams per kernel. The importance of kernel weight over all varieties is shown by the identical rankings of this component and yield. These findings show some similarity, although they are not as extreme as to those reported by Waldron (13) in which he compared small-seeded and large-seeded varieties of spring wheat. He found seed weight to contribute 91% of the difference in yield.

The fact that Triumph produced the highest yield must be attributed to its high kernel weight. This component compensated for the intermediate and low values for the number of heads per unit area and the number of kernels per head, respectively. The reason for the higher kernel weight and yield of Triumph may possibly be explained by its extreme earliness. The late date of seeding combined with a moisture stress that occured late in the plant development stage would naturally favor an early maturing variety. Laude (4) reported that the time a particular condition exists determines which component is affected--extremely late conditions affect seed weight. Therefore, it seems logical that Triumph probably escaped some of the stresses of late conditions by its earliness.

The associations of the average kernel weight with the number of heads per unit area and the number of kernels per head were discussed previously. The relationships were mostly negative.

Treatments

Treatments consisting of a high phosphorus to nitrogen ratio, in general, produced the highest kernel weights. The 0-17.6 treatment was significantly higher and the 80-17.6 treatment was significantly lower than any of the other treatments. As the amount of nitrogen was increased with 17.6 pounds of phosphorus, the kernel weight consistantly decreased (Figure 1A). However, as phosphorus increased with 40 pounds of nitrogen, no significant changes occured in kernel weight (Figure 1B).

Triumph, in contrast to the four other varieties, showed very little response to the fertilizer treatments. This, as well as its outstanding kernel weight, is illustrated in Figure 2. Because of the unequal response of varieties to treatments, a significant variety x treatment interaction occured as shown in the analysis of variance summary (Table IV).

McNeil and Davis (7) chose to combine the two com-

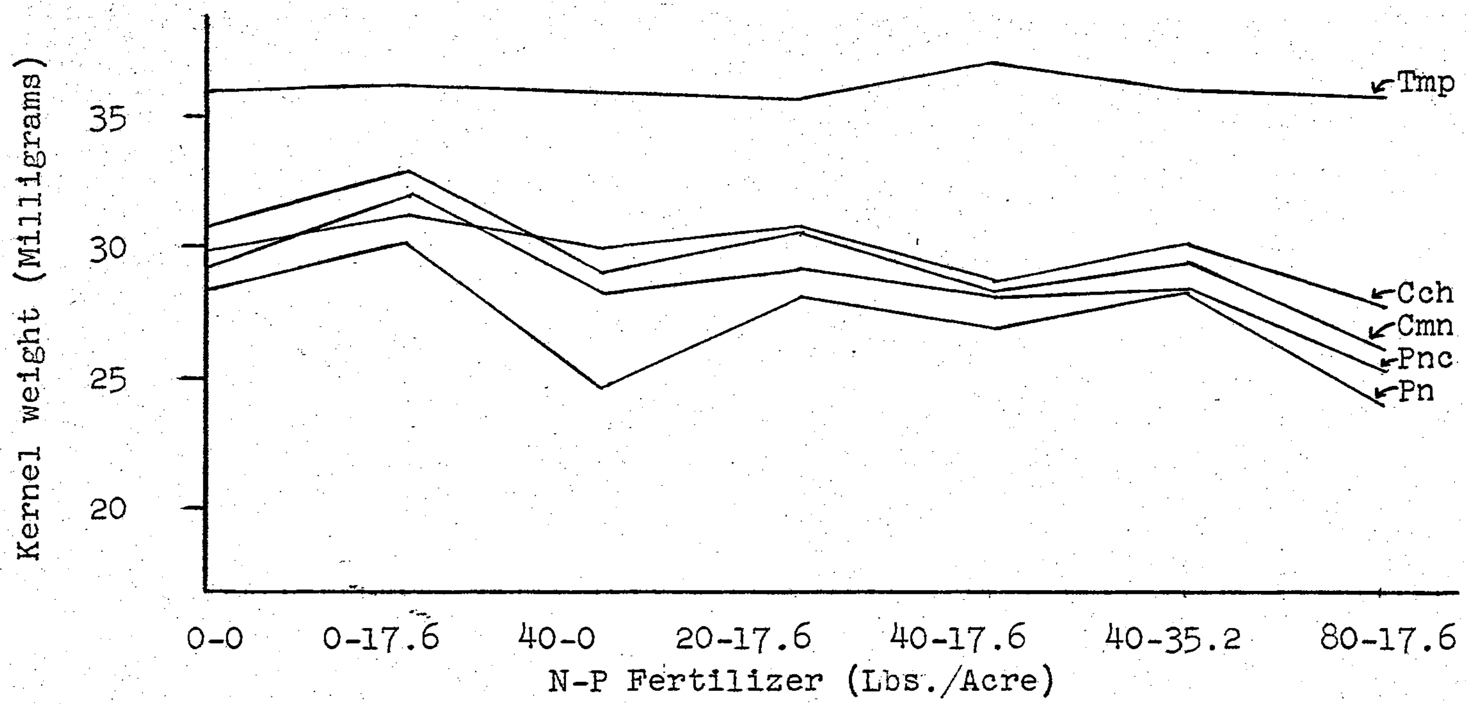

Figure 2. Average kernel weight for five varieties of winter wheat under seven treatments of fertilizer.

ponents, number of kernels per head and weight per kernel, into a single factor, weight per head. Had this been done in this study, the factor would have remained relatively stable for all treatments since an increase in one component was associated with a decrease in the other and vice-versa, depending on the nitrogen-phosphorus ratio. This situation would tend to add to the earlier suggestion that the number of heads per unit area was responsible for the major portion of increased yields as a result of treatments.

