GENETIC VARIATION OF SELECTED CHARACTERS AND THEIR RELATIONSHIPS TO PRODUCTIVITY IN WHEAT (*TRITICUM AESTIVUM* L.)

By

GHULAM SARWAR IBRAM

Bachelor of Science

Kabul University

Kabul, Afghanistan

1977

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
May, 1985

GENETIC VARIATION OF SELECTED CHARACTERS AND THEIR RELATIONSHIPS TO PRODUCTIVITY IN WHEAT (TRITICUM AESTIVUM L.)

Thesis Approved:

Owen G. Merkle
Thesis Adviser

Richard Johnson

Dean of the Graduate College

Norman N. Durham

ACKNOWLEDGEMENTS

I am proud to express my thanks and gratefulness to the governments and nations of Germany, U.S.A., especially the administration of President Ronald Reagan, France, and Great Britain for giving me refuge in West Berlin following my defect from East Germany and for their love toward human-beings.

I am grateful to the Agronomy Department of Oklahoma State University for the opportunity and financial assistance which made this study possible.

I wish to thank Dr. Owen G. Merkle, my major adviser, for his assistance, guidance, patience, and encouragement throughout the preparation of this thesis. Special apreciation is extended to Dr. Henry Nguyen, my former major adviser, for his encouragement and guidance throughout my graduate work and for his assistance in the statistical analysis of the data. Sincere appreciation is expressed to the other members of my research committee, Dr. Richard C. Johnson and Dr. John F. Stone, for advise during my research work. I would like to thank Dr. Ronald W. McNew for his assistance in the interpretation of the data. Appreciation is expressed to Dr. Edward L. Smith and Dr. Emil E. Sebesta for council and encouragement and

thanks to all my colleagues in Small Grains for their assistance in my research work.

I would like to thank Mr. and Mrs. Robert L. Jones for their encouragement and financial assistance during my undergraduate and graduate study. Special thanks are extended to Mr. John Lowerison, a Peace Corp volunteer in Afghanistan, for his financial help, special assistance with English, and his encouragement throughout my study. Special appreciation is expressed to Cathy J. Raisbeck for her encouragement. Thanks are extended to Pat Birdsall for the typing of this thesis.

I thank Allah for enabling me to emigrate to the United States and giving me the perserverance in my graduate program.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

This thesis has been prepared in a format for publication in Crop Science. The manuscript appears as it will be submitted to the journal for publication, except for modifications to comply with publication standards.

Genotype x environment interactions are of considerable importance in wheat breeding programs. These interactions usually cause changes in the relative rankings of wheat (*Triticum aestivum* L.) genotypes over a series of environments, making it difficult for the breeder to select superior genotypes. However, stratification of environments can be used to reduce genotype x environment interactions. This procedure usually seems ineffective in the Southern Great Plains, which has unpredictable weather with high seasonal variation in any one locality. Development of stable genotypes possessing general adaptability can decrease the effects of genotype x environment interactions.

Breeding for high and stable yield potential is generally a major goal in wheat breeding projects. Economic yield can be increased by increasing biological yield or by partitioning more of the dry matter production into economic yield. Because economic yield as well as biological yield have low heritability, selection for these characters is difficult.

Identification of agronomic traits that lead to adaptability of wheat genotypes and incorporation of them as genetic traits to improved genotypes are the challenging tasks of wheat breeders in the Southern Great Plains. Characters such as single kernel weight, number of kernels per spike, number of spikes per square meter, and harvest index (the ratio of economic yield to biological yield) may be less affected by genotype x environment interactions and, therefore, more stable for selection than yield itself.

The major objective of this research was to determine genetic variation and genotype x environment interactions of selected agronomic characteristics and to study the relationship between these characteristics and adaptability of selected wheat genotypes in the Southern Great Plains.

CHAPTER II

REVIEW OF LITERATURE

The performance of wheat genotypes are usually not the same across a series of environments. Several investigators have reported the existence of significant genotype x environment interactions in wheat productivity (2, 6, 7, 8, 11, 15, 23, 24, 26). Campbell and Lafever (8) found that the interaction of genotypes with environment was of considerable importance in determining relative yields. Baker (4) found that all the different types of genotype x environment interactions, except the genotype x year interaction, were significant and important in wheat yield.

Eberhart and Russell (12) partitioned the genotype x environment interaction of each genotype into the variation due to the response of the genotype to varying environmental indexes (sums of squares due to regression) and the unexplainable deviation from the regression or the environmental index. For grain yield, Jatasra and Paroda (15) found that both the linear and non-linear components of genotype x environment interaction were significant and concluded that the prediction of performance across environments appeared to be difficult for this trait. Talukdar and Bains (26) from the study of genotype x environment interaction in a diallel cross of wheat found that linearity was more pronounced in grain yield. Brennan and Byth (7) examined the utility of a linear model for genotype x environment interaction and found the linear model explained less than 40% of the total genotype x environment interaction in wheat yield. Singh and Singh (23) reported that for a complex trait like grain yield a larger proportion (0.62) of the genotype x environment interaction was predictable.

Genotype x environment interactions decrease the efficiency of selection. In order to reduce the effects of genotype x environment interactions in areas having extreme variations in environment, scientists have recommended genotypes with broad adaptation (8, 12, 13, 16).

To determine stability and adaptability in barley cultivars, Finlay and Wilkinson (13) computed for each genotype a linear regression of individual grain yield on the mean grain yield of all genotypes at each site in each season. Genotypes characterized by regression coefficients of approximately 1.0 had average stability. Genotypes with regression coefficients of approximately one and high mean grain yield had general adaptabiliity and those with low mean grain yield had poor adaptability. Genotypes characterized by regression coefficients of more than one had below average stability, and genotypes characterized by regression coefficients of less than one had above average stability. Eberhart and Russell (12) indicated that a desirable genotype is the one with a high mean grain yield ($\bar{y}$), unit regression coefficient (bi = 1.0) and the deviation from regression as small as possible ($S^2d \doteq 0$). Johnson, Shafer, and Schmidt (16) reported that the most acceptable genotypes of hard red winter wheat in the Central Plains of the United States, an area characterized by extreme variations in environment, are those with broad adaptation.

Grafius (14) emphasized that studies of individual yield components can ease the genetic explanation of yield stability and therefore are helpful to breeders to predict and determine the effects of the environment. Jatasra and Paroda (15) indicated that stability in grain yield appeared to be imparted by stability for the yield components. Talukdar and Bains (26) found that the high stability for grain yield shown by some parental lines appeared to be due to plasticity in some of the component and morphophysiological characters. They observed that the parental lines, stable for different characters, transmitted their stability to the maximum number of crosses in their arrays. They reported that tiller number and kernels per spike were the important homeostatic devices chiefly responsible for imparting stability to yielding ability.

Bains and Gupta (3) found that the populations of bread wheat which were otherwise low in stability for grain yield were in general more buffered for the component characters. They inferred that in a homeostatic genotype, the component characters may shift in a compensating manner to the changing environment in order to give consistent performance to the final character. If the component characters do not adjust themselves to a changed environment, the population will be less buffered for the final character.

From the study of several Indian and Mexican wheat varieties, Chaubey and Sastry (9) found that most cultivars were stable for days to flowering and number of spikes. They observed that medium height varieties were more stable than either tall or dwarf varieties. The number of spikes was the most influential yield component and breeding for stability of this trait might result in stable high yielding genotypes (9). Singh and Singh (24) found that high stability of tiller number per plant and plasticity for number of kernels per spike conferred highest stability for yield.

McNeal (19) indicated that of the various plant characters correlated with grain yield, only kernels per plant was highly associated among both F_2 plants and F_3 progenies. Spikes per plant and kernels per spike were more highly correlated with plant yield than was kernel weight.

Bhatt and Derera (5) indicated that the high correlation of harvest index of lines selected in one year with the grain yield and harvest index in the following year provided evidence for the usefulness of harvest index as a yield selection criterion.

CHAPTER III

MATERIALS AND METHODS

The experimental material consisted of 40 wheat genotypes with a wide range of observed adaptability under field conditions (Table I). These genotypes varied in productivity and drought tolerance. They were seeded in randomized complete blocks with three replications at Stillwater, Altus, and Goodwell, Oklahoma under rainfed conditions. Plots were four rows, 3.05 m long, with 0.30 m row spacings at all locations in both years except the 1983 nursery at Altus. The 1983 Altus nursery had five row plots and 0.23 m row spacing. Dates of planting were 19 October and 31 October for Stillwater, 21 December and 7 December for Altus, and 14 October and 27 October for Goodwell in 1982 and 1983, respectively. Seeding rate was 67 kg/ha at all locations.

At Stillwater 32 kg ammonium nitrate (NH_4NO_3) per hectare were applied on 1 March 1983 and 1 March 1984 as topdress. On 25 April 1983 and 14 May 1984 plots were sprayed with Bayleton to control fungal diseases. In order to control greenbugs at Stillwater, plots were sprayed with Malethion on 18 November 1983.

TABLE I

MEANS FOR YIELD, YIELD COMPONENTS, AND SEVERAL AGRONOMIC TRAITS OVER TWO YEARS AND THREE LOCATIONS

Genotype	I.D. No.	Grain Yield (kg/ha)	Spikes/ m^2	Kernels/ Spike	Mg/ Kernel	Harvest Index	Biomass (kg/ha)	Plant Height (cm)
Triplet	5408	2195	368	26	23.1	0.29	7374	89
Ashkof	6680	1383	448	20	18.1	0.21	6672	94
Sturdy	13684	2506	380	26	28.1	0.37	6601	68
CI 7126	7126	1999	366	24	23.9	0.28	7044	90
Akakawa		1856	305	24	33.1	0.26	7152	106
CI 8530	8530	1544	282	23	22.8	0.21	7011	100
Baca	15891	2625	508	23	26.7	0.34	7608	83
Turkey Sel	11735	2092	499	18	24.2	0.29	7089	86
Hope/Turkey	11966	2029	514	18	24.3	0.29	6843	86
Cheyenne/ Tenmarq	11972	1974	550	20	22.9	0.30	6494	80
Turkey 1069/ Cheyenne	11983	2465	445	23	26.9	0.33	7488	83
Turkey Sel	11984	2180	524	20	25.1	0.30	7198	83
Triumph	12132	2819	461	21	32.2	0.37	7418	82
Blue Jacket	12502	2350	383	22	28.5	0.29	8034	98
Newsar	12530	1012	374	21	30.8	0.26	7616	102
Clark R 169	12556	2107	327	23	32.1	0.27	7600	101
Roayl D 85	12558	1753	345	22	27.3	0.27	6558	95
Hope/Turkey/ Cheyenne	13182	2380	484	20	25.4	0.33	7215	83
CI 13898	13898	2703	349	27	29.6	0.37	7161	86
Blue Boy II	15281	2347	388	27	26.2	0.32	7132	76
Goens	4857	1966	329	23	28.6	0.29	6649	93
Turkey Sel	10096	1917	487	19	22.1	0.27	6840	85
Red Chief	12109	2381	434	21	30.1	0.30	7984	95
Tayland	12761	2136	327	25	30.2	0.29	7300	96
Ind 4126A 9-42-1	12799	1879	336	23	28.0	0.26	6925	94

TABLE I (Continued)

Genotype	I.D. No.	Grain Yield (kg/ha)	Spikes/ m^2	Kernels/ Spike	Mg/ Kernel	Harvest Index	Biomass (kg/ha)	Plant Height (cm)
NB67786	14061	2167	356	24	26.4	0.29	7262	89
Near Iso Pm I	14115	2356	405	24	27.4	0.32	7251	89
Centurk	15075	2629	562	25	22.1	0.35	7321	76
Cheyenne	8885	2202	458	21	25.0	0.30	7271	86
Kanking	12719	2602	446	20	30.8	0.32	8038	92
Ponca	12128	2455	536	19	27.4	0.30	7906	87
Triumph 64	13679	2705	433	21	31.4	0.37	7318	82
Scout 66	13996	2557	438	22	27.5	0.33	7577	85
Payne	17717	2878	520	25	25.9	0.36	7704	69
TAM W-101	15324	2848	377	23	33.7	0.37	7462	66
TAM 105	17826	2806	493	25	25.1	0.37	7504	69
Vona	17441	2765	502	28	23.3	0.38	6977	66
Newton	17715	2440	431	28	25.4	0.36	6656	69
Hawk		2641	418	29	28.2	0.38	6720	67
Chisholm	OK754615E	2976	415	26	30.4	0.42	7017	69
Grand Mean		2316	425	23	27.0	0.31	7225	85
L.S.D. (0.05)		203	72	2	1.4	0.01	529	3
C.V.		13.4	25.9	12.2	8.1	6.7	11.2	5.0

Additional data were recorded both years at Stillwater for anthesis date, flag leaf senescence, and physiological maturity. All date data were recorded as the number of days after 31 March. Anthesis date was recorded when about 50% of the spikes in a plot had extruded anthers. When about 75% of the peduncles in a plot turned yellow in color, physiological maturity was recorded. Flag leaf senescence was recorded when about 75% of the flag leaves in each plot were senesced. The difference between flag leaf senescence and anthesis dates measured flag leaf duration for each plot; while, the difference between physiological maturity and anthesis measured the grain filling period.

