AN ABSTRACT OF THE THESIS OF

Pedro Brajcich for the degree of Doctor of Philosophy

in Crop Science presented on October 27, 1980

Title: Nature of Inheritance, Genotype-Environment Interaction and Association of Selected Agronomic Characters in Crosses of Winter X Spring Wheats (*Triticum aestivum* L. em Thell).

Abstract approved: Redacted for Privacy

Warren E. Kronstad

This investigation was motivated by the apparent increase in genetic variability resulting from the systematic combining of gene pools represented by winter and spring types of wheats.

It was the objective of this study to provide information regarding the nature of this genetic variability for nine agronomic characters in populations resulting from winter x spring crosses. Evaluations were made for: 1) the amount of total genetic variability; 2) the nature of the gene action making up this genetic variability using parent-progeny regression and combining ability analysis and 3) possible direct and indirect associations for traits which influence grain yield. Experimental populations which involved parents, F1, F2 and backcross generations were grown at two locations where a spring and a winter environment could be utilized. At the winter site, the research was evaluated over a two year period.

When the two experimental sites were compared, greater genetic diversity was observed at the spring site for maturity date, plant height,

tillers per plant, kernel weight and grain yield. At the winter site, heading date, grain filling period, harvest index and kernels per spike were found to have more total genetic variation.

From the expected mean square values, it would appear that the winter parents contributed more to the total genetic variation for most traits measured at both locations. A large genotype-location interaction was also noted suggesting that estimates of gene action and selection for adapted plant types can be done only at the specific winter or spring site.

A large portion of the total genetic variation controlling the traits measured was due to additive gene action. However, at the winter site there was also a large influence of non-additive gene action associated with heading date, plant height, harvest index, tillers per plant, kernel weight, kernels per spike and grain yield.

Of special interest was that at the winter site the most promising parental combinations could be predicted based on the general combining ability effects of the individual cultivars for each trait studied. Such data were not available for the spring site.

Consistent and high correlations were observed between tillers per plant, kernels per spike and, to a lesser extent, kernel weight and grain yield at the winter location. Some negative associations were observed at the spring location between these traits and grain yield suggesting that yield component compensations were involved in the final expression of grain yield. The other characters measured did not reflect significant correlations with yield. When the correlation values were considered in terms of direct and indirect effects for specific traits, a large direct effect was noted for the three components and grain yield.

The other traits exhibited small or no direct effects on grain yield but did have a slight influence on grain yield through tillers per plant, kernels per spike or kernel weight.

Nature of Inheritance, Genotype-Environment Interaction and Association of Selected Agronomic Characters in Crosses of Winter X Spring Wheats (*Triticum aestivum* L. em Thell)

by

Pedro Brajcich

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Doctor of Philosophy
June, 1981

APPROVED:

Redacted for Privacy

Professor of Agronomy in charge of major

Redacted for Privacy

Head of Department of Crop Science

Redacted for Privacy

Dean of Graduate School

Date thesis is presented October 27, 1980

Typed by Kathie Klahn for Pedro Brajcich

IN DEDICATION TO:

Juana Maria, my wife

Rady, my son

Rodolfo and Petronila, my parents

Carlos and Aminta Elena, my wife's parents

ACKNOWLEDGEMENTS

I wish to express my sincere gratitude to my major professor, Dr. Warren E. Kronstad, for his encouragement, guidance, assistance and friendship during my course work and preparation of this thesis.

Appreciation is extended to Drs. Fred A. Cholick, Robert L. Powelson, William D. Hohenboken and Barry J. Schrumpf for serving on my graduate committee. Thanks are extended to Dr. Robert J. Metzger for his advise in the greenhouse and to Dr. Kenneth E. Rowe for his assistance on the experimental design and analysis of this study.

Special thanks are extended to Dr. Fred A. Cholick, Mary C. Boulger and Nan H. Scott for their critical review of different sections of the manuscript and to Kathie Klahn for typing the final draft.

To my wife, Juana Maria, my sincere appreciation for her patience, encouragement, understanding and help with typing the manuscript and tables several times.

I also wish to express my gratitude to the International Maize and Wheat Improvement Center for the help received at the Northwest Agricultural Research Center in Mexico and to the Rockefeller Foundation for its financial support throughout my course work.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDIX FIGURES

LIST OF APPENDIX TABLES

NATURE OF INHERITANCE, GENOTYPE-ENVIRONMENT INTERACTION AND ASSOCIATION OF SELECTED AGRONOMIC CHARACTERS IN CROSSES OF WINTER X SPRING WHEATS (Triticum aestivum L. em Thell)

INTRODUCTION

In recent years, progress in wheat breeding for higher yielding cultivars has been slow and concerns are expresed regarding possible yield plateaus. One reason could be the exhaustion of the useable genetic diversity available within winter and spring wheat populations. An approach to increasing grain yield is to combine, through hybridization, the winter and spring gene pools, thus hopefully broadening the useable genetic variation for further cultivar improvement.

Spring and winter wheats have evolved over time into separate gene pools due to their different ecological requirements and the reluctance of breeders to make crosses between such diverse types. It is significant, however, that the limited amount of winter x spring crossing carried out in the past gave rise to some important varieties. These included winter varieties such as Hybrid 128, Ridit and Rex and spring types such as Thatcher, Mentana and Federation 41. More recently the cultivars which started the "Green Revolution" resulted from combining daylength insensitivity from spring wheat (Gabo) with the semidwarf stature obtained from winter wheat (Norin 10).

Systematic crossing of winter and spring wheats became possible when the International Maize and Wheat Improvement Center (CIMMYT) discovered in 1972 that both types would flower simultaneously in the field at the Toluca Experimental Station in Mexico thus making wide scale crossing possible. This has allowed CIMMYT and Oregon State University to capitalize on the potential increased genetic diversity from such crosses to improve both spring and winter wheat using conventional breeding methods.

Information on winter x spring crosses is lacking regarding the nature of gene action contributing to the total genetic variation for the agronomic characters that influence the expression of grain yield. Thus, the objectives of this investigation were: 1) to measure the nature of genetic variability that can be obtained when winter x spring gene pools are combined; 2) to assess the potential of such crosses for the improvement of both winter and spring wheat cultivars when the experimental populations were grown at both winter and spring wheat growing locations; 3) to estimate and compare the type of gene action resulting from winter x spring with the winter x winter and spring x spring crosses; 4) to determine if the relative general combining ability estimates of gene action in winter x spring crosses can be used to predict those parental combinations with the greatest potential; and 5) to determine the possible association and interrelationship among selected agronomic characters and grain yield in winter x spring crosses when grown in winter and spring environments.

LITERATURE REVIEW

Breeding for grain yield per se in wheat is becoming more difficult due to its complex nature and the possible exhaustion of usable genetic diversity. Grain yield is the product of several morphological components which are in turn influenced by genetic and environmental factors. If further yield increases are to be made, the nature of gene action of those components controlling grain yield and their interrelationship must be better understood. Such information is lacking for the increased genetic variation now being created with the systematic hybridization of winter x spring cultivars. This literature review will cover combining ability estimates, associations and interrelationships among selected agronomic traits that influence grain yield, primarily in wheat.

Combining ability

Combining ability is the relative capacity of an individual to transmit desireable characteristics to its progeny. There are two types of combining ability as defined by Sprague and Tatum (1942). They are: (1) General combining ability, which refers to the average performance of a line in hybrid combinations and (2) Specific combining ability, which designates those cases in which certain crosses do better or worse than expected on the basis of the average performance of the two parental lines involved in the cross. The former is regarded as a measure of additive gene action, while the latter is an estimate of non-additive gene action.

