PLANT CHARACTERS RELATED TO YIELD IN WHEAT

by

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INTRODUCTION

The ability of wheat to yield has been most important since research work has been conducted in wheat improvement. High yielding strains have been retained for further testing and some have been released as improved varieties. Low yielding strains have been discarded because wheat producers are not interested in growing wheat that does not yield as well or better than something they already have available.

There is a large number of factors which affect yield in wheat, such as, plant diseases, insects, and environmental conditions. However, if it could be assumed that there was a group of wheat varieties in a test that were all equal in disease and insect resistance, it is probable that there still would be a wide range in yield among varieties as well as within varieties under different soil and climatic environment. This difference in yield could be attributed to the diversity in physiological and morphological characteristics and their relationship to environment. It is not an attempt to minimize the vast importance of insect and disease resistance in plant breeding work, but rather to point out some plant characteristics which are important from the standpoint of yield. The study of these characteristics give a much more thorough knowledge of why wheat makes a given yield. It seems important to know what characteristics a wheat may have that are conducive to its high or low yielding ability.

Yield has been defined as the final result of everything that takes place after growth begins. First, there must be heads produced, and second, there must be grains produced in the heads.

This suggests several different characters which are important in determining yield, such as the number of heads produced per unit of area, the number of kernels produced in each head, the weight of the kernels, and the total weight of the head.

Theoretically, if a given variety of wheat produces a large number of heads, with a large number of kernels per head, and a maximum kernel weight, it would be a high yielding wheat variety. It is quite evident that if a wheat makes a low yield it must fall short in at least one or more of these three characters. Likewise, if a certain soil treatment results in increased yield, the increased yield must be accounted for by an increase in one or more of these plant characters.

Eight hard red winter wheats have been studied to determine varietal differences in respect to yield and characters which determine it. Soil fertility treatments have also been studied to find relationships within the same variety.

REVIEW OF LITERATURE

The yield of wheat is dependent upon three morphological characters, first, the number of heads per unit of area, second, the number of grains per head, and third, the weight of the grain in the head.

Literature relating directly to this type of study is not extensive, however, there has been similar work reported and there has been most extensive work on the number of heads per unit area or the tillering habits of small grains.

Buffrum (1), in 1898, studied the stooling of grains and concluded that the number of mature heads produced by each seed of wheat, oats, or barley varied greatly with the locality, season, and distance apart the seeds were planted. An average of the number of heads produced by fifty seeds upon the same amount of land showed that barley produced the largest number of heads, oats second, and wheat third. A like comparison of the yields of grain produced from fifty seeds upon the same amount of land showed that barley produced the largest yield of grain followed by oats and wheat, respectively.

Schribaux (14) in 1900 reported that in cases of excessive tillering, the later formed secondary stems were barren or produced lower yields of grain per head than the primary stems, or were later in maturity. This indicated a disadvantage for excessive tillering. Later, Rimpau (13) in 1903 published results of investigations on the influence of the stooling capacity on productiveness of different varieties of wheat, oats, barley, and rye. His results were compared with those of Schribaux. Rimpau's results did not indicate as Schribaux asserted that the most productive varieties of grain have the lowest stooling capacity. This was found to be the case in a number of instances but was not regarded as occurring with sufficient regularity to be considered the rule.

Nilsson--Ehle (9) in working with oats, concluded that among both high and low yielding varieties of oats, some ranked high in tillering ability and others ranked low.

Work published by Lippoldes (7), in 1904, took exception to work reported by Schribaux. Initial stems were not found to be regularly superior to other stems of the plant. The study of a number of plants showed that almost without exception, the initial stem was the heaviest and its head contained the largest quantity of grain. In length of head and in weight per 1000 grams, it was frequently surpassed by stems of later growth.

Leschenko (6) made observations on stooling in cereals in 1911. Eight plants of winter wheat and ten plants of spring wheat were selected and placed under observation, the time of appearance of the heads of each stem being noted in order to determine relation to yield. From data collected, it appeared that the later the head formed and developed, the less was the yield. It was also noted that in the case of intense stooling, large quantities of energy were lost in producing barren stalks.

Data were collected in South Dakota by Hume, Champlin and Fowlds (2) on the relationship of length of head to yield in wheat. They found slight positive correlation between the yield in grams of longer mother heads in the progeny of the first generation and the length of the original mother heads. However, this correlation failed to persist in the progeny of succeeding generations. It was concluded that the process of multiplying wheat from long heads does not secure increased yields. The question arose why the capacity for high yields as determined for longer heads in the first generation did not persist, therefore was not hereditary, and why it appeared at all. They suggested that it might be caused by one of several fluctuations observed by Johannson. They also suggested that the kernels of the longer heads were larger or heavier than those of earlier heads.

Pridham (11) studied the size of seed in relation to wheat yields. His results indicated that the use of small seed does not result in any deterioration in respect to quality and vigor of the grain, but yields from the smaller seeds were invariably lower. It appeared that large and medium sized seed were equally reliable for sowing.

Smith (15) gave results of a tillering experiment with oats, barley, and wheat in North Dakota. He concluded that any attempt to select the highest yielding variety on tillering ability alone would be inconclusive. In comparing the tillering of cereal crops, results showed that oats tillered least and produced the highest yields. Barley tillered more than spring wheat and also yielded slightly more in grams per row.

Generally, research workers are not fully agreed as to the importance of tillering ability. Some have considered that scant tillering is an advantage while others have found positive correlations between tillering and yield. The later opinion has resulted in the conclusion that varieties with high tillering ability are likely to be good yielders. Smith (15) collected data from 8000 observations of 64 varieties of spring wheat, oats, and barley at the Dickinson, North Dakota, sub-station during the years 1909-1919. He concluded, first, that there is no uniform close relation between extent of tillering and yield in a comparison of varieties of a crop. Second, groups of crop varieties such as Durum wheats yielded more but tillered less than varieties of common wheat of the Bluestem group. Third, there was a close association of rainfall, tillering, and yield.

Kiesselbach and Sprague (3) in their report of the relation of development of the wheat spike to environmental factors, defined yield as an expression of three combined factors, the number of spikes per unit of area, the number of grains per spike, and the average weight of the kernels. Sprague (16) in 1926 reported on correlations and yield in bread wheats. Data were taken on three varieties, Red Rock, Kanred, and Nebraska 60. He found that the yields per acre and the means of the culm and spike characters varied widely with climatic conditions and variety. More favorable conditions resulted in a larger number of tillers per unit of area without influencing correlations between tiller characters. Correlations between tiller characters measured, except those involving culm length or weight per kernel, were fairly stable regardless of the variety considered or where it was grown. Within the variety of Nebraska 60, Sprague found a high positive correlation of yield and the number of spikes or heads produced. There was an intermediate correlation of yield with grain yield per spike and weight per kernel. An insignificant correlation was recorded for yield with spike length or grains per spike.

Quisenberry (12) in 1928 reported on samples of wheat which were obtained just prior to harvest in fields from Oklahoma, Kansas, Nebraska, and Montana. Characters determined included yield, number of heads per unit of area, number of kernels per head, and the weight of 1000 kernels. In winter wheat in Oklahoma, and Nebraska, and in spring wheat in Montana the number of heads per unit area and yield were most highly correlated. In winter wheat in Kansas and Montana, kernels per head seemed most important. In no case did the weight of 1000 kernels give the highest correlation with yield. A drought occurred in Kansas about heading time and thereafter which reduced the size of the heads and kernels but which did not affect the degree of tillering. No significant correlation was found between the number of heads and weights of 1000 kernels, or the number of kernels per head. In general, the weight of 1000 kernels had the least influence on yield. Quisenberry indicated that under cropping conditions in the fields sampled, the number of heads per unit of area was one of the most important factors in determining yield, closely followed by the number of kernels per head. There was little relationship between the number of heads per area and size of heads or plumpness of grain. This work emphasized the importance of full stands and indicated that thin seeding does not increase the size of kernel.

Laude (5) reported on the relation of certain plant characters to yield in winter wheats. Yield was defined as an exact measure or a final integration of all ecological conditions that have prevailed throughout the life of the plant--and is a function of the number of plants per acre, the number of heads per plant, the number of kernels per head, and the size of the kernel. It was pointed out that an increase in any one or more of these characters without a corresponding decrease in one or more of them results in an increased yield. Laude reported tests in 1932 showed a close relationship between yield and number of heads within a variety, as well as a positive relationship of kernel weight and test weight. In 1937 he found a closer relationship between the number of heads and yield, than size of kernel and yield. Laude suggested the importance of knowing why these various characteristics fluctuate from variety to variety or within a variety. He further stated that a knowledge of how the plant is influenced by environmental conditions and of the relation of those influences to yield will indicate what genetic features need to be changed in order to improve the adaptation and yield of a variety. Information of this type would also point out how ecological conditions for the crop can be improved by tillage practices, fertilizer treatments, time of seeding, and so forth.

Papadakis (10) studied the relation and number of tillers per unit of area to the yield of wheat. He concluded that high density (tillering) varieties are adapted to poor soils and low density varieties are adapted to good soils. He found a positive correlation between growth density at an early stage and grain yields, but the relation does not remain linear. Increments of grain yield corresponding to equal increments of density, gradually became smaller until a critical density was reached beyond which the yield did not increase. Papadakis further concluded that during the growth of the wheat plant the number of tillers increased to a certain point then decreased. Maximum density depended not only on environment but also on variety. Of the varieties tested, the order in which the varieties were classed with respect to their maximum density or their relative density was approximately the same at all 38 experiment fields. He generally found that early varieties are low in tillering, but varieties were studied which combined earliness with high tillering. Another conclusion drawn by Papadakis which is of interest is that low tillering varieties are capable of attaining the highest grain yields.

King and Jebe (4) reported an experiment in pre-harvest sampling of wheat fields in 1940. They concluded that the number of heads per sample was the best single indicator of yield.

The most recent work was reported in 1942 by Locke, Rauschschwalbe, and Mathews (8) in their study of the relation to yield of certain plant characters of winter wheat as influenced by different tillage and sequence treatments. They observed that the final yield of wheat was closely determined by the number of kernels per unit of area. The number of heads per unit area as an individual indicator of yield was exceeded only by the number kernels per unit area and number of spikelets per unit area. Variations in number of heads per unit area were much greater than those in the number of spikelets per head. They concluded that the initial requirement of good yields is a large number of heads and that the number of plants per area is not as important. Severe conditions during the heading and flowering period may reduce the number of kernels per spikelet enough to more than compensate for differences in head numbers between different treatments. Final adjustment in yield to environmental conditions is made through kernel weight as the plant nears maturity. Significant treatment differences were not apparent for this character indicating that hazards which reduce kernel weight on one treatment cause similar reductions on other treatments. Seasonal differences in kernel weight were apparent. As previously indicated Locke and his co-workers found that the number of kernels per unit area was most practical for estimating yields. When the number of kernels were not considered, the number of heads per unit area and plant height were most useful in determining yield. Their final conclusion was that there appears to be no simple answer to the problem of character response to different methods of cultivation and crop sequence.

CHARACTERS STUDIED AND METHODS OF DETERMINATION

Eight hard red winter wheat varieties grown in the wheat belt of Kansas were selected as a source of variety study. They were Tenmarq, Turkey, Nebred, Blackhull, Chiefkan, Early Blackhull, Comanche, and Pawnee. These varieties gave a range of early, medium, and late maturing strains.

Variety data representing twenty-three station years were collected from experiment stations and fields in Kansas during the period 1938 to 1942. Stations represented in this study include: Manhattan, Colby, Hays, Garden City, Tribune, Kingman, and Wichita, Kansas.

Similar data were collected on the fertility plots of the Kingman and Wichita Experiment Fields for the years 1940 and 1941. Tenmarq wheat was used as a uniform variety on these fertility plots. This included data on 59 different treatments each year which made a total of 118 plot observations for the two year period.

Number of Heads

This character is expressed in figures representing number of heads per one ten-thousandth acre. It was determined by counting the stubble in ten five-foot sections of drill row in each plot. This character is an expression of the final result of tillering. It assumes that each stubble produced a head. While this assumption may not be 100 percent correct, it is felt that it was accurate enough for comparable results.

Weight of 1000 Kernels

This measure was made by use of a counting machine designed to count 500 kernels. Three samples of wheat were taken from each plot which gave three 500 kernel samples. The three samples were weighed separately and the average of the weights was used. The average weight of each sample was multiplied by two to give weight per 1000 kernels.

Weight of Grain Per Head

Knowing the yield of grain per acre and the number of heads produced, the weight of grain per head is easily calculated by the following formula. The bushel yield is multiplied by 60 pounds and this product is multiplied by grams per pound. This equals the total grams per acre. The total grams per acre divided by the number of heads per acre equals the weight of grain per head.

Number of Kernels Per Head

The number of kernels per head is determined by dividing the weight of grain per head by the kernel weight.

Test Weight

Test weight was taken on all samples in the ordinary manner by using a calabrated regulation testing device.

Yield

Yield data were taken by the workers on the various experiment stations and fields. For the most part, yield was obtained by harvesting the entire test plot with the combine. In a few cases the plots were bound with a grain binder and threshed with a plot thresher.

DISCUSSION OF RESULTS

Varietal Differences in Respect to Characters

Number of heads produced per acre. The number of heads produced by any given variety appeared to be an inherited characteristic and in many cases associated with the maturity of the variety. The fertility of the soil, rainfall, and other environmental conditions caused the number of heads produced to fluctuate from year to year and from station to station within a given year. However, during the period the data were collected, it was found that the number of heads a given strain produced tended to remain in the same relative position when compared with other varieties

Table 1. Varietal differences in heads produced per one ten-thousandth acre (23 Station year average).

