RELATIONSHIP BETWEEN GRAIN YIELD, YIELD COMPONENTS AND MORPHOLOGIC PLANT PARTS ABOVE THE FLAG LEAF NODE IN WINTER WHEAT

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Wheat is one of man's principal foods and is grown nearly everywhere in the world for that purpose. As such, wheat is important in programs for increased world food production. Increased yield potential has always been a basic importance in plant breeding, management and production programs. A knowledge of the relationships of yield in winter wheat (Triticum aestivum L.), the components of yield (spikes per plant, kernels per spike, and kernel weight), and plant morphological structure above the flag-leaf node can be of great assistance to plant breeders in making selection for higher yields. Recently, it has been realized that selection on the basis of yield components alone may not necessarily be the most efficient way to attain yield increases.

Characters such as the number of seed bearing tillers per unit area, number of spikes per plant, number of kernels per spike and weight per kernel were considered as the units which produce high yield. Selection for these characters did not always lead to yield increases, since biological limitation or compensation mechanisms operate among the yield components. Economic yield (grain yield) of wheat and other cereals can be related to the photosynthetic area above the flag leaf node.

A number of reports have supported the importance of the structures above the flag leaf node in contributing carbohydrate supply to the developing grain of wheat (5, 15, 44). The range of this contribution is estimated to be between 60 to 70 percent.

The carbohydrate in the grain of cereals is largely derived from photosynthesis during the period of grain development, since the stored photosynthate in the stem prior to anthesis does not contribute much to the grain yield. The major source of assimilate for the seed is the photosynthesis by the flag leaf, peduncle and spike. The portion of photosynthesis from the ear in supplying the needs of grain for carbohydrate is influenced by the variety used, in particular, on the presence or absence of awns, since the awns contribute considerably to grain yield (14, 20).

The primary objectives of this study were:

1) to determine the relative importance and relationship between yield, yield components, and morphologic structures above flag leaf node on winter wheat varieties.

2) to evaluate the varieties in the survey for yield components and other plant and seed characters under Stillwater conditions.

CHAPTER II

REVIEW OF LITERATURE

Yield per unit area in wheat is the result of yield components and the amount of metabolic input. Light interception can be the factor of determining yield, if water and nutrients are present in the soil in sufficient amount. Selection for yield components have not always led to the yield increases which were expected. A biological limitation or compensation mechanism works among the yield components. Many physiological studies have been undertaken of the association of yield and structure above the flag leaf node.

Relation Between Yield and Selected Morphology in Cereals

A number of reports have supported the importance of the structures above the flag leaf node in their contributing of carbohydrate supply to the developing grains of wheat. Leaves, sheaths, and that part of the stem below the flag leaf, apparently contribute only a small percentage of the final grain weight. Some estimates of the contribution to grain dry weight from photosynthesis above the flag node are 60% (3), 85% (4), 83% (13) and 80-85% (38). Langer (28) found that 83% of the grain carbohydrate in wheat was accounted for by the flag leaf and other green parts of the shoot.

Saghir, et al. (41) studied the relative contribution of different parts of wheat and barley plants. As a result of shading the spike, yield decreased 59.7% and shriveling of the grain occurred at maturity. A 22.2% and an 11.5% yield decrease were obtained when shading affected upper and lower leaves, respectively. They concluded that varieties with larger spikes and greater leaf area in the upper part would give higher yield. Pendleton and Weibel (37) found that any shading after flowering (anthesis) reduced the grain yield of wheat. The trend of yield reduction was directly related to the degree of shading.

A number of works have shown the importance of the flag leaf area contribution to grain yield of wheat. Watson (51) reviewed the specific contribution of leaf area to plant weight (biological yield). From his study on wheat, sugar beet (Beta vulgaris) and potato (Solanum tuberosum) over a long period of time, he concluded that varietal, fertilizer, and seasonal effects on economic yield were highly correlated with variation in leaf area, but not with net assimilation rate.

Voldeng and Simpson (49), studying shading treatments on wheat, found that the ear and flag leaf contributed the major portion of the grain weight. They indicated a positive correlation coefficient of +0.54 to +0.90 between flag leaf area and grain per tiller with seven lines of wheat. Hsu and Walton (21) studied the relation of yield in spring wheat to some selected morphological characters under field and greenhouse conditions. They reported that ear length, flag leaf sheath length, and flag leaf breadth affected yield and its components. Niciporovic (35) pinpointed the importance of leaf area, a critical determinant of yield. Average optimal leaf area index (LAI) of 3.0 to 3.5 established early in the season and active till the end of the growing season gave greater yield.

Welbank et al. (52) reported that leaf area duration (area of green leaf for a period of time) above the flag leaf node after anthesis was related to grain yield. Takahashi and Yasuda (46) reported that leaf area duration dictates genetic control of early vs. late maturity. Several workers (9, 47, 51) emphasized that there is an association between prolonged active photosynthetic area after anthesis and high yield. Thorne (48) stated that leaf area has a great importance on the grain yield after the plant heads. At this period of time, most of the photosynthetic requirement of grain is furnished by photosynthesizing parts located above the flag leaf node. Rawson and Hofstra (39) in a detailed study of the movement of carbohydrates during development of wheat grain supported Thorne's conclusion. Hsu and Walton (21) agreed with Thorne's conclusion that grain yield of cereal plants was closely related to photosynthetic area above the flag leaf. Monteith (33) found that the profile of light absorption in grasses was more uniform than in clover. This was primarily due to the erect structure of the grass which allowed light transmission to the lower part of the plant canopy. Tanner et al. (47) reported that upright-leaved types of small grain varieties performed better under the condition where weeds were not a problem, but under a weedy condition, broad-leaf types produced higher yields.

Soil fertility as it affects plant growth and production may be considered an important factor in growth of plant photosynthetic parts. Langer (27) found that nitrogen, phosphorus, and potassium all had a pronounced effect in increasing leaf area per plant in timothy.

A number of workers have reported the importance of ear photosynthesis to grain yield. Evans and Rawson (14) emphasized that ear photosynthesis, which was much higher in awned wheat varieties contributed up to 76% to the total grain requirement during early growth. Over the whole period of grain development the contribution of ear photosynthesis was 33% in "Sonora" (awned) and 20% in "Gabo" (awnless). In the awned variety, net photosynthesis by ear, flag leaf blade, and stem plus sheath were 50, 126 and 42 mg CO_2 per day, respectively, during rapid grain growth. Evans and Rawson (14) further stated that photosynthesis by ear and flag leaf blade alone could supply the demands of substrate for grain growth at all times.

A number of methods have been used for estimating the contribution made by cereal ear photosynthesis to grain yield. Lupton and Ali (30) found that the estimate of variatal differences in photosynthesis of wheat differ by measurement techniques as well as by seasons. Kriedemann (26) found that the contribution of ear photosynthesis ranged from 10 to 44%. He showed that ear photosynthesis varies depending on the technique used and on the environmental conditions. He also reported that ear photosynthesis consisted of two processes, "(a) the assimilation of atmospheric CO_2 and (b) the photosynthetic refixation of the ear's respiratory CO_2". Evidence such as dry weight data and measurements of CO_2 exchange showed that the second item contributed much to grain yield.

Awns contribute to grain yield as an important green part through the photosynthetic assimilation. Grundbacher (20) suggested the importance of the awn through photosynthesis and transpiration on grain yield. He indicated that the awn as an assimilatory organ may contribute more than 10% of total kernel dry weight.

Kjak and Witters (24) studied the physiological activity of awns in isogenic lines differing only in the allels affecting awn length of "Atlas" barley by measuring the exchange rate of CO_2 on intact and de-awned spikes in light and darkness from anthesis through 30 days after anthesis. They found that full-awned spikes displayed the greatest photosynthetic rate followed by half-awned, and quarter-awned spikes accounted for an average of 90, 80, and 50% respectively of the intact spikes photosynthetic rate throughout the measurement period. They concluded that longer awns increased the area of chlorophyll-containing tissue on a spike. Also a greater number of stomata were present and thereby increased the gaseous exchange. Beside the effect on ear photosynthesis, the awn plays a role in dispelling excessive heat energy from heads of barley plants. Maximum ear photosynthetic rates were obtained from flowering to 12 days after flowering. Faris (15) also found that on the average the highest-yielding line was the half-awned type ($p<0.1$) and outyielded the awnless types by 5%. There was a linear relationship between weight per kernel and awn length with a regression coefficient of 0.33 mg per cm of awn. Increases in awn length were related with reduction in number of spikes and florets per plant. He suggested the trend of these yield components was dependent on competition from nutrients during early ontogeny of the spike between the awns at the base and developing floret at the tip of the spike. The long day length was suggested as a factor which might put full-awned types at a disadvantage in this experiment despite the high yield.

As a result of two years study of 22 varieties of spring wheat Nass (34) reported that morphological characters affected plot yields indirectly. The ear area, flag leaf breadth, and total photosynthetic area above the flag leaf node were associated with yield per ear. Walton (50) using a diallel cross of seven spring wheats showed that flag leaf area, peduncle length, head length, and yield were all controlled by minor genes. Additive gene action and general combining ability were shown to be important genetic factors for the characters mentioned. He concluded that increased "ear extrusion" and large flag-leaf areas were both associated with high yield.

Voldeng and Simpson (49) concluded that a combination of large flag leaf plus a large ear area showed promise as an index for selecting higher yielding individuals from a mixture of genotypes. Smocek (44) found that the maximum genetic advance could be expected if the flag leaf area was used in combination with the components of yield. Donald (10) described the wheat ideotype as having a short, strong stem; few, small, erect leaves; a large spike and erect ear, with awns. The design of the crop ideotypes may modify the environmental consideration for seeding rate, fertilizer application, plant management, and weed control. The design was based on obtaining high grain yield as a crop community.

Yield Components and Their Relationship to Yield

A number of workers have dealt with the relation of yield components and their effect on economic yield whereby a system selection on this basis would result in yield increases.

Engledow and Wadham (12) in 1923 tried to separate yield into its components. Characters such as the number of plants per unit area, number of spikes per plant, number of kernels per spike, and weight per kernel were regarded as the units from which high yield might be produced. Selection using these characters did not invariably make the progress toward increased yield which was expected. The variability of grain yield may be due to complex interaction of the three yield components, number of spikes per unit area, number of seeds per spike, and weight per seed. Increasing one of these components may result in decreasing one or two of the others. Varieties may have the same yield but have it as a result of different yield components.

Grafius and Okoli (19) studied the yield components of 28 F1 crosses from an $8^{x}8$ diallel cross of barley. They reported that yield components accounted for 72% of the variation in the yield. Grafius (17) represented yield in oats as the volume of a parallelepiped with 3 edges (x, y, z), corresponding to the 3 yield components, panicles per unit area (x), the average number of kernels per panicle (y), and the average kernel weight (z). He suggested the greatest rate of increase in yield occurs with changes in the shortest edge. He further added that it might be easier to increase yield by increasing the smallest yield component. Grafius (18) from his study on corn suggested that studying of yield components individually may account for valuable knowledge in producing high yielding varieties.