Plant height in each plot was measured after physiological maturity. Prior to harvest, the two middle rows of each plot were trimmed to 2.44 m. At Altus, three middle rows were trimmed to 2.44 m in 1984. Before harvest random subsamples for yield component comparisons were taken from 30 cm of one of the two middle rows of each plot. In 1984, at Altus, the subsamples were taken from one of the three middle rows. The two center rows of each plot were harvested on 1 July and 19 June at Stillwater, 27 June and 15 June at Altus, and 7 July and 10 July at Goodwell in 1983 and 1984, respectively. At Altus the three center rows of each plot were harvested in 1984. The dry bundles from each plot, which formed the biomass of that plot, were weighed before threshing to compute harvest index (the ratio of economic yield to biological yield). In each subsample, the number of spikes bearing kernels were counted for each subsample to estimate number of spikes per square meter (spikes/m^2). Grain yield of each subsample was weighed and then the total number of kernels of each subsample was counted with a seed counter to compute average number of kernels per spike (kernels/ spike) and weight per kernel (mg/kernel).

The statistical analysis of combined data for two years and three locations for genotype x environment interaction was carried out according to the model of Comstock and Moll (10) for grain yield, biomass, harvest index, plant height, and the three major components of yield-spikes/m^2, kernels/spike, and mg/kernel. For Stillwater, genotype x environment interaction for flag leaf duration, grain filling period, and anthesis was also analyzed. To analyze the stability of each trait, joint regression of all genotypes for that trait was utilized (12, 13, 21). To obtain information about the stability and adaptability of individual genotypes for each trait, the model proposed by Finlay and Wilkinson (13) was applied. In order to find the relative importance of each yield component, standard partial regression coefficients of individual components were computed, and to find the relationships of the traits with each other correlation coefficients were calculated (25).

CHAPTER IV

RESULTS AND DISCUSSION

Yield and Yield Components

Conventional analysis of variance (10) in which the environmental and genotype x environmental interaction effects have been separated into year, location, year x location, genotype x year, genotype x location, and genotype x year x location is presented in Table II. All mean squares were either significant or highly significant except for the genotype x year and genotype x year x location effects on spikes/m^2 which were non-significant.

Significant effects of the components of variance of environment on spikes/m^2, kernels/spike, mg/kernel, and grain yield per se, which are not unexpected in the Southern Great Plains, indicated that the mean performance of the genotypes for these traits differed over years, locations, years at the same location, and locations in the same year. Some reports (15, 16) have indicated highly significant effects of environment on mg/kernel, while others (9, 26) have reported highly significant mean squares of environment for kernels/spike. Since the wheat genotypes in this study were grown under rainfed condi-

TABLE II

MEAN SQUARES ON PLOT BASIS COMBINED OVER YEARS AND LOCATIONS

Source	df	Grain Yield (kg/ha)	Spikes/m²	Kernels/ Spike	Mg/ Kernel	Harvest Index x10^4	Biomass (kg/ha)	Plant Height (cm)
Year	1	137,787,056**	660,122**	110.5**	2,828.6**	2,180.57**	848,202,951**	28,552**
Location	2	94,483,278**	603,671**	1,641.9**	744.1**	92.19**	898,664,822**	68,657**
Year x Location	2	56,945,251**	48,956*	540.2**	1,212.1**	1,597.84**	346,141,195**	19,152**
Rep. (Year x Location)	12	468,678**	51,576**	61.9**	27.5**	40.99**	4,142,827**	168**
Genotype	39	2,597,728**	98,385**	145.0**	215.0**	401.05**	3,059,276**	2,094**
Genotype x Year	39	319,583**	11,495	13.0*	37.1**	31.18**	1,046,998*	201**
Genotype x Location	78	291,632**	17,661*	15.0**	13.7**	19.23**	1,052,103**	91**
Genotype x Year x Location	78	175,138**	13,710	17.7**	16.0**	14.32**	898,062*	51**
Error	468	96,823	12,158	7.9	4.8	4.44	655,851	18

*Significant at 0.05 level.
**Significant at 0.01 level.

tions, soil moisture differences may be the primary factor causing variation among the environments (18).

Highly significant mean squares for genotype indicate that the genotypes had different genetic potential for grain yield and its three major components in the years and locations of this study. The data are in agreement with previous reports (9, 15, 16) in the case of mg/kernel and with (9, 26) in the case of kernels/spike. Average grain yield over all combinations of years and locations, which formed six environments, ranged from 1383 kg/ha for Ashkof to 2976 kg/ha for Chisholm with a least significant difference (L.S.D.) of 203 kg/ha at the 0.05 probability level. Average spikes/m^2 ranged from 282 for CI 8530 to 562 for Centurk with an L.S.D. of 72 at 0.05 probability level. Chisholm produced 415 and Ashkof produced 448 spikes/m^2 over all six environments. Average kernels/-spike over all six environments ranged from 18 for Turkey Selection, C I 11735, and Hope/Turkey to 29 for Hawk with an L.S.D. of two kernels/spike. Ashkof produced 20 and Chisholm produced 26 kernels/spike. Average mg/kernel ranged from 18.1 for Ashkof to 33.7 for TAM W-101 with an L.S.D. of 1.4 at the 0.05 level of probability (Table I). The data indicated that mg/kernel was the major factor which caused Ashkof to be the lowest yielding among all genotypes and Kanking to produce significantly more average grain yield than the majority of the genotypes in this study.

Significant genotype x year interactions for grain yield, mg/kernel, and kernels/spike showed that the grain yield as well as these two components of yield behaved differently in the two years of study at individual locations. Significant mean squares of the effect of the genotype x location interaction on grain yield, kernels/-spike, mg/kernel, and spikes/m^2 revealed differential responses of the genotypes at the three locations in individual years. The highly significant effect of genotype x year x location interaction on grain yield, kernels/-spike, and mg/kernel indicated that the genotypes responded differently at the three locations in the same year and in the two years at the same location. Non-significant mean squares of genotype x year, and genotype x year x location for spikes/m^2 indicated tolerance of this character to environmental effects. It might be one of the major factors of adaptability which allows wheat genotypes to adjust to changing environments of the Southern Great Plains.

The joint regression analysis for grain yield, spikes/m^2, kernels/spike, and mg/kernel (Table III) indicated highly signficant mean squares of linear and residual components of genotype x environment interactions for all of these characters except spikes/m^2. For spikes/m^2 the effect of the residual component of genotype x environment interaction was highly significant, and the effect of the linear component of genotype x environment interaction was non-

TABLE III

MEAN SQUARES WITH YEAR X LOCATION AS ENVIRONMENT

Source	df	MS	%
GRAIN YIELD (kg/ha)			
Environment	5	29,376,274**	
Rep. (Environment)	12	156,226**	
Genotype	39	865,909**	
Genotype x Environment	195	83,541**	
Linear	(39)	126,046**	30
Residual	(156)	72,913**	70
Error	468	32,274	
SPIKES/M^2			
Environment	5	131,025**	
Rep. (Environment)	12	17,192**	
Genotype	39	32,795**	
Genotype x Environment	195	4,949*	
Linear	(39)	4,515	18
Residual	(156)	5,058**	82
Error	468	4,053	
KERNELS/SPIKE			
Environment	5	298.3**	
Rep. (Environment)	12	20.6**	
Genotype	39	48.3**	
Genotype x Environment	195	5.2**	
Linear	(39)	6.7**	26
Residual	(156)	4.8**	74
Error	468	2.7	
MG/KERNEL			
Environment	5	449.4**	
Rep. (Environment)	12	9.2**	
Genotype	39	71.6**	
Genotype x Environment	195	6.4**	
Linear	(39)	15.7**	49
Residual	(156)	4.0**	51
Error	468	1.6	

TABLE III (Continued)

Source	df	MS	%
HARVEST INDEX			
Environment	5	370.71**	
Rep. (Environment)	12	13.66**	
Genotype	39	133.68**	
Genotype x Environment	195	6.55**	
Linear	(39)	12.43**	38
Residual	(156)	5.08**	62
Error	468	1.48	
BIOMASS (kg/ha)			
Environment	5	222,520,999**	
Rep. (Environment)	12	1,380,942**	
Genotype	39	1,019,759**	
Genotype x Environment	195	329,822**	
Linear	(39)	220,749	13
Residual	(156)	357,090**	87
Error	468	218,617	
PLANT HEIGHT (cm)			
Environment	5	13,611**	
Rep. (Environment)	12	56**	
Genotype	39	698**	
Genotype x Environment	195	32**	
Linear	(39)	103**	64
Residual	(156)	15**	36
Error	468	6	

*Significant at 0.05 level
**Significant at 0.01 level

significant. In the case of grain yield, the data are in agreement with previous reports (3, 21). Some reports (15, 26) indicated highly significant effects of linear and residual components of genotype x environment interaction for kernels/spike and mg/kernel. For kernels/spike, highly significant linear and non-significant residual components of the genotype x environment interaction has been reported (9).

The highly significant linear component of the genotype x environment interaction provided difference among the regression of the genotypes on environmental indexes for grain yield, kernels/spike, and mg/kernel. The existence of different regression coefficients among the regression of these traits on environmental means for individual genotypes revealed the same results. The linear portions contained 30%, 18%, 26%, and 49% of the sums of squares of genotype x environment interactions for grain yield, spikes/m^2, kernels/spike, and mg/kernel, respectively. Genotype x environment interaction for yield, in which the major portion of the interaction can not be explained has been reported by Finlay and Wilkinson (13) in barley cultivars. The highly significant residual components of genotype x environment interactions revealed the unexplained portions of genotype x environment interactions. Since the sum of square due to regression explained 49% of the effect of genotype x environment interaction for mg/kernel, this character was more predictable than grain yield and kernels/spike. Because the effect of the linear portion of the genotype x evironment interaction for spikes/m^2 was non-significant, the predictability of the effect of genotype x environment interaction, whose genotype x location interaction portion was only significant, appears very difficult.

In order to determine the contribution of each of the three major yield components (spikes/m^2, kernels/spike, and mg/kernel) on grain yield, multiple regression of yield on the three major components (Table IV) was computed. Since the total value of standard partial regression coefficients of the three components is not equal to one, it indicated the negative correlation among some of the components and joint effect of the components on grain yield. Therefore, it was difficult to estimate the percentage of the contribution of each yield component on grain yield independently. It was concluded that each yield component should be considered in connection with the rest.