Combining ability has been used widely in both animal and plant breeding. Plant breeders of cross-pollinated species, especially corn, have used this concept for selecting inbred lines to be used in hybrid production (Sprague and Tatum, 1942; Rojas and Sprague, 1952; and Matzinger et al., 1959).

In self-pollinated species, combining ability was used in breeding programs on lima beans by Allard (1956), on soybeans by Leffel and Hanson (1961), on winter wheat by Kronstad and Foote (1964), Gyawali et al. (1968), Bitzer and Fu (1972) and Parodi and Patterson (1973) and with spring wheat by Walton (1971) and Bhatt (1971). Most of these studies have used a diallel crossing system and estimated general and specific combining ability following Griffing's model of diallel analysis (Griffing, 1956. Kronstad and Foote (1964) presented the first detailed information on general and specific combining ability in winter wheat. From a ten-parent diallel cross they reported that most of the total genetic variation for the components of yield and grain yield was associated with significant general combining ability effects. Specific combining ability effects were significant for grain yield and plant height but not for the yield components. Similar results were obtained by Brown, et al. (1966), Bitzer and Fu (1972) and Parodi and Patterson (1973). Gyawali et al. (1968) found that both general and specific combining ability were significant for grain yield, yield components, plant height and heading date. Only general combining ability effects were significant for heading date, plant height and kernels per spike (Bitzer, et al., 1971).

In spring wheat Walton (1971) detected highly significant general combining ability effects for grain yield, yield components, flowering date, maturity date and filling period. Specific combining ability was significant only for flowering date, maturity date and filling period. General and specific combining ability effects were important for the yield components with the exception of number of tillers per plant as reported by Bhatt (1971) also in spring wheat.

A diallel experiment consisting of six winter and two spring parents was conducted by Mihaljev (1976). The results indicated that general combining ability was highly significantly associated with grain yield and yield components. Specific combining ability effects were significant only for kernel weight.

To postpone diallel analysis of characters such as grain yield until the F2 generation when more seed is available was suggested by Bhatt (1973a). The breeder then can obtain estimates of the genotype-environment interaction on more experimental material. A diallel cross involving seven spring parents was evaluated by Bhullar et al. (1979). The analyses were conducted in the F1, F2 and F3 generations for grain yield, tillers per plant, kernels per spike and kernel weight. General combining ability effects were consistent over the generations for all the traits. However, specific combining ability effects showed little consistency and lacked repeatability over the generations. Similar results were obtained by Jatasra and Paroda (1978) and Alexander (1980).

Associations and Interrelationships Among Agronomic Traits

Plant breeders are often faced with the problem of improving a number of agronomic characters simultaneously; therefore, a better understanding of the association among these characters is needed for more effective selection. In wheat, increasing grain yield potential is the major goal in most breeding programs. Grain yield is a complex character controlled by several components. Direct selection for yield improvement has not always met with success, due in part to the susceptibility of this character to environmental changes. This situation may be alleviated by considering agronomic traits related to grain yield that are more highly heritable. Grafius (1956) visualized grain yield in oats as the volume of a rectangular parallelepiped with three edges corresponding to three yield components. However, an increase in one edge of the parallelipiped does not necessarily result in a corresponding increase of the volume, because the response of components are not biological independent. Adams (1967) suggested the yield components are genetically independent characters but are frequently negatively associated. He speculated that the negative relationships were due largely to competition for growth substances by sequentially developing characters. In barley, the negative correlation among the yield components was attributed to a linkage of genes controlling the components (Rasmusson and Cannel, 1970). Adams and Grafius (1971) proposed an alternative explanation based on an oscilatory response of yield components due to the sequential nature of components development and a limitation of environmental resources.

Correlations of agronomic characters with grain yield in wheat have been reported by several workers (Hsu and Walton, 1970; Sing _et al_., 1970; Anand _et al_., 1972; Khan _et al_., 1972; Nass, 1973; Bhatia, 1975; Fischer and Kertesz, 1976; Jatasra and Paroda, 1979). Although these estimates are helpful, they do not provide an exact picture of the relative importance of direct and indirect influences of the component characters on this trait. Path-coefficient analysis developed by Wright (1921), which is simply a standardized partial regression analysis, appears to be helpful in partitioning the correlation coefficients into direct and indirect effects. It is used in making selection by providing a causal picture of the correlations of the dependent variable with its components as has been shown by Dewey and Lu (1959).

Path-coefficient analysis was used by Kronstad (1963) to determine direct and indirect effects of tiller number, kernel weight, kernels per spikelet, spikelets per spike and plant height on grain yield for 45 winter wheat F1's. High positive correlations were found between grain yield and kernels per spikelet and spikelets per spike. Both associations were determined almost completely by large direct effects, and only small positive or negative effects were exerted indirectly. Negative associations between kernel weight and kernels per spikelet canceled out the large direct effect of kernel weight on grain yield. There was also a negative correlation between tiller number and grain yield which was the result of the negative associations of tiller number with kernels per spikelet and spikelets per spike. Plant height exerted a positive indirect effect via kernels per spikelet on grain yield.

A high direct effect on grain yield by tiller number, kernels per spike and kernel weight was reported by Fonseca and Patterson (1968). They also observed small direct effects of flowering date and plant height on grain yield. The authors concluded that progress in winter wheat by selection for yield components rather than grain yield per se may be limited somewhat by the strong negative correlation between tiller number and kernel weight. Abi-Antoun (1977) reported that grain yield correlated significantly with spike size and kernels per spike but not with tiller number or kernel weight. The yield components had a high direct effect in the expression of grain yield. Component compensation resulted in low correlation between grain yield, tiller number and seed size. He detected a very low direct and indirect effect of harvest index, filling period and plant height on grain yield. Sidwell et al. (1976) concluded, based on path-coefficient analysis, that selection of kernel weight in early generations of winter wheat is the most important factor for increasing grain yield.

Correlations and path-coefficient analysis suggested that in spring wheat, tiller number and kernel weight are important primary components of grain yield (Das, 1972; Bhatt, 1973b). Maya de Leon (1975) indicated that tiller number had a high direct effect on grain yield. Kernels per spike and kernel weight had no direct effect on grain yield but their indirect effect via spike weight were positive and significant. Virk et al. (1977) reported a positive association of yield components and plant height with grain yield. The correlation of plant height always resulted from its indirect effect with other traits correlated with grain yield.

Correlation and path-coefficient analysis was used by Firat (1978) in four winter x spring wheat crosses. He observed that tiller number had the highest direct effect on grain yield. However, due to negative associations between tiller number and kernel weight, selection in these types of crosses would have to be balanced between these two yield components.

Combining ability has been useful in selecting parental cultivars that could produce more desireable progenies in many different crop species. It has also appeared to be successful in identifying the most promising parental combination in wheat, especially when the relative contribution of each parent can be identified in terms of their gene action. The literature suggests that both additive and non-additive nature of gene actions influence the expression of grain yield in wheat. However, additive genetic variance is preponderant in the expression of yield components in both winter and spring type cultivars. Also, it appears that component approach may have limited value due to possible compensating effects between morphological factors influencing the final grain yield, especially under high production environments.