McNeal (31) in the study of yield components in F2 and F3 crosses of "Lemi" X "Thatcher" (two spring varieties of wheat) found that spikes per plant and kernels per spike were more highly correlated with plant yield than was kernel weight. Grafius and Okoli (19) reported a negative correlation between spikes per plant and kernel weight. Increased yield and increased spikes per plant was achieved at the cost of seed weight. According to Bingham (7) the grain size of wheat increased when the number of kernels per spike decreased. He pointed out that both characteristics are equally important in contributing to grain yield.

Austenson and Walton (5) in a study carried out on three varieties of spring wheat found that the size of individual seeds planted accounted for 2.5 to 4.5% of the observed variation in yield and other mature plant characteristics including the number of spikes per plant.

Johnson, et al. (22) compared the yield components of four winter wheat varieties with yield. It was found that the variety "CI 13678" had a uniformly large number of kernels per spike. This trait seemed to be more stable than the affect of the two other components.

Adams, (1) and Adams and Grafius (2) indicated that yield components are largely genetically independent characters which are frequently characterized by negative association. The compensation of one component by another is explained as the contest for both organic and inorganic food. Metabolic input to the yield components varies by external forces or metabolic control as soon as pollination is started. Adams (1), further stated that the development of yield components occurs in a sequential pattern. As the first component in the sequence uses up more or less of the substrate because of genetic or environmental causes, the second component varies in compensating manner using the left over amount regardless of the amount which is left. He concluded that the negative correlation among the components is not the result of linkage, but rather of higher competition of two or more components for a common limited nutrient or a osillatory input which is limiting at a critical stage. Yield is thus a result of genetic physiological response. The goal for obtaining higher yield will be reached when there is a high genetic ceiling, and a flexibility in response to the growth factors present.

Of the three yield components in wheat the one which is a primary yield determinent is a matter of speculation. Knott and Talukar (25) found a highly significant positive correlation between weight per kernel with grain yield and negative correlation with the number of kernels per spike. The correlation of weight per kernel with kernels per plot was highly significant and negative. The number of kernels per spike showed a high negative correlation with the number of spikes per plot. Fonesca and Patterson (16) obtained a positive (+0.24) correlation between tiller number and kernel weight and a negative (-0.22) correlation between kernels per spike and kernel weight. There was a highly significant negative correlation between number of spikes and kernels per spike. Hsu and Walton (21) reported that the correlation between yield per plant and 1000-kernel weight was not significant. A negative correlation between ear number and 1000-kernel weight was found. The spike number per plant was the most important yield component in their study.

Fonseca and Patterson (16) reported from a study of heritability of yield components using a diallel cross. The interrelationships among these components in winter wheat showed that heritability for number of spikes and kernels per spike were generally found to be greater than that for seed weight and grain yield. They also suggested that in order to be effective in using the components for selection, the components, must have high heritability, be genetically independent, and must not be physiologically associated. They concluded that negative correlations between number of spikes and kernels per spike may limit the progress of selection based on yield components.

Sun et al. (45) reported that kernel weight in a study of spring wheats had a heritability from 51 to 85%. Sharma and Knott (42) indicated that seed weight in wheat is controlled by relatively few genes. Knott and Taluker (25) demonstrated success in transferring high seed weight from "Selkirk" to "Thatcher" spring wheat varieties by backcrossing.

Hsu and Walton (21) from a study with spring wheat found that spike number was the most important component in determining yield; however, in late flowering plants longer spikes made significant contributions to higher yield. They further discussed that fact that flag leaf length was associated with kernel weight, and flag leaf width was associated with kernel number.

Ryle (40) observed in timothy plants that late tillers have a smaller potential to produce spikes. The number of florets per spike is determined during the period between spikelet initiation and spike emergence. Nitrogen in the soil had a direct effect in determining the number of florets per spike.

Borojevic (8) summarized the maximum optimal conditions that should be available for the development of yield components in order to assure the utilization of genetic potential. The optimal number of spikes per area for each variety depended on the resistance to lodging and intensity of tillering. High nitrogen rate and top dressing of nitrogen in the spring are valuable means of increasing production per spike. Correct planting time and good seedbed preparation are prerequisites for the optimal response of all other factors.

Baker and Dyck (6) crossed four hexaploid spring wheats, which were different only in their D genomes in all combinations. Heterosis for number of spikes, kernel weight, and grain yield appeared in first and second generations (F_1 and F_2). They were not able to detect specific combining ability among F_1 progeny, which suggested that only additive genetic variance is involved in the inheritance of these traits.

Yield and Some Other Factors

The ratio of grain yield (economic yield) to total yield (biological yield) is harvest index (HI). Singh and Stoskopf (43) as a result of three years study of the HI of winter wheat and other cereals reported that HI of wheat is positively correlated with economic yield, but negatively correlated with biological yield. Improved HI represents increased physiological capacity (sink) to mobilize synthesized nutrients and translocate it to organs having economic value. They further reported that reduction in plant height reduced the sink size of the stem. A significant negative correlation between height and harvest index in winter wheat suggests that HI can be improved by reducing the plant height. Johnson et al. (23) have shown that plant height is correlated with grain yield.

The systems (photosynthetic area and yield components) for producing yield that have been reviewed can be modified by external factors. Pests and diseases can affect yield and alter the growth of the plant and rate of photosynthesis. Last (29) reported that yield losses caused by cereal powdery mildew, Erysiphe graminis Merat, can be attributed to smaller and less efficient photosynthetic systems in the infected plant. He found that inoculating 30% of the leaves decreased photosynthesis to 7.3 mg $CO_2/dm^2/hr$ from 12.9 mg $CO_2/dm^2/hr$ in the uninoculated controls.

Doodson, et al. (11) reported a direct effect of late yellow rust, Puccina striiformis, on yield reduction and on the indirect effect of early infection greatly reducing the number of florets per spike, number of grains per spike, in some cases the weight per kernel, and on number of leaves, which contribute to yield reductions.

CHAPTER III

MATERIALS AND METHODS

The study was conducted on the Fifth International Winter Wheat Performance Nursery (IWWPN) grown at Stillwater, Oklahoma during the 1972-73 crop year. The IWWPN was organized in 1968 by the Nebraska Agricultural Experiment Station and the Agricultural Research Service, U. S. Department of Agriculture, under a contract with the Agency for International Development, U. S. Department of State, and with informal cooperation of the International Maize and Wheat Improvement Center, Mexico, D. F. and FAO Rome, Italy. The nursery is comprised of winter wheat varieties developed by various breeding programs around the world and is grown each year in some 25 countries. The Oklahoma Agricultural Experiment Station is one of the agencies that cooperates in evaluation of this nursery.

The growing season at Stillwater was characterized by above normal precipitation (Table I). The precipitation during the growing season (October to June), was above normal.

The Field Layout

The experiment consisted of 30 varieties. Six of them originated in the U.S.A. and the other 24 cultivars were from different countries (Table II). According to information provided with the experiment the varieties differ widely in maturity, plant height, straw strength,

TABLE I

RAINFALL RECEIVED AND DEVIATIONS FROM NORMAL BY MONTH FOR CROP YEAR 1972-1973 AT STILLWATER, OKLAHOMA

		Rainfall (mm)		
Year	Month	Received	Normal	Deviation From Normal
1972	July	72.64	89.66	-17.01
	August	74.93	81.53	- 6.60
	September	63.75	85.85	-21.08
	October	125.22	70.61	+54.61
	November	95.75	46.99	+48.76
	December	39.11	34.04	+ 5.08
1973	January	82.29	29.46	+52.83
	February	30.48	34.29	- 3.81
	March	196.34	47.24	+149.09
	April	87.37	72.64	+14.73
	May	81.28	117.34	-36.06
	June	54.61	107.69	-53.08
	Total	1003.80	817.37	+186.43

TABLE II

ENTRY NUMBER, NAME, AND ORIGIN OF WHEAT VARIETIES

Entry No.	Cultivar	Origin
1	Strampelli	Italy
2	Probstdorfer Extrem	Austria
3	Victor I	Italy
4	Carifen 12	Chile
5	Caribo	West Germany
6	C.I. 15074	USA (Nebraska)
7	Golden Valley (Zg 5994/66)	Yugoslavia
8	Hokuei	Japan
9	Atlas 66	USA (No. Carolina)
10	Diplomat	West Germany
11	Blueboy	USA (No. Carolina)
12	Maris Nimrod	England
13	Marimp 3	Italy
14	Jyva	Finland
15	Sava	Yugoslavia
16	NE 701132	USA (Nebraska)
17	Bezostaya 1	USSR
18	Lilifen	Chile
19	Vakka	Finland
20	Zenith	Switzerland
21	Clarion	Netherlands
22	Lerma Rojo 64	Mexico
23	Centurk	USA (Nebraska)
24	Backa	Yugoslavia
25	Roussalka	Bulgaria
26	Moldova	Romania
27	Tamwheat 102 (TX 62A4793-7)	USA (Texas)
28	Dacia	Romania
29	Starke	Sweden
30	Kirac 66	Turkey

winterhardiness, and reaction to diseases. Entries 6, 9, and 16 possessed genes for high grain protein, and entry 22 was "Lerma Rojo 64" a spring variety. Lerma Rojo 64 was included to obtain a measure of the severity of the different environments where the nurseries are to be grown. The varieties were planted in a randomized complete block design with four replications on October 2, 1972 and emerged on October 9, 1972. The experiment was located on the Stillwater Agronomy Experiment Station on a previously summer-fallowed land. The experiment received a preplant application of 20 kg/ha of N and 50 kg/ha P_2O_5 on 9-19-72. A top dressing of 45 g/ha N was applied on 2-29-73. Each variety was planted in a plot in four rows 3.0 m long and 30 cm apart between rows.

Characters Evaluated

Data were collected on grain yield, tiller number, kernel weight number of kernels per spike, heading date, maturity date, plant height, flag leaf length, flag leaf width, flag leaf sheath length, peduncle length, peduncle diameter, chaff weight, total dry matter weight, leaf rust severity, powdery mildew, winterkilling, lodging, and grain protein content. Flag leaf area and peduncle area were also estimated.

Yield determination was based on the weight of the threshed and cleaned grain harvested from each 1.486m^2 area from plot and was expressed in grams per plot.

Tiller count was based on the number of tillers bearing heads in an area 25 cm x 30.4 cm = 762 cm^2. Two observations were made at random in two central rows. Each observation was on a 25 cm length of the row from the area where yield was obtained. The averages of the two measurements were reported.

Kernel weight was determined on a sample of 200 seeds taken at random from the grain harvested from each plot. Broken seeds were removed from each sample and the weight of 200 whole seeds was recorded in grams.

Twenty tillers were taken at random from the border rows of each plot, one inch above the soil surface. The average number of seeds per spike, chaff weight, flag leaf sheath length, peduncle length, diameter, and total dry matter were measured and recorded on these twenty tillers.