Phenotypic correlations (Table V) among yield and yield components indicated significant linear correlation among these traits. The correlation coefficients between grain yield and spikes/m^2, kernels/spike, and mg/kernel were 0.36, 0.39 and 0.38, respectively. A report (19) indicated that spikes/plant and kernels/spike were more highly correlated with plant yield than kernel weight. Mg/kernel had a highly significant negative correlation with spikes/m^2 and a non-significant correlation with kernels/spike in this

TABLE IV

MULTIPLE REGRESSION OF YIELD COMPONENTS ON YIELD

Variable	df	Parameter Estimate	Standard Error	Standardized Estimate
Intercep	1	-3636.5	448.3	0.00
Spikes/m^2	1	4.5	0.4	0.88
Kernels/Spike	1	84.7	9.8	0.63
Mg./Kernel	1	76.9	8.4	0.70

TABLE V

PHENOTYPIC CORRELATIONS ON MEAN BASIS OVER YEARS AND LOCATIONS

	Biomass	Grain Yield	Harvest Index	Plant Height	Spikes/ M^2	Kernels/ Spike	Mg/ Kernel
Biomass		.41**	.09	.20	.11	-.18	.39*
Grain Yield			.94**	-.71**	.36*	.39*	.38*
Harvest Index				-.83**	.33*	.49**	.30
Plant Height					-.51**	.43**	.14
Spikes/M^2						-.35*	-.43**
Kernels/ Spike							.10

*Significant at .05 level
**Significant at .01 level

study. The highly significant negative association between mg/kernel and spikes/m^2, whose relationship could be explained by a linear correlation of 43%, indicated that increasing the quantity of one of these components would cause a reduction in the other. Furthermore, it depicted certain limitations on either source or sink. The non-significant correlation among mg/kernel and kernels/spike indicated that these two traits did not affect each other mutually. The significant negative correlation between kernels/spike and spikes/m^2 showed that increasing kernels/spike would decrease spikes/m^2 or vice versa. Linear correlation could explain 35% of the relationship between kernels/spike and spikes/m^2 and 65% of that relationship could not be accounted by linear correlation. It was concluded that increasing mg/kernel would effectively increase adaptability of wheat genotypes in the Southern Great Plains if spikes/m^2 remain unchanged. Some reports (6, 24) indicated that the components of yield had a direct effect on the stability and responsiveness of yield.

In this research, none of the genotypes were acceptable according to Eberhart and Russell (12). However, Chisholm had the highest average grain yield among all genotypes, a regression coefficient not significantly different from one but also the highest deviation from regression (S^2d) among all genotypes. Turkey Selection, CI 11984, had the lowest residual among all 40 wheat genotypes and a slope of unity, but it could not be considered an acceptable genotype because it had an average grain yield significantly less than the mean grain yield over all six environments. The highest deviation from regression for Chisholm, which also had the highest standard error, indicated specific instability and might be due to specific genotype x environment interaction (17). The occurance of large value of S^2d for Chisholm should be investigated.

According to Finlay and Wilkinson (13) Akakawa, Newsar, Royal D 85, with regression coefficients of significantly less than one had above average stability, and Payne with a regression coefficient of significantly more than one had below average stability. The other genotypes with regression coefficients not significantly different from one had average stability.

Akakawa, Newsar, and Royal D 85 had resistance to environmental changes. None of these genotypes produced significantly higher than average grain yield in any environment and thus were poorly adapted to all six environments. Akakawa produced above average mg/kernel in six environments, Newsar in four environments,and Royal D 85 in one environment. Failure of these genotypes to produce above average grain yield in any environment indicated relatively less contribution of spikes/m^2 or kernels/spike or both of these yield components.

Although, Payne ranked second in yielding ability, it failed to produce significantly higher than average grain yield at Goodwell in 1984. Since the response of Payne to environmental changes was above average, it may produce below average grain yield in poor environments. Payne can, therefore, be described as being specifically adapted to high yielding environments, which is the characteristic of genotypes with regression coefficients significantly more than one. Payne exhibited significant regression coefficients for all the components of yield. Since none of the yield components of Payne were buffered against environmental changes, the genotype was unable to adjust to to environmental variation.

Chisholm and TAM W-101 appeared the best of all genotypes in this study because they had average stability and produced significantly above average grain yield in all environments except during 1983 at Goodwell. These genotypes were generally adapted to all environments except one. Chisholm produced above average mg/kernel in three environments and TAM W-101 in six environments. Chisholm had a regression coefficient not significantly different from one for mg/kernel and TAM W-101 regression coefficient not significantly different from one for kernels/spike and mg/kernel. Adaptability of Chisholm appears to originate from the buffering characters of kernels/spike and spikes/m^2 and the responsiveness and predictability of mg/kernel. The buffering characteristic of spikes/m^2 and the responsiveness and predictability of kernels/spike and mg/kernel gave TAM W-101 adaptability. The other genotypes with average stability produced significantly more than average grain yield either in less than five environments or none of the environments. It was concluded that finding genotypes to satisfy the requirements of adaptability is extremely difficult in the Southern Great Plains. Finding genotypes that satisfy the requirements of Eberhart and Russell (12) appears more difficult than those that will satisfy the requirements of Finlay and Wilkinson (13). It might be possible to find a genotype which produces significantly above average grain yield in all environments but because of the extreme environmental variations of the Southern Great Plains it might not exhibit the lowest deviation from regression ($S^2d=0$).

Harvest Index, Biomass, and Plant Height

Conventional analysis of variance (10) indicated that all mean squares for harvest index, biomass, and plant height were either significant or highly significant (Table II). The significant genotype effect indicates genetic differences for these traits. Average harvest index, biomass, and plant height of the genotypes, in this study, ranged from 0.21 to 0.42, 6494 to 8038 kg/ha, and 66 to 106 cm with L.S.D. of 0.01, 529 kg/ha, and three cm, respecively. The significant effect of genotype x year interaction on harvest index, biomass, and plant height indicated that the genotypes ranked differently in the two years of study at individual locations for these traits. The highly significant mean squares of genotype x location interaction revealed that harvest index, biomass, and plant height of the genotypes responded differently at the three locations in individual years. The significant effect of genotype x year x location interaction on harvest index, biomass, and plant height indicated differential responses of the genotypes at the three locations in the same year and in the two years at the same location for these traits.

Partitioning of genotype x environment interaction sum of squares into their components (Table III) indicated highly significant effects of linear and residual components except for the linear component of genotype x environment interaction for biomass. The linear effect of genotype x environment interaction on biomass was not significant. The highly significant effect of the linear component of the genotype x environment interaction on harvest index and plant height indicated different coefficients of regression of the mean of individual genotypes on the mean of all genotypes at each location in each year. Furthermore, it indicated the predictability of the effect of genotype x environment interaction on harvest index and plant height at the locations and in the years of this study. Talukdar and Bains (26) also reported highly significant environment, genotype, genotype x environment interaction, and the two components of genotype x environment interaction variances for harvest index. Chaubey and Sastry (9) indicated highly significant effects of genotype, environment, genotype x environment interaction, linear and residual components of genotype x environment interaction on plant height. However, the highly significant effect of the linear component of genotype x environment interaction on harvest index, in this study, indicated that although the variation due to the effect of genotype x environment interaction was predictable, it only accounted for 38% of the total variation. The high percentage for residual made a large portion of the effect of genotype x environment interaction on harvest index unexplainable. Predictability of the effect of genotype x environment interaction on harvest index appeared to be 8% more than the predictability of the effect of this component on grain yield. These data indicate that harvest index might be more predictable than grain yield in a series of environments. In the case of biomass, which had a non-significant linear component of genotype x environnment interaction, the residual contained 87% of the effect of genotype x environment interaction. The variation due to the effect of genotype x environment interaction on biomass appeared mostly unpredictable and unexplainable. In the case of plant height, the linear component could explain 64% of the effect of genotype x environment interaction. This large portion of genotype x environment interaction due to the effect of the linear portion indicated more predictability of the responses of plant height to different environments than any other traits studied.

The correlations of harvest index and biomass with grain yield were highly significant, and the correlation of harvest index with biomass was non-significant (Table V). The correlation of grain yield with harvest index and biomass accounted for 0.94 and 0.41, respectively. A report (20) indicated that the mean biological yield, grain yield, and harvest index of F_4 lines selected on the basis of high harvest index were greater than for those from F_2 plants with low harvest index. Plant height was highly and negatively correlated with grain yield and harvest index and non-significantly correlated with biomass in this study. The correlation coefficents of plant height with grain yield and harvest index were -0.71 and -0.83, respectively. Significant negative correlation of plant height with grain yield,which were also reported previously (19, 22),revealed that the proportion of variation in grain yield was partially accounted for by plant height. Allan (1) reported the existance of significant negative correlation between harvest index value and culm height. In this study, plant height exhibited higher correlation with harvest index than with grain yield.

To determine more of the effect of plant height, the wheat genotypes have been grouped into short, medium, and tall classes. Wheat genotypes with average heights of 79 cm or less were considered short and those with average height of 93 cm or more were placed in the tall class. The genotypes with heights between the short and tall classes were considered medium height. The ten highest yielding genotypes, in this study, were in the short or medium classes and the ten lowest yielding wheat genotypes were in the tall or medium classes. The rest of the genotypes were either tall, medium, or short. A similar relationship existed between harvest index value and plant height, but this relationship appeared more straightforward than the relationship between plant height and grain yield. Although the effects of plant height on grain yield appeared clear, biomass did not show any significant correlation with plant height. A reasonable conclusion might be that while short plant height might have some effects on productivity through lodging resistance and response to agricultural practices, the high correlation coefficients of plant height with harvest index and grain yield may be partly due to recent emphasis on the development of productive short statured genotypes. The higher correlation of plant height with harvest index than with grain yield indicated simultaneous selection for harvest index and plant height. Since plant height did not have a significant correlation with biomass, selection for short statured wheat genotypes might have some superiority over the tall genotypes.

Regression analyses for individual wheat genotypes indicated that short statured genotypes tended to exhibit above average stability for height while tall statured genotypes had average or below average stability. The tall and short classes consisted of 10 and 11 genotypes, respectively. The ten highest yielding wheat genotypes except for Triumph and Triumph 64 were short statured and exhibited above average stability for height. Triumph and Triumph 64, with medium height, exhibited average stability for height. Adaptability of Chisholm and TAM W-101 might be related to their above average stability for height. Above average stability for height might be a useful factor to develop wheat genotypes with a wide range of adaptability in the Southern Great Plains.

Eight percent more predictability (38% vs. 30%) of the effect of genotype x environment interaction on harvest index in comparison with grain yield and the highly significant correlation coefficient of 0.94 between grain yield and harvest index indicated that harvest index would be more useful than grain yield to predict the performance and adaptability of wheat genotypes in a series of environments. Analysis of stability parameter estimates for harvest index values of the genotypes showed general adaptability for Chisholm, CI 13898, and Sturdy in this study. However, Chisholm failed to produce above average grain yield in one environment, and CI 13898 and Sturdy only produced above average grain yield in three environments. Several other genotypes had high average harvest index values but low average grain yield in these six environments. Most of the recent genotypes showed more improvement in harvest index values.

Analysis of stability parameter estimates for biomass showed that only Blue Jacket and Red Chief produced significantly above average biomass in more than two environments. It indicated that adaptability of the genotypes in a series of environments was primarily due to improvements in the harvest index values. Chisholm, which showed specific instability also had the highest deviation from regression for biomass, and Turkey Selection, CI 11984, which had the lowest residual for grain yield, also had the lowest residual for biomass. The failure of Chisholm to produce above average grain yield in one environment might be due to the factor or factors which were involved before the grain filling period. In the search for adapted wheat genotypes, biomass should also be considered because examining harvest index values alone might fail to predict genotype performance over a series of environments.

Summary

Forty wheat genotypes with a wide range of observed adaptability under field conditions were planted in randomized complete blocks with three replications to determine genetic variation and genotype x environment interactions of yield, yield components, harvest index, biomass, and plant height and to study the relationships between these characteristics and adaptability over two years (1982-83 and 1983-84) at three locations in Oklahoma (Stillwater, Altus, and Goodwell).