Station		Nebred		Turkey		Pawnee		Blackhull		Tenmarq		Comanche		Chiefkan		Early Blackhull	
		No.	Rank	No.	Rank	No.	Rank	No.	Rank	No.	Rank	No.	Rank	No.	Rank	No.	Rank
Manhattan	(1938-42)	245	1	222	2	233	3	210	4	189	6	192	5	187	7	171	8
Garden City	(1941-42)	248	1	225	5	240	2	236	3	213	7	228	4	215	6	222	8
Hays	(1939-41)	263	1	244	2	240	4	242	3	210	5	208	6	202	7	183	8
Tribune	(1940-41)	268	1	263	2	237	3	235	4	222	5	216	6	201	7	197	8
Colby	(1941)	311	2	268	4	332	1	293	3	231	5	230	6	222	7	171	8
Kingman	(1940-41)	212	1	190	2	183	4	188	3	160	6	140	8	165	5	150	7
Wichita	(1939-41)	239	1	205	2	202	3	195	4	177	6	176	7	178	5	172	8
Average		254	1	232	2	232	3	224	4	201	5	199	6	194	7	182	8

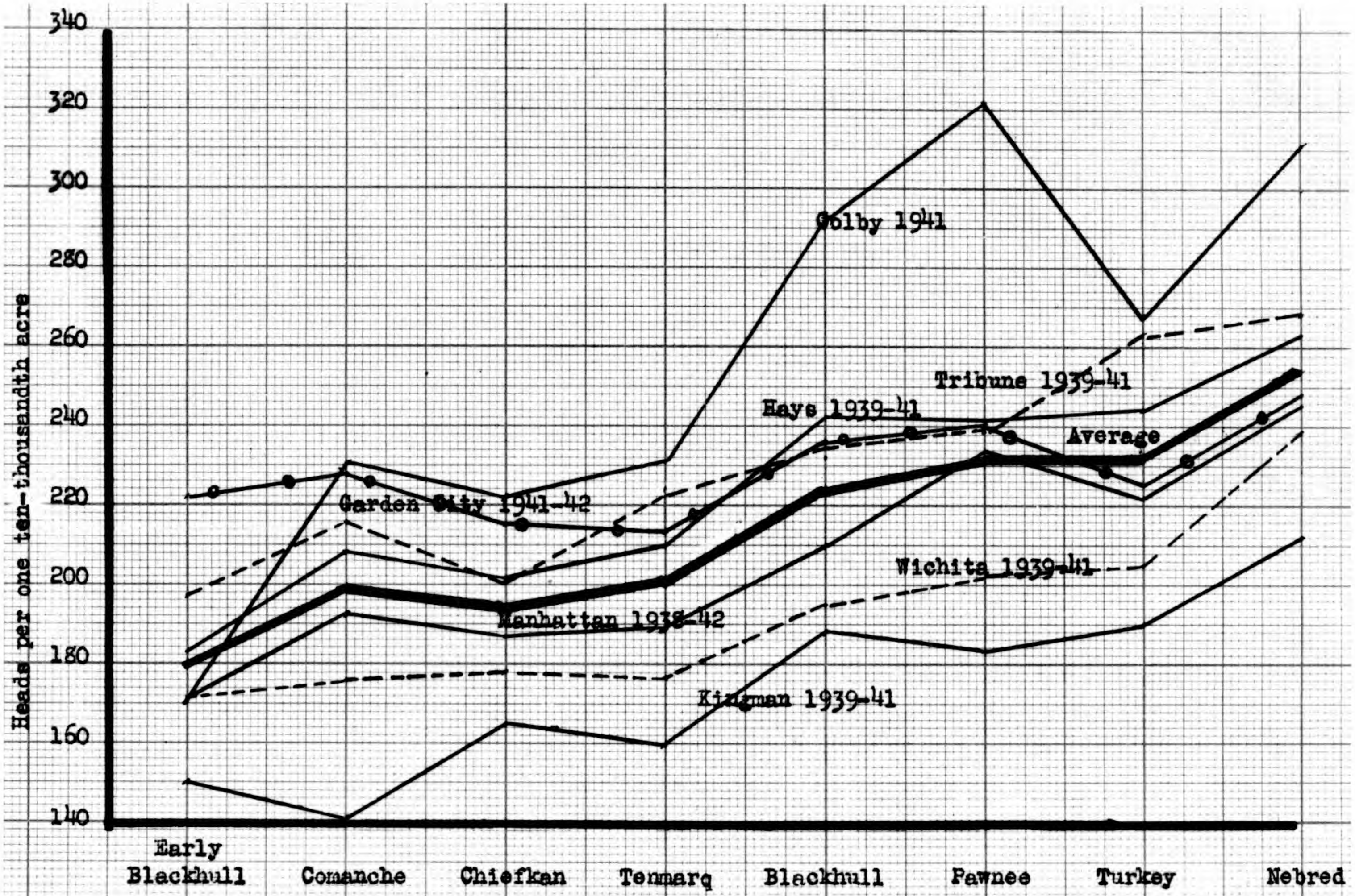

Fig. 1. Comparison of number of heads per unit area produced among different varieties (23 station year average).

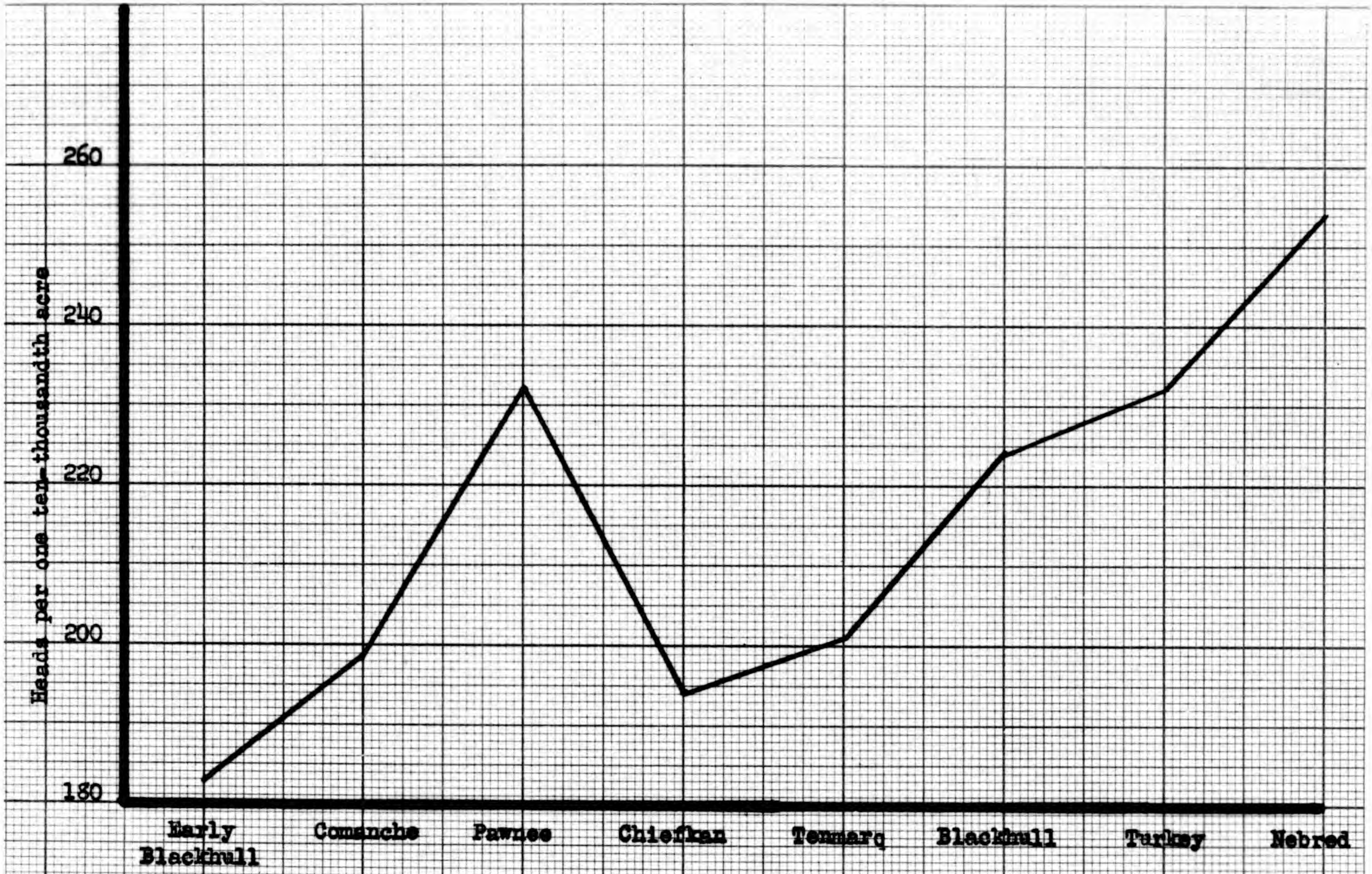

Fig. 2. Varieties ranked as to maturity showing the relationship of maturity and number of heads produced (23 station year average).

under similar environments. Figure 1 illustrates this point graphically. Average numbers of heads are given in Table 1.

These results indicated that varieties have a definite ability for tillering and that they all respond similarly to environmental conditions which might stimulate or retard tillering.

In most cases early varieties tillered less than late varieties as shown in Fig. 2. Early Blackhull which is nearly a week earlier than most of the other varieties produced the least number of heads while Nebred, which is one of the latest varieties, produced the largest number of heads per unit of area. Nebred, with one exception, ranked first in number of heads produced at the stations reported. The only exception to this general trend was the variety Pawnee. Pawnee is approximately two days earlier than Tenmarq and four to five days earlier than Turkey and Nebred, yet it produced a large number of heads per unit of area which more nearly compared with the later types. Perhaps there would be other similar examples if a more comprehensive study of varieties were made. However, this indicated that the association of high tillering and earliness has not been common in Kansas wheats, but this combination may be highly desirable from the standpoint of securing high yielding strains. The maturity of Pawnee wheat appears to be well suited for a large portion of Kansas.

Seventeen strains which were grown in the 1941 Wichita Intra-State Wheat Nursery were studied in regard to earliness and the number of heads produced. Figure 3 shows that the general trend indicated that the later the strain, the more heads

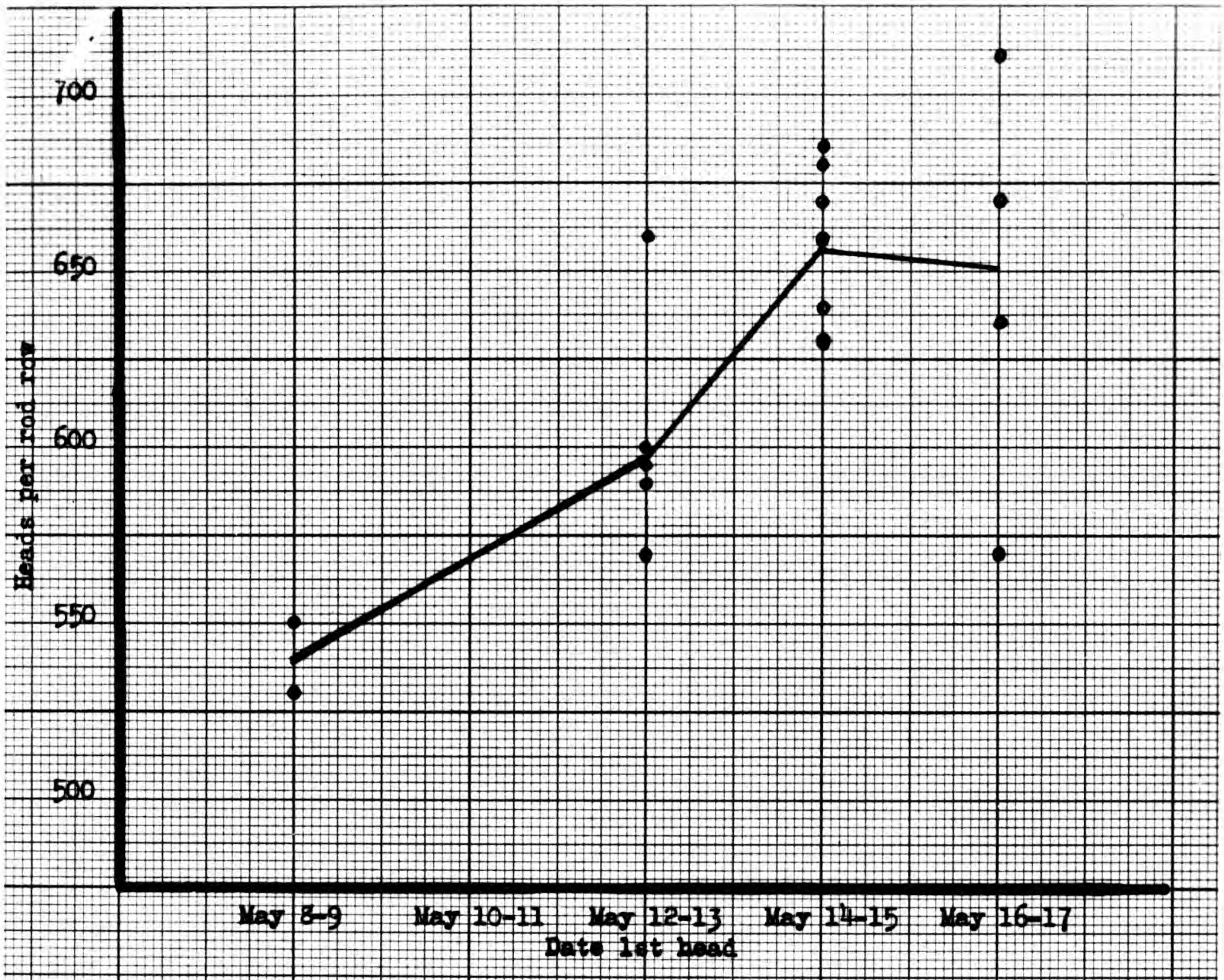

Fig. 3. Relation of heads per unit of area to maturity among 17 strains of wheat in 1941 intra-state wheat nursery at the Wichita Experiment Field.

were produced. This confirms the conclusion made by Papadakis (10) in his studies.