Heads of twenty randomly taken samples were threshed using a hand "thresh board" and then the seeds were seperated from the chaff by a "blowing cylinder". Number of seeds per twenty heads were recorded. This character was expressed as the average numbers of seeds per head.

The total weight of 20 heads (excluding rachis) was recorded, then the weight of seeds per 20 heads was measured. The chaff weight was determined by subtracting the grain weight from the total weight. Chaff weight was expressed in mg per head.

Flag leaf length and maximum leaf width (taken at widest point perpendicular to the length measurement) of ten flag leaves on different randomly selected tillers were measured.

Based on individual leaf measurements, simple regression and correlation coefficients between area and length, and between area and width, and between area and length x width were computed.

A constant (K) value was obtained from a linear regression analysis of 261 flag leaves of five varieties. Those varieties which were visually selected seemed to be representative of other entries in this study. These leaves were traced on paper, and the length, width, and area of individual leaves were measured. The area of traced leaves was measured by a planimeter. The LW of individual traced leaves as an independent variable and area by planimeter as a dependent variable were used for computing the regression coefficient. After testing for zero intercept the value of K (0.736) was estimated using the least square method.

The peduncle length of twenty randomly taken tillers was measured. The measurement was based on the length from auricle to the base of head. Peduncle diameter was estimated by measuring 20 tillers side by side on a smooth surface. The average was calculated and recorded as the average diameter of a peduncle. Peduncle area was estimated by length x Π diameter.

Flag leaf sheath length, peduncle length (from auricle to the base of head), and peduncle diameter were measured on samples from each plot.

Heading date was estimated as the date at which approximately 75 percent of the plants in the plot were headed. Data on heading is reported as days to heading from January first.

Maturity was visually estimated as the number of days from January 1st to the time when the plants appeared to be physiologically mature. In recording maturity data, physiologic maturity was estimated to have occurred when the peduncles turned yellow.

Plant height was measured from the distance from the ground surface to the tip of terminal spikelet (excluding awns). Four measurements were taken from the two center rows of each plot to represent the height of plants harvested for grain yield. The average of 4 measurements taken in centimeters is reported here.

Grain protein was determined by "Udy" colorimetric method of protein determination.

Winterkill was determined visually by estimating percent dead plants per plot.

Lodging was estimated by a visual rating of the percent of the plants that were not standing erect in a plot. Lodging data was taken when the plants were physiologically mature.

Rust-leaf rust (P. recondita) severity was determined as infection type, percent severity and percent prevelance on two replications.

Powdery mildew (Erysiphe graminis t) was measured on a scale of 1-5. All data except rust readings were obtained from each plot on all replications.

The total dry matter of twenty randomly selected tillers was measured after oven drying and was recorded in grams.

Statistical Analysis

Statistical analysis was carried out on the grain yield and some other plant characters on means of samples per plot. Tiller count analysis was made on the average of two counts per plot. Plant height analysis was done on the average of four measurements per plot. Flag leaf length, width, and area analysis were performed on the average of ten samples per plot. Peduncle length, area, and flag leaf sheath analysis were made on the average of 20 samples per plot. Analysis of variance for each character on the basis of an average measurement per plot was performed on 25 varieties. Four late-maturing varieties and the spring wheat variety were not included in analyses.

The analyses for possible relationship between the grain yield and other variables was determined on means per plot. Analysis of variance and cross product analysis for obtaining correlations on variety mean, and simple correlations were performed. The coefficient $r_{X_1 X_2}$ of correlation between two variables X_1 and X_2 is given by the formula:

$$r_{X_1X_2} = \frac{\Sigma(X_1-\bar{X}_1)\ (X_2-\bar{X}_2)}{\sqrt{\Sigma(X_1-\bar{X}_1)^2\ \Sigma(X_2-X_2)^2}}$$

Where $\Sigma(S_1-\bar{X}_1)^2$ is the sum of squares of the deviations of the variable X_1, $\Sigma(X_2-\bar{X}_2)^2$ is the sum of squares of the deviations of the variable X_2, and $\Sigma(X_1-\bar{X}_1)\ (X_2-\bar{X}_2)$ is the sum of products of the deviation of X_1 and X_2.

Simple correlation coefficients were obtained on the basis of cross product of X_1 X_2 (total corrected sum of product) as numerator and sum of squares of X_1 and X_2 (total corrected) as denominator from analysis of variance of those variables. Correlation (variety mean) was calculated by using cross product of X_1 X_2 (Variety) as numerator and variety sum of squares of X_1 and X_2 as denominator from the analysis of variance.

The regression coefficients were obtained by using yield as the dependent variable and the other plant characters as independent variables. The common regression is estimated by the following formula:

$$ry.x = \frac{\Sigma xy}{\Sigma x^2}$$

Where Σxy is cross products of variety and Σx^2 is sum of squares of variety from the analysis of variance and cross product analysis.

CHAPTER IV

RESULTS AND DISCUSSION

On the basis of analysis of variance of yield and other plant characters, the F value for variety was found to be highly significant ($p<.01$). Thus the cultivars grown in this study varied significantly in yield and other characters.

Analyses of variance of photosynthetic area above the flag leaf node are represented in Tables III and IV, and the means of the data in Appendix Table XII. There was a highly significant difference ($p<.01$) among varieties for flag leaf length, flag leaf width, flag leaf area, flag leaf sheath length, peduncle length, peduncle diameter, peduncle area and chaff weight.

Analyses of variance for the three yield components in Table V showed that there was a highly significant difference ($p<.01$) among varieties for the yield components (tillers per unit area, kernels/spike and kernel weight) with coefficients of variability, 9.2, 6.1 and 5.4, respectively.

The varieties in this study were from different geographical areas and showed different responses under climatic conditions prevalent at Stillwater. Some showed susceptibility to cold weather and disease. The analysis of variance (Table VI) and mean of data (Appendix Tables XI and XIII) show a high coefficient of variability (C.V.) for lodging and winterkill. The high C.V. occurred because some varieties had a zero

TABLE III

MEAN SQUARES FOR FLAG LEAF AREA AND OTHER CHARACTERS OF 25 WINTER WHEAT VARIETIES

Source	df	Flag Leaf Area	Flag Leaf Length	Flag Leaf Width	Flag Leaf Sheath Length
		Mean Squares			
Rep	3	24.937	5.920	0.04269	0.452
Var	24	59.024	18.457	0.13375	15.148
R X V	72	4.587	1.579	0.00564	0.305
Corrected Total	99	18.393	5.802	0.03782	3.908
Cal F		12.89	11.68	23.69	49.52
Prob > F		0.0001	0.0001	0.0001	0.0001
C. V. %		8.5	5.0	4.9	3.0

TABLE IV

MEAN SQUARES FOR PEDUNCLE LENGTH AND OTHER CHARACTERS OF 25 WINTER WHEAT VARIETIES

Source	df	Peduncle Length	Peduncle Diameter	Peduncle Area	Chaff Weight
		Mean Squares			
Rep	3	16.052	0.00003	10.235	1353.24
Var	24	76.352	0.00420	62.566	7753.87
R X V	72	2.391	0.00011	1.981	637.44
Corrected Total	99	20.735	0.00110	16.918	2384.33
Cal. F		31.92	35.44	31.57	12.16
Prob > F		0.0001	0.0001	0.0001	0.0001
C. V. %		11.0	4.3	17.7	11.5

TABLE V

MEAN SQUARES FOR GRAIN YIELD AND OTHER CHARACTERS
OF 25 WINTER WHEAT VARIETIES

Source	df	Grain Yield	Tiller Number	Kernels/ Spike	Kernel Weight	Grain Protein Percent
		Mean Squares				
Rep	3	1664.28	117.17	3.780	0.032	3.574
Var	24	57210.05	547.54	85.479	4.691	8.060
R X V	72	2631.50	23.69	3.445	0.110	0.690
Corrected Total	99	15833.25	153.52	23.312	1.218	2.564
Cal. F		21.74	23.11	24.81	42.44	11.68
Prob. > F		0.0001	0.0001	0.0001	0.0001	0.0001
C. V. %		8.7	9.2	6.1	5.4	6.2

TABLE VI

MEAN SQUARES FOR SOME CHARACTERS OF 25 WINTER WHEAT VARIETIES

Source	df	Days to Heading	Days to Maturity	Height	Lodging %	Winter Kill	Powdery Mildew	Total Dry Matter
		Mean Squares						
Rep	3	0.99	11.06	78.34	449.34	8.66	1.050	20.230
Var	24	249.52	140.01	596.64	956.52	49.22	1.497	226.365
R X V	72	0.43	0.65	9.44	105.55	2.59	0.265	13.008
Corrected Total	99	60.83	34.75	153.88	323.78	14.08	0.587	64.950
Cal F		574.72	213.13	63.17	9.06	19.01	5.64	17.40
Prob > F		0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
C. V. %		0.5	0.5	2.9	107.57	100.5	32.39	7.0

value and some a high value. The zero value lowered the mean which increased the C.V.

Simple correlation analysis as well as correlation using variety means between 14 characters among 25 varieties were carried out. The correlation based on the mean of each variety (average of 4 replications) was used for the discussion.

Grain Yield

The overall mean of the grain yield for 25 varieties was 3794 kg/ha and yields ranged from 992 to 5109 kg/ha. "Golden Valley" was highest with 5109 kg/ha, and ranked eighth, fifth, and 18th, respectively, for kernel weight, kernel per spike, and tillers per area. The low-yielding varieties were mostly late, and their maturity was hastened by hot dry winds. The yield per plot and mean for each variety is reported in Appendix Table X. "Centurk" had the highest number of tillers and "C.I. 15074" was the second highest, and they ranked 12th and 19th, respectively, in yield (Appendix Table XI). "Marimp 3" with the highest number of kernels per spike ranked ninth in yield. "Roussalka" with the highest kernel weight ranked sixth in yield.

The high yield of Golden Valley may be the result of a good balance of yield components. In addition it ranked 19th in tiller counts.

The correlation coefficients of yield vs other characters are shown in Tables VII and VIII, but only those in Table VII will be discussed. A highly significant correlation between yield and kernel weight ($r=0.646^{**}$) and significant correlation between yield and peduncle length ($r=0.469^{*}$) was observed. Yield was negatively correlated

TABLE VII

CORRELATION COEFFICIENTS FOR GRAIN YIELD AND SOME OTHER PLANT CHARACTERS AMONG 25 WINTER WHEAT VARIETIES[1]

Plant Character	Plant Character													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Yield g/plot		-.182	.353	.646**	-.664**	.041	-.041	.09	-.366	.469*	.523**	.277	-.268	-.759**
2. Tiller count			-.663**	-.459*	.034	-.612**	-.072	-.74**	-.031	.165	-.153	-.518**	.577**	.299
3. Kernels/spike				.046	-.299	.541**	.016	.683**	-.195	-.115	.113	.359	-.543**	-.293
4. Kernel weight					-.141	.094	.03	.102	0.054	.404*	.568**	.424*	-.098	-.673**
5. Percent protein						.049	.035	.018	.412*	-.393	.387	-.128	.367	.508**
6. Flag leaf area							.631**	.797**	.376	-.364	-.177	.486*	-.285	.215
7. Flag leaf length								.041	.695**	-.154	-.142	.161	.240	.325
8. Flag leaf width									-.063	-.363	-.129	.490	-.573	.018
9. Flag leaf sheath length										-.282	-.328	-.155	.551**	.573**
10. Peduncle length											.92**	.211	.228	-.621**
11. Peduncle area												.398*	-.007	-.762**
12. Chaff weight													-.347	-.261
13. Plant height														.384
14. Days to heading														

Significant values for correlations are 0.396 and 0.505 at the 5% and 1% level of probability, respectively, (23 degrees of freedom).