Significant effects of genotype, and genotype x environment interaction on all studied traits and the three components of yield, spikes/m^2, kernels/spike, and mg/kernel were observed. Conventional analysis of variance indicated significant effects of all components of genotype x environment interactions for all agronomic traits except for spikes/m^2. Spikes/m^2 only showed significant variance for genotype x location interaction. Tolerance of spikes/m^2 to environmental effects might be one of the major factors of adaptability which allows wheat genotypes to adjust to changing environments in the Southern Great Plains. The effect of the linear component was significant for grain yield, kernels/spike, mg/kernel, harvest index, and plant height and contained 30%, 26%, 49%, 38%, and 64% of the effects of genotype x environment interactions on these traits, respectively. The remainder contained the unexplainable parts of genotype x environment interactions. The effect of the genotype x environment interaction on plant height was more predictable than for other traits. Harvest index showed 8% more predictability than grain yield, indicating that harvest index might be more predictable than grain yield in a series of environments. Standard partial regression coefficients of the three components indicated a joint effect of the component on grain yield. Mg/kernel had a highly significant negative correlation with spikes/m^2 but was not correlated with kernels/spike. Increasing mg/kernel would effectively increase adaptability of wheat genotypes in the Southern Great Plains if spikes/m^2 remain constant. Adaptability of wheat genotypes appears to originate from the buffering character of either spikes/m^2 or spikes/m^2 and kernels/spike together and the responsiveness of either mg/kernel and kernels/spike or mg/kernel alone in the Southern Great Plains. Finding genotypes to satisfy the requirements of adaptability is extremely difficult in the Southern Great Plains because of environmental variations. Finding genotypes that satisfy the requirements of Eberhart and Russell appears more difficult than those that will satisfy the requirements of Finlay and Wilkinson. However, eight percent more predictability of the effect of genotype x environment interaction on harvest index in comparison with grain yield and the highly significant correlation coefficient of 0.94 between grain yield and harvest index indicted that harvest index would be a more useful agronomic trait to predict the performance and adaptability of wheat genotypes in a series of environments, but harvest index values failed to predict general adaptability of wheat genotypes in the Southern Great Plains. Linear correlation covered shortcomings of harvest index. The search for adaptable wheat genotypes should consider biomass because studying harvest index values without regard to biomass might fail to predict the performance of the genotypes in a series of environments. Plant height had highly significant negative correlations with grain yield and harvest index. While plant height might have some effects on productivity of wheat genotypes, the existance of large correlation coefficients of plant height with harvest index and grain yield might be partly due to more emphasis on selection of short statured productive genotypes. Since plant height did not have significant correlation with biomass, selection for short statured genotypes of wheat might have some superiority over the tall genotypes. Because the highest yielding genotypes had above average stability for height, above average stability for height might be a useful factor in developing wheat genotypes with a wide range of adaptability in the Southern Great Plains.

CHAPTER V

ANTHESIS, FLAG LEAF DURATION, AND GRAIN FILLING PERIODS

The effects of year and genotype were highly significant on anthesis date, flag leaf duration, and grain filling period at Stillwater during the two years of study. The mean square due to the effect of genotype x year interaction was only significant for flag leaf duration (Table VI). Talukdar and Bains (26) reported highly significant mean squares due to the effects of genotype, environment, and genotype x environment interaction on anthesis date. Chaubey and Sastry (9) only found significant effects of genotype and genotype x environment interaction on anthesis date and genotype and environment on maturity date.

The highly significant mean squares of genotype indicated potential genetic differences among some of the genotypes for anthesis date, flag leaf duration, and grain filling period. Average anthesis date, flag leaf duration, and grain filling period at Stillwater during the two years of study, ranged from 38 to 55, 18 to 27, and 26 to 31 days with L.S.D. of two, two, and one day, respectively. The effect of genotype x year interaction on flag

TABLE VI

MEAN SQUARES FOR COMBINED YEARS AT STILLWATER

Source	df	Anthesis	Flag Leaf Duration	Grain Filling Period
Year	1	119.0**	633.8**	1,092.3**
Rep. (Year)	4	66.9**	43.8**	1.7
Genotype	39	86.8**	31.5**	9.7**
Genotype x Year	39	2.4	5.7**	1.5
Error	156	1.7	2.1	1.2

**significant at 0.01 level

leaf duration showed that the genotypes responded differently for this trait when grown in different years. Non-significant mean squares of genotype x year for anthesis and grain filling period demonstrated stability of these traits during the two years of study.

Table VII shows a highly significant negative correlation between anthesis date and grain yield and a highly significant positive correlation between anthesis data and plant height. However, these correlations may be misleading in that most of the tall genotypes in this study were old late selections, and the short genotypes were developed more recently under selection pressure for early maturing and short stature. Ashkof with the lowest average grain yield and tall stature was the latest flowering genotype at Stillwater during the two years of study. The average anthesis date of the ten highest yielding genotypes with medium and short statures did not exceed 44 days after March 31. Chisholm was one of the earliest flowering genotypes. The presence of both tall and medium statured classes in early flowering genotypes indicated that the highly significant correlation between anthesis and plant height might be partly due to simultaneous selection for early flowering and short stature. The significant and negative association between anthesis date and grain yield, previously reported (22), indicate that it is possible to develop early flowering genotypes with high grain yield for the Southern Great Plains. The highly significant positive

TABLE VII

PHENOTYPIC CORRELATIONS ON MEAN BASIS FOR STILLWATER OVER TWO YEARS

	Plant Height	Biomass	Grain Yield	Kernels/ Spike	Spikes/ M^2	Mg/ Kernel	Harvest Index	Flag Leaf Duration	Grain Filling Period	Anthesis
Plant Height		.17	-.75**	-.45**	-.36*	.03	-.87**	-.26	-.62**	.71**
Biomass			.38*	-.27	.12	.37*	.05	.17	-.04	-.03
Grain Yield				.30	.26	.46**	.94**	.56**	.61**	-.84**
Kernels/Spike					-.43**	.12	.44**	.46**	.55**	-.48**
Spikes/M^2						-.41**	.23	-.29	-.11	-.04
Mg/Kernel							.36*	.72**	.38*	-.48**
Harvest Index								.54**	.68**	-.89**
Flag Leaf Duration									.72**	-.76**
Grain Filling Period										-.82**

*Significant at .05 level
**Significant at .01 level

correlations of grain filling period and flag leaf duration with grain yield and the highly significant negative correlation of grain filling period with plant height indicate the possibility of the selection of short stature genotypes with a longer period of grain filling and flag leaf duration to get the maximum transfer of metabolites from source to sink. In this research, the highest yielding wheat genotypes appeared to have relatively longer periods of grain filling and flag leaf duration. The higher correlation of grain yield with anthesis in comparison with flag leaf duration and grain filling period indicate the importance of early flowering genotypes to escape the hot dry period of early summer in the Southern Great Plains. The incorporation of early flowering and medium maturing traits into improved wheat genotypes might bring more adaptability in Oklahoma.

Summary

In order to determine genetic variations and genotype x environment interactions of anthesis date, flag leaf duration, and grain filling period and to study the relationships between these characteristics and adaptability of wheat genotypes in the Southern Great Plains, the data of anthesis date, flag leaf senescence, and physiological maturity were recorded from forty wheat genotypes at Stillwater during the two years of study. The difference between flag leaf senescence and anthesis dates measured flag leaf duration for each plot while the difference between physiological maturity and anthesis measured the grain filling period.

The effects of year and genotype were highly significant on anthesis date, flag leaf duration, and grain filling period. The mean square due to the effect of genotype x year interaction was only significant for flag leaf duration. Anthesis date and grain filling period appeared stable during both years of the study. The significant and negative association between anthesis date and grain yield indicated that it is possible to develop early flowering genotypes with high grain yield for the Southern Great Plains. The highly significant positive correlations of grain filling period and flag leaf duration with grain yield and the highly significant negative correlation of grain filling period with plant height indicate the possibility of the selection of short genotypes with a longer period of grain filling and flag leaf duration to get the maximum potential transfer of metabolites from source to sink. Since grain yield had a higher correlation with anthesis date, in comparison with flag leaf duration and grain filling period, the incorporation of early flowering and medium maturing traits into improved wheat genotypes might bring more adaptability of wheat genotypes at Oklahoma.

CHAPTER VI

SUMMARY AND CONCLUSIONS

A two-year study (1982-83 and 1983-84) at three locations of Oklahoma (Stillwater, Altus, and Goodwell) was conducted on forty wheat genotypes with wide range of observed adaptability under field conditions to determine genetic variations and genotype x environment interactions of yield, yield components,harvest index, biomass,and plant height and to study the relationships between these characteristics and adaptability of wheat genotypes in the Southern Great Plains. In order to conduct the same study on anthesis date, flag leaf duration, and grain filling period, data were recorded both years at Stillwater for flowering date, flag leaf senescence, and physiological maturity. The difference between flag leaf senescence and anthesis date measured flag leaf duration for each plot; while, the difference between physiological maturity and anthesis measured grain filling period.

The following conclusions may be drawn from this research:

1. Tolerance of spikes/m^2 to the effects of genotype x year and genotype x year x location interaction portions of genotype x environment interaction might be one of the

major factors of adaptability which allows wheat genotypes to adjust to changing environments in the Southern Great Plains.

2. The effect of the genotype x environment interaction on mg/kernel was more predictable than grain yield and the other yield components. The predictability of the effect of genotype x environment interaction, whose genotype x location interaction portion was only significant, on spikes/m^2 appears difficult over a series of environments. Since mg/kernel had a highly significant negative correlation with spikes/m^2 and higher responsiveness and predictability than the other yield components, increasing mg/kernel would effectively increase adaptability of wheat genotypes in the Southern Great Plains if spikes/m^2 remain constant.

3. Because the sum of the standard partial regression coefficients of spikes/m^2, kernels/spike, and mg/kernel did not equal to one, it indicated joint effects of the components on grain yield. Therefore, each yield component should be considered in conjunction with the others.

4. Finding genotypes to satisfy the requirements of adaptability is extremely difficult in the Southern Great Plains. None of the genotypes studied satisfied the requirements of Eberhart and Russell model; while, according to the Finlay and Wilkinson model, Chisholm and TAM W-101 appeared to be the best genotypes in this study.

It might be possible to find a genotype which produces significantly above average grain yield in all environments but because of the extreme environmental variation of the Southern Great Plains it might not exhibit the lowest residual.

5. Adaptability of Chisholm appears to originate from the buffering characters of kernels/spike and spikes/m^2 and the responsiveness and predictability of mg/kernel. The buffering characteristic of spikes/m^2 and the responsiveness and predictability of kernels/spike and mg/kernel gave TAM W-101 adaptability.

6. Eight percent more predictability of the effect of genotype x environment interaction on harvest index in comparison with grain yield indicated that harvest index might be more predictable than grain yield in a wide range of environments. This seemed to be enforced by the correlation coefficient of 0.94 between harvest index and grain yield and higher predictability of harvest index in comparison with grain yield. However, harvest index values failed to predict general adaptability of wheat genotypes in the Southern Great Plains. Linear correlation masked shortcoming of harvest index as a selection criterion. The search for adaptable wheat genotypes should consider biomass because studying harvest index values without examining biomass may fail to predict grain yield of genotypes in a wide range of environments.

7. While plant height might have some effects on

productivity of wheat genotypes, the large correlation coefficients of plant height with harvest index and grain yield might be partly due to recent emphasis on the selection of productive short statured genotypes. Since plant height did not have a significant correlation with biomass, selection for short statured wheat genotypes might have some superiority over the tall genotypes.

8. The ten highest yielding genotypes, except Triumph and Triumph 64, were short statured and exhibited above average stability for plant height. Above average stability for height might be a useful factor to develop stable wheat genotypes in the Southern Great Plains. However, the short statured genotypes of more recent origin represent breeding improvements in yield and early maturity over most of the intermediate and tall genotypes studied. Likewise, the highly significant correlation of plant height with anthesis date might be partly due to recent selection pressure for early flowering and short stature genotypes included in this study.

9. It is possible to select for short stature genotypes with longer period of grain filling and flag leaf duration to get the maximum transfer of metabolites from source to sink. Anthesis date and grain filling period appeared stable during the two years of study at Stillwater because they did not show significant effect of genotype x year interaction. Since anthesis date shows highly significant negative correlations with flag leaf duration

and grain filling period, it is possible to develop early flowering wheat genotypes with high grain yield for the Southern Great Plains.

10. Since grain yield shows higher correlation with anthesis date than with flag leaf duration and grain filling period, the incorporation of early flowering and medium maturing traits into improved wheat genotypes might bring more adaptability of wheat genotypes at Oklahoma.