The association over all treatments for kernel weight and yield was probably slighly negative. However, a highly negative association appeared to exist when only nitrogen was increased (Figure 1A).

The relationships of kernel weight with the number of heads per unit area and the number of kernels per head have been previously mentioned.

SUMMARY

An experiment was initiated to study the association of the components of yield of five winter wheat varieties and the effect of seven nitrogen-phosphorus fertilizer combinations on these yield components.

The yield components varied from variety to variety and were independent of each other over all varieties. The only factor that appeared to be highly associated with yield based on rankings was kernel weight.

Within varieties (disregarding fertilizer treatments) the highest r values were for the number of heads per unit area and yield. The r values for the number of kernels per head and yield were highly significant, but somewhat lower than those for the number of heads and yield. Kernel weight was not correlated with yield, but was negatively correlated with the number of heads per unit area and the number of kernels per head.

Both the number of heads per unit area and yield were increased with nitrogen and phosphorus. The number of kernels per head increased with nitrogen at a constant phosphorus level and decreased with phosphorus at a constant nitrogen level. The average weight per kernel decreased with nitrogen, but showed little change with phosphorus.

Over all treatments the number of heads per unit area appeared to be highly associated with yield and was responsible for most of the yield increase caused by fertilizer applications. The number of kernels per head and kernel weight appeared to be highly negatively correlated, each increasing at the expense of the other. Neither component seemed to contribute directly to yield due to this relationship.

Within treatments (disregarding varieties), high r values were obtained for the number of heads per unit area and yield. Significant but lower values were found for kernel weight and yield. The number of kernels per head and yield r values were highly variable. The components of yield were generally independent of each other.

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APPENDIX

LIST OF APPENDIX TABLES

TABLE IX

OVERALL CORRELATION COEFFICIENTS FOR FOUR CHARACTERS OF WINTER WHEAT.

	Number of kernels per head	Average weight per kernel	Yield
Number of heads per unit area	0.052	-0.163**	0.847**
Number of kernels per head		-0.272**	0.278**
Average weight per kernel			0.182**

* Significant at the 5% level of confidence. (558 D.F.)
** Significant at the 1% level of confidence.

TABLE X

CORRELATION COEFFICIENTS FOR THE NUMBER OF HEADS PER UNIT AREA AND YIELD BY TREATMENT, BY VARIETY.

Treatments	Varieties				
	Comanche	Concho	Pawnee	Ponca	Triumph
0-0 #	0.831**	0.921**	0.643**	0.946**	0.902**
0-40	0.946**	0.931**	0.881**	0.833**	0.934**
40-0	0.691**	0.827**	0.847**	0.903**	0.852**
20-40	0.795**	0.935**	0.733**	0.885**	0.906**
40-40	0.845**	0.870**	0.843**	0.908**	0.926**
40-80	0.776**	0.941**	0.932**	0.848**	0.871**
80-40	0.866**	0.914**	0.680**	0.581 *	0.936**

* Significant at the 5% level of confidence. (14 D.F.)
** Significant at the 1% level of confidence.
#=N-P_2O_5. To convert P_2O_5 to P multiply by 0.44.

TABLE XI

CORRELATION COEFFICIENTS FOR THE NUMBER OF KERNELS PER HEAD AND YIELD BY TREATMENT, BY VARIETY.

Treatments	Varieties				
	Comanche	Concho	Pawnee	Ponca	Triumph
0-0	0.540*	0.461	0.401	0.373	0.291
0-40	0.538*	0.672**	0.846**	0.236	0.651**
40-0	0.666**	0.375	0.020	0.032	-0.142
20-40	0.153	-0.050	0.412	0.620*	0.588*
40-40	0.330	-0.044	-0.019	0.591*	0.130
40-80	0.406	0.485	0.052	0.406	-0.060
80-40	-0.008	-0.052	0.083	0.403	0.103

* Significant at the 5% level of confidence. (14 D.F.)
** Significant at the 1% level of confidence.

TABLE XII

CORRELATION COEFFICIENTS FOR WEIGHT PER KERNEL AND YIELD BY TREATMENT, BY VARIETY.

Treatments	Varieties				
	Comanche	Concho	Pawnee	Ponca	Triumph
0-0	0.031	0.480	0.527*	0.081	0.006
0-40	0.589*	0.069	0.148	-0.126	-0.003
40-0	0.294	0.155	0.551*	0.168	0.092
20-40	0.664**	0.312	0.308	0.081	-0.383
40-40	0.177	0.074	0.338	0.120	0.102
40-80	0.060	-0.024	0.154	0.629**	0.421
80-40	0.190	-0.151	0.488	0.725**	0.157

* Significant at the 5% level of confidence. (14 D.F.)
** Significant at the 1% level of confidence.