Average Number of Kernels Per Head. There is a wide variation in number of kernels produced per head among varieties. In general, the earlier varieties produced a larger number of kernels per head than the late varieties. Also the varieties which tillered the most produced the fewest kernels per head. In the previous discussion it was noted that Pawnee was a high tillering strain, yet was also early in maturity. While Pawnee didn't produce as many kernels per head as some of the lower tillering varieties, it still ranked well above the late, high tillering types as Nebred and Turkey as indicated in Table 2. It is apparent that early, low tillering varieties produced more kernels per head than late high tillering varieties, possibly in a response to counteract for their lack of tillering.

The number of kernels per head among different varieties was influenced by environmental conditions between stations and years as shown in Fig. 4. Here again, the number of kernels per head produced by any one variety remained about in the same relative position when compared with other varieties at different stations and different years. As indicated in Table 2, Turkey, Nebred, Blackhull, Chiefkan, Tenmarq, and Comanche remained in a more stable relative position in regard to number of heads per acre than did Pawnee and Early Blackhull. This suggests that some varieties may be affected more by environmental conditions than others in regard to the number of kernels produced in the head. Also, differences in maturity may cause fluctuations in

Table 2. Varietal differences in number of kernels per head (23 Station year average).

Station		Nebred		Turkey		Pawnee		Blackhull		Tenmarq		Comanche		Chiefkan		Early Blackhull	
		No.	Rank	No.	Rank	No.	Rank	No.	Rank	No.	Rank	No.	Rank	No.	Rank	No.	Rank
Manhattan	(1938-42)	10.6	7	10.0	8	13.6	3	10.6	6	13.7	2	14.4	1	13.0	4	11.9	5
Garden City	(1941-42)	8.9	6	6.2	8	10.9	1	8.1	7	9.6	3	9.8	2	8.9	5	9.2	4
Hays	(1939-41)	10.4	6	9.7	8	12.8	5	9.8	7	13.5	3	13.9	2	13.0	4	15.3	1
Tribune	(1940-41)	8.3	7	6.3	8	9.9	5	8.5	6	10.2	4	10.8	2	10.5	3	12.0	1
Colby	(1941)	13.0	7	14.2	5	12.1	8	13.2	6	17.5	1	15.5	3	14.6	4	17.1	2
Kingman	(1940-31)	13.4	6	13.2	8	16.2	3	13.3	7	16.2	2	19.4	1	15.2	4	14.6	5
Wichita	(1939-41)	17.4	8	17.8	7	20.0	4	19.3	6	20.4	3	20.8	2	19.6	5	21.0	1
Average		11.0	7	10.1	8	13.3	4	11.2	6	13.7	3	14.3	1	13.1	5	13.9	2

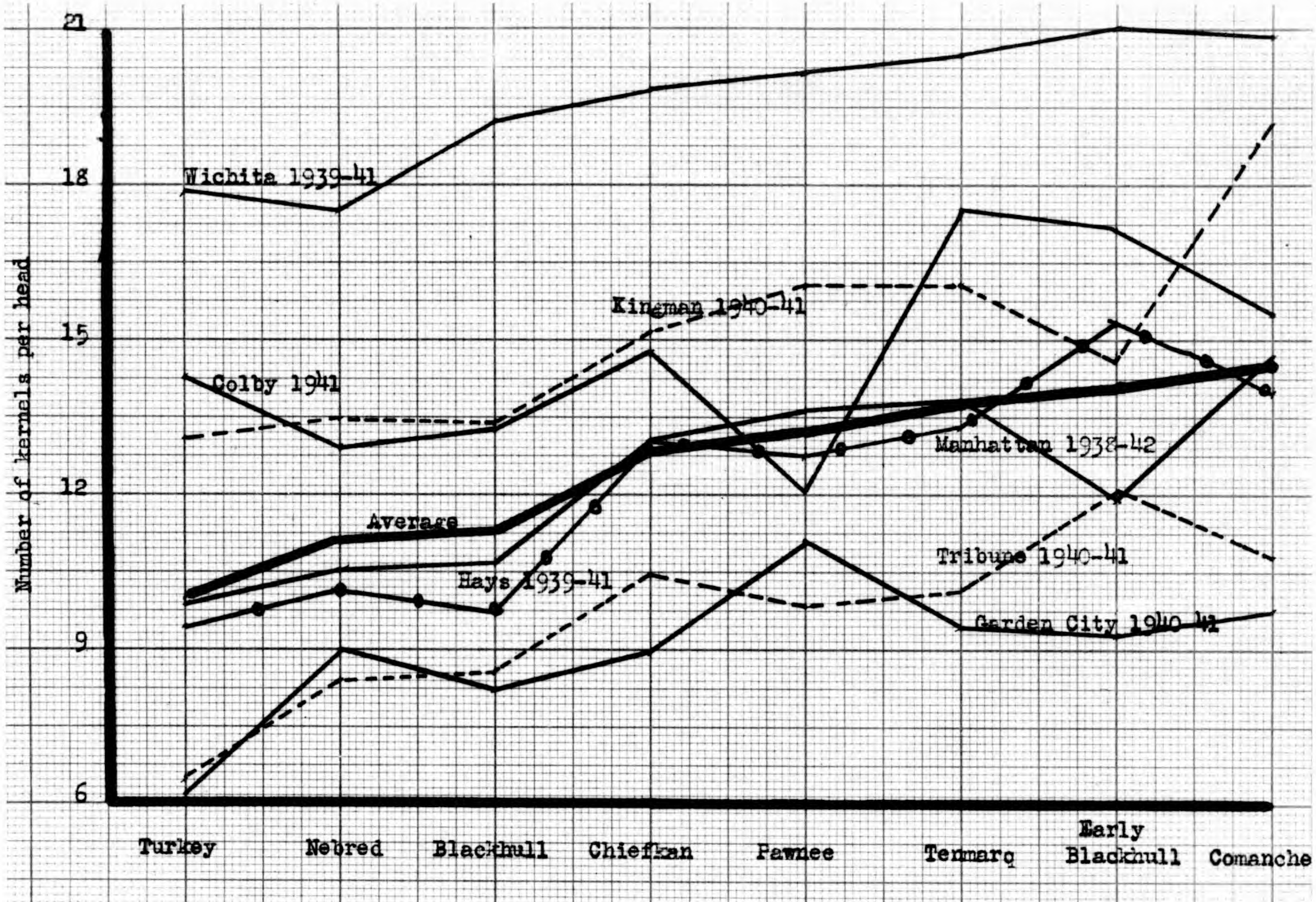

Fig. 4. Varietal differences in number of kernels per head (23 station year average).

kernel numbers. Environmental conditions may be ideal when an early strain is pollinating and the kernel begins forming, while conditions may be poor by the time a later variety goes through the same process. While it was noted that certain varieties usually ranked near the top or near the bottom in number of kernels produced per head, there often were wide variations. For example, Pawnee ranked first in number of kernels produced per head at Garden City and eighth at Colby as recorded in Table 2.

Weight Per One Thousand Kernels. The size of kernel which is expressed as the weight of 1000 kernels is closely related to test weight within a variety as shown in Table 8. However, this was not always the situation when different varieties were compared. Quite a differentiation was noted among the eight varieties studied as to weight of 1000 kernels. In the 23 station years represented the eight varieties ranked themselves as follows:

Nebred..................	22.0)	
Turkey..................	22.8)	
Blackhull...............	23.7)	
Tenmarq.................	25.0)	Grams per 1000 kernels
Pawnee..................	25.2)	
Early Blackhull.........	25.6)	
Comanche................	26.8)	
Chiefkan................	27.8)	

Figure 5 shows graphically the average weight per 1000 kernels for all varieties at each station. While the data represented do not give identical years for each station, they do show the variation that occurs from year to year and station to station in the weight of kernel. As illustrated in Fig. 5, there appears to be a direct association of varieties and weight per kernel among the stations with the exception of the Garden City data. The Garden City data indicated quite clearly that the relative position of the varieties may change due to environmental conditions. This could be explained by adverse weather conditions at the time the kernel was developing. As a result, an under-sized kernel would develop. For example, Fig. 5 shows that Early Blackhull at Garden City fell far below where it is usually expected to fall in relative kernel weights, while some of the later maturing varieties produced fairly good sized kernels. This difference in environment at the time the kernel was forming appeared to cause this difference in kernel weight.

If every variety produced its kernels under optimum conditions, there would no doubt be variation in kernel weight, or each variety has a certain inherited ability to produce its size of kernel. Yet, differences in environment caused the relative kernel weight of varieties to fluctuate from year to year or station to station. This was attributed largely to the difference in maturity among the varieties and also the difference in tillering habits.

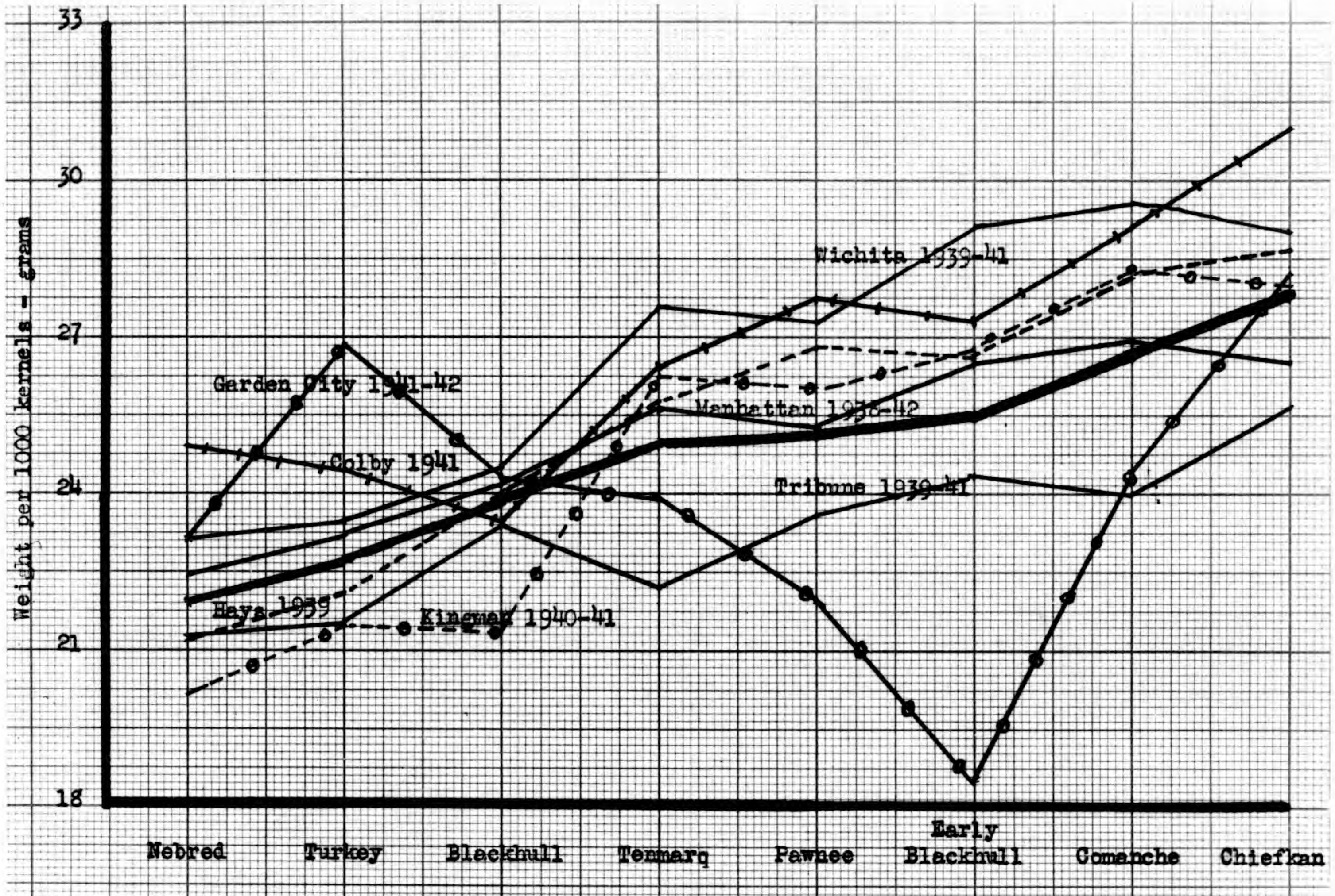

Fig. 5. Varietal differences in weight of 1000 kernels (23 station year average).

Table 3. Varietal differences in weight per 1000 kernels (23 Station year average).