MATERIALS AND METHODS

Five winter and five spring wheat cultivars were chosen for this study. The winter wheat cultivars were Kavkaz, Roussalka, Yamhill, Hyslop and Weique Red Mace. Inia 66, Siete Cerros 66, Torim 73, Jupateco 73 and Huacamayo "S" were identified as the spring wheat cultivars. These ten cultivars differ in growth habit, plant height, grain yield, yield components and other agronomic characteristics. Pedigree and description of each cultivar is listed in the Appendix Table 1. Three studies were conducted: two at Hyslop Agronomy Farm, Corvallis, Oregon during two crop seasons (1976-77 and 1977-78) and one at Northwest Agricultural Research Center (CIANO), located near Ciudad Obregon, Sonora in northwest Mexico. They are identified as Study I, Study II and Study III.

Crosses between the winter and spring wheats were made in the summer of 1976 at the Toluca Experimental Station in Mexico. Subsequent crosses within winter and spring types, backcrosses to winter and spring parents and the winter x spring F2's were obtained in the greenhouse at Corvallis, Oregon in 1977.

Study I. Hyslop Farm, 1976-77.

The winter and spring wheat parents and the F1 generation resulting from crosses between the two groups were planted on October 23, 1976. A complete randomized block design with four replications was used to determine possible differences for the traits and generations measured.

Each replication consisted of one row for each parent and F1. The rows consisted of ten plants, spaced 20 cm apart with 30 cm spacing between rows. Where missing plants occurred, barley was planted in the spring to provide uniform competition. Weeds were controlled by hand cultivation. Before planting, 300 kg/ha of fertilizer (16-20-0) was applied. Later, at the tillering stage, an additional 400 kg/ha of urea was broadcast.

Study II. Hyslop Farm, 1977-78.

A split plot design was used with crosses as main plot, and parents and generations as sub-plots. Four replications were planted. The crosses consisted of two experimental populations: 1) winter x spring and 2) winter x winter. The winter x spring populations included the winter and spring parents, F1's, F2's and both backcrosses. Only parents and F1's were included in the winter x winter population.

There was one row for the parents and F1's, six rows for F2's and four rows for backcrosses. Each row consisted of ten plants spaced 20 cm apart. The distance between rows was 30 cm. This experiment was planted on October 12, 1977.

Before planting, 300 kg/ha of fertilizer (16-20-0) was applied. Later, at the tillering stage, an additional 400 kg/ha of urea was broadcast. On May 18, 1978, 0.5 kg/ha of Bayleton was applied to avoid a stripe rust (Puccinia striiformis) epidemic.

Study III. CIANO, 1977-78.

This study had the same experimental design at Study II with four replications. The crosses consisted of two populations: 1) winter x spring and 2) spring x spring. The winter x spring populations consisted of spring parents, F1's, F2's and backcrosses. Only parents and F1's were included in the spring x spring populations.

There was one row for the parents and F1's, six rows for F2's and four rows for backcrosses. Each row consisted of ten plants spaced 20 cm apart. The distance between rows was 30 cm. This experiment was planted on November 29, 1977. Before planting, 150 kg/ha of Nitrogen and 60 kg/ha of Phosphorus as P_2O_5 was applied. The experiment was irrigated six times during the growing season to avoid any possible water stress. Bayleton at the rate of 0.75 kg/ha was applied three times to avoid stem rust (Puccinia graminis f. sp. tritici) and leaf rust (Puccinia recondita) epidemics.

The total number of seeds planted per cross for each generation in their respective studies were: Parents, 40; F1's, 40; F2's, 240; backcrosses to winter parents, 160; and backcrosses to spring parents, 160.

One of the objectives of this investigation was to evaluate the amount of usable genetic variability that can be obtained from the winter x spring crosses. For that purpose a check variety was used as a reference point at each location. At Hyslop Farm, Federation was identified as standard level of winterhardiness. However, during the course of this investigation no winter injury was detected and all the plants from the experiment were utilized. At CIANO, Zaragoza 75 was used as a measure of heading date. This is the variety with the latest heading date that a farmer can use for commercial production in the Yaqui Valley, Mexico. All plants that headed before or at the same time as Zaragoza 75 (96 days) were included in the experiment.

A summary of climatic data for the three studies is presented in Appendix Table 2. The soil type at Hyslop Farm is a Woodburn silt loam. At CIANO, the soil type is brown clay loam developed as a coastal plain outwash under desert conditions.

Data were collected on an individual plant basis in the three studies.

1. Heading date was obtained by recording the number of days from January 1 for the studies conducted at Hyslop Farm and at CIANO from November 29 (planting date) to the date when approximately one-half of the developed tillers of each individual plant had exerted the complete spike beyond the auricules of the flag leaf.
2. Maturity date was recorded when approximately half of the tillers of an individual plant had reached physiological maturity.
3. Grain filling period was calculated as the difference between heading and maturity date.
4. Plant height was obtained at maturity by measuring from the base of the crown to the tip of the spike of the main tiller, excluding awns if present.
5. Number of tillers per plant was recorded as the number of culms bearing fertile spikes.
6. Grain yield per plant was determined by the weight of the grain in grams.
7. Harvest index, expressed in percent, was the ratio of grain yield per plant to the weight of the whole plant excluding roots (this character was recorded for only two replications in Study II, Hyslop Farm, 1977-78).
8. One hundred kernel weight was recorded in grams by weighing 100 kernels

randomly selected from each individual plant.

9. Number of kernels per spike (x) was determined indirectly from the following data: (a) grain yield per plant, (b) 100 kernel weight and (c) number of tillers per plant

$$x = \frac{100\ (a/b)}{c}$$

An analysis of variance was conducted on the above characteristics. Each study was analyzed separately. The F test was utilized to determine significant differences (Snedecor and Cochran, 1967). Plot means were used for the analysis. The mean values in each study for each generation were compared using Duncan's new multiple range test at the 5 percent probability level.

Phenotypic variances among winter x spring F2's for all crosses were computed by pooling variances among plants within replications for each cross. Environmental variance was estimated by taking the average of pooled variances from non-segregating generations (parents and winter x spring F1's in Study II and for Study III the pooled variances of the spring parent). The genetic variances of each cross in Study II and III were obtained by subtracting the environmental variances from the phenotypic variances.

Parent-offspring regression estimates were obtained for the nine agronomic characters by regression in standard units from replication means (Frey and Horner, 1957); F1 on mid-parent (MP) for winter x spring (Study I and II), winter x winter and spring x spring crosses; F2 on spring parent (SP) for winter x spring crosses from Study III; also F2 on MP and F2 on F1 for the winter x spring crosses for Study II.

The variation between winter x spring F1's from Study I and II and winter x spring F2's from Study II and III were partitioned into general combining ability due to winter parents (GCA-winter parents), to spring parents (GCA-spring parents) and to specific combining ability (SCA). The model given by Kempthorne (1959) and Lupton (1965) was followed, which is similar to experiment II of Comstock and Robinson (1952). Each study was analyzed separately and then the two years (Study I and II) and two locations (Study II and III) were combined for further examination.

Estimates of general combining ability effects were computed by subtracting the winter or spring parent progeny mean ($\overline{X}_{i.}$ or $\overline{X}_{.j}$, respectively) from the grand mean ($\overline{X}_{..}$). Specific combining ability effects were computed by subtracting the winter and spring array means from the individual cross mean over replications ($\overline{X}_{ij}$), then adding the grand mean.

Thus,

$$g_{i.} = \overline{X}_{i.} - \overline{X}_{..}$$
$$g_{.j} = \overline{X}_{.j} - \overline{X}_{..}$$
$$s_{ij} = \overline{X}_{ij} - \overline{X}_{i.} - \overline{X}_{.j} + \overline{X}_{..}$$

Estimates of general and specific combining ability were also obtained for winter x winter F1's (Study II) and spring x spring F1's (Study III) by using Method 4, Model I proposed by Griffing (1956). In this method, one set of F1's are included in a matrix and neither parents nor reciprocal F1's are used. The fixed model was used because parents constituted a selected set of cultivars. Contributions of the parents due to general combining ability (GCA) and specific combining ability (SCA) effects were also computed for the agronomic characters studied (Griffing, 1956).