REFERENCES

1. Allan, R. E. 1983. Harvest indexes of backcross-derived wheat lines differing in culm height. Crop Sci. 23:1029-1032.

2. Allard, R. W., and A. D. Bradshaw. 1964. Implications of genotype-environmental interactions in applied plant breeding. Crop Sci. 4:503-508.

3. Bains, K. S., and V. P. Gupta. 1972. Stability of yield and yield components in bread wheat. Indian J. Genet. Pl. Breed. 32(2):306-312.

4. Baker, R. J. 1969. Genotype-environment interactions in yield of wheat. Can. J. Plant Sci. 49:743-751.

5. Bhatt, G. M., and N. F. Derera. 1978. Selection for harvest index among near-homozygous lines of wheat. J. of the Aust. Institute of Agric. Sci. 44(2):111-112.

6. Borojevic, Slavko, and William A. Williams. 1982. Genotype x environment interactions for leaf area parameters and yield components and their effects on wheat yields. Crop Sci. 22:1020-1025.

7. Brennan, P. S., and D. E. Byth. 1979. Genotype x environmental interactions for wheat yields and selection for widely adapted wheat genotypes. Aust. J. Agric. Res. 30:221-232.

8. Campbell, L. G., and H. N. Lafever. 1977. Cultivar x environment interactions in soft red winter wheat yield tests. Crop Sci. 17:604-608.

9. Chaubey, J. S., and E. V. D. Sastry. 1981. Stability analysis of yield and yield components in some Indian and Mexican varieties of wheat. Indian J. Agric. Sci. 51(9):611-614.

10. Comstock, R. E., and R. H. Moll. 1963. Genotype-environment interactions. In W. D. Hanson and H. F. Robinson (ed.). Statistical genetics and plant breeding. NAS-NRC No. 982 p. 164-196.

11. DePauw, R. M., D. G. Faris, and C. J. Williams. 1981. Genotype-environment interaction of yield in cereal crops in northwestern Canada. Can. J. Plant Sci. 61:225-263.

12. Eberhart, S. A., and W. A. Russell. 1966. Stability parameters for comparing varieties. Crop Sci. 6:36-40.

13. Finlay, K. W., and G. N. Wilkinson. 1963. The analysis of adaptation in a plant-breeding programme. Aust. J. Agric. Res. 14:742-754.

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

15. Jatasra, D. S., and R. S. Paroda. 1980. Phenotypic adaptability of characters related to productivity in wheat cultivars. Indian J. Genet. Pl. Breed 40(1):132-139.

16. Johnson, V. A., S. L. Shafer, and J. W. Schmidt. 1968. Regression analysis of general adaptation in hard red winter wheat (*Triticum aestivum* L.). Crop Sci. 8:187-191.

17. Joppa, L. R., K. L. Lebsock, and R. H. Busch. 1971. Yield stability of selected spring wheat cultivars (*Triticum aestivum* L. em Thell) in the uniform regional nurseries, 1959 to 1968. Crop Sci. 11:238-241.

18. Keim, D. L., and W. E. Kronstad. 1979. Drought resistance and dryland adaptation in winter wheat. Crop Sci. 19:574-576.

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

20. Nass, H. G. 1980. Harvest index as a selection criterion for grain yield in two spring wheat crosses grown at two population densities. Can. J. Plant Sci. 60:1141-1146.

21. Perkins, J. M., and J. L. Jinks. 1968. Environmental and genotype-environmental components of varia-

bility. III. Multiple lines and crosses. Heredity. 23:339-356.

22. Sharma, J. C., and Ziauddin Ahmad. 1978. Indirect selection response in spring wheat. Indian J. Genet. Pl. Breed. 38(3):292-298.

23. Singh, R. B., and S. V. Singh. 1980. Phenotypic stability and adaptability of durum and bread wheats for grain yield. Indian J. Genet. Pl. Breed. 40(1):86-92.

24. Singh, S. V., and R. B. Singh. 1980. Stability of component characters in relation with the stability of yield. Indian J. Genet. Pl. Breed. 40(1):93-98.

25. Steel,R. G. D., and J. H. Torrie. Principles and procedures of statistics a biometrical approach. McGraw-Hill Book Company, New York.

26. Talukdar, P., and K. S. Bains. 1982. Genotype x environment interaction in a diallel cross of wheat. Z. Pflanzenzuchtung. 89(3):197-205.

APPENDIX

TABLE VIII

REGRESSION ANALYSES FOR YIELD, YIELD COMPONENTS, AND SEVERAL AGRONOMIC TRAITS

Genotype	df	bi	Standard Error	S^2di
GRAIN YIELD (kg/ha)				
Triplet	4	0.9459**	0.0953	33374
Ashkof	4	0.6346*	0.2196	177155
Sturdy	4	1.0444**	0.2062	156136
CI 7126	4	0.6391**	0.1310	63017
Akakawa	4	0.7636**x	0.0837	25715
CI 8530	4	0.7935**	0.1619	96282
Baca	4	1.0795**	0.1331	65066
Turkey Sel	4	0.9904**	0.1063	41470
Hope/Turkey	4	0.9754**	0.1311	63093
Cheyenne/Tenmarq	4	0.8873**	0.1563	89754
Turkey 1069/Cheyenne	4	1.0741**	0.1173	50542
Turkey Selection	4	1.0001**	0.0375	5158
Triumph	4	1.1936**	0.1646	99440
Blue Jacket	4	0.9542**	0.1056	40999
Newsar	4	0.7934**x	0.0512	9635
Clark R 169	4	0.8825**	0.0836	25670
Royal D 85	4	0.6209**x	0.1276	59754
Hope/Turkey /Cheyenne	4	0.9878**	0.1399	71861
CI 13898	4	1.1623**	0.1911	134160
Blue boy II	4	1.1039**	0.1258	58094
Goens	4	0.7959**	0.1417	73678
Turkey Selection	4	0.8448**	0.1245	56962
Red Chief	4	0.8706**	0.1436	75754
Tayland	4	0.9432**	0.1140	47705
Ind 4126A 9-42-1	4	0.8830**	0.0868	27676

TABLE VIII (Continued)

Genotype	df	bi	Standard Error	S^2di
GRAIN YIELD (kg/ha), Continued				
NB67786	4	1.0456**	0.1050	40472
Near Iso Pm I	4	1.0555**	0.1599	93863
Centurk	4	1.1968**	0.1368	68696
Cheyenne	4	0.9312**	0.1071	42090
Kanking	4	1.0048**	0.0436	6978
Ponca	4	1.1344**	0.1423	74313
Triumph 64	4	0.9713**	0.1166	49927
Scout 66	4	1.1136**	0.1092	43752
Payne	4	1.4072**xx	0.0865	27493
TAM W-101	4	1.2249**	0.1519	84678
TAM 105	4	1.1604**	0.0946	32832
Vona	4	1.4018**	0.1618	96125
Newton	4	1.1015**	0.1109	45188
Hawk	4	1.2145**	0.1874	128920
Chisholm	4	1.1723*	0.3132	360130
$SPIKES/M^2$				
Triplet	4	1.1587	0.4255	2965
Ashkof	4	1.8461*	0.5291	4586
Sturdy	4	0.5536	0.8819	12737
CI 7126	4	1.1669*	0.2941	1416
Akakawa	4	0.6429	0.3610	2135
CI 8530	4	0.8944*	0.2497	1021
Baca	4	1.5897*	0.5445	4855
Turkey Sel	4	1.0179*	0.3294	1777
Hope/Turkey	4	1.4947*	0.4572	3423
Cheyenne/Tenmarq	4	1.6470*	0.4454	3249

TABLE VIII (Continued)

Genotype	df	bi	Standard Error	S^2di
SPIKES/M^2, Continued				
Turkey 1069/Cheyenne	4	0.5873	0.5597	5132
Turkey Selection	4	1.9647*	0.6643	7227
Triumph	4	1.0130	0.5810	5528
Blue Jacket	4	0.0696	0.7163	8404
Newsar	4	0.6456*	0.2098	721
Clark R 169	4	0.5660	0.4059	2698
Royal D 85	4	0.6280	0.4747	3690
Hope/Turkey Cheyenne	4	0.5698	0.8994	13249
CI 13898	4	0.7749	0.4149	2820
Blue Boy II	4	1.1020	0.7593	9442
Goens	4	0.9340	0.6490	6899
Turkey Selection	4	1.0313	0.7911	10251
Red Chief	4	1.9801	1.0309	17406
Tayland	4	0.9429	0.5381	4742
Ind 4126A 9-42-1	4	0.4531	0.4376	3136
NB67786	4	1.1852*	0.3911	2505
Near Iso Pm I	4	0.8624*	0.3079	1552
Centurk	4	1.4278	0.9873	15966
Cheyenne	4	0.8777	0.5565	5071
Kanking	4	1.0761**	0.1019	170
Ponca	4	1.5204**	0.3144	1619
Triumph 64	4	0.6809	0.5661	5248
Scout 66	4	0.3657	0.2901	1378
Payne	4	1.9985**	0.3909	2502
TAM W-101	4	-0.1943	0.3789	2351
TAM 105	4	1.1809	0.7360	8872
Vona	4	1.6847*	0.4625	3504
Newton	4	0.7168*	0.2439	974

TABLE VIII (Continued)

Genotype	df	bi	Standard Error	S^2di
SPIKES/M^2, Continued				
Hawk	4	0.1987	0.2799	1283
Chisholm	4	1.1440	0.5378	4737
KERNELS/SPIKE				
Triplet	4	1.0885	0.4304	6.91
Ashkof	4	1.2551**	0.1372	0.70
Sturdy	4	0.7103	0.3675	5.04
CI 7126	4	0.6382	0.5951	13.21
Akakawa	4	1.2936*	0.3654	4.98
CI 8530	4	1.6799*	0.4528	7.65
Baca	4	0.5534*x	0.1446	0.78
Turkey Sel	4	0.9490*	0.3266	3.98
Hope/Turkey	4	0.5322	0.2565	2.45
Cheyenne/Tenmarq	4	0.2374	0.1467	0.80
Turkey 1069/Cheyenne	4	0.9659*	0.2926	3.19
Turkey Selection	4	0.6538	0.3315	4.10
Triumph	4	0.6758	0.2972	3.29
Blue Jacket	4	1.3746**	0.1588	0.94
Newsar	4	1.1090**	0.2210	1.82
Clark R 169	4	1.5668**xx	0.0900	0.30
Royal D 85	4	0.9144	0.6630	16.39
Hope/Turkey/Cheyenne	4	0.8696	0.3190	3.80
CI 13898	4	0.8956*	0.2783	2.89
Blue boy II	4	1.1857	0.4758	8.44
Goens	4	2.0992*	0.5566	11.55
Turkey Selection	4	1.6693**	0.2534	2.39
Red Chief	4	0.7515	0.2860	3.05
Tayland	4	1.0227	0.5104	9.71

TABLE VIII (Continued)

Genotype	df	bi	Standard Error	S^2di
KERNELS/SPIKES, Continued				
Ind 4126A 9-42-1	4	1.0052*	0.3541	4.67
NB67786	4	1.2509*	0.3252	3.94
Near Iso Pm I	4	1.2063*	0.3717	5.15
Centurk	4	1.3642	0.6626	16.37
Cheyenne	4	1.3686*	0.3327	4.13
Kanking	4	0.2501	0.2043	1.56
Ponca	4	0.5657*x	0.1457	0.79
Triumph 64	4	0.5024*x	0.1766	1.16
Scout 66	4	0.6125*x	0.1354	0.68
Payne	4	0.5521*	0.1697	1.07
TAM W-101	4	1.0822*	0.3350	4.19
TAM 105	4	0.6978	0.2660	2.64
Vona	4	1.7493**	0.3678	5.04
Newton	4	1.4774**	0.2759	2.84
Hawk	4	0.7781	0.5002	9.33
Chisholm	4	0.7861	0.4288	6.86
MG/KERNEL				
Triplet	4	0.4613	0.2284	2.93
Ashkof	4	0.0313	0.5232	15.38
Sturdy	4	1.0560**	0.1497	1.26
CI 7126	4	0.1902	0.4355	10.66
Akakawa	4	0.7386*	0.1833	1.89
CI 8530	4	-0.3142	0.1850	1.92
Baca	4	1.3516**	0.1694	1.61
Turkey Sel	4	0.4814	0.1755	1.73
Hope/Turkey	4	0.5719*	0.1901	2.03
Cheyenne/Tenmarq	4	0.9124**	0.1662	1.55