Station		Nebred		Turkey		Pawnee		Blackhull		Tenmarq		Comanche		Chiefkan		Early Blackhull	
		Grams	Rank	Grams	Rank	Grams	Rank	Grams	Rank	Grams	Rank	Grams	Rank	Grams	Rank	Grams	Rank
Manhattan	(1938-42)	22.6	8	23.1	7	25.2	5	24.2	6	25.7	4	26.8	1	26.5	2	26.4	3
Garden City	(1941-42)	23.0	6	26.8	2	22.1	7	24.3	4	23.8	5	24.3	3	28.2	1	18.5	8
Hays	(1939-41)	21.2	8	22.2	7	26.7	3	24.0	6	25.9	5	28.2	2	28.8	1	26.4	4
Tribune	(1940-41)	21.2	8	21.6	7	23.5	4	23.3	5	22.3	6	24.0	3	25.8	1	24.3	2
Colby	(1941)	25.0	6	24.5	7	27.8	3	23.3	8	26.4	5	29.0	2	31.1	1	27.4	4
Kingman	(1940-41)	20.1	8	21.6	6	25.9	5	21.3	7	26.2	4	28.3	1	28.1	2	26.6	3
Wichita	(1939-41)	23.0	8	23.4	7	27.4	5	24.6	6	27.7	4	29.5	1	28.9	3	29.0	2
Average (18 Sta. years)		22.0	8	22.8	7	25.2	4	23.7	6	25.0	5	26.7	2	27.5	1	25.6	3

Weight of Grain Per Head. This character is a combination of the number of kernels per head and the kernel weight. It has been pointed out that the number of kernels per head and the kernel weight are dependent to a large degree upon the variety itself and the environmental conditions at the time that particular character was being determined. The weight of grain per head varied widely among varieties as shown in Table 4. As a general trend, the higher tillering varieties produced the smaller heads and the lower tillering varieties produced the larger heads. Comanche produced the largest head and Turkey the smallest head. The relative position of the varieties in weight of grain per head as indicated in Fig. 6 was about the same among stations and years, except that it also was subject to changes caused by the environment at the time it was determined.

Test Weight. This grain character is generally measured by experimental workers and is regarded as highly important because price paid for wheat varies with test weight.

The test weight of these varieties studied fluctuated greatly. All varieties studied produced a 60 pound per bushel test weight one or more times over the period tested. Certain varieties showed more genetic ability to produce high test weights. Also, different response among the varieties to environmental conditions made deviations still greater.

The test weight and rank of each of the eight varieties is given in Table 5. The relative position of test weight among varieties was not always the same. Environment changed the relation to some extent, however, it was generally noted that a

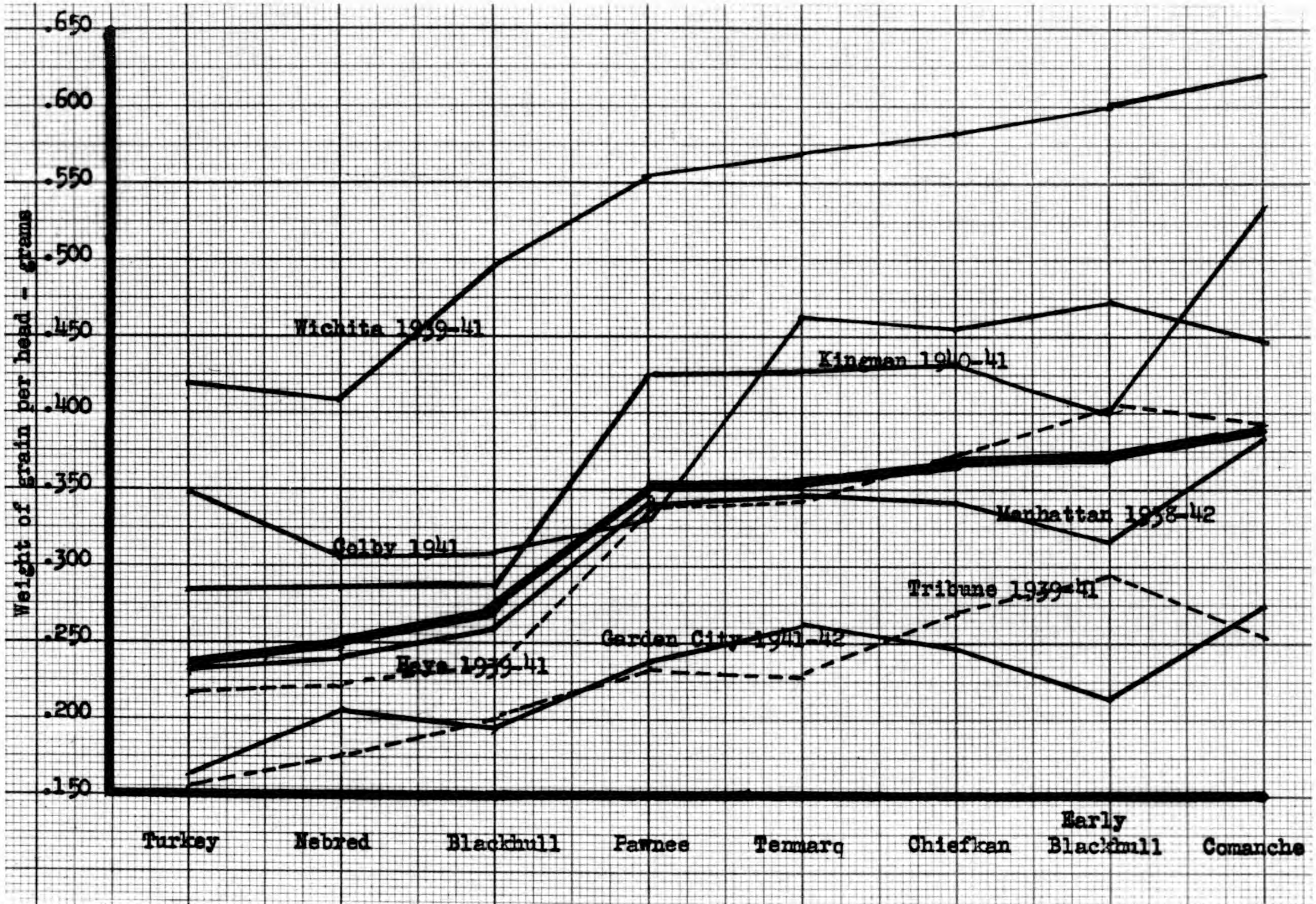

Fig. 6. Varietal differences in weight of grain per head (23 station year average).

Table 4. Varietal differences in weight of grain per head (23 station year average).

Station		Nebred		Turkey		Pawnee		Blackhull		Tenmarq		Comanche		Chiefkan		Early Blackhull	
		Grams	Rank	Grams	Rank	Grams	Rank	Grams	Rank	Grams	Rank	Grams	Rank	Grams	Rank	Grams	Rank
Manhattan	(1938-42)	.238	7	.232	8	.342	4	.257	6	.348	2	.382	1	.343	3	.315	5
Garden City	(1941-42)	.204	6	.163	8	.286	1	.192	7	.261	3	.273	2	.246	4	.213	5
Hays	(1939-41)	.222	7	.215	8	.341	5	.236	6	.348	4	.391	2	.373	3	.404	1
Tribune	(1940-41)	.176	7	.138	8	.233	4	.200	6	.228	5	.253	3	.268	2	.294	1
Colby	(1941)	.304	8	.347	5	.337	6	.307	7	.462	2	.446	4	.453	3	.472	1
Kingman	(1940-41)	.284	7	.283	8	.425	4	.286	6	.427	3	.535	1	.431	2	.403	5
Wichita	(1939-41)	.408	8	.419	7	.553	5	.494	6	.568	4	.620	1	.581	3	.599	2
Average		.245	7	.232	8	.343	5	.268	6	.350	4	.388	1	.364	3	.367	2

Table 5. Varietal differences in test weight.

Station		Nebred		Turkey		Pawnee		Blackhull		Tenmarq		Comanche		Chiefkan		Early Blackhull	
		Test weight	Rank	Test weight	Rank	Test weight	Rank	Test weight	Rank	Test weight	Rank	Test weight	Rank	Test weight	Rank	Test weight	Rank
Manhattan	(1938-42)	56.3	5	55.1	8	57.3	3	56.8	4	55.4	7	56.1	6	58.7	1	57.7	2
Garden City	(1941-42)	60.3	2	60.0	3	56.6	7	59.8	4	57.7	6	57.8	5	60.9	1	54.8	8
Hays	(1939-41)	60.0	7	59.0	8	61.0	3	61.0	4	60.0	6	61.0	5	63.0	1	62.0	2
Tribune	(1940-41)	54.9	4	53.4	7	54.5	5	55.0	2	52.9	8	54.4	6	57.5	1	55.0	3
Colby	(1941)	57.7	5	57.5	6	57.7	4	57.0	8	59.5	2	57.3	7	60.0	1	58.5	3
Kingman	(1940-41)	55.5	7	54.6	8	57.4	3	55.6	6	56.3	5	56.9	4	59.1	1	58.5	2
Wichita	(1939-41)	58.2	7	57.0	8	59.6	3	59.5	4	58.5	6	59.3	5	61.0	1	61.0	2
Average		57.4	6	56.4	8	57.7	4	57.8	3	56.7	7	57.4	5	60.0	1	58.3	2

Table 6. Factors contributing to yield among varieties.

Variety	Yield		No. of heads		No. of kernels per head		Weight per 1000 kernels	
	Bushel per acre	Rank	1/10000 acre	Rank	No.	Rank	Grams	Rank
Pawnee	28.2	1	232	3	13.3	4	25.2	4
Comanche	26.9	2	199	6	14.3	1	26.7	2
Tenmarq	25.1	3	201	5	13.7	3	25.0	5
Chiefkan	25.0	4	194	7	13.1	5	27.5	1
Early Blackhull	23.1	5	182	8	13.9	2	25.6	3
Nebred	21.9	6	254	1	11.0	7	22.0	8
Blackhull	20.7	7	224	4	11.2	6	23.7	6
Turkey	18.9	8	232	2	10.1	8	22.8	7

high test weight variety in one section was also a high testing variety in other sections.

Yield. Variations in yield among the varieties was wide. Pawnee produced the highest yield for the 23 station year period with 28.2 bushels per acre. Turkey produced the lowest yield with 18.9 bushels per acre. Table 6 gives the average yield of each variety as well as the rank of each variety in the number of heads per acre, the number of kernels per head and the weight of 1000 kernels. From this table it is possible to see at a glance why certain varieties made a good or poor yield performance. For example, Turkey ranked second in the number of heads produced but fell short in the number of kernels per head and kernel weight. It is interesting to note that Pawnee did not rank first because of any one character but because it combined the three characters to best advantage.

Relationships

There is a large number of relationships involved in this study, all of which might be discussed separately. For the most part, relationships discussed will be mainly between yield and the other characters studied. Consideration will be given to relationships among varieties as well as relationships within a variety.

Yield and Number of Heads Produced. The relationship between yield and number of heads produced among varieties is a complex association. When the group of varieties were considered as a whole, the relationship or correlation is negative, that is, the varieties which produced the largest number of heads per acre produced the lowest yields. However, Pawnee again was an exception to this because it produced a large number of heads and exceptionally good yields. Pawnee does differ from the other high tillering types as Turkey, and Nebred in that it is a distinctly earlier variety.

It was of interest to consider the earlier varieties as a unit. This included Early Blackhull, Pawnee, Comanche, Chiefkan, and Tenmarq. When these varieties were considered, high tillering appeared to be an advantage. Early Blackhull produced the lowest number of heads of this group and also the lowest yield while Pawnee produced the highest number of heads and also the highest yields as shown in Table 6.

In general, most of the early wheats tend to be low in tillering ability and late wheats high in tillering ability. Pawnee illustrates the fact that high tillering early wheats are not an impossibility but that they have been the uncommon association of factors in Kansas wheats of the past.

The data from these eight winter wheats suggest that high tillering may be an important factor for high yields when associated with earliness. In addition to this it was clearly shown that tillering alone could not be used as a basis for selecting one variety over another.

It is also of interest to note how yields relate to the number of heads produced per unit of area within a variety grown under similar climatic environment but under different soil fertility levels or moisture levels. The data from this study clearly indicated that in areas where moisture is not a determining factor, high tillering within a variety is directly associated with higher yields. This phase was studied at several different stations with respect to fertility plots where a selected variety was used on all plots. Differences in yield among plots was due to differences in the nutrient condition of the soil, type of soil, moisture level, or other environmental conditions.

Studies reported here were made on fertility plots at the Kingman and Wichita Experiment Fields in 1940 and 1941. These fields lie in an area of Southcentral Kansas where soil fertility is most usually the limiting factor in wheat production, however, the Kingman Experiment Field is close to the area where soil moisture quite often becomes the limiting factor. Observations on 59 different treatments for a two year period, making a total of 118 different observations, showed an exceptionally high correlation of yields per acre and number of heads per acre. This correlation was 0.8553 as shown in Fig. 9. In general, anything that was done in regard to the environment which stimulated tillering also increased the yield.