[1]Correlation obtained on mean of the varieties.

TABLE VIII

SIMPLE CORRELATION COEFFICIENTS FOR GRAIN YIELD AND SOME OTHER PLANT CHARACTERS AMONG 25 WINTER WHEAT VARIETIES

Plant Character	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Yield g/plot		-.138	.293**	.617**	-.565**	-.002	-.065	.056	-.340**	.431**	.479**	.221*	-.222*	-.713**
2. Tiller count			-.586**	-.409**	.040	-.488**	-.039	-.638**	-.039	.154	-.124	-.457**	.540**	.279**
3. Kernels/spike				.024	-.222*	.488**	.048	.615**	-.171	-.116	.098	.362**	-.519**	-.275**
4. Kernel weight					-.140	.041	-.003	.064	-.044	.374**	.527**	.376**	-.087	-.654**
5. Percent Protein						.051	.053	.013	.343**	-.381**	-.371**	-.067	.290**	.451**
6. Flag leaf area							.671**	.785**	.330**	-.292**	-.135	.401**	-.239*	.200*
7. Flag leaf length								.077	.618**	-.117	-.105	.148	.229*	.291**
8. Flag leaf width									-.065	-.310**	-.106	.410**	-.527*	.024
9. Flag leaf sheath length										-.242*	-.280**	.109	.537**	.555**
10. Peduncle length											.922**	.178	.259**	-.585**
11. Peduncle area												.354**	.041	-.720**
12. Chaff weight													-.315**	-.227*
13. Plant height														.370**
14. Days to heading														

Significant values for simple correlations are 0.197 and 0.256 at the 5% and 1% level of probability, respectively, (98 degrees of freedom).

with percent protein, ($r=-.664^{**}$) and days to heading ($r=-.759^{**}$). Yield was positively related with kernels per spike, flag leaf area, flag leaf width, and chaff weight, but none of these correlations were statistically significant. In this study it was found that tillers were negatively related to yield, so low tillering apparently favored the development of other yield components. These data agree with Thorne's (48) results in which the ear number was affected by environmental factors occurring during early developmental stages whereas the seed weight is influenced by changes occurring after pollination. A non-significant negative association of yield with tillers per area, flag leaf length, flag leaf sheath length, and plant height was obtained.

Photosynthetic Components

The correlation coefficients of these parts except peduncle length and peduncle area were found to be statistically non-significant to grain yield.

Flag leaf area was obtained as the product of flag leaf length x flag leaf width x K 0.73, and by using this formula a higher correlation between estimated leaf area and area of the traced leaves were obtained. The results agree with Palaniswamy and Gomez (36).

A positive significant relationship of flag leaf area with chaff was obtained in the study reported herein. Flag leaf length showed a high positive correlation with flag leaf sheath length and a non-significant relation to chaff weight. Flag leaf sheath length is highly associated with plant height and days to heading. Peduncle length and area are positively related to chaff weight (Tables VII and VIII).

It was found that peduncle length and area are negatively associated with number of days to heading; this association was highly significant. Late varieties had shorter peduncles, even at the time of harvest, because they did not receive optimum growing conditions to develop their peduncles completely.

The result shows that under the conditions of this study the morphological characters influenced yield indirectly rather than directly. Increase in any one of the morphological structures above the flag leaf node would increase the material availability to supply more kernel substrate resulting in increased kernel size, and hopefully increased yield. Hsu's (21) results support the other research indicating that morphological structures above the flag leaf node are associated with yield components as well as yield. The importance of flag leaf width on kernels per spike (Figure 1) is in agreement with Hsu (21). Flag leaf width was found to be important to yield per plot and yield per spike by Tanner et al. (47). Leaf area was significantly related to kernels per spike and positively related to kernel weight. Also, these results agreed well with those of Smock (44).

At the outset of this study, it was hypothesized that a direct relationship existed between flag leaf area and yield. However, this relationship was found to be non-significant although still positive. This may be due to a larger supply of grain photosynthate as a result of ear photosynthesis. Chaff weight as an estimator of head photosynthesis related more to yield than leaf area. The results agree with those of Volding and Simpson (49) in that ear and flag leaf photosynthesis contribute the major portion of grain dry weight.

Disease infection (Appendix Table XIII) may be another factor in

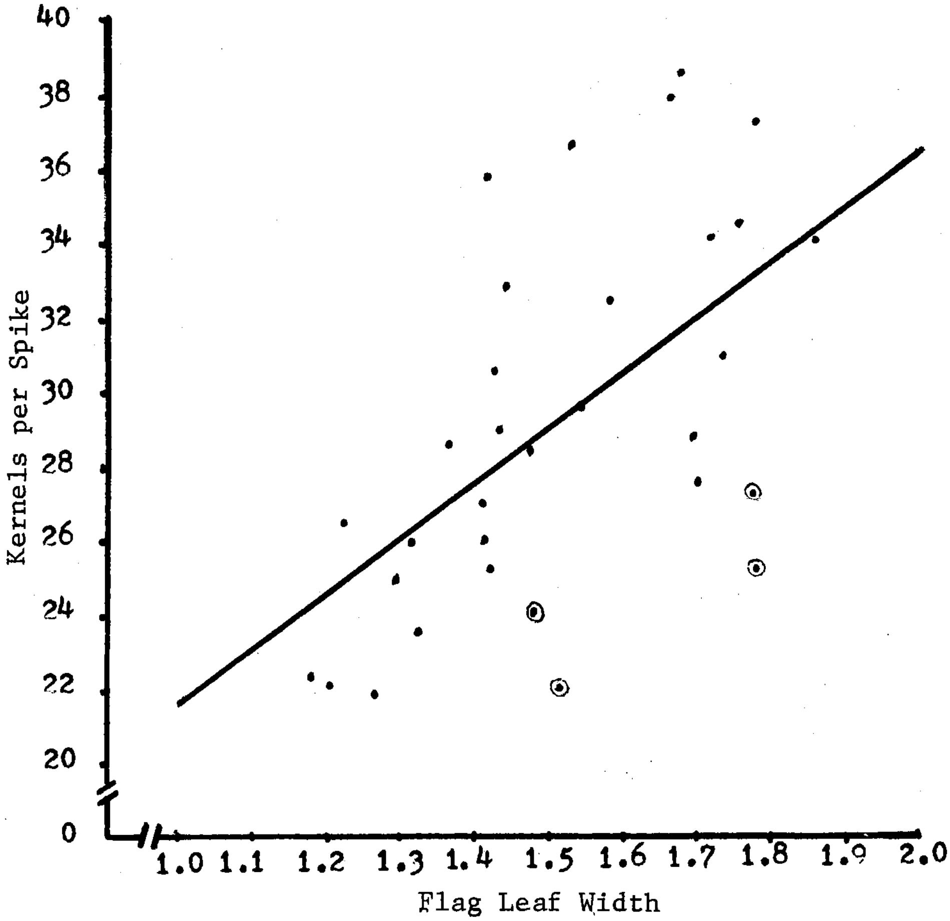

Figure 1. Regression of Kernels per Spike on Flag Leaf Width. (Varieties whose points are circled were eliminated when calculating the regression line).

decreasing the contribution of leaf area to yield. Leaf rust and powdery mildew may have reduced the yield through decreasing the efficiency of photosynthetic area, as Last (29) observed. The relative contribution of photosynthetate from different organs also can be affected by drought, which seems to increase the contribution of ears, probably because of early leaf senisence.

Yield Components

There was a highly significant negative correlation between tiller number and the other two components of yield (Tables VII and VIII). Tiller count was positively correlated with peduncle length and days to heading. A strong negative relationship between tiller number and flag leaf area and tillers vs flag leaf width was obtained. A non-zero positive correlation between kernels per spike and kernel weight may be due to their development at different times, when competition for metabolites did not occur. Kernels per spike was highly ($r=0.541^{**}$) related to flag leaf area and flag leaf width ($r=0.683^{**}$). A negative relationship between kernels per spike vs plant height and days to heading was obtained. The number of kernels per spike is normally considered to be very sensitive to environmental factors such as drought stress and plant density, and this appears to be true in this study.

Tiller count is negatively associated with yield in this study, but correlation was not statistically significant. Some other workers have showed a positive association of tillers per area with yield. Since ear number is affected by environmental factors occurring during early developmental stages (48), high yielding varieties could not produce many tillers because of unfavorable environmental factors of the early developmental stages or high yielding varieties did not have the genetic potential of producing many tillers under this study (Figure 2). As an overall mean the number of tillers were high in this study, and probably due to genetic potential, a wide range in tiller number was observed which may have resulted in negative correlation. Seed weight which is influenced by environmental changes after pollination and was positively correlated ($r=0.646^{**}$) to yield may be a factor in favor of high yielding varieties. As a result of data in Appendix Tables X, and XI, it can be easily seen that the first three top varieties in seed weight, Entries 25, 17, and 24 ranked sixth, third, and fourth in yield respectively. Seed weight showed a positive relationship with above flag leaf node photosynthetic components except flag leaf sheath length.

Some Other Plant Characters

Percent grain protein showed a significant positive relation to flag leaf sheath length and significant negative relation to peduncle length (Tables VII and VIII). Since grain protein had a highly significant negative relation to grain yield its negative correlation with peduncle length is to be expected because of a positive relationship to yield with peduncle length. It was found that grain protein was positively significantly related to number of days to heading.