Simple correlation coefficients among the agronomic characters studied were computed for each winter x spring cross. The correlation coefficients of yield and other characters were further partitioned into direct and indirect effects by the path-coefficient analysis (Li, 1956; Dewey and Lu, 1959). For Study II, replication means of the F1, F2 and reciprocal backcrosses were studied and spring parents, F2 and backcrosses to spring parents from Study III. The association of yield with all measured characters is illustrated in Figure 1 and 2 (Appendix). Standardized partial regression coefficients were obtained by the simultaneous solution of the equations observed in Appendix Tables 3 and 4.

EXPERIMENTAL RESULTS

Analysis of Variance

The results were obtained from three studies (Study I and Study II conducted at Hyslop Agronomy Farm and Study III conducted at the Northwest Agricultural Research Center (CIANO) in Mexico) by measuring nine agronomic characters in winter x spring, winter x winter and spring x spring crosses. For Study I the winter parents, spring parents and winter x spring Fl's were used. In Study II, in addition to parents and winter x spring Fl's, winter x winter Fl's, winter x spring F2's and reciprocal backcrosses of the winter x spring Fl's were considered. For Study III a maximum days to heading limit was established for winter x spring crosses to avoid selecting unadapted late progeny. Only spring parents, winter x spring F2's and backcrosses to spring parents plus the spring x spring Fl's were used as the experimental material in this later study.

Study I

Observed mean square values from analysis of variance for nine agronomic characters are presented in Table 1. Highly significant differences were noted among the 35 genotypes for all the characters measured. The same was true for between and within groups (winter parents, spring parents and their Fl's) with the exception of tillers per plant, which was not significant between groups. The sources of variation were further partitioned within each group. Significant differences (P = 0.01) were detected within winter parents and Fl's for

Table 1. Observed mean square values obtained for nine agronomic characters of wheat from five winter parents, five spring parents and their 25 winter x spring F1's. Hyslop Farm, 1976-77.

Source of Variation	df	Heading Date	Maturity Date	Filling Period	Plant Height	Tillers Per Plant	Grain Yield	Harvest Index	100 Kernel Weight	Kernels Per Spike
Replications	3	1.42	25.57**	21.13**	50.73**	0.94	123.26	18.66	.12	123.24**
Genotypes	34	263.28**	36.34**	131.05**	422.59**	14.89**	436.45**	73.66**	1.21**	310.46**
Between Groups	2	2,027.67**	180.39**	3,694.26**	2,341.70**	4.61	1,707.99**	72.50**	8.45**	213.22**
Within Groups	32	153.01**	27.34**	74.59**	302.65**	15.53**	356.98**	73.73**	.76**	316.53**
Within Winter Parents	4	434.17**	139.84**	106.10**	350.63**	35.66**	398.98**	114.13**	.53**	202.79**
Within Spring Parents	4	184.94**	11.92**	152.71**	270.08**	13.93*	491.70**	20.29*	.79**	231.70**
Within WXS F1's	24	100.83**	11.16**	56.32**	300.08**	12.44**	327.52**	75.91**	.79**	349.63**
Error	102	1.31	4.02	4.61	6.93	6.25	66.79	7.33	.04	27.02
Total	139									
C.V. %		0.84	1.05	3.91	2.68	14.78	18.54	7.36	4.33	9.60

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

all the characters. Within spring parents the same was true with the exception of tillers per plant and harvest index. These were significantly different at a lower probability level (P = 0.05).

Study II

Highly significant differences were noted among the 25 winter x spring crosses for eight of the characters measured. Tillers per plant was the exception not being significantly different (Table 2). Generations and the interaction of crosses x generations were significantly different (P = 0.01) for all the characters evaluated. For harvest index (Table 3), which was measured for only two generations, a highly significant difference was observed for crosses, generations and the crosses x generations interaction.

In the winter x winter populations, crosses were significantly different for all the characters with the exception of tillers per plant and grain yield (Table 4). Generations also resulted in highly significant differences for all the characters except tillers per plant. There was a highly significant interaction of crosses x generation in all traits. For harvest index (Table 5), which was measured for only two replications, a significant difference was observed for crosses at the 5% probability level and at the 1% probability level for generations and the interaction of crosses x generations.

Study III

In winter x spring crosses (Table 6) the differences were highly significant for all traits measured except kernels per spike, where

Table 2. Observed mean square values for eight agronomic characters from 25 winter x spring wheat crosses. Hyslop Farm, 1977-78.

Source of Variation	df	Heading Date	Maturity Date	Filling Period	Plant Height	Tillers Per Plant	Grain Yield	100 Kernel Weight	Kernels Per Spike
Replications	3	19.56	106.23**	181.94**	96.87	7.70	264.75	1.12*	247.70*
Crosses	24	1,343.20**	245.04**	526.10**	1,089.64**	16.58	281.78**	.98**	424.94**
Error (a)	72	10.87	25.02	38.78	62.34	10.71	112.91**	.29	87.88
Generations	5	8,859.57**	803.49**	4,598.07**	4,501.39**	276.81**	4,209.85**	16.33**	1,782.08**
Crosses X Generations	120	133.34**	44.97**	43.59**	104.65**	6.58**	88.90**	.20**	149.81**
Error (b)	375	5.71	4.35	8.08	15.38	2.77	24.61	.05	27.64
Total	599								
C.V. %		1.12	1.55	7.11	3.32	16.98	26.31	7.07	13.26

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

Table 3. Observed mean square values for Harvest Index from 25 winter x spring wheat crosses. Hyslop Farm, 1977-78.

Source of Variation	df	Harvest Index
Replications	1	5.50
Crosses	24	106.69**
Error (a)	24	21.71
Generations	5	208.64**
Crosses X Generations	120	18.96**
Error (b)	125	6.67
Total	299	
C.V. %		7.31

**Significant at the 1% probability level.

Table 4. Observed mean square values for eight agronomic characters from 10 winter x winter wheat crosses. Hyslop Farm, 1977-78.

Source of Variation	df	Heading Date	Maturity Date	Filling Period	Plant Height	Tillers Per Plant	Grain Yield	100 Kernel Weight	Kernels Per Spike
Replications	3	10.47	64.53**	110.69**	144.73	10.89	319.26*	.73*	202.24*
Crosses	9	915.16**	269.07**	203.22**	531.49**	7.67	223.64	.51**	441.70**
Error (a)	27	8.72	14.36	23.47	57.64	10.46	103.73	.18	50.92
Generations	2	1,074.93**	513.33**	94.59**	1,857.47**	3.70	1,108.58**	1.93**	1,311.90**
Crosses X Generations	18	409.92**	80.77**	154.36**	335.69**	11.15**	144.38**	.41**	219.56**
Error (b)	60	8.54	6.79	8.53	16.43	4.28	38.29	.07	27.44
Total	119								
C.V. %		2.04	1.64	8.99	5.50	19.03	28.04	7.38	12.38

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

Table 5. Observed mean square values for Harvest Index from 10 winter x winter wheat crosses. Hyslop Farm, 1977-78.

Source of Variation	df	Harvest Index
Replications	1	7.15
Crosses	9	71.27*
Error (a)	9	18.34
Generations	2	134.06**
Crosses X Generations	18	22.46**
Error (b)	20	7.06
Total	59	
C.V. %		8.10

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

Table 6. Observed mean square values for nine agronomic characters from 25 winter x spring wheat crosses. CIANO, 1977-78.