All of these studies of fertility plots included applications of superphosphate. Without exception, the addition of superphosphate stimulated tillering and in most cases yield. In 1940, superphosphate applied on continuous wheat at the Kingman Experiment Field caused stimulated growth and tillering in the fall, however, the following spring the wheat which received super-

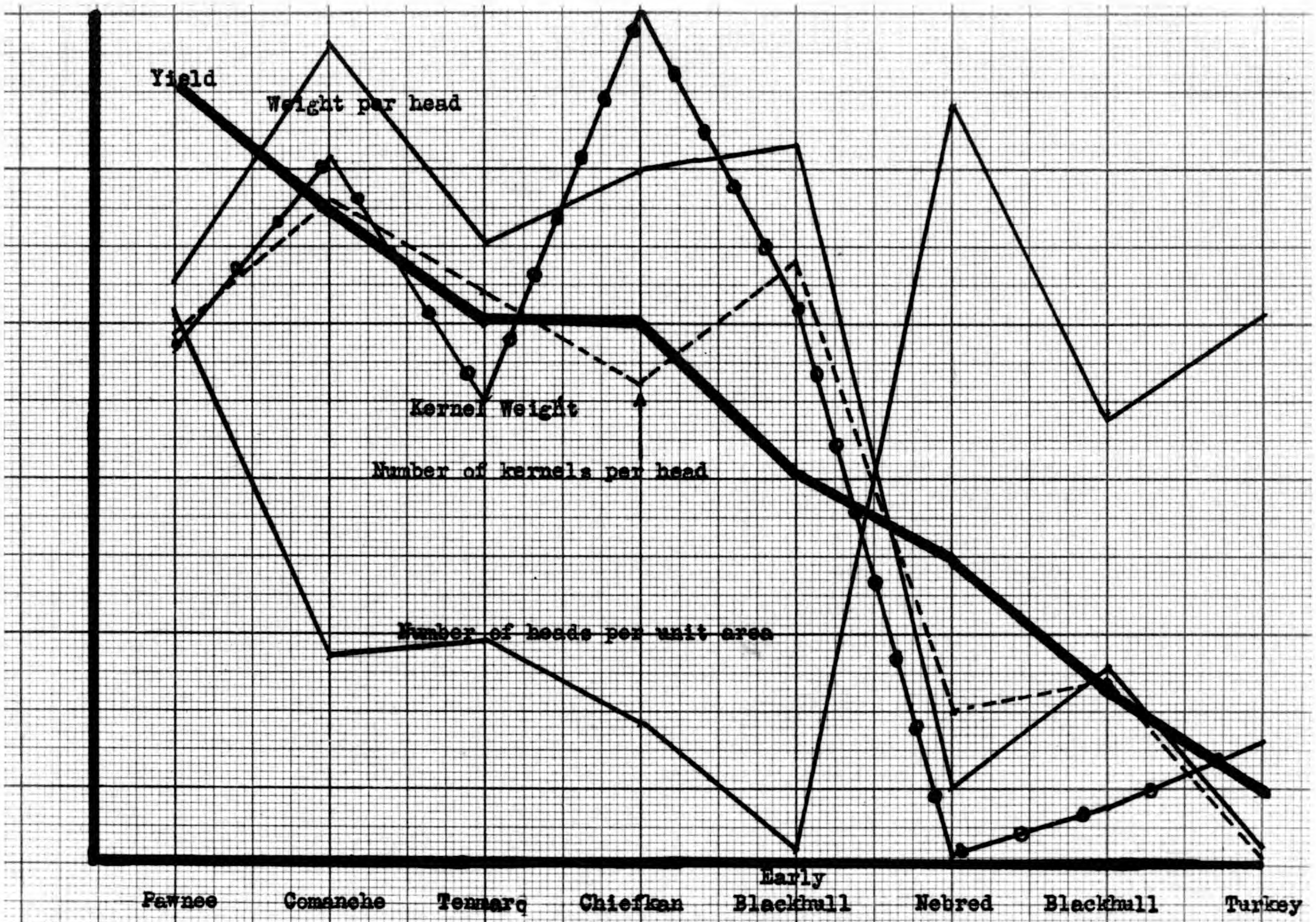

Fig. 7. Relationship of characters to yield (23 station year average).

phosphate turned a yellow color indicating nitrogen deficiency. When culm counts were made, it was found that the superphosphate plot had produced more heads per unit area than the check plots. Apparently stimulated growth had utilized the limited amount of available nitrogen and the plants could not complete normal production of heads and kernels. The result was a decrease in yield of the superphosphate plot over the check plot. On the adjoining plot, which received nitrogen as well as phosphate, an increase in yield was recorded. This suggested that there must be a proper balance of soil nutrients to support increased tillering. While this observation is not entirely new, more information of this type would be useful in studying the effects of fertilizer on crop yields.

Data secured from areas where moisture is usually the limiting factor are not extensive, and trends that were found are far from conclusive. However, it was indicated that heavy tillering within a variety may become a disadvantage in some years. This was indicated at the Hays Experiment Station on the Dry Land Project in 1941. This particular year there was very high tillering and considerably above average yields. The highest tillering plots produced the lower yields and the lower tillering plots produced the higher yields. This observation confirms Papadakis in his statement that all varieties have a critical tillering point, above which, yields may be reduced. Data taken from the Colby Experiment Station on the Dry Land Project in 1939 and 1941 showed positive relationship between the number of heads and yield. Yields ranged from 2.5 bushels per acre to 12 bushels per acre. Tillering was low, ranging from 300,000 heads to 1,250,000 heads per acre. This same condition existed in 1941, except that the number of heads produced per acre and the yields were slightly above average.

When considering yields within a variety, the initial stand obtained appears to be a very important factor in resulting yields regardless of variation in environment. In areas where moisture is the limiting factor in production, limited study indicated that heavy tillering may not always be an advantage, but under the best farming methods where water conservation practices are fully utilized, high tillering will usually result in higher yields. In areas where soil nutrients become the determining factor, it was found desirable to have a balance of nutrients in the soil that induce tillering whether it is through the application of commercial fertilizers, manure, growth of soil building crops, or cultural practices.

Yield and Number of Kernels Per Head. The relationship between yield and the number of kernels produced per head was found to be very important. While there were other interacting factors, there was a direct relationship between the two when different varieties were compared. Among the varieties studied for the 23 station year period, the single character studied having the highest correlation coefficient with yield was the number of kernels per head. The correlation coefficient between yield and the number of kernels was 0.8670 as shown in Table 7. Over the period studied, Turkey, Nebred, and Blackhull produced the lowest

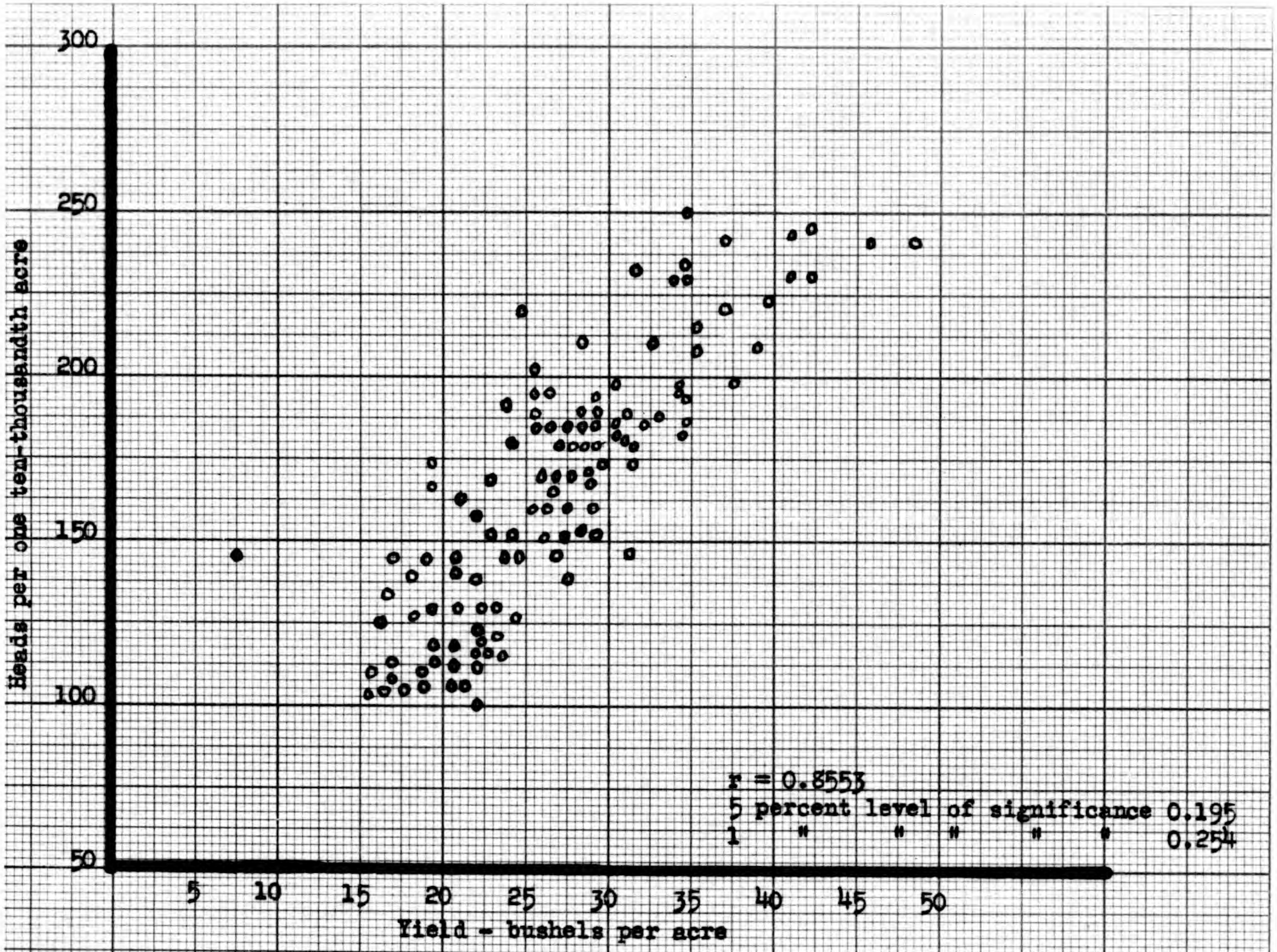

Fig. 8. Relationship of yield and number of heads per acre on the Kingman and Wichita fertility plots in 1940 and 1941.

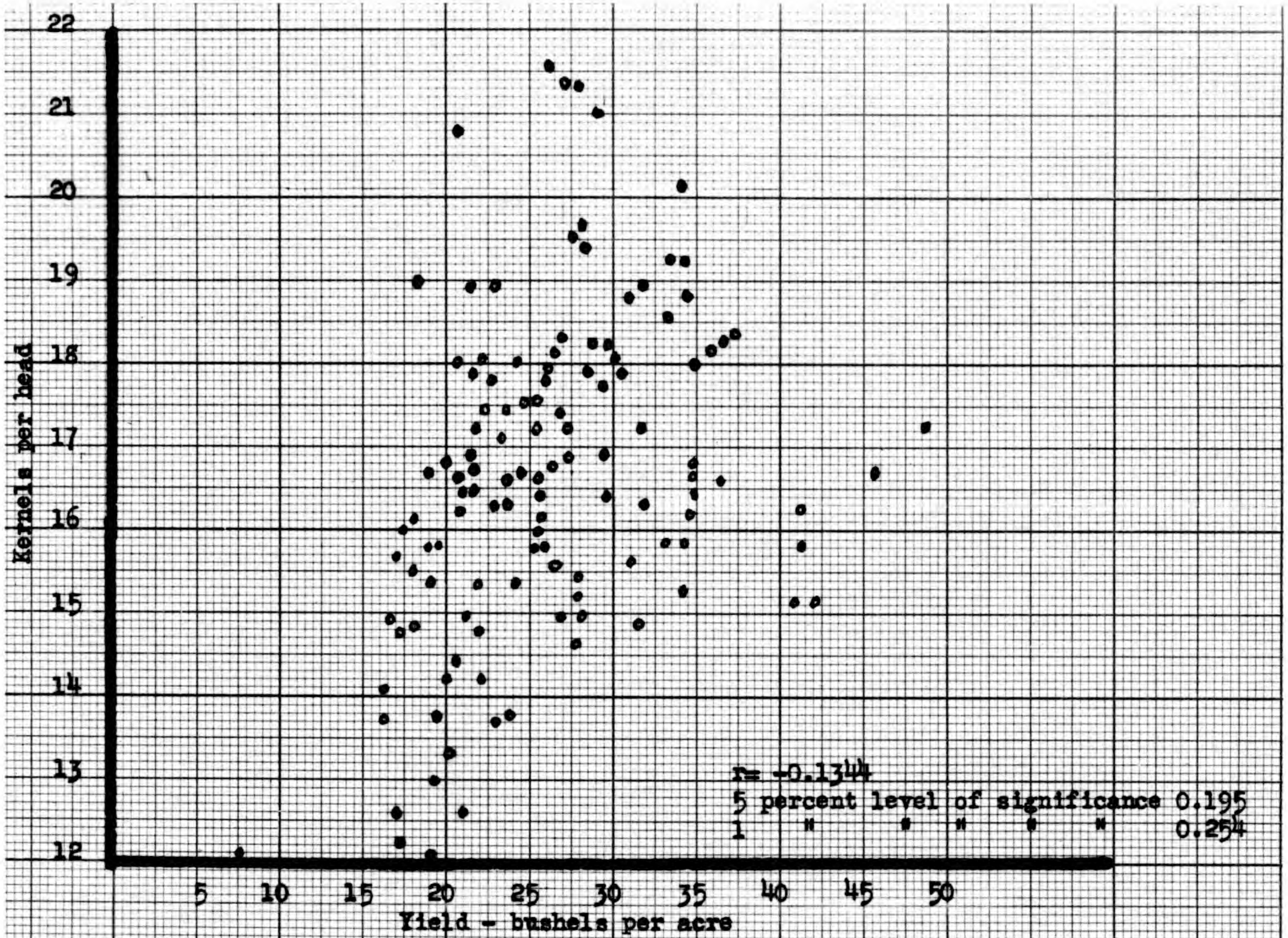

Fig. 9. Relationship of yield and number of kernels per head on the Kingman and Wichita fertility plots in 1940 and 1941.

number of kernels per head and also the lowest yields. Early Blackhull failed to yield as high as expected and Pawnee exceeded its expected yield on the basis of number of kernels per head. This was due to the limited tillering of Early Blackhull and the high tillering of Pawnee.