Plant height was negatively related to grain yield (Tables VII, and VIII). Plant height was also negatively related to both kernels per spike and kernel weight. A highly significant association of both tillers per area and flag leaf sheath length, and a non-significant

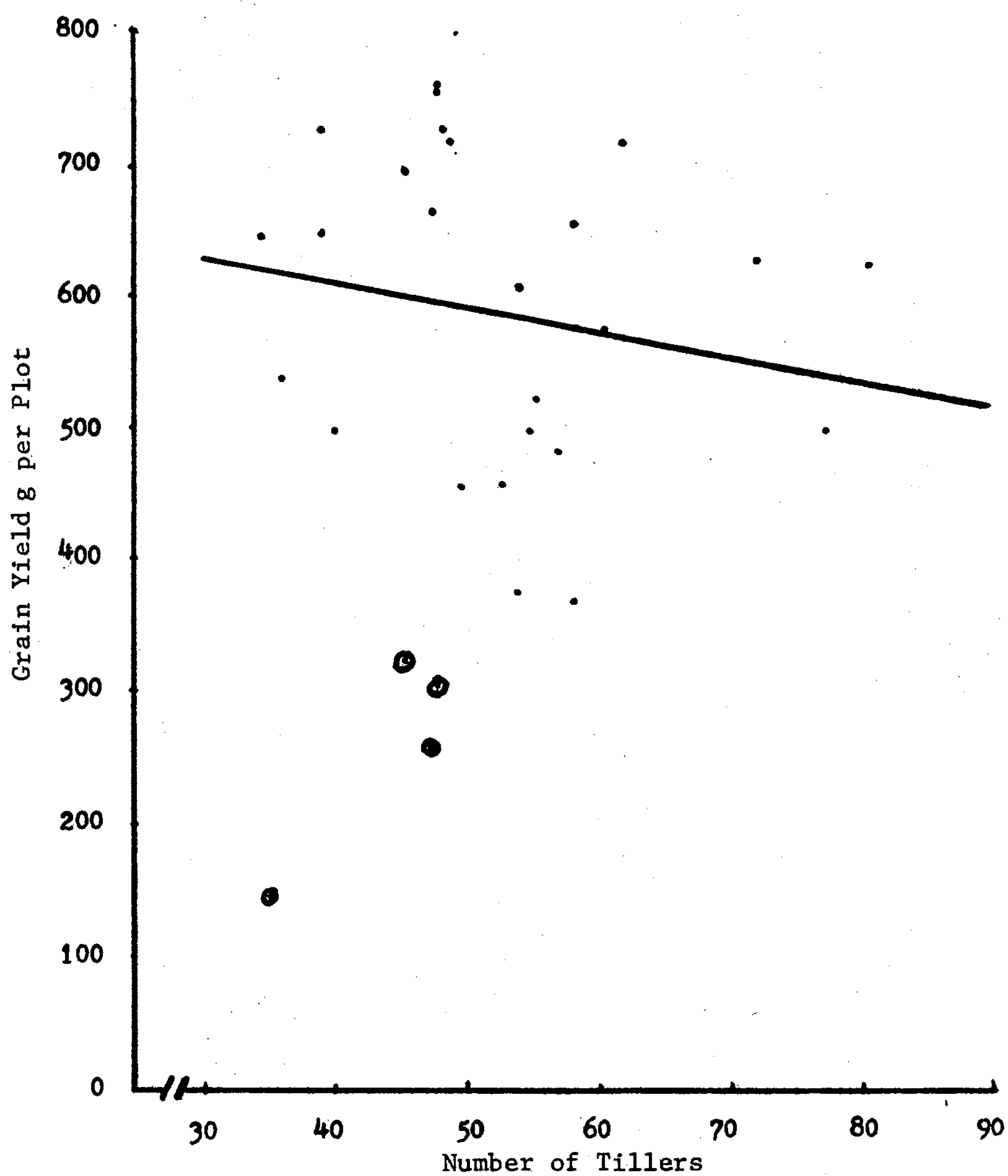

Figure 2. Regression of Grain Yield on Number of Tillers. (Varieties whose points are circled were eliminated when calculating the regression line).

positive correlation with flag leaf length and peduncle length was obtained. A high positive association of tillers per area and plant height showed that in dense population the tillers may use the metabolites for biological yield rather than economic yield (grain yield). Singh and Stoskopf (43) found that harvest index (HI) of wheat is positively correlated with economic yield. Thus, improved HI represents increased sink capacity to metabolize photosynthate and translocate it to the organ having economic value.

The r value between days to heading and grain yield was found to be negative and highly significant ($r=-0.759^{**}$). Since the regression coefficient of yield on days to heading is negative (Figure 3), the regression line shows that late heading varieties produced lower yield. The importance of leaf area duration after anthesis was reported by Welbank (52) and can be a factor for the low yield in late varieties. Although it is known that a longer growing season may result in the assimilation of more metabolates that might be used for vegetative production. If the developing seeds are subjected to an unfavorable environment such as hot, dry, winds growth likely will be depressed. In late varieties beside having a relatively short leaf area duration after heading, the green parts were not efficient in photosynthesis and translocation of photosynthate to the physiological sink, the seed.

Relative Importance of Different Characters on Grain Yield

Assuming a linear relationship between the grain yield and some other characters under the study over the four replications, the simple common regression coefficients of yield on each character can be

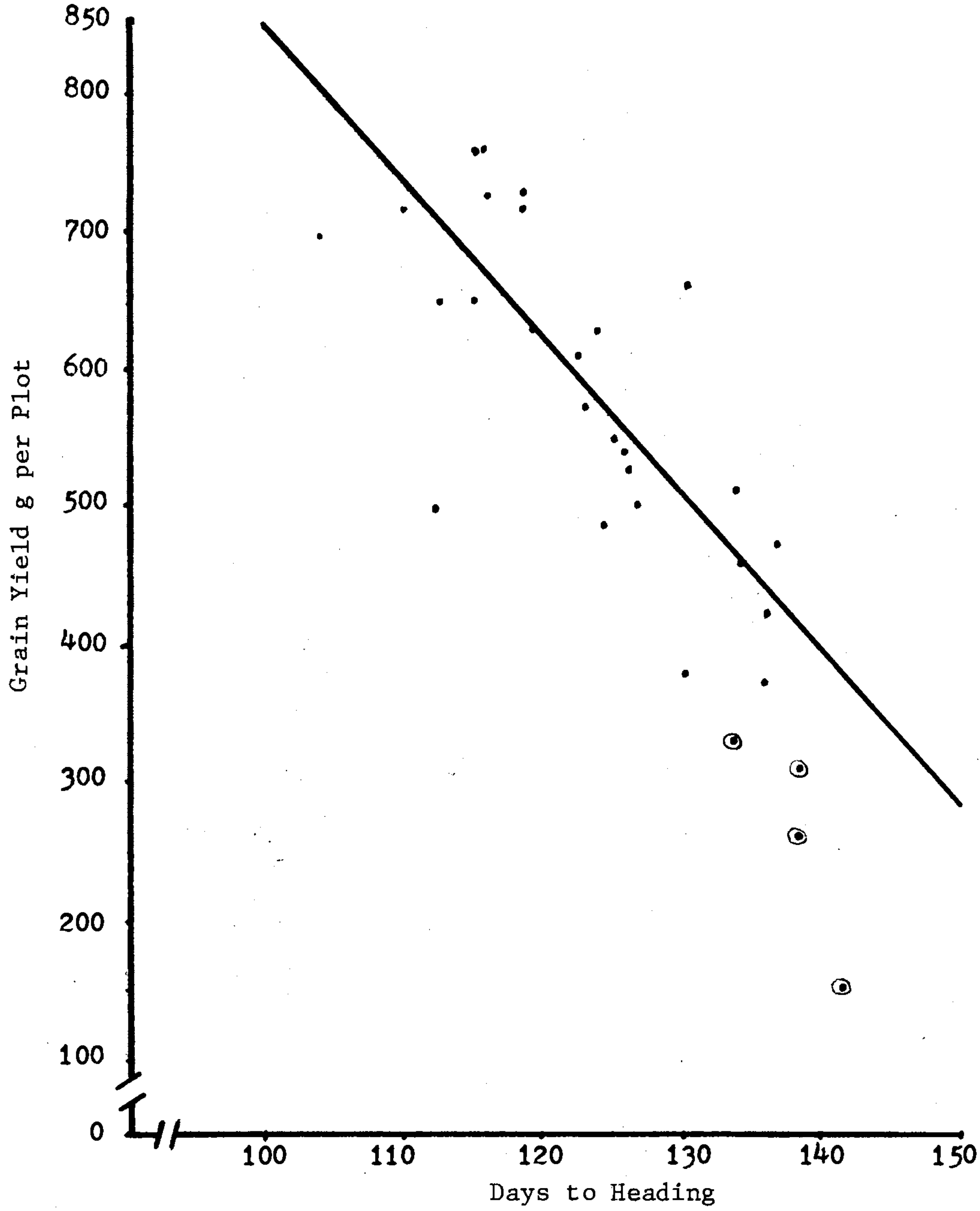

Figure 3. Regression of Grain Yield on Days to Heading. (Varieties whose points are circled were eliminated when calculating the regression line).

estimated (Table IX). The coefficient of regression of yield on kernel weight (Figure 4) was the highest and was followed by flag leaf width. The importance of kernel weight in the determination of winter wheat yield has been previously suggested (48). Peduncle area and peduncle length (Figure 5) ranked third and fourth respectively, in the determination of yield. The trend of regression line of yield on kernel per spike in Figure 6 is upward, but it is not as steep as the other figures already presented.

The coefficient of determination r^2 which represents the fraction of the sum squares of the variation of yield that is due to the variations in each character is presented in Table X. The value of this coefficient for seed weight agrees with the regression coefficients. It was found that 71.3% variation of yield was due to a variation in kernel weight. The results show that the kernel weight is associated more closely to grain yield than tillers per plant, or kernels per spike. Seed weight in wheat has generally been reported to be more highly heritable than other components of yield (Sharma and Knott, (42)). The slope of yield on kernel weight is 71.33 and yield on flag leaf width is 58.91. These two factors should be useful characters for improving wheat yield.

TABLE IX

RELATIVE IMPORTANCE OF DIFFERENT PLANT CHARACTERS ON GRAIN YIELD OF 25 WINTER WHEAT VARIETIES

	Regression Coefficient			Coefficient of Determination r^2*		
Grain Yield With:	Simple	Var(Mean)	RXV	Simple	Var(Mean)	RXV
Tiller Count	-1.408	-1.865	1.259	0.019	0.033	0.014
Kernels/Spike	7.641	9.141	-4.601	0.085	0.124	0.027
Kernel Weight	70.351	71.334	59.240	0.380	0.411	0.146
Flag Leaf Area	-0.080	1.280	-5.590	0.000004	0.001	0.054
Flag Leaf Length	-3.411	-2.287	-9.350	0.004	0.001	0.052
Flag Leaf Width	36.532	58.919	-92.540	0.003	0.008	0.018
Flag Leaf Sheath Length	-21.674	-22.531	-11.269	0.115	0.133	0.014
Peduncle Length	11.946	12.850	5.528	0.185	0.219	0.028
Peduncle Area	14.625	15.829	5.411	0.229	0.213	0.021
Chaff Weight	0.570	0.753	-0.095	0.048	0.076	0.002
Plant Height	-2.258	-2.63	4.288	0.049	0.071	0.065
Days to Heading	-11.516	-11.506	-14.761	0.508	0.576	0.035

*The coefficient of determination r^2 represents the proportion of the sum of squares of the dependent variable (yield) that can be attributed to the independent variable (x).