Source of Variation	df	Heading Oate	Maturity Date	Filling Period	Plant Height	Tillers Per Plant	Grain Yield	Harvest Index	100 Kernel Weight	Kernels Per Spike
Replications	3	169.22**	29.55**	89.26**	63.79	22.22*	403.88**	678.29**	.063	1,078.97**
Crosses	24	70.24**	65.95**	18.94**	738.63**	50.88**	254.48**	86.61**	1.144**	106.65*
Error (a)	72	5.96	2.86	5.29	23.82	7.27	58.28	32.46	.059	51.97
Generations	2	4,260.05**	979.75**	1,182.18**	4,737.88**	199.34**	258.50**	976.92**	.539**	190.95**
Crosses X Generations	48	14.73**	12.59**	7.63**	82.57**	15.31**	89.76**	12.20	.139*	52.58**
Error (b)	150	3.83	1.71	3.38	9.58	3.52	29.82	15.49	.028	27.18
Total	299									
C.V. %		2.56	1.11	4.23	4.48	12.55	18.56	12.34	4.91	12.09

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

a significant difference at a lower probability level (P = 0.05) was noted. Generations and the interaction of crosses x generations were highly significant for all the traits measured with the exception of harvest index involving the crosses x generations interaction.

Nine traits were measured in the ten spring x spring crosses. Highly significant differenced among crosses were found for six traits (Table 7). Tillers per plant and grain yield were significantly different at the 5% probability level. No significant difference was noted for harvest index. For generations, significant differences at the 1% probability level were detected for maturity date, grain filling period and kernel weight. Significant difference was noted for kernels per spike at the 5% probability level. The other five characters were not significantly different. With the exception of harvest index, a highly significant interaction of crosses x generations was noted for all the characters.

Consistent low coefficients of variation (C.V.) were noted in the three studies for maturity date, heading date, grain filling period, plant height, kernel weight and harvest index. Usually the highest C.V. was obtained for grain yield. Intermediate C.V. values corresponded to kernels per spike and tillers per plant.

The observed mean values were ranked according to Duncan's new multiple range test for each generation in the three studies. They are presented in the Appendix Tables 5 to 15.

The nine agronomic characters measured expressed either significant differences for crosses and/or the interaction of crosses x generations, indicating that enough variability existed for further analysis.

Table 7. Observed mean square values for nine agronomic characters from 10 spring x spring wheat crosses. CIANO, 1977-78.

Source of Variation	df	Heading Date	Maturity Date	Filling Period	Plant Height	Tillers Per Plant	Grain Yield	Harvest Index	100 Kernel Weight	Kernels Per Spike
Replications	3	67.87**	33.23*	23.73*	73.48	13.19	269.78*	627.44**	.259*	707.33**
Crosses	9	24.68**	54.17**	17.64**	408.32**	24.83*	191.52*	29.80	.477**	230.72**
Error (a)	27	5.98	8.22	5.89	30.99	8.19	75.96	26.55	.066	65.82
Generations	2	1.60	31.64**	19.10**	10.47	5.18	43.45	13.88	.589**	96.61*
Crosses X Generations	18	24.90**	37.31**	9.32**	168.30**	12.83**	91.27**	22.66	.369**	101.92**
Error (b)	60	2.64	1.89	3.36	4.65	4.67	32.90	17.21	.027	30.26
Total	119									
C.V. %		2.53	1.54	3.92	4.67	14.83	20.24	10.74	4.76	12.67

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

Magnitude of Genetic Variances

Genetic variability for nine agronomic characters was measured in 25 winter x spring F2's grown at Hyslop Farm and CIANO in 1977-78 for Study II and III, respectively.

Study II

The magnitude of genetic variance observed for each cross at Hyslop Farm for the traits measured is given in Table 8. Crosses with Weique Red Mace or Hyslop and the specific cross, Yamhill-Inia 66, produced the greatest amount of genetic variability for heading date. Hyslop-Jupateco 73, Yamhill-Torim 73 and Roussalka-Juapteco 73 crosses resulted in the most genetic variability for maturity date. The crosses of Hyslop with Jupateco 73 and Torim 73 had greater variability for grain filling period. Greater variability for plant height was noted for Yamhill-Torim 73. For tillers per plant the following crosses produced the greatest variability: Weique Red Mace-Jupateco 73, Weique Red Mace-Huacamayo "S", Yamhill-Huacamayo "S" and Weique Red Mace-Siete Cerros 66. Crosses of Weique Red Mace with Jupateco 73, Siete Cerros 66 and Huacamayo "S" had greater variability for grain yield. Roussalka-Torim 73 and Kavkaz-Jupateco 73 crosses produced the greatest variability for harvest index. Kavkaz-Inia 66 for kernel weight and Weique Red Mace-Huacamayo "S" for kernels per spike were the highest.

Study III

Genetic variability generated by each cross at CIANO is presented

Table 8. Magnitudes of Genetic Variances generated by 25 winter x spring wheat crosses grown at Hyslop Farm, 1977-78.

Cross	Heading Date	Maturity Date	Filling Period	Plant Height	Tillers Per Plant	Grain Yield	Harvest Index	100 Kernel Weight	Kernels Per Spike
Kavkaz-Inia 66	35.72	4.40	12.88	20.05	6.39	10.68	---*	.3266	40.77
Kavkaz-Siete Cerros 66	8.28	4.49	18.16	91.68	6.18	1.91	79.44	.0378	130.52
Kavkaz-Torim 73	3.19	---	---	125.14	4.97	97.66	32.47	.0437	91.92
Kavkaz-Jupateco 73	8.57	4.66	21.72	105.20	8.63	88.81	179.68	.1838	102.70
Kavkaz-Huacamayo "S"	7.45	13.84	24.93	85.10	---	---	64.65	.2353	138.34
Roussalka-Inia 66	11.80	8.45	6.55	55.05	8.25	56.70	73.67	.0754	33.53
Roussalka-Siete Cerros 66	12.50	11.51	18.23	165.12	13.52	87.23	---	.1317	56.24
Roussalka-Torim 73	22.95	1.05	25.56	126.13	6.07	79.39	230.05	.1177	99.08
Roussalka-Jupateco 73	15.89	19.11	30.49	29.06	1.54	50.33	31.89	.3012	41.96
Roussalka-Huacamayo "S"	15.43	4.50	9.90	162.24	7.58	44.55	9.08	.1414	102.78
Yamhill-Inia 66	42.09	6.01	18.15	96.95	1.41	---	4.37	---	110.64
Yamhill-Siete Cerros 66	20.68	12.68	6.17	152.07	4.89	82.32	30.81	.2188	123.33
Yamhill-Torim 73	36.39	19.33	25.02	209.30	13.41	92.39	4.78	.0973	159.10
Yamhill-Jupateco 73	8.08	3.18	---	100.60	12.14	57.76	---	.1415	81.04
Yamhill-Huacamayo "S"	30.29	6.85	10.17	132.07	15.92	73.06	4.54	.0403	41.30
Hyslop-Inia 66	13.59	16.47	21.37	19.01	3.45	17.69	50.78	.0374	87.16
Hyslop-Siete Cerros 66	46.40	10.88	29.95	63.06	8.80	95.48	50.60	.1879	142.70
Hyslop-Torim 73	43.82	10.96	37.94	102.26	4.63	15.68	14.45	.1566	84.74
Hyslop-Jupateco 73	44.88	25.81	38.35	71.15	5.04	---	19.48	.2603	.82
Hyslop-Huacamayo "S"	45.33	15.41	21.90	64.28	10.72	11.24	12.53	.1908	52.85
W. R. Mace-Inia 66	51.50	---	---	82.39	9.47	78.12	---	---	103.98
W. R. Mace-Siete Cerros 66	63.08	---	3.99	71.86	15.33	132.45	.86	---	17.33
W. R. Mace-Torim 73	51.59	---	11.07	190.31	1.11	41.36	---	.0728	95.73
W. R. Mace-Jupateco 73	63.68	---	---	89.93	18.90	137.57	---	.2352	160.21
W. R. Mace-Huacamayo "S"	65.92	13.74	28.29	109.60	17.24	101.96	91.65	.2535	230.68
Average	30.76	8.53	16.83	100.78	8.22	58.17	39.43	.1392	90.09