TABLE XIII.

CORRELATION COEFFICIENTS FOR THE NUMBER OF HEADS PER UNIT AREA AND THE NUMBER OF KERNELS PER HEAD BY TREATMENT, BY VARIETY.

Treatments	Varieties				
	Comanche	Concho	Pawnee	Ponca	Triumph
0-0	0.095	0.221	-0.269	0.215	-0.082
0-40	0.294	0.411	0.602*	-0.272	0.425
40-0	0.120	0.029	-0.322	-0.288	-0.498*
20-40	-0.040	-0.251	-0.026	0.364	0.327
40-40	0.055	-0.373	-0.169	0.518*	-0.151
40-80	-0.008	0.270	-0.211	0.161	-0.315
80-40	-0.427	-0.198	-0.454	-0.186	0.038

* Significant at the 5% level of confidence. (14 D.F.)
** Significant at the 1% level of confidence.

TABLE XIV.

CORRELATION COEFFICIENTS FOR THE NUMBER OF HEADS PER UNIT AREA AND WEIGHT PER KERNEL BY TREATMENT, BY VARIETY.

Treatments	Varieties				
	Comanche	Concho	Pawnee	Ponca	Triumph
0-0	-0.277	0.329	-0.031	-0.058	-0.273
0-40	0.368	-0.224	-0.161	-0.155	-0.203
40-0	-0.309	-0.234	0.178	-0.171	-0.135
20-40	0.503*	0.051	-0.154	-0.172	-0.531*
40-40	-0.220	-0.312	0.032	-0.201	-0.151
40-80	-0.405	-0.127	-0.024	0.351	0.249
80-40	-0.159	-0.420	-0.206	0.125	-0.119

* Significant at the 5% level of confidence. (14 D.F.)
** Significant at the 1% level of confidence.

TABLE XV

CORRELATION COEFFICIENTS FOR THE NUMBER OF KERNELS PER HEAD AND WEIGHT PER KERNEL BY TREATMENT, BY VARIETY.

Treatments	Varieties				
	Comanche	Concho	Pawnee	Ponca	Triumph
0-0	0.073	-0.004	0.289	-0.366	0.262
0-40	0.598*	0.379	0.132	-0.050	0.233
40-0	0.364	-0.131	0.178	0.473	-0.122
20-40	-0.360	-0.052	-0.077	-0.217	-0.247
40-40	-0.065	0.370	-0.407	-0.342	0.145
40-80	0.189	-0.377	0.181	0.169	-0.059
80-40	0.368	-0.110	0.380	0.100	0.067

* Significant at the 5% level of confidence. (14 D.F.)
** Significant at the 1% level of confidence.

TABLE XVI.

THE ANALYSIS OF VARIANCE FOR CHARACTERS STUDIED IN FIVE VARIETIES OF WINTER WHEAT PRODUCED WITH SEVEN TREATMENTS OF FERTILIZER.

Source of variation	D.F.	No. of heads per unit area		No. of kernels per head		Weight per kernel	
		Mean square	F value	Mean square	F value	Mean square	F value
Total	559						
Replications	3	263.67	2.23	19.88	2.08	48.00	5.72**
Treatments	6	2,126.00	18.00**	147.66	15.45**	190.00	22.65**
Error (a)	18	118.11		9.56		8.39	
Varieties	4	404.25	5.67**	123.27	21.14**	1,239.25	15.69**
Var. x Treat.	24	91.92	1.29	7.92	1.36	17.33	2.19 *
Error (b)	84	71.26		5.83		7.90	
Sections	3	109.00	1.41	14.37	3.86**	42.67	6.96**
Sect. x Treat.	18	90.78	1.17	5.65	1.52	6.17	1.01
Sect. x Var.	12	103.92	1.34	3.41	.92	6.75	1.10
Sect. x Var. x Treat.	72	54.44	.70	3.24	.87	6.85	1.12
Error (c)	315	77.50		3.72		6.13	

* Significant at the 5% level.
** Significant at the 1% level.

TABLE XVI. (Continued)

Source of variation	2-ft. plot yield			Main plot yield		
	D.F.	Mean square	F value	D.F.	Mean square	F value
Total	559			139		
Replications	3	251.09	3.45*	3	112.48	13.00**
Treatments	6	1,359.48	18.66**	6	188.52	21.79**
Error (a)	18	72.86		18	8.65	
Varieties	4	827.87	14.98**	4	230.35	85.31**
Var. x Treat.	24	87.64	1.59	24	5.29	1.96*
Error (b)	84	55.26		84	2.70	
Sections	3	347.91	5.75**			
Sect. x Treat.	18	89.94	1.49			
Sect. x Var.	12	48.26	.80			
Sect. x Var. x Treat.	72	48.14	.80			
Error (c)	315	60.53				

* Significant at the 5% level.
** Significant at the 1% level.

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