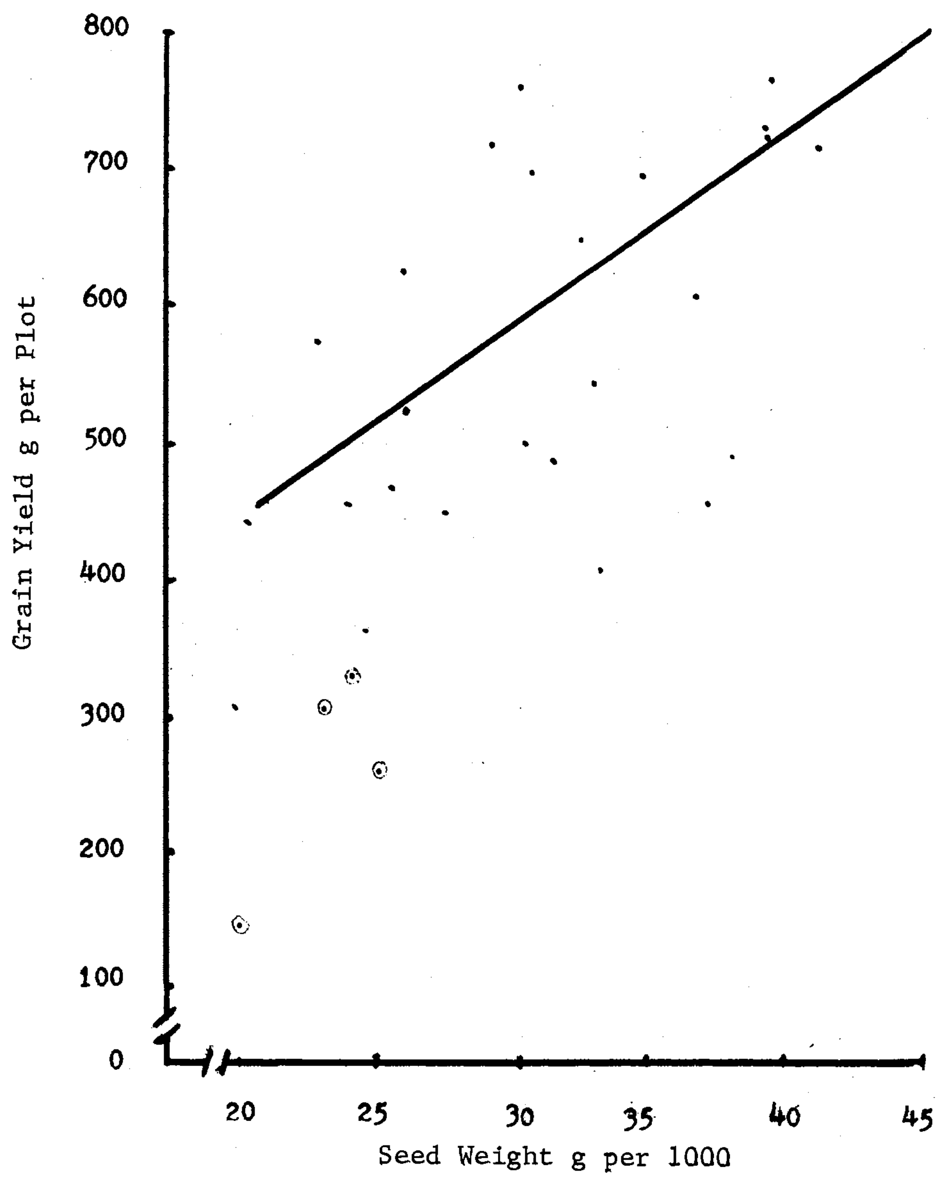

Figure 4. Regression of Grain Yield on Seed Weight. (Varieties whose points are circled were eliminated when calculating the regression line).

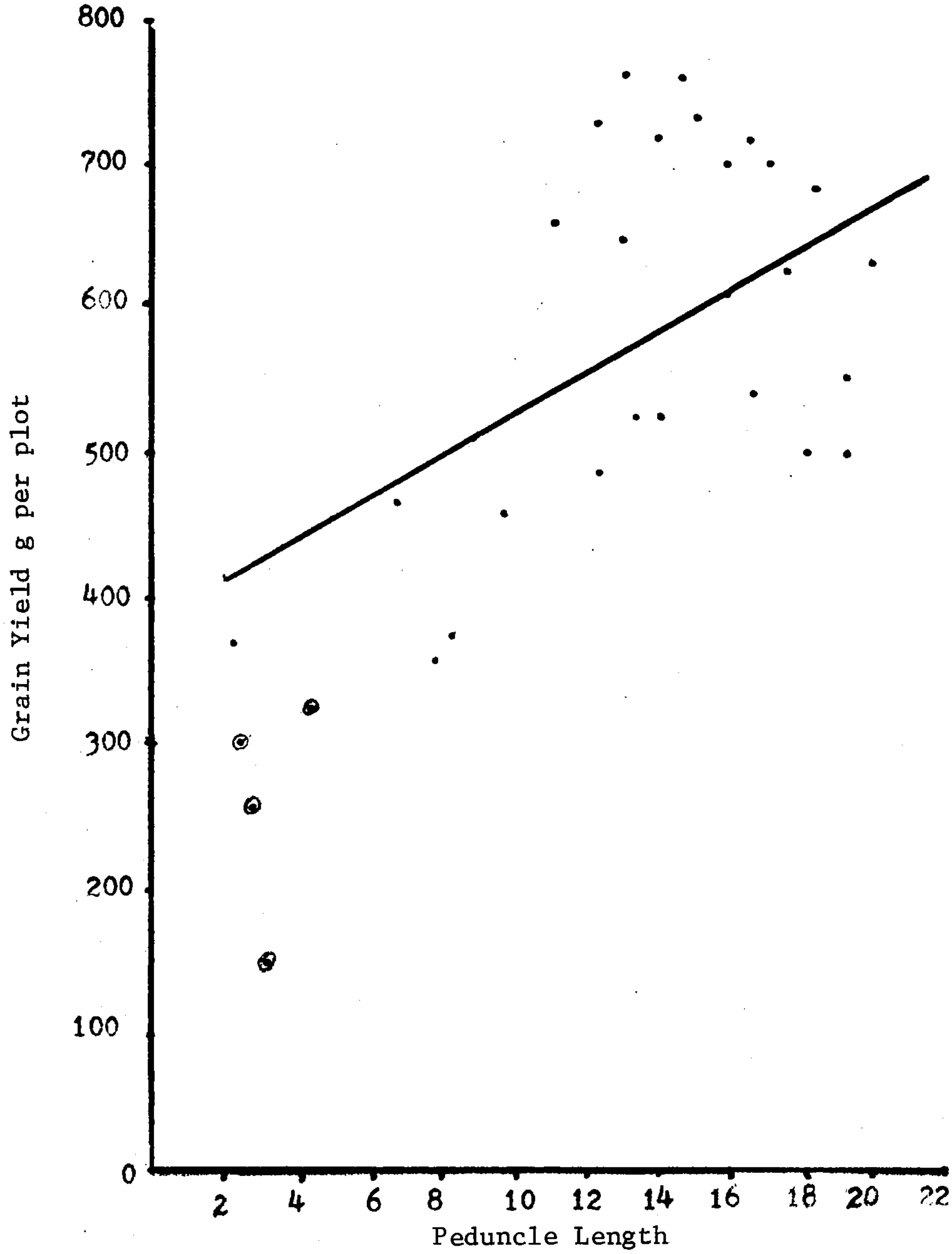

Figure 5. Regression of Grain Yield on Peduncle Length. (Varieties whose points are circled were eliminated when calculating the regression line).

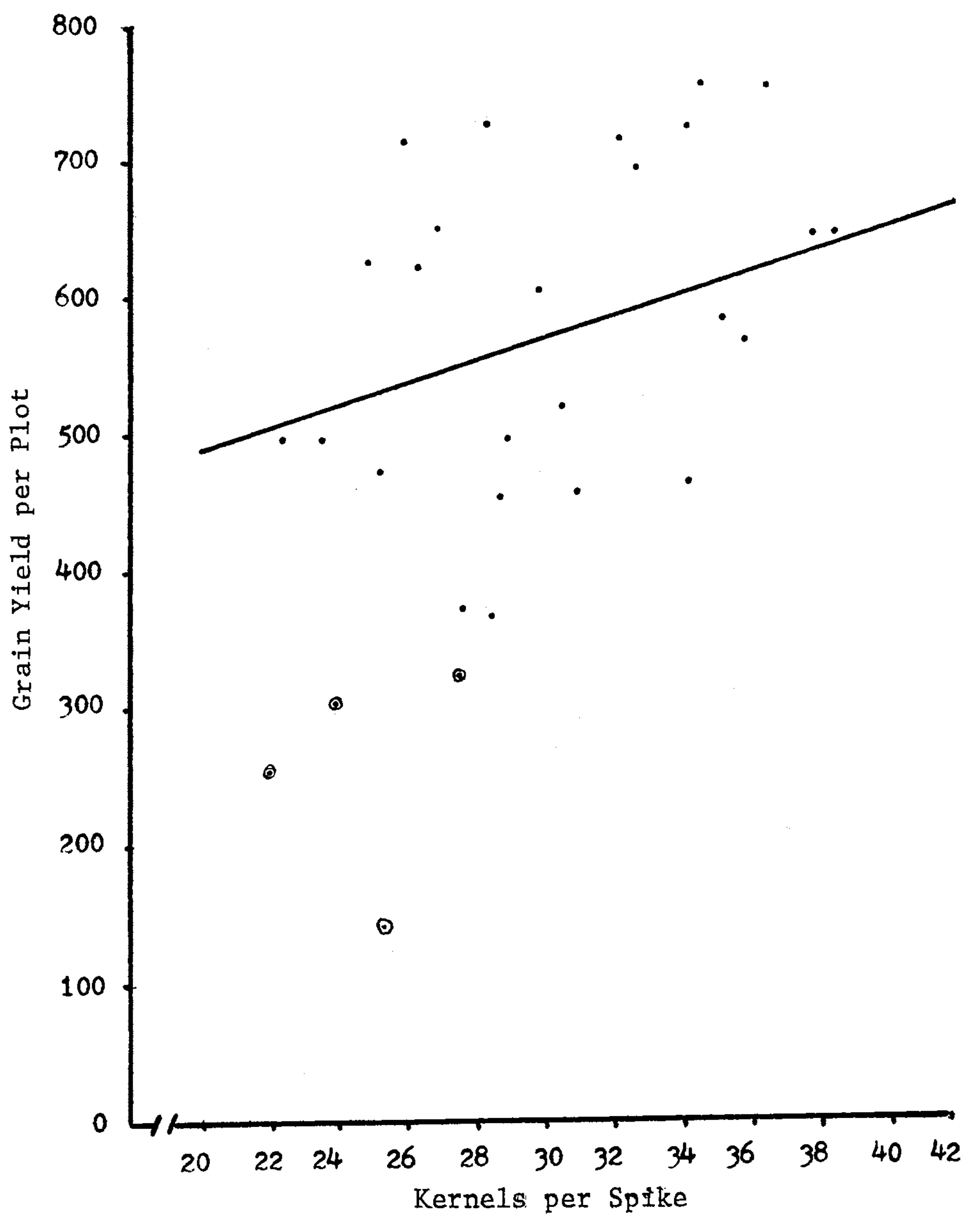

Figure 6. Regression of Grain Yield on Kernels per Spike. (Varieties whose points are not circled were eliminated when calculating the regression line).