---* Undetected amount.

in Table 9. The crosses of Roussalka with Torim 73 and Jupateco 73 resulted in greater variability for heading date. For maturity date and grain filling period the cross with the most variability was Roussalka-Siete Cerros 66. Hyslop-Jupateco 73 produced the highest value for plant height and tillers per plant. The greatest variability for grain yield was found in the Kavkaz-Jupateco 73 cross, followed closely by Hyslop-Torim 73. Kavkaz-Jupateco 73 also exhibited the greatest value for kernel weight. For harvest index and kernels per spike the following crosses had more genetic variability: Yamhill-Jupateco 73 and Yamhill-Huacamayo "S", respectively.

When the results of average genetic variability are compared between Hyslop Farm (Table 8) and CIANO (Table 9), four of the nine characters measured had greater average genetic variability at Hyslop Farm. They were heading date, grain filling period, harvest index and kernels per spike. At CIANO, the greater amount of genetic variability over the average was noted for maturity date, plant height, tillers per plant, grain yield and kernel weight.

Parent-offspring Standard Regression

To obtain information regarding the nature of gene action controlling the agronomic characters measured for each study, standardized regression coefficients were calculated.

Study I

The standardized regressions of F1 on mid-parent (MP) for the traits measured in the 25 winter x spring crosses are presented in Table 10.

Table 9. Magnitudes of Genetic Variances generated by 25 winter x spring wheat crosses grown at CIANO, 1977-78.

Cross	Heading Date	Maturity Date	Filling Period	Plant Height	Tillers Per Plant	Grain Yield	Harvest Index	100 Kernel Weight	Kernels Per Spike
Kavkaz-Inia 66	26.24	15.03	11.36	89.39	---*	110.76	31.18	---	74.14
Kavkaz-Siete Cerros 66	---	12.88	9.90	143.54	---	---	3.90	.1025	---
Kavkaz-Torim 73	24.60	13.95	7.63	202.68	1.37	51.41	15.91	.1528	36.70
Kavkaz-Jupateco 73	14.67	11.60	7.68	140.55	9.77	244.88	14.10	2.8400	131.16
Kavkaz-Huacamayo "S"	---	---	.91	188.78	8.08	87.85	---	.2060	---
Roussalka-Inia 66	20.23	32.19	29.47	72.71	9.63	10.21	---	.1062	---
Roussalka-Siete Cerros 66	21.97	38.34	47.81	78.42	5.29	21.66	---	.1149	46.59
Roussalka-Torim 73	44.99	18.94	10.81	132.07	16.10	---	26.52	.2236	47.30
Roussalka-Jupateco 73	40.58	8.42	2.10	41.98	2.23	47.86	---	.1845	66.59
Roussalka-Huacamayo "S"	16.57	10.68	10.92	248.91	---	---	37.30	.1916	93.29
Yamhill-Inia 66	18.34	6.39	3.23	111.23	22.67	20.54	3.44	.0607	57.90
Yamhill-Siete Cerros 66	18.75	5.74	2.26	173.88	---	---	7.00	.1908	61.13
Yamhill-Torim 73	14.40	10.64	3.57	111.20	5.60	123.58	42.16	.0684	89.48
Yamhill-Jupateco 73	18.39	---	23.14	120.75	---	---	150.19	.2338	---
Yamhill-Huacamayo "S"	---	.16	3.60	117.24	---	183.84	27.25	.1210	287.93
Hyslop-Inia 66	36.72	13.50	17.99	64.84	20.21	107.00	---	.0759	40.11
Hyslop-Siete Cerros 66	1.30	4.58	---	2.29	14.78	189.21	79.73	.1097	193.75
Hyslop-Torim 73	7.45	9.89	---	155.09	48.34	242.34	---	.1214	111.87
Hyslop-Jupateco 73	3.86	9.53	---	302.56	70.40	201.40	---	---	51.93
Hyslop-Huacamayo "S"	6.32	3.44	3.35	61.48	38.55	45.53	9.91	.0567	4.12
W. R. Mace-Inia 66	12.26	4.33	9.74	111.46	26.01	137.53	14.23	.1098	79.12
W. R. Mace-Siete Cerros 66	3.69	2.85	12.11	103.48	4.33	---	5.25	.1927	---
W. R. Mace-Torim 73	7.08	7.06	5.95	253.49	31.07	166.55	6.99	.3010	46.67
W. R. Mace-Jupateco 73	24.76	14.89	12.93	76.26	---	---	---	.1066	---
W. R. Mace-Huacamayo "S"	15.74	9.65	6.43	103.31	42.33	227.96	---	.1920	.79
Average	15.95	10.58	9.71	128.30	15.07	88.80	19.00	.2425	60.82

---* Undetected amount

Table 10. Parent-offspring Standardized Regression for nine agronomic characters in 25 winter x spring wheat crosses. Hyslop Farm, 1976-77.

Character	F1 on MP
Heading Date	.888**
Maturity Date	.715**
Filling Period	.856**
Plant Height	.785**
Tillers Per Plant	.762**
Grain Yield	.310
Harvest Index	.238
100 Kernel Weight	.609**
Kernels Per Spike	.001

**Significant at the 1% probability level.

A highly significant regression value was found for six of the nine characters. They were heading date (.888), grain filling period (.856), plant height (.785), tillers per plant (.762), maturity date (.715) and kernel weight (.609).

Study II

In winter x spring crosses standardized regression values were obtained for the F1 and F2 on mid-parent (MP) and F2 on F1 for the nine characters measured (Table 11). The estimates for the various comparisons were in agreement being high and significant with the exception of tillers per plant, grain yield and kernels per spike. For these three characters the regression of F2 on F1 was higher.

For winter x winter crosses the regression of F1 on MP resulted in high and significant estimates for all characters with the exception of tillers per plant (Table 11).

The comparison of estimates of F1 on MP regression in winter x spring and winter x winter crosses is particularly interesting. Highly significant estimates were observed on both types of crosses for heading date, maturity date, grain filling period and plant height. The regressionsion for tillers per plant was not significant. Differences were observed for harvest index and kernel weight which were highly significant at lower probability with the winter x spring crosses. The greatest differences were observed for grain yield and kernels per spike; in winter x winter crosses they were highly significant and in winter x spring crosses they were not significant.

Table 11. Parent-offspring Standardized Regression for nine agronomic characters in 25 winter x spring and 10 winter x winter wheat crosses. Hyslop Farm, 1977-78.