TABLE VIII (Continued)

Genotype	df	bi	Standard Error	S^2di
MG/KERNEL, Continued				
Turkey 1069/Cheyenne	4	1.2477**	0.2567	3.70
Turkey Selection	4	0.8714*	0.0864	4.61
Triumph	4	2.0180**x	0.2450	3.37
Blue Jacket	4	1.0224**	0.1959	2.16
Newsar	4	0.4294	0.2477	3.45
Clark R 169	4	0.5288**xx	0.0259	0.00
Royal D 85	4	0.7205*	0.1993	2.23
Hope/Turkey/Cheyenne	4	1.1232*	0.2850	4.56
CI 13898	4	1.6609*	0.3943	8.74
Blue boy II	4	1.3601**x	0.1220	0.84
Goens	4	0.5290	0.2971	4.96
Turkey Selection	4	0.1092	0.2588	3.76
Red Chief	4	1.0010**	0.1602	1.44
Tayland	4	1.1716**	0.2197	2.71
Ind 4126A 9-42-1	4	0.7616	0.5072	14.45
NB67786	4	0.7949*	0.2642	3.92
Near Iso Pm I	4	1.1839*	0.3887	8.49
Centurk	4	1.3008**	0.1881	1.99
Cheyenne	4	0.7675	0.2954	4.90
Kanking	4	1.5292**	0.2790	4.37
Ponca	4	1.6815**	0.2473	3.44
Triumph 64	4	1.3667**	0.2032	2.32
Scout 66	4	1.3217**	0.2303	2.98
Payne	4	1.2134**	0.2018	2.29
TAM W-101	4	1.2832**	0.2065	2.39
TAM 105	4	0.8978*	0.3185	5.70
Vona	4	1.6110**	0.2455	3.39
Newton	4	1.3877**	0.2211	2.74

CHAPTER VIII (Continued)

Genotypes	df	bi	Standard Error	S^2di
MG/KERNEL, Continued				
Hawk	4	1.9855**x	0.2717	4.15
Chisholm	4	1.6399**	0.2864	4.61
HARVEST INDEX				
Triplet	4	0.6825	0.2506	2.910
Ashkof	4	-0.0143	0.8089	30.319
Sturdy	4	1.1981**	0.2278	2.404
CI 7126	4	0.1549	0.3250	4.895
Akakawa	4	0.2458	0.2791	3.609
CI 8530	4	0.4965	0.6356	18.723
Baca	4	1.5372**	0.3077	4.388
Turkey Sel	4	0.6821*	0.1774	1.459
Hope/Turkey	4	0.7644	0.2997	4.163
Cheyenne/Tenmarq	4	1.2197*	0.2961	4.063
Turkey 1069/Cheyenne	4	1.1826*	0.3820	6.764
Turkey Selection	4	0.9722*	0.2554	3.024
Triumph	4	1.5006**	0.2641	3.233
Blue Jacket	4	0.7644**	0.1237	0.709
Newsar	4	0.2279	0.2002	1.856
Clark R 169	4	0.4942**x	0.1442	0.963
Royal D 85	4	0.2515	0.3540	5.807
Hope/Turkey/Cheyenne	4	1.3440*	0.3119	4.507
CI 13898	4	1.4106*	0.3845	6.849
Blue boy II	4	1.3963*	0.3472	5.586
Goens	4	0.7558	0.3503	5.687
Turkey Selection	4	0.6543	0.2640	3.231
Red Chief	4	0.5741*	0.1897	1.668
Tayland	4	0.5740**xx	0.0725	0.243

TABLE VIII (Continued)

Genotype	df	bi	Standard Error	S^2di
<u>HARVEST INDEX, Continued</u>				
Ind 4126A 9-42-1	4	0.8076	0.4269	8.443
NB67786	4	1.5179**	0.2764	3.539
Near Iso Pm I	4	0.6100	0.4206	8.197
Centurk	4	1.7224**x	0.1946	1.755
Cheyenne	4	0.9211*	0.3099	4.451
Kanking	4	0.8684	0.3261	4.929
Ponca	4	1.1801**	0.2257	2.360
Triumph 64	4	0.7739	0.2823	4.694
Scout 66	4	1.2246*	0.2728	3.449
Payne	4	1.2736*	0.3061	4.344
TAM W-101	4	1.3952**	0.2172	2.186
TAM 105	4	1.5157**	0.2384	2.633
Vona	4	2.2104**x	0.4353	8.779
Newton	4	1.7105**x	0.2441	2.761
Hawk	4	1.9183**x	0.2382	2.630
Chisholm	4	1.2805*	0.3885	6.995
<u>BIOMASS (kg/ha)</u>				
Triplet	4	1.0159**	0.0793	175235
Ashkof	4	1.0839**	0.1232	422456
Sturdy	4	0.8998**	0.1480	609555
CI 7126	4	0.8419**	0.1237	425505
Akakawa	4	1.0744**	0.0754	158179
CI 8530	4	1.1390**	0.0984	269561
Baca	4	0.9985**	0.0560	87277
Turkey Sel	4	1.0863**	0.0940	245766
Hope/Turkey	4	1.1038**	0.0761	161412
Cheyenne/Tenmarq	4	0.9120**	0.1262	443118

TABLE VIII (Continued)

Genotype	df	bi	Standard Error	S^2di
<u>BIOMASS (kg/ha), Continued</u>				
Turkey 1069/Cheyenne	4	1.1256**	0.1044	302989
Turkey Selection	4	0.9874**	0.0504	70768
Triumph	4	0.9587**	0.1197	398214
Blue Jacket	4	1.0775**	0.1318	483381
Newsar	4	1.0510**	0.0535	79478
Clark R 169	4	1.0597**	0.0970	261585
Royal D 85	4	0.7873**	0.0539	80856
Hope/Turkey /Cheyenne	4	1.0144**	0.1306	474283
CI 13898	4	0.9005**	0.1058	311367
Blue boy II	4	0.9238**	0.1004	280498
Goens	4	0.8530**	0.1014	286252
Turkey Selection	4	0.9329**	0.0984	269283
Red Chief	4	0.9479**	0.1849	950578
Tayland	4	1.1206**	0.1142	362972
Ind 4126A 9-42-1	4	1.0338**	0.0789	173156
NB67786	4	0.9745**	0.0756	158873
Near Iso Pm I	4	1.0804**	0.0989	272087
Centurk	4	1.0349**	0.0930	240799
Cheyenne	4	0.9392**	0.0745	154278
Kanking	4	0.9870**	0.1221	414995
Ponca	4	1.1126**	0.1195	397405
Triumph 64	4	0.9282**	0.1116	346252
Scout 66	4	1.0738**	0.0682	129227
Payne	4	1.1646**	0.1389	537010
TAM W-101	4	0.9982**	0.1110	342651
TAM 105	4	1.0048**	0.1165	377274
Vona	4	0.9786**	0.1625	734598
Newton	4	0.9801**	0.1227	418741

TABLE VIII (Continued)

Genotype	df	bi	Standard Error	S²di
BIOMASS (kg/ha), Continued				
Hawk	4	0.9040**	0.1175	384405
Chisholm	4	0.9093*	0.2106	1234202
PLANT HEIGHT (cm)				
Triplet	4	1.1263**	0.1097	20.485
Ashkof	4	1.4707**	0.1943	64.223
Sturdy	4	0.5121**xx	0.0836	11.878
CI 7126	4	1.0498**	0.1109	20.938
Akakawa	4	1.3121**x	0.0832	11.766
CI 8530	4	1.1593**	0.1468	36.707
Baca	4	0.9728**	0.0726	8.961
Turkey Sel	4	1.2148**xx	0.0406	2.811
Hope/Turkey	4	1.1446**	0.1091	10.235
Cheyenne/Tenmarq	4	1.0843**	0.0699	8.324
Turkey 1069/Cheyenne	4	1.2477**	0.1281	27.898
Turkey Selection	4	1.0168**	0.0650	7.187
Triumph	4	0.8364**	0.0878	13.122
Blue Jacket	4	1.1487**	0.0790	10.625
Newsar	4	1.2370**x	0.0593	5.985
Clark R 169	4	1.2221**x	0.0677	7.807
Royal D 85	4	1.2867**x	0.0873	12.957
Hope/Turkey/Cheyenne	4	1.0038**	0.0725	8.936
CI 13898	4	0.7138**x	0.0695	8.223
Blue boy II	4	0.7244**x	0.0696	8.246
Goens	4	1.1152**	0.0984	16.482
Turkey Selection	4	1.0592**	0.1159	22.866
Red Chief	4	1.0636**	0.0939	14.990
Tayland	4	1.2239**	0.1201	24.553

TABLE VIII Continued

Genotype	df	bi	Standard Error	S^2di
PLANT HEIGHT (cm) Continued				
Ind 4126A 9-42-1	4	1.2932**xx	0.0294	1.474
NB67786	4	0.9835**	0.0861	12.610
Near Iso Pm I	4	1.1035**	0.0805	11.039
Centurk	4	0.8842**x	0.0274	1.279
Cheyenne	4	1.2871**x	0.0831	11.755
Kanking	4	1.0533**	0.0487	4.033
Ponca	4	1.0953**	0.0542	5.007
Triumph 64	4	0.7540**	0.1401	33.378
Scout 66	4	1.0266**	0.0651	7.212
Payne	4	0.7248**x	0.0829	11.699
TAM W-101	4	0.5624**xx	0.0895	13.616
TAM 105	4	0.7001**x	0.0917	14.318
Vona	4	0.5851**xx	0.0872	12.932
Newton	4	0.7826**	0.0882	13.242
Hawk	4	0.6620**xx	0.0560	5.327
Chisholm	4	0.5562**x	0.1074	19.628

*Significantly different from 0 at 0.05 level.

**Significantly different from 0 at 0.01 level.

xSignificantly different from 1 at 0.05 level.

xxSignificantly different from 1 at 0.01 level.