A positive correlation was found between the number of kernels per head and yield within each variety for the 23 station year period. These correlations are given in Table 8. In a detailed study of the fertility plots on the Kingman and Wichita Experiment Fields during 1940 and 1941 a negative but insignificant correlation of -0.1344 was secured between the number of kernels per head and yield. This was contradictory to the results obtained in the 23 station year variety test as reported above. No particular reason can be given for this except the variety study covered a longer period of years, more stations, and many different environments.

In supporting the data from the Kingman and Wichita fertility plots, frequent observations were made where a single plant was isolated with no close competition from other plants and the isolated plant produced large heads with a large number of kernels. In this instance, heavier stands which contained somewhat smaller heads with fewer kernels yielded more than plots with thinner stands that contained heads with a larger number of kernels.

These results show that the number of kernels per head among varieties is very important from the standpoint of yield. The relationship within a variety is rather complex and may or may not be positively correlated with yield.

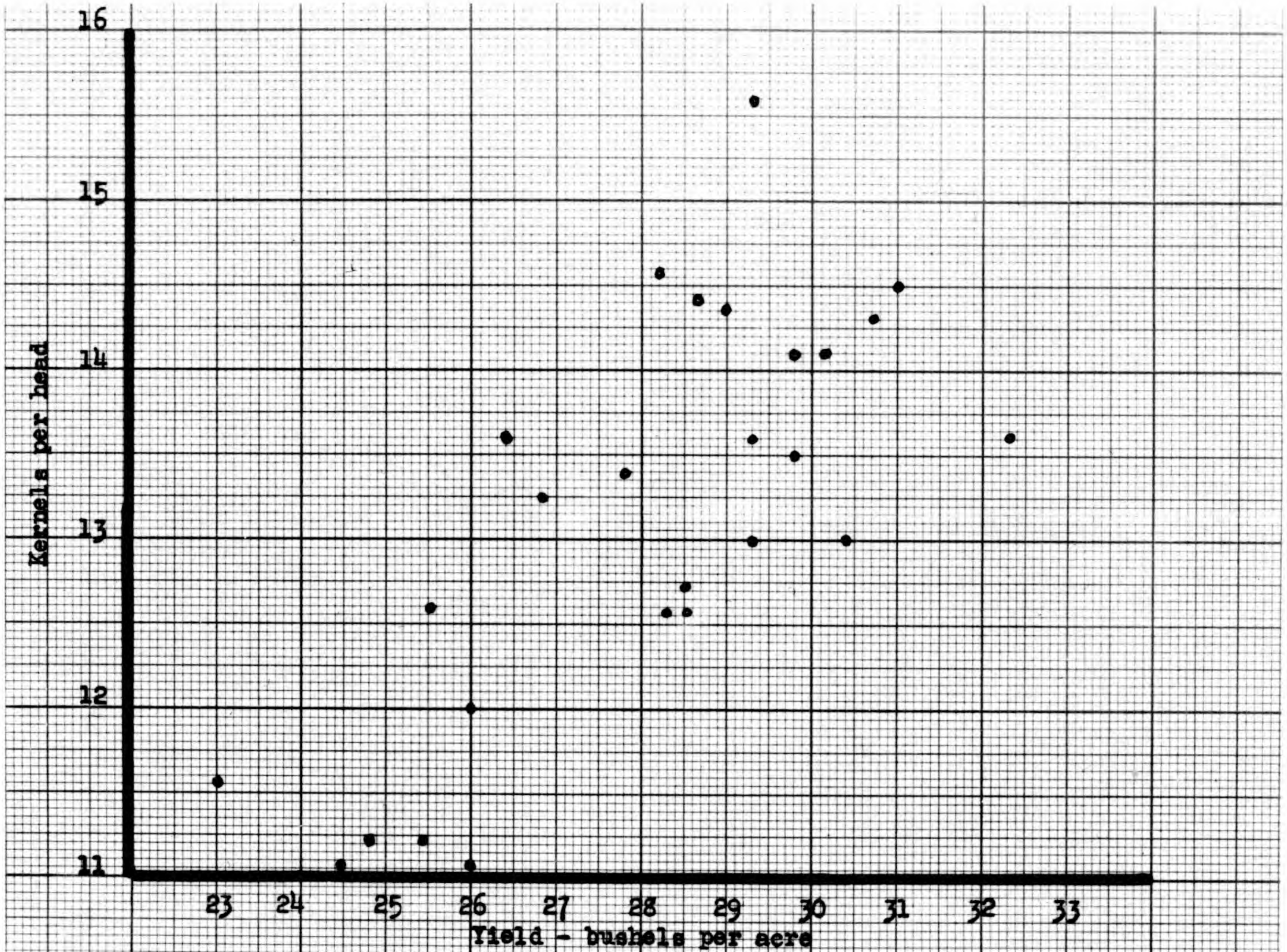

Fig. 10. Relation of yield and number of kernels per head among varieties at Manhattan in 1940.

<u>Yield and Kernel Weight.</u> Kernel weight varied widely among varieties and did not give a consistent correlation with yield among varieties. The correlation among the varieties for the 23 station year period was significantly positive. Generally, the varieties which produced the heaviest kernels also produced the highest yields. However, Nebred, which normally produces a small kernel, yielded higher than Turkey and Blackhull which produce a slightly larger kernel. Chiefkan produced the largest kernel of any variety studied, yet, it yielded less than Comanche or Pawnee which had significantly smaller kernels. These differences occurred frequently between years and stations which made an association of the two characters difficult. The appeal of large plump kernels cannot be overlooked but as a genetic factor related to yield it could be emphasized too much.

Within varieties, the same situation was found with yield and kernel weight as with yield and number of kernels per head. There may or may not be a positive association of yield and kernel weight within a given variety. Within each variety in the 23 station year test, a significant positive correlation was secured as shown in Table 8. The fertility plots on the Kingman and Wichita Experiment Fields for the period of 1941-42 gave a negative correlation of -0.3702 which is significant. The most probable explanation of this is that the higher yielding plots produced larger numbers of heads with somewhat smaller kernels, while the lower yielding plots tillered less but produced larger kernels. As a whole, the kernel weights were good and differences did not materially affect the test weight. It was observed that

Data on Kingman experiment field fertility plots in 1941. Tenmarq wheat used as uniform variety.

Series no.	Plot no.	Culm count	Kernels per head	Weight per head	Weight per 1000 kernels	Test weight	Yield
I	1	1933	18.7	.481	25.68	59.7	34.1
	2	2162	18.3	.461	25.22	59.9	36.6
	3	1584	19.3	.500	25.88	59.3	28.9
	4	1805	18.0	.466	25.92	59.2	30.9
	5	1872	18.4	.473	25.70	59.1	32.5
IV	4	1948	20.2	.477	23.62	58.9	34.1
	5	2340	16.5	.405	24.58	58.7	34.8
	1	2502	15.3	.378	24.72	59.0	34.7
	3	1974	19.3	.476	24.62	59.6	34.5
	2	2400	16.6	.419	25.20	59.8	36.9
VI	1	1901	13.7	.327	23.84	59.0	22.8
	2	2347	14.9	.366	24.50	59.0	31.5
	3	1774	18.2	.458	25.22	57.6	29.8
	4	2306	16.8	.411	24.52	58.5	34.8
	5	1823	18.7	.451	24.16	58.4	30.2
IX	2	1839	13.8	.351	25.52	59.0	23.7
	3	1918	15.1	.391	25.84	59.5	27.5
	1	1663	14.2	.370	26.10	57.7	22.6
	4	1864	15.0	.399	26.52	58.8	27.3
	5	1703	16.1	.405	25.12	58.8	25.3
X	1	1519	16.4	.416	25.28	59.0	23.2
	2	1396	15.4	.420	27.20	59.1	21.5
	3	1451	17.1	.443	25.90	59.3	23.6
	4	1721	15.6	.421	26.90	59.0	26.6
	5	1464	15.1	.385	25.56	58.2	20.7
XIII	1	1834	17.9	.447	24.92	59.4	30.1
	2	1725	16.6	.433	26.08	59.6	27.4
	3	1534	17.8	.449	25.14	59.1	25.3
	4	1431	16.6	.415	25.02	58.8	20.8
XIV	5	1814	17.8	.447	25.04	59.0	29.8

some plots showed an excess of nitrogen by producing rank growth and a large number of heads but environmental conditions became adverse which caused the kernels to be smaller than on plots which had larger kernels but lower yields.

As far as these data were concerned, the weight of 1000 kernels was more important among varieties in relationship to yield than within varieties.

Yield and Test Weight. There was no consistent correlation of yield and test weight among varieties as far as this study was concerned. Test weight can in no way be used as an indicator of yield among varieties because the two characters are apparently independent of each other. Tenmarq, which was a good yielding variety was one of the lowest in test weight. Turkey was low in test weight as well as yield. Early Blackhull was one of the higher testing varieties but one of the poorest in yield. Test weight was effected by many things in relation to the environment. Difference in kernel properties among varieties caused them to respond individually to whatever environmental conditions existed. For example, the difference in bleaching or deteriorating qualities due to the standing of the grain in the field after it is mature affects test weight materially. Some varieties were affected to a greater extent and more rapidly than others. The alteration of the test weight did not necessarily change the resulting yield.

When yield and test weight are related within a variety which is grown under similar climatic environment but with different cultural or fertilizer treatments, the two characters

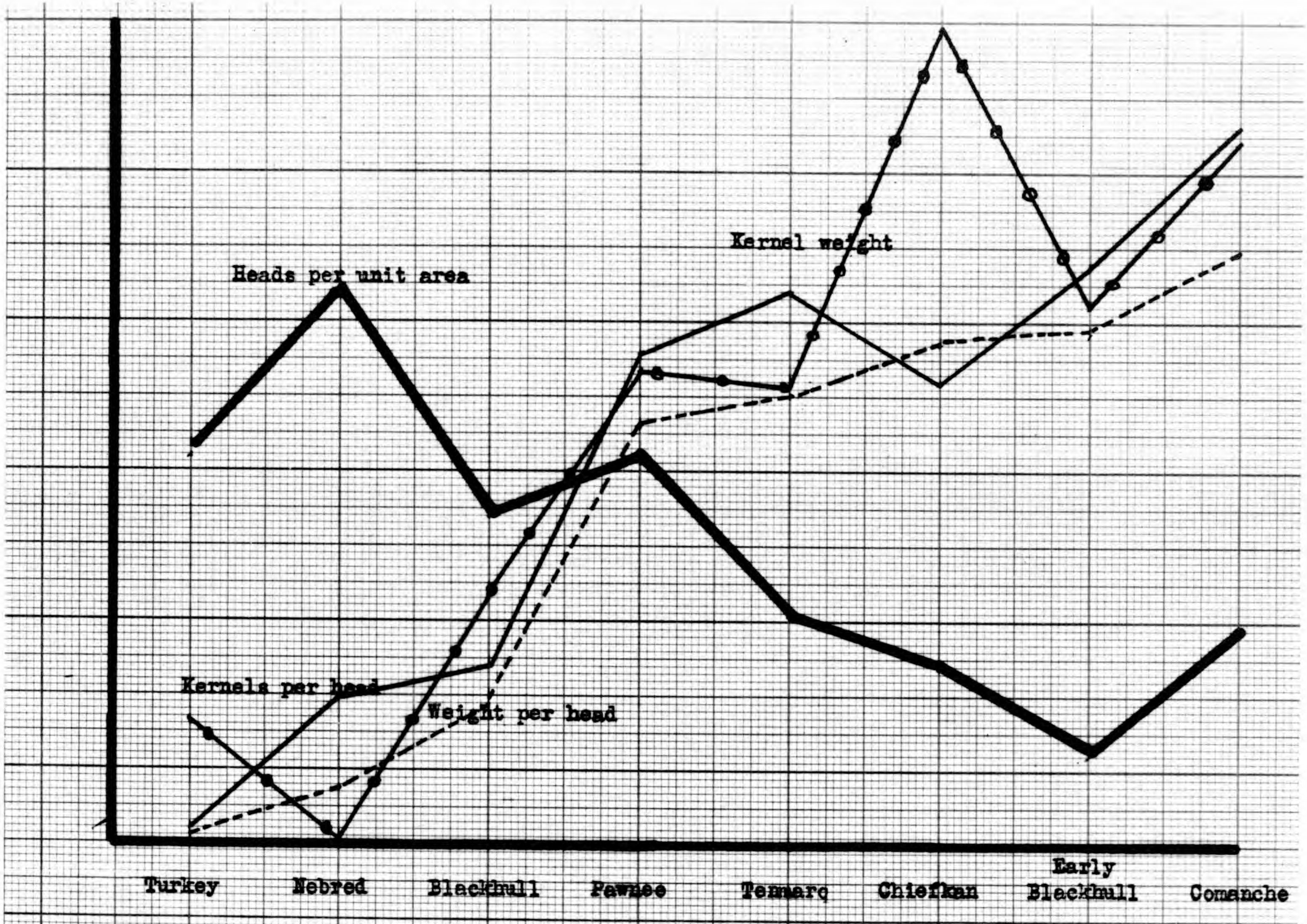

Fig. 11. Relationship of heads per unit of area with kernels per head, weight per head, and kernel weight (23 station year average).

Table 7. Correlation coefficients among varieties for 23 station year average.