	Heading Date	Maturity Date	Filling Period	Plant Height	Tillers Per Plant	Grain Yield	Harvest Index	100 Kernel Weight	Kernels Per Spike
WXS Crosses									
F1 on MP	.895**	.829**	.855**	.747**	.059	.153	.340*	.400*	-.019
F2 on MP	.940**	.897**	.827**	.817**	.322	.267	.539**	.741*	-.031
F2 on F1	.915**	.907**	.842**	.868**	.559**	.715**	.694**	.700**	.839**
Average	.917	.878	.842	.810	.313	.378	.524	.614	.280
WXW Crosses									
F1 on MP	.928**	.965**	.805**	.901**	.128	.650**	.918**	.718**	.813**

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

Study III

In Table 12 are presented the estimates of parent-offspring regression for nine agronomic characters in winter x spring and spring x spring crosses grown at CIANO. The estimates of F2 on spring parent (SP) from winter x spring crosses were multiplied by two in order to make comparison with the estimates obtained using mid-parent values in the spring x spring crosses. This, in part, explains why values greater than one were obtained for plant height, harvest index and kernel weight. With the exception of tillers per plant, grain yield and kernels per spike, highly significant estimates were observed for other characters evaluated. Seven out of the nine characters were highly significant in spring x spring crosses. Plant height was significant at a lower probability level and harvest index was not significant.

Similar estimates were obtained for heading date, maturity date, grain filling period, plant height and kernel weight for winter x spring and spring x spring crosses. In spring x spring crosses the highest estimates were noted for tillers per plant, grain yield and kernels per spike. Harvest index had a greater value in winter x spring crosses.

Combining Ability Estimates

Combining ability analysis (GCA) was used to partition the total genetic variability into the type and relative magnitude of gene action controlling each character measured.

Study I

Observed mean squares for general combining ability for the winter

Table 12. Parent-offspring Standardized Regression for nine agronomic characters in 25 winter x spring and 10 spring x spring wheat crosses. CIANO, 1977-78.

	Heading Date	Maturity Date	Filling Period	Plant Height	Tillers Per Plant	Grain Yield	Harvest Index	100 Kernel Weight	Kernels Per Spike
<u>WXS Crosses</u>									
F2 on SP	.575**	.942**	.631**	1.130**	.340	.351	1.129**	1.086**	.334
<u>SXS Crosses</u>									
F1 on MP	.408*	.809**	.616**	.980**	.647**	.675**	.276	.717**	.816**

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

(GCA-winters) and spring (GCA-springs) parents and specific combining ability (SCA) for the 25 F1 crosses involving the nine agronomic characters are presented in Table 13. General combining ability associated with the winter parents was highly significant for all nine characters. Highly significant differences for GCA due to spring parents were found for heading date, grain filling period, plant height, harvest index and kernel weight. General combining ability estimates for the spring parents were significantly different for maturity date, grain yield and kernels per spike but not significantly different for tillers per plant. Highly significant SCA was noted for heading date, plant height and kernels per spike while harvest index was significantly different.

The individual contribution to GCA effects of each winter and spring parent for each character is provided in Table 14. Yamhill had the highest GCA effect for heading and maturity date and plant height. For maturity date, Yamhill differed significantly only from Roussalka. Yamhill was singificantly different from the other cultivars with the exception of Kavkaz for plant height. Roussalka had the largest effect for grain filling period and harvest index. Its GCA effect on grain filling period was not significantly different from Kavkaz. Kavkaz was significantly different from the other winter parents for kernel weight. For tillers per plant, Hyslop was significantly different from the other winter parents. Weique Red Mace had a significant GCA effect for grain yield and kernels per spike when compared to the other winter cultivars.

Siete Cerros 66 had the highest value when the spring parents were

Table 13. Observed mean square values for general combining ability of winter parents (GCA-winters) and spring parents (GCA-springs) and specific combining ability (SCA) for nine agronomic characters measured in 25 winter x spring wheat F1's grown at Hyslop Farm, 1976-77.

Source of Variation	df	Heading Date	Maturity Date	Filling Period	Plant Height	Tillers Per Plant	Grain Yield	Harvest Index	100 Kernel Weight	Kernels Per Spike
Within WXS F1's	24	10.80**	11.16**	56.32**	300.08**	12.44**	327.52**	75.91**	.7916**	349.63**
GCA-winters	4	82.72**	9.42**	38.69**	311.98**	13.61**	354.81**	66.95**	.9333**	463.82**
GCA-springs	4	65.14**	2.88*	40.34**	92.24**	1.37	48.24*	33.06**	.1303**	18.81*
SCA	16	.86**	1.11	1.35	11.48**	.92	22.13	3.46*	.0316**	10.50
Error	72	.33	.98	1.30	1.30	1.50	18.32	1.96	.0126	7.60

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

Table 14. Estimates of general combining ability effects of winter and spring wheat parents for nine agronomic characters from 25 winter x spring F1's grown at Hyslop Farm, 1976-77.

Parent	Heading Date	Maturity Date	Filling Period	Plant Height	Tillers Per Plant	Grain Yield	Harvest Index	100 Kernel Weight	Kernels Per Spike
Winters									
Kavkaz	-1.52 c*	-.08 a	1.56 ab	7.21 a	-.52 bc	-6.49 cd	-5.72 c	.68 a	-11.76 d
Roussalka	-5.86 d	-2.29 b	3.54 a	-10.36 d	-1.84 c	-8.26 d	4.47 a	-.11 c	-2.74 c
Yamhill	5.20 d	1.30 a	-3.91 c	7.60 a	-.53 bc	4.04 b	.14 b	-.27 c	9.18 b
Hyslop	1.17 b	.57 a	-.62 b	-5.60 c	2.63 a	-1.71 bc	.19 b	-.43 d	5.32 c
W.R. Mace	1.04 b	.51 a	-.56 b	1.14 b	.27 b	12.42 a	.92 b	.14 b	10.62 a
Springs									
Inia 66	-4.51 d	-1.08 b	3.41 a	-.34 c	-.52 a	-1.33 ab	1.28 b	.14 ab	-1.78 b
Siete Cerros 66	4.48 a	.81 a	-3.68 c	2.43 b	.87 a	1.67 ab	-3.80 d	-.05 bc	-.67 ab
Torim 73	.77 c	.09 ab	.84 ab	-6.65 d	-.14 a	-1.21 ab	3.01 a	-.19 c	.95 ab
Jupateco 73	-1.90 c	-.31 ab	1.48 ab	-.29 c	-.21 a	-3.57 b	.52 bc	-.09 bc	-1.43 b
Huacamayo "S"	2.73 b	.57 a	-2.07 bc	4.84 a	.00 a	4.45 a	-1.01 c	.19 a	2.91 a

*Duncan's new multiple range test. Effects with the same letter are not significantly different at the 5% probability level.

considered for GCA effects for heading and maturity date. It was significantly different from the other cultivars for the former and only from Inia 66 for the latter trait. Inia 66 had the highest effect for grain filling period being significantly different from Huacamayo "S" and Siete Cerros 66. For plant height, grain yield, kernel weight and kernels per spike, the highest GCA effect was contributed by Huacamayo "S". For grain yield, the Huacamayo "S" GCA effect was significantly different from Jupateco 73. Huacamayo "S" was not different from Inia 66 for kernel weight. For kernels per spike, Huacamayo "S" was significantly different from Jupateco 73 and Inia 66. Torim 73 had the highest and significant GCA effect for harvest index.

Estimates of specific combining ability effects for heading date, plant height, harvest index and kernel weight are listed in Table 15. Crosses resulting in the highest SCA effect for each character were Kavkaz-Inia 66 for heading date (1.67), Kavkaz-Huacamayo "S" for plant height (4.78) and kernel weight (.40) and Roussalka-Siete Cerros 66 for harvest index (3.80). No significant differences were detected for the other characters; thus the individual cross effects were not determined (Table 13).