CHAPTER V

SUMMARY AND CONCLUSION

The study was conducted on the Fifth International Winter Wheat performance nursery which was grown at the Agronomy Research Station, Stillwater, Oklahoma. The nursery consisted of 29 winter wheat varieties and one spring wheat variety (Lerma Rojo 64). The varieties originated from different countries. The objectives of this study were: (1) to determine the relative importance and relationship between grain yield, yield components, and structure above flag leaf node on winter wheat varieties, and (2) to evaluate the varieties in the nursery for yield components and other plant and seed characters under Stillwater conditions. The varieties were planted in a randomized complete block design with four replications. Each variety was planted in a plot of four rows 3.0 m long spaced 30 cm apart. The characters studied were: grain yield, number of tillers per unit area, kernels per spike, kernel weight, flag leaf area, flag leaf length, flag leaf width, flag leaf sheath length, peduncle length, peduncle area, chaff weight, percent grain protein, plant height, and heading date. Some other plant characters were also evaluated such as total dry matter, winterkill, lodging, maturity date, rust severity, and powdery mildew. Statistical analyses were carried out on 25 varieties with the spring wheat and four varieties which headed extremely late being excluded from the analysis.

The analysis of variance of all characters under the study showed that varieties were different ($P<.01$) for all the characters studied; therefore, the nursery was suitable with presumed different genetic make up for most of the traits, for the purpose of this study. There was no significant difference among the top seven yielding varieties for yield at 5% Duncan multiple range test. Golden Valley (Zg 5994/64) produced the highest yield ranking 8th, 5th and 18th, respectively, for kernel weight, kernel per spike, and tillers.

The data showed that among the yield components, kernel weight was the most important in terms of its influence on grain yield and tiller number the least. Most high yielding varieties had high kernel weight. The low-yielding varieties were mostly late, and their maturity was hastened by hot dry wind.

A highly significant positive correlation between yield and seed weight and significant positive correlation between yield and peduncle length was obtained. Yield was highly negatively correlated to percent protein and days to heading. Yield was positively related to kernels per spike, flag leaf area, flag leaf width, and chaff weight, but none of these correlations were significant. A non-significant negative association of yield with tillers per area, flag leaf length, and plant height was obtained.

Most of above flag leaf photosynthetic parts were positively assoicated with grain yield. Tall and late varieties generally did not produce high yield as the data showed a negative relationship of these characters with yield under study. While the results of this one year study are preliminary in nature the findings showed that consideration of the above flag leaf photosynthetic area and a good balance of yield components with more emphasis on seed weight might be helpful in selecting for increased yield.

LITERATURE CITED

1. Adams, M. W. 1967. Basis of yield component compensation in crop plants with special reference to field bean, Phaseolus vulgaris. Crop Sci. 7:505-510.

2. Adams, M. W. and J. E. Grafius. 1971. Yield component compensation alternative interpretations. Crop Sci. 11:33-35.

3. Archbold, H. K. 1942. Physiological studies in plant nutrition. XIII, Experiments with barley on defoliation and shading of the ear in relation to sugar metabolism. Ann. Bot. (N.S.) 6:487-531.

4. Asana, R. D. and V. S. Mani. 1950. Studies in physiological analysis of yield, varietal differences in photosynthesis in the leaf, stem and ear of wheat. Physiol. Plant. 3:22-38.

5. Austenson, N., and P. D. Walton. 1970. Relationship between initial seed weight and mature plant characters in spring wheat. Can. J. Plant. Sci. 50:53-58.

6. Baker, R. J. and P. L. Dyck. 1974. Combining ability for yield of synthetic hexaploid wheats. Can J. Plant Sci. 54:235-239.

7. Binghham J. 1967. Investigations on the physiology of yield in winter wheat by comparison of varieties and by artificial variation in grain number per ear. J. Agr. Sci. 68:411-422.

8. Borojevic, S. 1972. Utilization of the genetic potential of high-yielding wheat varieties. Z. Pflanzenzuchtg. 68:1-17.

9. Carr, D. J. and I. F. Wardlaw. 1965. The supply of photosynthetic assimilate to the grain from the flag leaf and ear of wheat. Aust. J. Biol. Sci. 18:711-719.

10. Donald, C. M. 1968. The breeding of crop ideotypes. Euphytica 17:385-403.

11. Doodson, J. K., J. G. Manners and A. Myers. 1964. Some effects of yellow rust (Puccina striiformis) on the growth and yield of spring wheat. Ann. Bot. (N.S.) 28:459-472.

12. Engledow, F. L., and S. M. Wadham. 1923. Investigation on yield in the cereals. Part I. J. Agr. Sci. 13:390-439.

13. Enyi, B. A. C. 1962. The contribution of different organs on grain weight in upland and swamp rice. Ann. Bot. (N.S.) 26:529-531.

14. Evans, L. T. and H. M. Rawson. 1970. Photosynthesis and respiration by flag leaf and components of the ear during grain development in wheat. Aust. J. Biol. Sci. 23:245-251.

15. Faris, D. G. 1974. Yield development in four isogenic lines differing in awn length. Can. J. Plant Sci. 54:315-322.

16. Fonseca, S. and F. L. Patterson. 1968. Yield component heritabilities and interrelationships in winter wheat (Triticum aestivum L.). Crop Sci. 8:614-617.

17. Grafius. J. E. 1956. Components of yield in oats, a geometrical interpretation. Agron. J. 48:419-423.

18. Grafius. J. E. 1960. Does overdominance exist for yield in corn? Agron. J. 352-361.

19. Grafius. J. E. and L. B. Okoli. 1974. Dimensional balance among yield components and maximum yield in a 8 x 8 diallel of barley. Crop Sci. 14:353-355.

20. Grundbacher, F. J. 1963. The physiological function of the cereal awn. Bot. Rev. 29:366-381.

21. Hsu, P. and P. D. Walton. 1971. Relationship between yield and its components and structures above the flag leaf node in spring wheat. Crop Sci. 11:190-193.

22. Johnson, V. A., J. W. Schmidt, and W. Mekasha. 1966. Comparison of yield components and agronomic characters of four winter wheat varieties differing in plant height. Agron. J. 58: 538-441.

23. Johnson, V. A., K. J. Biever, A. Haunold, and J. W. Schmidt. 1966. Inheritance of plant height, yield of grain, and other plant and seed characteristics in a cross of hard red winter wheat (Triticum aestivum L.). Crop Sci. 6:336-338.

24. Kjak, J. L. and R. E. Witters. 1974. Physiological activity of awns in isolines of Atlas barley. Crop Sci. 14:243-247.

25. Knott, D. R. and B. Talukdar. 1971. Increasing seed weight in wheat and its affect on yield, yield components, and quality. Crop Sci. 11:280-283.

26. Kriedemann, P. 1966. The photosynthetic activity of the wheat ear. Ann. Bot. (N.S.) 30:349-363.

27. Langer, R. H. M. 1959. Growth and nutrition of timothy (Phleum pratense) IV. The effect of nitrogen, phosphorus and potassium supply on growth during the first year. Ann. Appl. Biol. 47:211-221.

28. Langer, R. H. M. 1967. Physiological approaches to yield determination in wheat and barley. Field Crop Abstr. 20:101-105.

29. Last, F. T. 1962. Analysis of the effects of Erysiphe graminis on the growth of barley. Ann. Bot.(N.S.) 26:279-289.

30. Lupton, F. G. H. and M. A. M. Ali. 1966. Studies on photosynthesis in the ear of wheat. Ann. Appl. Bio. 57, 281-286.

31. McNeal, F. H. 1960. Yield components in Lemhi x Thatcher wheat cross. Agron. J. 52:348-349.

32. McNeal, F. H., E. P. Smith and M. A. Berg. 1974. Plant height, grain yields and yield component relationships in spring wheat. Agron. J. 66:575-578.

33. Monteith, J. L. 1966. Analysis of microclimate in cereals and grasses. In "The growth of cereals and grasses." ed. Milthorpe and Ivins. Butterworths, London, pp. 123-137.

34. Nass, G. H. 1973. Determination of characters for yield selection in spring wheat. Can. J. Plant Sci. 53:755-762.

35. Niciporovic, A. A. 1960. Photosynthesis and the theory of obtaining high crop yields. Field Crop Abstr. 13:169-175.

36. Palaniswamy, K. M. and K. A. Gomez. 1974. Length-width method for estimating leaf area of rice. Agron. J. 66:430-433.

37. Pendleton, J. W. and R. O. Weibel. 1965. Shading studies on winter wheat. Agron. J. 57:292-293.

38. Quinlan, J. D., and G. R. Sagar. 1965. Grain yield in two contrasting varieties of spring wheat. Ann. Bot. 29, 683-697.

39. Rawson, H. M., and G. Hofstra. 1969. Translocation and remobilization of ^{14}C assimilates at different stages by each leaf of the wheat plant. Aust. J. Biol. Sci. 22:321-331.

40. Ryle. G. J. A. 1966. Physiological aspects of seed yield in grasses. In "The growth of cereals and grasses." ed. Milthorpe and Ivins. Butterworth, London. pp. 106-117.

41. Saghir, A. R., A. R. Khan and W. W. Worzella. 1968. Effects of plant parts on the grain yield, kernel weight, and plant height in wheat and barley. Agron. J. 60:95-97.

42. Sharma, D. and D. R. Knott. 1964. The inheritance of seed weight in a wheat cross. Can. J. Gent. Cytol. 6:419-425.

43. Singh, I. D. and N. C. Stoskopf. 1971. Harvest index in cereals. Agron. J. 63:224-226.

44. Smocek, J. 1969. A contribution to the analysis of associations between economic yield components and four morpho-physiological subcharacters in winter wheat. Bioloiga. Pl. 260-269.

45. Sun, P. L. F., H. L. Shands and R. A. Foresberg. 1972. Inheritance of kernel weight in six spring wheat crosses. Crop Sci. 12:1-5.

46. Takahashi, R. and S. Yasuda. 1971. International barley genetic symposium. p. 389. Washington State University Press. Pullman, Washington.

47. Tanner, J. W., C. J. Gardner, N. C. Stoskopf, and E. Reinbergs. 1966. Some observations on upright-leaf-type small grains. Can. J. Plant Sci. 46:690.

48. Thorne, G. N. 1966. Physiological aspects of grain yield in cereals. In "The growth of cereals and grasses". Edited by F. L. Milthorpe and J. D. Ivins. Butterworths, London. pp. 88-105.

49. Voldeng, H. D., and G. M. Simpson. 1967. The relationship between photosynthetic area and grain yield per plant in wheat. Can. J. Plant Sci. 47:359-365.

50. Walton, P. D. 1969. Inheritance of morphological characters associated with yield in spring wheat. Can. J. Plant Sci. 49:587-596.

51. Watson, D. J. 1958. The dependence of net assimilation rate on leaf area index. Ann. Bot. (N.S.) 22:37-54.

52. Welbank, P. J., S. A. W. French and K. J. Witts. 1966. Dependence of yields of wheat varieties on their leaf area duration. Ann. Bot. (N.S.) 30:291-229.