TABLE IX

ANTHESIS, FLAG LEAF DURATION, GRAIN FILLING PERIOD AND GRAIN YIELD MEANS AT STILLWATER FOR TWO YEARS

Genotype	Anthesis	Flag Leaf Duration	Grain Filling Period	Grain Yield
	No. of days			(kg/ha)
Triplet	48	23	29	2886
Ashkof	55	18	26	1946
Sturdy	39	26	31	3517
CI 7126	47	22	28	2271
Akakawa	47	25	29	2466
CI 8530	50	19	28	2049
Baca	45	21	28	3196
Turkey Sel	48	21	28	2981
Hope/Turkey	48	21	28	2844
Cheyenne/Tenmarq	45	24	29	2765
Turkey 1069/Cheyenne	49	20	28	3067
Turkey Selection	47	22	27	2958
Triumph	38	27	31	3820
Blue Jacket	46	24	27	3169
Newsar	48	25	29	2552
Clark R 169	49	25	28	2697
Royal D 85	49	22	27	2150
Hope/Turkey/Cheyenne	45	22	27	2984
CI 13898	40	26	29	3522
Blue Boy II	42	26	31	3107
Goens	46	24	28	2462
Turkey Selection	49	20	28	2639
Red Chief	46	26	29	2903
Tayland	44	27	30	2938
Ind 4126A 9-42-1	49	24	27	2555

TABLE IX (Continued)

Genotype	Anthesis	Flag Leaf Duration	Grain Filling Period	Grain Yield
	No. of days			(kg/ha)
NB67786	47	22	28	2967
Near Iso Pm I	42	27	29	3318
Centurk	43	23	29	3335
Cheyenne	50	20	27	2842
Kanking	45	24	27	3268
Ponca	46	22	28	3104
Triumph 64	39	26	30	3593
Scout 66	43	23	28	3214
Payne	43	25	28	3866
TAM W-101	43	25	30	3925
TAM 105	44	23	29	3615
Vona	40	25	30	3548
Newton	44	23	29	3156
Hawk	42	24	30	3252
Chisholm	38	27	31	4155
Grand Mean	45	23	29	3040
L.S.D. (0.05)	2	2	1	422
C.V.	2.9	6.2	3.9	12.3

TABLE X

MEANS FOR YIELD, YIELD COMPONENTS, AND SEVERAL AGRONOMIC TRAITS OVER INDIVIDUAL ENVIRONMENTS

	1983			1984		
Genotype	Stillwater	Altus	Goodwell	Stillwater	Altus	Goodwell
GRAIN YIELD (kg/ha)						
Triplet	2731	2150	2848	3042	1204	1193
Ashkof	1975	837	2054	1917	648	870
Sturdy	3649	2757	2410	3385	1649	1185
CI 7126	2032	2240	2623	2510	1442	1143
Akakawa	2444	2075	2085	2488	953	1093
CI 8530	1911	1375	2382	2187	647	761
Baca	3140	3041	3462	3252	1695	1161
Turkey Sel	2939	2078	2377	3023	1126	1010
Hope/Turkey	2460	2157	2288	3228	1089	954
Cheyenne/Tenmarq	2456	2200	1977	3074	1313	825
Turkey 1069/Cheyenne	3046	2886	3214	3088	1552	1002
Turkey Selection	2865	2288	2629	3051	1218	1028
Triumph	3902	3204	2963	3738	1906	1203
Blue Jacket	3183	2578	2523	3156	1367	1293
Newsar	2439	2288	2398	2664	1159	1124
Clark R 169	2544	2279	2680	2849	1086	1202
Royal D 85	1781	2020	2040	2519	1058	1097
Hope/Turkey/Cheyenne	2716	2874	2812	3252	1694	932
CI 13898	3835	2676	3587	3209	1639	1273
Blue boy II	3218	2355	3180	2996	1320	1014
Goens	2181	2401	2334	2744	939	1197
Turkey Selection	2382	1846	2285	2897	965	1126
Red Chief	2604	2355	3183	3202	1657	1288
Tayland	3068	2267	2384	2809	1363	928
Ind 4126A 9-42-1	2487	2090	2240	2624	819	1013
NB67786	3140	2317	2659	2795	1224	870
Near Iso Pm I	3151	2350	2539	3485	1703	907

TABLE X (Continued)

Genotype	1983			1984		
	Stillwater	Altus	Goodwell	Stillwater	Altus	Goodwell
GRAIN YIELD (kg/ha), Continued						
Centurk	3360	3178	3314	3311	1666	944
Cheyenne	2874	2231	2910	2809	1178	1212
Kanking	3118	2833	3206	3418	1638	1396
Ponca	3085	2704	3426	3124	1216	1176
Triumph 64	3419	2733	2884	3767	1840	1589
Scout 66	3053	3087	3168	3374	1595	1062
Payne	3792	2972	3780	3939	1687	1095
TAM W-101	3678	3118	2966	4172	1782	1371
TAM 105	3424	3321	3216	3807	1628	1438
Vona	3336	3080	3921	3760	1592	902
Newton	3089	2910	2927	3222	1624	866
Hawk	3130	2932	3776	3375	1684	948
Chisholm	3979	3508	2511	4331	2085	1442
Means of Environment	2940	2515	2804	3140	1391	1103
L.S.D. (0.05)	720	259	735	456	240	358
L.S.D. (0.05) for treatment and Environment	515	185	526	326	172	256
C.V.	15.1	6.4	16.2	9.0	10.6	20.1
SPIKES/M²						
Triplet	481	373	387	402	233	330
Ashkof	563	398	538	563	305	319
Sturdy	524	337	221	391	462	344
CI 7126	452	319	409	423	336	255
Akakawa	384	291	351	265	305	233
CI 8530	359	237	312	330	242	215

TABLE X (Continued)

Genotype	1983 Stillwater	 Altus	 Goodwell	1984 Stillwater	 Altus	 Goodwell
SPIKES/M^2, Continued						
Baca	585	520	459	642	520	323
Turkey Sel	585	448	560	531	462	409
Hope/Turkey	595	592	448	624	421	402
Cheyenne/Tenmarq	696	595	556	595	390	470
Turkey 1069/Cheyenne	502	430	563	398	377	402
Turkey Selection	674	459	646	606	354	402
Triumph	574	574	402	430	390	398
Blue Jacket	269	384	459	473	408	305
Newsar	405	384	423	384	345	301
Clark R 169	362	387	384	287	269	273
Royal D 85	334	362	448	369	300	258
Hope/Turkey/Cheyenne	456	681	387	520	462	398
CI 13898	398	423	344	330	463	237
Blue boy II	488	366	398	380	498	201
Goens	441	366	398	276	188	305
Turkey Selection	470	459	522	681	368	423
Red chief	750	430	334	416	287	387
Tayland	377	265	416	362	345	194
Ind 4126A 9-42-1	391	416	273	326	289	323
NB67786	430	427	287	430	305	258
Near Iso Pm I	488	441	430	373	381	316
Centurk	717	620	420	574	673	369
Cheyenne	516	477	355	577	408	416
Kanking	513	456	473	491	395	348
Ponca	660	506	527	638	444	441
Triumph 64	441	502	344	516	453	341
Scout 66	466	427	502	427	395	412
Payne	681	456	556	631	426	369

TABLE X (Continued)

Genotype	1983			1984		
	Stillwater	Altus	Goodwell	Stillwater	Altus	Goodwell
SPIKES/M^2, Continued						
TAM W-101	362	380	350	409	318	445
TAM 105	556	463	441	599	583	316
Vona	664	516	577	484	395	373
Newton	491	456	445	445	350	398
Hawk	430	420	477	387	412	384
Chisholm	423	416	409	567	386	287
Means of Environment	499	436	431	464	381	340
L.S.D. (0.05)	198	162	177	188	197	139
L.S.D. (0.05) for treatment and Environment	142	116	127	135	141	100
C.V.	24.6	22.9	25.5	25.1	32.0	25.4
KERNELS/SPIKE						
Triplet	23.0	26.2	30.3	30.7	21.3	26.9
Ashkof	20.6	18.1	22.4	25.4	15.5	18.5
Sturdy	28.0	26.9	23.6	30.1	22.5	26.1
CI 7126	23.4	22.4	22.9	25.6	19.1	30.1
Akakawa	24.9	25.1	25.4	26.8	15.6	23.7
CI 8530	22.8	20.7	30.1	27.2	15.2	24.5
Baca	24.7	21.4	24.2	24.0	20.4	22.6
Turkey Sel	19.8	19.8	19.8	20.1	12.0	18.2
Hope/Turkey	19.5	17.6	21.0	18.2	15.1	18.9
Cheyenne/Tenmarq	18.6	19.9	20.6	21.5	19.2	19.6
Turkey 1069/Cheyenne	23.1	24.4	24.4	26.3	17.8	20.7
Turkey Selection	17.2	18.9	23.1	22.6	17.6	18.6
Triumph	22.8	18.5	21.4	23.9	19.3	17.8
Blue Jacket	22.1	18.5	24.3	27.2	16.6	21.3

TABLE X (Continued)

Genotype	1983			1984		
	Stillwater	Altus	Goodwell	Stillwater	Altus	Goodwell
KERNELS/SPIKE, Continued						
Newsar	20.9	20.1	25.0	24.3	15.9	21.2
Clark R 169	23.3	20.2	25.6	28.6	16.1	22.4
Royal D 85	20.9	23.5	17.6	28.9	17.2	24.0
Hope/Turkey/Cheyenne	22.6	16.9	22.1	24.2	18.6	18.1
CI 13898	28.2	23.8	27.5	31.2	24.1	28.9
Blue boy II	32.0	22.0	28.2	30.5	22.6	29.1
Goens	23.0	23.8	22.6	34.1	13.6	23.5
Turkey Selection	21.6	16.6	20.4	23.2	9.9	19.4
Red Chief	21.0	19.5	21.9	26.4	20.0	20.0
Tayland	31.1	20.8	27.3	26.6	21.2	24.1
Ind 4126A 9-42-1	24.3	20.2	23.7	26.2	17.5	26.3
NB67786	27.5	19.4	25.4	28.5	19.7	24.1
Near Iso Pm I	26.0	20.6	23.2	30.9	20.6	23.3
Centurk	23.9	24.5	33.6	27.0	18.4	21.4
Cheyenne	22.9	20.2	25.4	23.6	14.0	18.4
Kanking	20.8	19.3	19.8	22.8	20.6	19.5
Ponca	19.5	17.1	21.1	20.9	17.3	18.7
Triumph 64	20.3	20.3	23.0	23.2	19.2	22.4
Scout 66	22.7	20.6	24.5	24.6	20.5	22.0
Payne	27.0	24.9	25.3	26.2	21.9	24.4
TAM W-101	25.4	21.2	27.1	27.1	20.1	19.7
TAM 105	27.1	22.4	27.7	27.1	23.3	23.3
Vona	28.8	27.4	32.0	35.7	21.7	23.7
Newton	30.2	24.1	32.0	31.9	22.1	25.5
Hawk	28.6	32.6	27.7	32.2	23.5	26.5
Chisholm	29.9	25.6	23.4	30.6	23.1	25.6

TABLE X (Continued)

Genotype	1983			1984		
	Stillwater	Altus	Goodwell	Stillwater	Altus	Goodwell
KERNELS/SPIKE, Continued						
Means of Environment	24.0	21.6	24.7	26.7	18.7	22.6
L.S.D. (0.05)	6.3	2.9	3.3	4.8	4.8	4.5
L.S.D. (0.05) for Treatment and Environment	4.5	2.1	2.4	3.4	3.4	3.2
C.V.	16.2	8.4	8.3	11.1	15.7	12.2
MG/KERNEL						
Triplet	21.8	22.3	24.9	26.6	22.3	20.8
Ashkof	18.4	11.3	21.2	19.0	18.3	20.2
Sturdy	29.3	29.9	33.1	28.9	23.9	23.7
CI 7126	18.9	26.2	26.1	25.6	21.5	25.0
Akakawa	35.8	32.4	34.9	35.4	31.3	28.8
CI 8530	22.7	20.7	22.9	21.6	25.3	23.9
Baca	27.7	28.7	33.1	28.2	21.3	21.0
Turkey Sel	26.5	25.5	24.5	25.2	22.5	21.2
Hope/Turkey	26.5	23.1	25.2	26.9	22.6	21.1
Cheyenne/Tenmarq	23.6	23.5	25.5	26.6	20.2	18.0
Turkey 1069/Cheyenne	29.0	24.1	32.9	30.3	23.6	21.2
Turkey Selection	24.6	22.8	30.0	28.7	23.4	21.2
Triumph	38.0	31.8	38.6	37.2	25.1	22.5
Blue Jacket	29.3	31.5	32.0	30.3	25.1	22.9
Newsar	29.2	32.3	31.7	33.8	30.2	27.7
Clark R 169	32.9	32.6	34.0	33.4	30.0	29.8
Royal D 85	29.8	26.1	31.0	27.6	25.9	23.5
Hope/Turkey/Cheyenne	27.6	29.1	27.3	28.4	20.6	19.5
CI 13898	35.9	31.6	33.1	33.1	20.4	23.5
Blue boy II	27.1	27.8	31.4	29.6	21.6	19.5
Goens	26.3	29.4	32.1	30.3	29.0	24.8

TABLE X (Continued)