Characters correlated		r value
Yield and number of heads per unit area		-0.3318
Yield and number of kernels per head		0.8670
Yield and weight per 1000 kernels		0.7237
Yield and test weight		0.1849
Yield and weight per head		0.8371
Number of heads per unit area and number of kernels per head		-0.7580
Number of heads per unit area and weight of 1000 kernels		-0.8383
Number of heads per unit area and test weight		-0.3943
Number of heads per unit area and weight per head		-0.8110
Number of kernels per head and weight 1000 kernels		0.8329
Number of kernels per head and test weight		0.5722
Number of kernels per head and weight per head		0.9773
Weight per 1000 kernels and test weight		0.6283
Weight per head and weight per 1000 kernels		0.9477
Weight per head and test weight		0.3429
5% level of significance	.707	
1% level of significance	.834	

may be closely associated in some years but widely separated in other years. On the Manhattan fertility plots in 1941 located on the Experiment Station and also the Wichita fertility plots in 1940 there was a close association of the two characters with

Table 8. Correlation coefficients within each variety for 23 station year period.

Characters correlated	r values							
	Turkey	Blackhull	Tenmarq	Chiefkan	Pawnee	Comanche	Early Blackhull	Nebred
Yield - number of heads	.2312	.2441	.4746	.4542	.5420	.4196	.3122	.4582
Yield - number of kernels	.7207	.6696	.5598	.5210	.5424	.4184	.6250	.6076
Yield - weight per head	.8342	.7583	.6915	.6632	.6875	.6036	.6863	.7298
Yield - weight per kernel	.5615	.5348	.7324	.6705	.7215	.8099	.4518	.6671
Number of heads - number of kernels	-.1531	-.4709	-.3863	-.4617	-.7939	-.5992	-.4471	-.2610
Number of heads - weight per head	-.3118	-.3649	-.2486	-.2627	-.2465	-.4432	-.4106	-.1429
Number of heads - kernel weight	-.0941	-.1508	-.1500	-.2991	-.2850	-.3286	-.3547	-.2511
Number of kernels - weight per head	.9418	.9506	.9560	.9361	.9340	.9352	.9455	.9260
Kernel weight - test weight	.5470	.5062	.7091	.6742	.7565	.7163	.6163	.5700

5% level of significance 0.413

1% level of significance 0.526

the higher test weight plots producing the higher yields. Conditions which favored higher yields also favored higher test weights. In other years there appeared to be no line of correlation between the two characters. This was illustrated in 1940 fertility plots on the Wichita Experiment Field.

Test weight is exceptionally important in selecting a variety but in view of these data it did not have any relationship to the resulting yield of wheat.

Other Relationships. A large number of relationships could be made in a study of this type. A few additional relationships which were studied in a very limited way are shown in the correlation coefficient charts in Tables 7 and 8. In a general way, the following relationships may be of interest. Significant positive correlations were found among varieties between yield and number of kernels per head, yield and weight per 1000 kernels, yield and weight per head, number of kernels per head and kernel weight, number of kernels per head and weight per head, and kernel weight and weight per head. Significant negative correlations were found among varieties between number of heads and number of kernels per head, number of heads and kernel weight, number of heads and weight per head. Within varieties significant positive correlations were determined between yield and number of kernels per head, yield and weight per head, yield and kernel weight, number of kernels per head and weight per head, and kernel weight and test weight. A negative correlation was determined within varieties between the number of heads and number of kernels per head.

SUMMARY AND CONCLUSIONS

A study was made of several plant characters in wheat. Special emphasis was given to varietal differences in respect to these characters as well as their relationship to yield.

Data were secured from 23 station year tests of eight hard red winter wheats located at seven different stations in Kansas. Fertility work was studied at several different locations but the work reported here includes, for the most part, wheat fertility plots at the Kingman and Wichita Experiment Fields for the years 1940 and 1941. The following conclusions were made.

Varieties differed extensively in tillering habits. Early varieties as a rule, produced the lowest number of tillers. The combination of high tillering and earliness is not impossible as exemplified in the variety of Pawnee, but has been the uncommon association in Kansas wheats of the past.

Varieties responded similarly to environment as far as tillering or number of heads produced per unit area was concerned. Conditions which stimulated or retarded tillering affected all varieties alike and the varieties remained in the same relative position in tillering regardless of conditions under which they were grown.

The number of kernels produced per head varied widely among varieties. The early varieties produced the highest number of kernels per head and the late varieties produced the lowest number.

The weight of the kernel differed with variety. Early varieties produced the larger kernels and late varieties produced the smaller kernels. Kernel weight, as well as number of kernels per head, were often influenced by conditions between pollination and maturity.

The number of heads per unit area cannot be used alone in selecting high yielding varieties, but must be used in combination with other characters. An insignificant negative correlation was secured for yield and number of heads among varieties, while a significant positive correlation was secured within varieties.

In areas where soil moisture was not the limiting factor, practices which stimulated tillering also increased yield.

The number of heads per unit area is the most suitable indicator of yield within a variety when all characters are considered separately.

The number of kernels per head was the most important single character influencing yields among varieties. Within a variety, the correlation may be either negative or positive depending upon the environment at that particular stage.

The weight of kernel and yield were positively correlated among varieties, but the correlation was not as significant as the number of kernels per head and yield. Within varieties the kernel weight fluctuates widely and may or may not be correlated with yield depending upon the environment.

There was no consistent line of correlation between test weight and yield either among varieties or within a variety.

Significant negative correlations were determined among varieties for number of heads and number of kernels per head, number of heads and kernel weight, and number of heads and weight per head. Within varieties a significant negative correlation was determined for number of heads and number of kernels per head.

The study indicated the possibilities in determining the effects of various soil treatments and why practices may or may not increase yield.

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APPENDIX

Yield in bushels per acre of eight varieties of hard red winter wheat at several locations in Kansas.

Year	Turkey	Black-hull	Tenmarq	Chiefkan	Pawnee	Comanche	Early Blackhull	Nebred
				Wichita				
1939	36.8	38.6	34.6	40.4	38.2	41.0	37.3	40.7
1940	34.9	41.5	43.8	42.7	48.7	43.6	46.7	42.8
1941	22.4	20.8	30.4	26.6	34.0	32.7	27.9	20.7
				Kingman				
1940	16.8	20.0	20.5	20.7	22.0	21.8	20.0	21.4
1941	20.5	17.1	27.2	27.1	31.4	32.1	21.8	16.1
				Hays				
1939	16.5	16.2	20.5	20.6	19.4	19.4	18.8	17.5
1940 Fallow	12.5	15.6	16.8	18.5	17.5	19.0	18.7	14.8
1941 Cropped	22.1	23.8	35.2	34.6	41.5	39.8	30.9	25.4
1941 Fallow	21.5	23.5	34.8	35.4	44.2	41.5	36.7	21.5
				Tribune				
1939 Common drill	7.0	17.1	19.0	20.7	14.8	14.4	21.3	16.7
1939 Furrow drill	10.9	17.2	15.3	14.6	14.6	18.9	18.4	14.1
1940 Common drill	7.3	9.5	8.4	9.0	10.1	7.3	11.5	7.8
1940 Furrow drill	6.0	9.9	8.3	12.2	9.6	13.0	12.2	7.8
1941 Common drill	29.7	26.0	35.7	32.2	33.2	33.1	24.7	37.7
1941 Furrow drill	17.1	13.9	27.7	27.3	34.7	27.0	20.8	23.4
				Colby				
1941	33.2	32.5	38.6	36.7	41.0	37.5	29.2	34.6

Yield in bushels per acre (concl.).

Year	Turkey	Blackhull	Tenmarq	Chiefkan	Pawnee	Comanche	Early Blackhull	Nebred
				Garden City				
1941	19.8	22.0	29.0	24.6	35.0	32.6	20.1	25.1
1942	7.6	11.9	12.9	14.7	15.7	14.3	14.6	13.0
				Manhattan				
1938	12.3	11.9	18.6	19.5	27.2	22.4	10.4	12.2
1939	16.8	17.1	18.4	16.3	18.2	17.3	17.8	19.3
1940	25.2	28.5	30.2	29.9	32.3	28.6	26.2	28.3
1941	19.6	23.3	23.9	26.4	31.4	29.6	23.8	22.0
1942	18.8	19.3	27.7	23.4	34.3	30.9	22.0	20.1
Grand total	435.3	477.2	577.5	574.1	649.0	617.8	531.8	503.0
Average	18.9	20.7	25.1	25.0	28.2	26.9	23.1	21.9

Number of heads per 1/10000 acre of eight varieties of hard red winter wheat at several locations in Kansas.

Year	Turkey	Black-hull	Tenmarq	Chiefkan	Pawnee	Comanche	Early Blackhull	Nebred
				Wichita				
1939	213	175	167	174	201	179	173	236
1940	194	177	164	155	187	145	162	213
1941	208	232	198	205	217	205	180	268
				Kingman				
1940	136	143	113	106	120	103	112	142
1941	243	234	206	224	246	177	188	283
				Hays				
1939	203	191	188	176	216	179	148	215
1940 Fallow	154	139	122	123	140	118	110	170
1941 Cropped	279	337	248	231	268	244	236	308
1941 Fallow	301	302	281	277	337	291	237	358
				Tribune				
1939 Common drill	347	315	302	241	344	269	233	316
1939 Furrow drill	225	204	211	173	221	180	141	238
1940 Common drill	141	117	115	104	129	101	101	139
1940 Furrow drill	95	97	97	93	86	91	73	112
1941 Common drill	398	341	315	295	342	339	324	424
1941 Furrow drill	369	333	293	297	296	314	310	382

Number of heads per 1/10000 acre (Concl.).

Year	Turkey	Black-hull	Tenmarq	Chiefkan	Pawnee	Comanche	Early Blackhull	Nebred
				Colby				
1941	268	293	231	222	332	230	171	311
				Garden City				
1941	243	262	226	248	280	247	238	279
1942	207	209	200	182	201	208	206	217
				Manhattan				
1938	147	149	127	139	161	118	116	159
1939	262	243	214	219	234	210	182	267
1940	207	213	198	184	248	186	182	238
1941	244	230	179	208	261	205	201	291
1942	252	222	229	185	260	239	173	270
Grand total	5337	5158	4625	4459	5327	4578	4195	5835
Average	232	224	201	194	232	199	182	254

Weight of 1000 kernels in grams of eight varieties of hard red winter wheat at several locations in Kansas.

Year	Turkey	Blackhull	Tenmarq	Chiefkan	Pawnee	Comanche	Early Blackhull	Nebred
				Wichita				
1939	28.2	28.8	30.0	30.2	28.0	30.2	30.3	28.7
1940	24.5	27.7	29.8	32.7	30.1	31.4	32.6	24.2
1941	17.5	17.3	23.3	23.8	24.1	27.0	24.2	16.1
				Kingman				
1940	25.6	26.6	29.1	32.9	29.0	30.1	31.2	25.3
1941	17.5	15.9	23.3	23.3	22.9	26.5	21.9	15.0
				Hays				
1939	21.5	23.8	22.4	23.8	20.6	23.0	23.8	21.2
1940 Fallow	21.9	25.2	25.0	27.9	25.4	27.4	31.2	21.2
1941 Cropped	22.8	23.8	28.9	32.0	31.1	31.7	25.8	22.0
1941 Fallow	22.6	23.3	27.3	31.5	29.6	30.7	24.9	20.5
				Tribune				
1939 Common drill	18.3	20.2	18.2	22.6	19.6	20.5	20.7	19.6
1939 Furrow drill	18.9	25.9	20.3	20.9	21.2	23.2	26.8	19.6
1940 Common drill	21.0	22.7	20.8	24.4	21.8	22.0	25.4	20.1
1940 Furrow drill	20.9	22.5	19.2	26.0	20.4	20.2	24.9	20.1
1941 Common drill	28.5	26.6	29.9	32.3	30.8	31.3	25.4	27.1
1941 Furrow drill	22.0	21.8	25.6	28.7	26.9	27.0	22.8	20.9

Weight of 1000 kernels in grams (Concl.).

Year	Turkey	Black-hull	Tenmarq	Chiefkan	Pawnee	Comanche	Early Blackhull	Nebred
				Colby				
1941	24.5	23.3	26.4	31.1	27.8	29.0	27.4	25.0
				Garden City				
1941	29.9	26.5	29.6	32.2	29.2	29.6	21.9	26.5
1942	23.6	22.1	18.0	24.2	15.1	18.9	15.0	19.6
				Manhattan				
1938	21.1	22.3	22.2	24.1	25.3	24.8	23.2	20.9
1939	24.4	25.4	27.5	27.5	26.3	28.4	28.2	25.5
1940	28.3	28.6	29.2	31.2	25.9	29.1	28.9	26.0
1941	21.2	24.0	25.8	26.3	25.9	26.6	27.0	21.4
1942	20.3	20.5	23.6	23.7	22.7	25.2	24.6	18.9
Grand total	525.0	544.8	575.4	633.3	579.7	613.8	588.1	505.5
Average	22.8	23.7	25.0	27.5	25.2	26.7	25.6	22.0

Number of kernels per head of eight varieties of hard red winter wheat at several locations in Kansas.