APPENDIX

TABLE X

MEANS AND RANK FOR GRAIN YIELD OF THIRTY
WINTER WHEAT VARIETIES

Variety No.	Rank	Yield per plot in (gms) Rep. I.	Rep II.	Rep. III.	Rep. IV.	Variety Mean	Yield kg/ha	Yield lbs/ac
1	7	670	648	803	663	696.00	4682	4177
2	8	657	679	633	634	650.75	4377	3905
3	10	557	628	716	694	648.75	4364	3893
4	24	389	444	354	301	372.00	2502	2232
5	23	460	486	424	442	453.00	3047	2718
6	19	482	506	510	490	497.00	3343	2982
7	1	764	688	706	880	759.50	5109	4558
8	15	464	510	532	579	521.25	3506	3128
9	20	468	504	511	448	482.75	3247	2897
10	28	224	203	210	306	255.75	1720	1535
11	5	728	681	744	710	715.75	4814	4296
12	26	268	380	348	292	322.00	2166	1932
13	9	629	592	719	658	649.5	4369	3898
14	27	267	306	349	280	300.5	2021	1803
15	2	680	786	788	771	756.25	5087	4539
16	11	650	651	616	595	628.00	4224	3769
17	3	776	587	750	800	728.25	4899	4371
18	15	540	520	555	544	539.75	3631	3239
19	25	390	320	384	381	368.75	2430	2213
20	22	433	455	456	482	456.50	3071	2740
21	21	450	492	506	408	464.00	3121	2784
22	29	241	140	158	190	182.25	1226	1093
23	12	622	616	628	824	622.50	4187	3736
24	4	732	712	742	718	726.00	4884	4357
25	6	704	697	773	685	714.75	4808	4290
26	17	562	586	324	518	497.50	3346	2986
27	14	600	524	560	598	570.50	3838	3424
28	13	580	588	628	832	607.00	4083	3643
29	30	164	138	78	210	147.50	992	885
30	18	524	494	455	517	497.50	3346	2986
LSD 0.01						95.97		
0.05						72.30		

TABLE XI

MEANS OF YIELD COMPONENTS AND SOME CHARACTERS FOR TWENTY-NINE WINTER WHEAT VARIETIES

Var.	Number of Tillers/ 762 cm^2	No. of Seed per head	Weight of 200 seeds (gm)	% Grain Protein	No. of Days to 75% Heading 1/	Days to Maturity 2/	Height (cm)	Lodging (%)
1.	45.50	32.8	6.78	11.7	113.7	150.7	96.7	50.0
2.	58.50	26.9	6.38	13.5	130.2	163.2	116.0	4.0
3.	34.50	38.0	6.15	12.6	112.5	151.2	78.0	0
4.	54.00	27.7	4.08	13.3	130.0	162.7	80.2	0
5.	49.75	28.8	5.53	15.5	134.0	166.5	107.7	0.5
6.	77.50	22.0	5.00	13.9	126.7	160.0	119.5	2.0
7.	48.00	34.7	6.82	11.8	115.5	152.0	86.7	1.0
8.	55.50	30.6	5.24	11.8	126.2	162.5	110.5	18.7
9.	57.00	25.3	6.34	16.5	124.2	160.2	120.2	30.0
10.	47.50	22.0	5.04	16.3	138.0	168.2	99.5	1.0
11.	62.00	32.4	5.85	12.0	118.5	158.7	111.2	6.7
12.	45.50	27.6	4.86	14.6	133.5	166.7	99.0	2.2
13.	39.00	38.6	6.51	12.5	114.7	152.5	103.0	4.2
14.	48.00	24.0	4.65	15.0	138.2	168.0	109.5	3.5
15.	48.25	36.7	6.04	11.5	115.0	152.7	93.5	1.0
16.	72.50	24.9	6.31	13.0	124.0	159.2	1117.5	7.5
17.	48.50	28.4	7.86	12.3	118.5	155.7	105.7	8.0
18.	36.00	35.3	6.59	13.8	125.7	166.0	100.5	0
19.	58.50	28.6	4.99	14.8	135.7	166.2	112.7	6.7
20.	53.00	31.1	4.82	14.7	133.7	166.5	105.2	3.5
21.	47.25	34.2	5.12	16.3	136.5	169.2	102.5	0.5
22.*	-	-	-	-	-	-	-	-
23.	81.00	26.4	5.20	13.3	119.0	155.0	110.2	17.5
24.	39.00	34.3	7.86	13.9	116.0	153.0	98.5	2.2
25.	48.25	26.0	8.23	13.5	109.7	150.7	88.5	0

"TABLE XI CONTINUED"

Var.	Number of Tillers/ 760 cm^2	No. of Seed per head	Weight of 200 Seeds (gm)	% Grain Protein	No. Days to 75% Heading	Days to Maturity	Height (cm)	Lodging %
26.	44.25	29.1	7.44	15.7	112.2	150.2	109.0	60.0
27.	60.75	35.9	4.54	13.9	123.0	156.7	108.0	1.0
28.	54.50	29.7	6.83	14.3	122.5	158.0	120.2	6.7
29.	35.00	25.3	4.02	17.4	141.2	172.0	101.0	2.2
30.	55.00	23.6	6.15	13.6	125.0	162.0	119.7	6.7
LSD .01	7X9.10	3.47	0.62	1.55	1.23	1.51	5.74	19.22
.05	6.86	2.61	0.46	1.17	0.92	1.14	4.33	14.48

*Data were not recorded because of winterkill.

1/ Days after January 1 to heading.

2/ Days after January 1 to physiologic maturity, yellowing of peduncle.

TABLE XII

MEANS OF PHOTOSYNTHETIC COMPONENTS OF TWENTY-NINE WINTER WHEAT VARIETIES

Var. No.	Flag Leaf Length (cm)	Flag Leaf Width (cm)	Flag Leaf Area (cm^2)	Flag Leaf Sheath Length (cm)	Peduncle Length (cm)	Peduncle Diameter (mm)	Peduncle Area (cm^2)	Chaff Weight (mgs)
1.	20.4	1.45	21.9	17.1	16.2	238	12.2	221
2.	26.2	1.42	27.5	20.2	11.4	220	7.9	219
3.	21.7	1.67	26.8	16.4	13.2	311	12.9	228
4.	20.5	1.71	25.8	15.3	8.4	233	6.1	240
5.	24.8	1.70	31.1	21.5	8.0	223	5.6	189
6.	19.2	1.19	17.0	16.6	18.3	220	12.6	154
7.	20.9	1.76	27.3	15.7	13.4	256	10.8	231
8.	19.0	1.43	20.1	17.5	14.2	240	10.7	194
9.	19.1	1.43	20.3	18.9	12.5	207	8.2	172
10.	24.8	1.52	27.7	21.8	2.8	225	2.0	158
11.	23.4	1.59	27.6	18.7	16.8	252	13.3	262
12.	23.2	1.78	30.5	20.1	4.4	237	3.3	216
13.	23.4	1.68	29.0	18.8	17.5	303	16.7	197
14.	25.5	1.49	28.0	20.0	2.5	230	1.8	157
15.	21.5	1.57	25.0	16.8	15.0	270	12.7	204
16.	24.5	1.30	23.6	17.9	20.1	230	14.5	241
17.	22.8	1.48	24.9	20.6	15.4	260	12.6	222
18.	24.3	1.78	32.0	19.1	16.8	292	15.4	361
19.	25.7	1.37	26.1	21.5	2.3	226	1.6	156
20.	19.9	1.74	25.7	18.8	9.8	240	7.4	189
21.	22.7	1.72	29.0	20.9	6.4	232	4.6	227
22.*	-	-	-	-	-	-	-	-
23.	20.6	1.23	18.8	16.5	17.8	218	12.2	150
24.	21.7	1.86	29.8	16.3	12.6	282	11.2	249
25.	20.1	1.42	21.0	16.2	14.3	306	13.7	261

"TABLE XII CONTINUED"

Var No.	Flag Leaf Length (cm)	Flag Leaf Width (cm)	Flag Leaf Area (cm^2)	Flag Leaf Sheath Length (cm)	Peduncle Length (cm)	Peduncle Diameter (mm)	Peduncle Area (cm^2)	Chaff Weight (mgs)
26.	20.7	1.44	22.1	17.6	19.3	307	18.7	250
27.	21.9	1.42	22.9	17.2	13.6	222	9.5	222
28.	21.4	1.55	24.5	18.7	16.1	250	12.7	240
29.	22.1	1,79	29.4	21.6	3.2	200	2.0	189
30.	25.3	1.33	24.9	22.0	19.3	222	13.5	189
L.S.D. .01	2.35	0.14	3.46	1.03	2.89	20.3	2.63	47.23
.05	1.77	0.10	2.60	0.77	2.180	15.3	1.98	35.58

*Data were not recorded due to winterkill.

TABLE XIII

MEANS OF SOME CHARACTER OF TWENTY-NINE WINTER WHEAT VARIETIES

Variety No.	Total dry matter of 20 Tillers (gms)	% Winter-kill	Powdery Mildew (1-5)	Leaf Rust T[1]	Leaf Rust Sev.[2]	Leaf Rust Prev.[3]
1	51.5	7.5	1.5	4	15.0	99
2	52.1	0	1.0	4	10.0	99
3	55.5	11.2	1.0	4	40.0	99
4	40.1	0	1.5	4	50.0	99
5	51.4	0	2.7	4	21.0	99
6	35.8	0	2.0	4	35.0	99
7	54.6	0	1.5	4	1.0	15
8	45.3	0	3.0	4	11.0	99
9	51.3	2.5	1.0	4	10.0	99
10	44.0	0	3.0	4	60.0	99
11	54.1	0	2.2	4	12.0	99
12	48.5	0	1.0	4	80.0	99
13	60.9	1.2	1.0	4	30.0	99
14	45.3	0	1.7	4	50.0	99
15	53.5	0	1.0	4	3.5	99
16	46.2	0	1.2	4	1.5	55
17	54.2	0	2.0	4	2.0	44
18	63.7	12.5	2.2	4	1.0	99
19	43.1	0	1.7	4	50.0	99
20	51.6	0	1.0	4	50.0	99
21	51.7	0	2.0	4	3.5	99
22*	-	-	-	-	-	-
23	35.9	0	1.0	4	25.0	99
24	63.6	2.5	1.0	4	40.0	99
25	50.8	0	1.5	4	0.5	10
26	61.4	0	1.0	4	20.0	20
27	46.5	0	2.5	4	12.5	13
28	58.3	0	1.2	4	1.0	32
29	43.1	0	1.0	4	11.0	99
30	50.6	2.5	1.7	4	79.5	99
L.S.D. .01	6.74	3.01	0.93		34.59	
.05	5.08	2.26	0.72		25.52	

*Data were not recorded because of winterkill.

[1]Type 4 (susceptible).

[2]Severity of disease infection in percentage.

[3]Prevelance, size and number of rust pustules.

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