	1983			1984		
Genotype	Stillwater	Altus	Goodwell	Stillwater	Altus	Goodwell
MG/KERNEL, Continued						
Turkey Selection	24.2	20.1	21.4	23.7	23.3	20.3
Red Chief	30.4	32.1	33.2	33.4	25.9	25.7
Tayland	30.4	33.0	34.3	33.5	24.4	25.9
Ind 4126A 9-42-1	34.2	23.9	30.3	29.1	27.8	22.6
NB67786	28.9	29.7	27.6	27.3	22.5	22.3
Near Iso Pm I	30.9	27.6	28.2	33.8	22.6	21.4
Centurk	25.5	23.4	27.6	22.7	16.6	16.7
Cheyenne	26.8	22.1	28.6	27.5	24.5	20.3
Kanking	31.7	33.0	36.6	35.0	22.3	26.4
Ponca	29.8	29.1	35.5	29.0	19.2	22.0
Trimph 64	32.3	30.8	37.3	35.7	25.0	27.1
Scout 66	28.1	30.6	32.0	31.0	20.9	22.6
Payne	29.2	28.2	30.0	27.0	20.3	20.7
TAM W-101	36.5	34.7	38.7	35.6	26.6	29.9
TAM 105	24.9	28.4	29.6	25.3	19.4	22.9
Vona	25.5	24.9	31.6	24.1	16.4	17.4
Newton	26.2	26.1	32.9	26.9	21.7	18.7
Hawk	30.9	29.4	38.5	29.4	21.4	19.5
Chisholm	33.5	29.8	39.4	31.1	23.8	24.5
Means of Environment	28.5	27.5	31.0	29.2	23.2	22.7
L.S.D. (0.05)	5.2	2.3	4.1	2.9	2.3	3.3
L.S.D. (0.05) for Treatment and Environment	3.7	1.6	2.9	2.1	1.6	2.4
C.V.	11.3	5.3	8.2	6.2	6.4	9.1

TABLE X (Continued)

Genotype	1983			1984		
	Stillwater	Altus	Goodwell	Stillwater	Altus	Goodwell
HARVEST INDEX						
Triplet	0.31	0.27	0.33	0.31	0.29	0.27
Ashkof	0.21	0.12	0.26	0.22	0.20	0.25
Sturdy	0.41	0.38	0.41	0.37	0.37	0.30
CI 7126	0.25	0.27	0.31	0.28	0.30	0.29
Akakawa	0.26	0.27	0.28	0.24	0.23	0.26
CI 8530	0.20	0.18	0.28	0.24	0.17	0.23
Baca	0.32	0.36	0.42	0.33	0.34	0.26
Turkey Sel	0.30	0.30	0.31	0.30	0.27	0.25
Hope/Turkey	0.27	0.30	0.33	0.33	0.29	0.25
Cheyenne/Tenmarq	0.30	0.31	0.33	0.32	0.31	0.22
Turkey 1069/Cheyenne	0.30	0.33	0.38	0.32	0.36	0.26
Turkey Selection	0.31	0.28	0.33	0.32	0.28	0.24
Triumph	0.40	0.37	0.42	0.39	0.38	0.28
Blue Jacket	0.29	0.29	0.32	0.31	0.29	0.25
Newsar	0.25	0.28	0.28	0.27	0.25	0.25
Clark R 169	0.28	0.28	0.30	0.27	0.25	0.26
Royal D 85	0.23	0.27	0.28	0.29	0.25	0.26
Hope/Turkey/Cheyenne	0.31	0.33	0.39	0.32	0.35	0.25
CI 13898	0.42	0.38	0.42	0.35	0.36	0.30
Blue boy II	0.34	0.31	0.39	0.34	0.27	0.26
Goens	0.28	0.31	0.34	0.30	0.25	0.27
Turkey Selection	0.27	0.27	0.30	0.31	0.25	0.24
Red Chief	0.29	0.30	0.31	0.30	0.31	0.26
Tayland	0.30	0.29	0.31	0.29	0.29	0.26
Ind 4126A 9-42-1	0.29	0.27	0.31	0.26	0.21	0.24
NB67786	0.32	0.29	0.35	0.29	0.25	0.21
Near Iso Pm I	0.35	0.30	0.32	0.34	0.34	0.27
Centurk	0.36	0.38	0.42	0.35	0.35	0.25

TABLE X (Continued)

Genotype	1983			1984		
	Stillwater	Altus	Goodwell	Stillwater	Altus	Goodwell
HARVEST INDEX, Continued						
Cheyenne	0.32	0.27	0.35	0.30	0.28	0.26
Kanking	0.34	0.32	0.34	0.32	0.35	0.26
Ponca	0.31	0.33	0.36	0.31	0.27	0.25
Triumph 64	0.37	0.37	0.40	0.37	0.40	0.32
Scout 66	0.33	0.36	0.37	0.32	0.34	0.26
Payne	0.38	0.39	0.39	0.38	0.36	0.28
TAM W-101	0.39	0.37	0.42	0.40	0.38	0.29
TAM 105	0.37	0.39	0.44	0.36	0.38	0.29
Vona	0.43	0.42	0.45	0.38	0.34	0.26
Newton	0.34	0.37	0.44	0.37	0.36	0.27
Hawk	0.38	0.41	0.46	0.38	0.37	0.28
Chisholm	0.45	0.44	0.44	0.42	0.41	0.33
Means of Environment	0.32	0.32	0.36	0.32	0.31	0.26
L.S.D. (0.05)	0.04	0.02	0.02	0.03	0.04	0.04
L.S.D. (0.05) for Treatment and Environment	0.03	0.01	0.02	0.02	0.03	0.03
C.V.	8.0	3.9	4.1	5.4	8.2	10.1
BIOMASS (kg/ha)						
Triplet	8907	8111	8601	9940	4201	4483
Ashkof	9488	6855	7879	8826	3288	3694
Sturdy	8957	7348	5828	9113	4507	3852
CI 7126	8013	8178	8388	8854	4803	4029
Akakawa	9421	7597	7348	10227	4088	4235
CI 8530	9397	7699	8529	9270	3836	3336
Baca	9820	8527	8254	9717	4934	4395
Turkey Sel	9653	7011	7649	10057	4183	3981

TABLE X (Continued)

Genotype	1983			1984		
	Stillwater	Altus	Goodwell	Stillwater	Altus	Goodwell
BIOMASS (kg/ha), Continued						
Hope/Turkey	9232	7276	7030	9969	3766	3783
Cheyenne/Tenmarq	8228	7080	6021	9538	4281	3816
Turkey 1069/Cheyenne	10074	8778	8386	9512	4339	3843
Turkey Selection	9065	8259	7937	9416	4304	4206
Triumph	9732	8663	7113	9634	5064	4302
Blue Jacket	11030	8967	7970	10332	4739	5165
Newsar	9744	8096	8747	10050	4695	4404
Clark R 169	9113	8132	8924	10485	4263	4684
Royal D 85	7687	7417	7233	8584	4224	4204
Hope/Turkey/Cheyenne	8596	8694	7227	10174	4871	3725
CI 13898	9105	7133	8584	9132	4614	4400
Blue boy II	9330	7522	8259	8893	4910	3881
Goens	7848	7829	6946	9005	3780	4485
Turkey Selection	8809	6815	7550	9445	3830	4591
Red Chief	8811	7965	10090	10734	5329	4973
Tayland	10370	7769	7690	9722	4655	3596
Ind 4126A 9-42-1	8632	7735	7226	9988	3786	4182
NB67786	9660	7915	7539	9490	4936	4034
Near Iso Pm I	8993	7879	7953	10322	4990	3367
Centurk	9662	8465	7901	9380	4811	3704
Cheyenne	8936	8216	8295	9323	4263	4591
Kanking	9153	8900	9358	10695	4721	5399
Ponca	10212	8252	9603	10229	4433	4706
Triumph 64	9215	7470	7262	10334	4631	4993
Scout 66	9089	8622	8412	10490	4717	4134
Payne	9832	7692	9648	10499	4631	3921
TMA W-101	9385	8345	7116	10511	4743	4670
TAM 105	9328	8536	7319	10495	4351	4997
Vona	7800	7314	8618	9935	4721	3477

TABLE X (Continued)

Genotype	1983			1984		
	Stillwater	Altus	Goodwell	Stillwater	Altus	Goodwell
BIOMASS (kg/ha), Continued						
Newton	9046	7848	6595	8775	4499	3175
Hawk	8118	7075	8273	8830	4579	3443
Chisholm	8838	7891	5710	10318	5031	4314
Means of Environment	9158	7897	7875	9756	4483	4179
L.S.D. (0.05)	1779	721	1836	1314	554	1094
L.S.D. (0.05) for Treatment and Environment	1273	516	1315	941	397	783
C.V.	12.0	5.6	14.4	8.3	7.6	16.2
PLANT HEIGHT (cm)						
Triplet	106	84	104	111	60	71
Ashkof	121	91	113	117	60	60
Sturdy	74	64	71	84	61	57
CI 7126	99	86	102	117	67	68
Akakawa	121	102	116	139	73	83
CI 8530	118	104	111	123	76	71
Baca	102	78	87	105	61	67
Turkey Sel	107	82	94	113	59	63
Hope/Turkey	108	83	97	105	58	63
Cheyenne/Tenmarq	101	76	87	102	54	61
Turkey 1069/Cheyenne	109	80	94	105	56	56
Turkey Selection	101	81	87	105	58	65
Triumph	92	79	84	106	65	65
Blue Jacket	118	93	109	120	69	77
Newsar	121	97	115	128	72	79
Clark R 169	122	96	112	127	70	81
Royal D 85	114	96	104	122	65	67

TABLE X (Continued)

Genotype	1983 Stillwater	 Altus	 Goodwell	1984 Stillwater	 Altus	 Goodwell
PLANT HEIGHT (cm)						
Hope/Turkey/Cheyenne	100	80	85	108	62	64
CI 13898	95	80	93	105	69	76
Blue boy II	87	69	81	95	62	62
Goens	105	92	105	118	64	72
Turkey Selection	107	85	93	103	59	63
Red chief	106	89	104	123	69	78
Tayland	112	92	113	121	70	69
Ind 4126A 9-42-1	115	90	103	123	64	71
NB67786	100	88	93	115	68	68
Near Iso Pm I	103	82	98	118	68	67
Centurk	89	71	83	96	57	58
Cheyenne	108	83	97	111	57	58
Kanking	109	87	98	116	66	75
Ponca	107	81	93	110	62	67
Triumph 64	89	78	80	106	64	71
Scout 66	97	78	93	111	62	66
Payne	78	63	76	89	56	54
TAM W-101	76	62	65	83	54	58
TAM 105	82	64	69	87	53	59
Vona	70	64	70	84	53	57
Newton	85	63	73	87	50	59
Hawk	76	64	71	84	50	58
Chisholm	74	67	69	88	58	60
Means of Environment	100	81	92	108	62	66
L.S.D. (0.05)	10	6	8	5	5	6
L.S.D. (0.05) for Treatment and Environment	7	5	6	4	4	4
C.V.	6.3	4.8	5.1	3.1	5.2	5.2

VITA 2

Ghulam Sarwar Ibram

Candidate for the Degree of

Master of Science

Thesis: GENETIC VARIATION OF SELECTED CHARACTERS AND THEIR RELATIONSHIPS TO PRODUCTIVITY IN WHEAT (TRITICUM AESTIVUM L.)

Major Field: Agronomy

Biographical:

Personal Data: Born in Jabul Saraj, Parwan, Afghanistan, March 2, 1952, the son of Mr. and Mrs. Mohammad Khaliq.

Education: Graduated from Jabul Saraj High School, Jabul Saraj, Parwan, Afghanistan, in December, 1971; obtained a Fulbright Inter-Cultural Scholarship and attended Pittsburgh University, Pittsburgh, Pennsylvania, in 1976; received Bachelor of Science degree in Agriculture from Faculty of Agriculture, Kabul University, Kabul, Afghanistan, in January, 1977; obtained a UNEP/UNESCO Scholarship on "Postgraduate Training Course on Ecosystem Management" and attended Dresden Technical University, Dresden, East Germany, in 1979-1980; completed the requirements for the Master of Science degree at Oklahoma State University in May, 1985.

Professional Experience: Assistant Professor in the Faculty of Agriculture, Kabul University, Kabul, Afghanistan, from 1977 to 1979; Graduate Research Assistant, Department of Agronomy, Oklahoma State University, Stillwater, Oklahoma, 1982-1984.

Professional Organization: Member of the American Society of Agronomy and the Crop Science Society of America.