Year	Turkey	Black-hull	Tenmarq	Chiefkan	Pawnee	Comanche	Early Blackhull	Nebred
				Wichita				
1939	16.8	20.9	19.0	21.0	18.6	20.8	19.4	16.4
1940	19.9	22.9	24.1	23.1	23.6	25.4	23.8	22.5
1941	16.8	14.2	18.0	14.8	17.7	16.1	19.7	13.2
				Kingman				
1940	13.1	14.0	17.0	16.2	17.2	19.1	15.6	16.3
1941	13.2	12.6	15.5	14.2	15.2	19.7	13.5	10.4
				Hays				
1939	10.3	9.8	13.3	13.4	11.9	12.8	14.5	10.5
1940 Fallow	10.1	12.2	14.8	14.7	13.4	16.0	14.8	11.2
1941 Cropped	9.6	8.0	13.5	12.8	13.6	14.0	14.6	10.2
1941 Fallow	8.6	9.0	12.3	11.2	12.1	12.7	17.4	9.8
				Tribune				
1939 Common drill	3.0	7.3	9.4	10.3	6.0	7.1	12.0	7.4
1939 Furrow drill	7.0	8.8	9.8	11.0	8.5	12.3	13.2	8.3
1940 Common drill	6.7	9.7	9.6	9.7	9.8	8.9	12.2	7.6
1940 Furrow drill	8.2	12.4	12.1	13.8	14.8	19.3	18.4	9.5
1941 Common drill	7.1	7.8	10.3	9.2	8.6	8.5	8.2	8.9
1941 Furrow drill	5.7	5.2	10.1	8.7	11.9	8.7	8.0	8.0

Number of kernels per head (Concl.)

Year	Turkey	Black-hull	Tenmarq	Chiefkan	Pawnee	Comanche	Early Blackhull	Nebred
				Colby				
1941	14.2	13.2	17.5	14.6	12.1	15.5	17.1	13.2
				Garden City				
1941	7.5	8.7	11.8	8.5	12.3	12.2	10.6	9.2
1942	4.9	7.6	7.4	9.3	9.4	7.4	7.9	8.6
				Manhattan				
1938	10.8	9.7	18.0	15.8	18.1	20.8	10.6	12.6
1939	7.3	7.5	8.5	7.4	8.0	7.9	9.5	7.7
1940	11.7	12.7	14.1	14.1	13.6	14.4	13.6	12.5
1941	10.4	11.5	14.1	13.2	12.6	15.0	11.9	9.7
1942	10.0	11.6	13.9	14.5	15.8	14.0	14.1	10.5
Grand total	232.9	257.3	314.1	301.5	304.8	328.6	320.6	254.2
Average	10.1	11.2	13.7	13.1	13.3	14.3	13.9	11.0

Test weight of eight varieties of hard red winter wheat at several locations in Kansas.

Year	Turkey	Black-hull	Tenmarq	Chiefkan	Pawnee	Comanche	Early Blackhull	Nebred
Wichita								
1939	61.0	62.5	60.0	62.0	60.5	61.0	60.5	61.0
1940	56.0	59.8	58.3	61.0	60.0	59.3	62.5	59.3
1941	54.0	56.2	57.2	59.9	58.4	57.5	60.1	54.4
Kingman								
1940	54.3	55.7	54.8	58.2	56.1	55.5	57.2	56.5
1941	54.8	55.5	57.8	60.1	58.7	58.4	59.8	54.5
Hays								
1939	60	61	59	61	57	58	61	60
1940 Fallow	58	60	58	62	59	59	62	58
1941 Cropped	60	61	62	65	64.0	63	62	61
1941 Fallow	60	61	61	65	63.5	63	62	61
Tribune								
1940 Common drill	51.5	54.0	49.0	53.5	51.0	50.0	55.0	52.0
1940 Furrow drill	51.0	55.0	48.6	56.3	49.6	52.6	55.0	52.0
1941 Common drill	57.5	57.0	57.0	60.0	58.5	58.0	56.0	58.5
1941 Furrow drill	53.5	54.0	57.0	60.0	59.0	57.0	54.0	57.0
Colby								
1941	57.5	57.0	59.5	60.0	57.7	57.3	58.5	57.7

Test weight of eight varieties (Concl.).

Year	Turkey	Black-hull	Tenmarq	Chiefkan	Pawnee	Comanche	Early Blackhull	Nebred
				Garden City				
1941	61.0	60.1	60.3	61.8	60.6	60.0	56.3	61.3
1942	59.0	59.5	55.1	60.1	52.5	55.5	53.4	59.2
				Manhattan				
1938	50.9	52.0	50.9	57.0	56.1	53.0	54.0	50.1
1939	55.3	57.4	56.3	57.7	57.0	56.5	58.8	57.6
1940	60.9	61.3	59.6	62.0	59.4	59.8	61.0	61.0
1941	54.8	58.2	56.0	60.0	58.3	56.7	59.9	57.3
1942	53.6	54.9	54.3	56.9	55.7	54.5	54.6	55.3
Grand total	1184.6	1213.1	1191.7	1259.5	1212.6	1205.6	1223.6	1204.7
Average	56.4	57.8	56.7	60.0	57.7	57.4	58.3	57.4

Weight of grain per head in grams of eight varieties of hard red winter wheat at several locations in Kansas.

Year	Turkey	Blackhull	Tenmarq	Chiefkan	Pawnee	Comanche	Early Blackhull	Nebred
				Wichita				
1939	.474	.602	.567	.636	.518	.628	.590	.469
1940	.487	.634	.719	.752	.712	.797	.778	.543
1941	.296	.245	.419	.354	.428	.436	.428	.211
				Kingman				
1940	.336	.372	.494	.532	.502	.574	.488	.412
1941	.230	.200	.361	.330	.348	.496	.318	.156
				Hays				
1939	.222	.231	.298	.320	.245	.295	.346	.222
1940 Fallow	.222	.307	.372	.410	.339	.437	.466	.238
1941 Cropped	.220	.192	.386	.412	.422	.443	.374	.225
1941 Fallow	.194	.213	.336	.350	.357	.389	.432	.202
				Tribune				
1939 Common drill	.055	.148	.171	.234	.117	.146	.249	.144
1939 Furrow drill	.132	.229	.198	.230	.180	.285	.354	.162
1940 Common drill	.141	.221	.199	.237	.213	.196	.309	.153
1940 Furrow drill	.172	.279	.233	.358	.303	.390	.458	.191
1941 Common drill	.203	.208	.308	.297	.264	.266	.208	.242
1941 Furrow drill	.126	.114	.258	.250	.320	.234	.183	.167
				Colby				
1941	.347	.307	.462	.453	.337	.446	.472	.304

Weight of grain per head (Concl.).

Year	Turkey	Black-hull	Tenmarq	Chiefkan	Pawnee	Comanche	Early Blackhull	Nebred
				Garden City				
1941	.226	.229	.348	.272	.359	.360	.232	.245
1942	.100	.155	.175	.220	.212	.187	.193	.163
				Manhattan				
1938	.227	.217	.399	.381	.459	.516	.245	.264
1939	.179	.191	.234	.203	.209	.225	.269	.197
1940	.331	.363	.413	.441	.354	.418	.393	.323
1941	.221	.276	.363	.348	.327	.398	.321	.206
1942	.203	.236	.329	.344	.359	.351	.346	.199
Grand total	5.344	6.169	8.044	8.364	7.884	8.913	8.452	5.638
Average	.232	.268	.350	.364	.343	.388	.367	.245

Data on Wichita experiment field fertility plots in 1940. Tenmarq wheat used as uniform variety.

Series no.	Plot no.	Culm count	Kernels per head	Weight per head	Weight per 1000 kernels	Test weight	Yield
I	1	1882	18.0	.496	27.6	57.8	34.27
	2	2311	16.3	.410	25.16	55.8	34.82
	3	1456	15.6	.326	20.94	51.4	17.45
	4	2202	15.4	.306	19.92	49.8	24.71
	5	2137	18.1	.448	24.80	55.5	35.18
	6	2038	19.0	.469	24.68	55.9	35.11
II	1	1989	18.5	.511	27.62	58.1	37.30
V	1N	1644	13.8	.324	23.46	54.6	19.55
	2N	1464	11.6	.146	12.58	42.9	7.83
	3N	1542	16.3	.395	24.28	53.3	22.37
	1S	1426	19.4	.526	27.14	56.6	27.55
	2S	1947	16.6	.488	29.46	59.7	34.90
	3S	1464	21.0	.579	27.60	57.3	31.10
VI	1	1401	16.0	.362	22.56	53.7	18.62
	2	1507	18.0	.466	25.90	56.6	25.78
	3	1516	18.3	.485	26.56	57.8	26.97
IX	1	2458	15.1	.461	30.46	60.1	41.60
	2	2281	16.4	.498	30.44	60.2	41.72
	3	1666	16.9	.477	28.22	57.4	29.20
	4	2422	16.6	.509	30.72	59.7	45.23
	5	2407	17.2	.550	32.06	60.9	48.57

Data on Wichita experiment field fertility plots in 1940 (Concl.).

Series no.	Plot no.	Culm count	Kernels per head	Weight per head	Weight per 1000 kernels	Test weight	Yield
XI	7	1199	19.2	.400	20.80	50.9	17.62
XIV	1	2070	15.9	.518	32.61	59.6	39.34
	2	2439	15.1	.458	30.30	59.1	40.98
	3	2364	15.8	.473	30.02	59.5	41.04
	4	1704	16.4	.477	29.10	58.6	29.83
	5	1843	17.3	.469	27.06	57.8	31.74
	6	1795	16.3	.480	29.44	58.9	31.64
	7	1676	18.2	.468	25.78	56.3	28.77

Data on Kingman experiment field fertility plots in 1940. Tenmarq wheat used as uniform variety.

Series no.	Plot no.	Culm count	Kernels per head	Weight per head	Weight per 1000 kernels	Test weight	Yield
I	1	1063	14.9	.439	29.40	55	17.15
	2	1353	11.9	.346	29.14	55	17.18
	3	1138	14.8	.425	28.74	54.2	17.76
	4	1257	12.4	.361	29.18	54.2	16.66
	5	1561	12.6	.370	29.42	55.0	21.23
III	1	1121	17.9	.521	29.06	55.2	21.43
	2	1197	18.9	.530	28.08	55.0	23.27
	3	1192	16.8	.494	29.36	54.9	21.62
	4	1243	16.4	.480	29.26	54.7	21.90
	5	1273	18.1	.517	28.56	55.4	24.17
VI	1	1121	15.8	.465	29.32	55.1	19.15
	2	1515	17.4	.480	27.62	55.1	26.68
	3	1061	18.9	.531	28.06	53.9	20.67
	4	1468	16.5	.451	27.30	53.9	24.31
	5	1112	16.6	.474	28.59	54.2	19.35
VIII	1	1068	18.0	.513	28.48	54.4	20.10
	2	1168	15.8	.460	29.12	54.1	19.71
	3	1138	18.0	.515	28.54	54.8	21.51
	4	1153	16.2	.479	29.46	55.0	20.27
	5	1209	17.8	.504	28.24	55.1	22.35

Data on Kingman experiment field fertility plots in 1940 (Concl.).

Series no.	Plot no.	Culm count	Kernels per head	Weight per head	Weight per 1000 kernels	Test weight	Yield
X	1	1110	13.8	.407	29.52	55.3	16.60
	2	1290	14.4	.441	30.50	56.1	20.88
	3	1306	13.0	.397	30.40	56.6	19.04
	4	1057	15.5	.469	30.30	55.7	18.19
	5	1029	14.1	.436	30.84	56.1	16.48
XII	5	1189	15.4	.448	29.16	54.2	19.54
XIV	1	1099	16.5	.504	30.60	55.2	20.32
	2	1380	14.8	.437	29.42	55.0	22.13
	3	1304	16.2	.464	28.58	54.6	22.22
	4	1145	17.2	.513	29.74	53.8	21.58

Data on Wichita experiment field fertility plots in 1941. Tenmarq wheat used as uniform variety.

Series no.	Plot no.	Culm count	Kernels per head	Weight per head	Weight per 1000 kernels	Test weight	Yield
II	1	1693	16.7	.449	26.88	59.5	27.9
	2	1935	16.7	.365	21.90	56.0	25.9
	3	2107	15.4	.363	23.50	57.5	28.1
	4	1887	17.2	.363	21.02	56.4	25.1
	5	2047	16.0	.338	21.12	55.9	25.4
	6	1953	17.5	.349	19.98	55.0	25.0
V	1N	1949	15.6	.423	27.14	60.1	30.3
	2N	2116	15.9	.418	26.34	59.6	32.5
	3N	1856	14.2	.382	26.86	59.9	26.0
	1S	1632	17.9	.474	26.50	58.4	28.4
	2S	1610	17.3	.457	26.44	59.9	27.0
	3S	1872	14.5	.409	28.20	59.5	28.1
VI	1N	1037	20.7	.562	27.14	58.9	21.4
	2N	1742	19.0	.491	25.86	58.5	31.4
	3N	1479	17.5	.486	27.70	60.1	26.4
VII	1	1861	18.1	.382	21.12	56.2	26.1
	2	1668	21.4	.430	20.04	55.5	26.3
	3	1801	19.6	.425	21.62	56.0	28.1
	4	1822	21.2	.443	20.88	56.5	29.6
	5	1881	21.2	.411	19.36	54.5	28.4
XIV	1	1744	11.7	.305	25.98	59.4	19.5
	2	1931	15.1	.387	25.56	60.0	27.4
	3	1619	16.6	.422	25.36	59.0	25.1
	4	1273	14.8	.389	26.26	60.4	18.2
	5	1456	16.6	.370	22.30	57.1	19.8
	6	1615	13.3	.351	26.38	59.8	20.8
	7	1867	15.8	.381	24.04	57.3	26.1
XIII	7	1598	16.5	.430	26.02	58.9	25.2
IV	1	1873	21.1	.446	26.5	59.5	30.7