Study II

Observed mean square estimates from combining ability analysis involving eight agronomic characters from winter x spring F1's are presented in Table 16. General combining ability associated with winter parents was highly significant for all the characters including harvest index (Table 17). The same was true for GCA associated with spring

Table 15. Estimates of specific combining ability effects for those agronomic characters that had significant SCA differences in the analysis of variance from winter x spring wheat F1's grown at Hyslop Farm, 1976-77.

Cross	Heading Date	Plant Height	Harvest Index	100 Kernel Weight
Kavkaz-Inia 66	1.67	-2.38	-.38	-.21
Kavkaz-Siete Cerros 66	-.70	-.56	-2.71	-.09
Kavkaz-Torim 73	-.30	-.78	.79	-.15
Kavkaz-Jupateco 73	-.42	-1.06	.41	.03
Kavkaz-Huacamayo "S"	-.30	4.78	1.91	.40
Roussalka-Inia 66	.53	1.42	-1.42	-.03
Roussalka-Siete Cerros 66	-.33	.65	3.80	.06
Roussalka-Torim 73	.64	-2.91	-1.25	-.02
Roussalka-Jupateco 73	.47	-.82	.14	.03
Roussalka-Huacamayo "S"	-1.36	1.68	-1.27	-.03
Yamhill-Inia 66	-1.28	-6.07	.77	-.07
Yamhill-Siete Cerros 66	.76	1.17	1.31	-.15
Yamhill-Torim 73	-.04	.58	.24	.17
Yamhill-Jupateco 73	.74	2.91	-.04	.07
Yamhill-Huacamayo "S"	-.22	1.40	-2.27	-.02
Hyslop-Inia 66	-.29	4.08	.87	.10
Hyslop-Siete Cerros 66	-.30	.99	-2.34	.13
Hyslop-Torim 73	.57	-1.24	.87	-.05
Hyslop-Jupateco 73	-.52	-1.43	-1.60	-.12
Hyslop-Huacamayo "S"	.55	-2.38	2.18	-.02
W. R. Mace-Inia 66	-.67	2.97	.17	.22
W. R. Mace-Siete Cerros 66	.54	-2.25	-.07	.06
W. R. Mace-Torim 73	.91	4.34	-.64	.05
W. R. Mace-Jupateco 73	-.30	.42	1.08	-.03
W. R. Mace-Huacamayo "S"	1.32	-5.47	-.53	-.32
S.E.*	.41	.81	.99	.08

*Standard error of the difference between two effects.

Table 16. Observed mean square values for general combining ability of winter (GCA-winters) and spring parents (GCA-springs) and specific combining ability (SCA) for eight agronomic characters measured in 25 winter x spring wheat F1's grown at Hyslop Farm, 1977-78.

Source of Variation	df	Heading Date	Maturity Date	Filling Period	Plant Height	Tillers Per Plant	Grain Yield	100 Kernel Weight	Kernels Per Spike
Within WXS F1's	24	237.46**	26.31**	132.10**	286.29**	15.59**	266.43**	.1772**	356.92**
GCA-winters	4	216.03**	18.94**	113.85**	256.97**	3.59**	59.17**	.1431**	213.76**
GCA-springs	4	123.12**	13.74**	66.89**	119.59**	8.69**	159.54**	.0502*	111.87**
SCA	16	4.26**	1.69	4.37	13.22**	2.78*	45.22**	.0183	52.43**
Error	72	2.02	1.44	3.70	5.40	1.41	18.11	.0251	10.92

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

Table 17. Observed mean square values for general combining ability on winter (GCA-winters) and spring parents (GCA-springs) for Harvest Index measured in 25 winter x spring wheat Fl's grown at Hyslop Farm, 1977-78.

Source of Variance	df	Harvest Index
Within WXS Fl's	24	50.12**
GCA-winters	4	62.28**
GCA-springs	4	8.79
SCA	16	19.82**
Error	49	4.34

**Significant at the 1% probability level.

parents with the exception of kernel weight that was significant at a lower probability while harvest index was not significant. Specific combining ability estimates were found to be highly significant for heading date, plant height, grain yield, kernels per spike and harvest index. A significant SCA estimate was noted for tillers per plant. No significant differences were observed for the SCA involving maturity date, grain filling period and kernel weight.

Estimates of GCA effects for individual winter and spring parents are given in Table 18. For the winter parents, Yamhill had the superior and significant GCA effect on heading date. Also, Yamhill had high GCA effect for kernels per spike being significantly different from other cultivars except Weique Red Mace. For maturity date, Weique Red Mace's effect was the highest and significantly different from Kavkaz and Roussalka. Also, Weique Red Mace had the highest GCA effect for grain yield. However, it was only significantly different from Kavkaz. Roussalka had the highest and a significantly different GCA effect for grain filling period and harvest index. Kavkaz's GCA effect for plant height was the highest but not significantly different from Yamhill. Also, Kavkaz had the highest effect for kernel weight. However, it was not significantly different from Roussalka and Weique Red Mace. The Hyslop GCA effect was the highest for tillers per plant. Its GCA effect was significantly different only from Kavkaz.

General combining ability effects of Siete Cerros 66 were superior for heading date, maturity date, tillers per plant, grain yield and kernels per spike. For tillers per plant it differed significantly only from Inia 66. Siete Cerros 66's GCA effect was not significantly

Table 18. Estimates of general combining ability effects of winter and spring wheat parents for nine agronomic characters from 25 winter x spring F1's grown at Hyslop Farm, 1977-78.

Parent	Heading Date	Maturity Date	Filling Period	Plant Height	Tillers Per Plant	Grain Yield	Harvest Index	100 Kernel Weight	Kernels Per Spike
Winters									
Kavkaz	-.26 c*	-1.03 b	-.80 b	6.92 a	-1.05 b	-4.65 b	-4.59 b	.26 a	-8.64 c
Roussalka	-11.05 d	-2.95 c	8.11 a	-9.08 d	-.15 ab	-1.07 ab	5.29 a	.05 ab	-1.02 b
Yamhill	5.91 a	1.41 a	-4.50 c	6.68 a	-.50 ab	1.81 ab	.82 b	-.13 b	7.46 a
Hyslop	1.96 b	1.02 a	-.93 b	-5.45 c	1.05 a	-.66 ab	-.81 b	-.16 b	-3.22 b
W.R. Mace	3.44 b	1.55 a	-1.88 bc	.93 b	.64 ab	4.56 a	-.61 b	-.02 ab	5.41 a
Springs									
Inia 66	-3.64 d	-2.44 d	1.20 b	-1.01 b	-1.95 b	-5.86 b	.04 ab	-.04 ab	-2.07 bc
Siete Cerros 66	6.49 a	1.89 a	-4.59 c	4.95 a	1.41 a	6.52 a	-.55 ab	-.05 ab	6.34 a
Torim 73	-1.26 c	.01 bc	1.23 b	-5.37 c	-.30 ab	-1.92 b	-.03 ab	-.11 b	-1.10 bc
Jupateco 73	-5.29 d	-.53 c	4.76 a	-3.77 bc	-.20 ab	-4.19 b	2.08 a	.03 ab	-5.99 c
Huacamayo "S"	3.70 b	1.08 b	-2.61 c	5.21 a	1.02 a	5.43 a	-1.55 b	.16 a	2.82 ab

*Duncan's new multiple range test. Effects with the same letter are not significantly different at the 5% probability level.

different from Huacamayo "S" for grain yield and kernels per spike. For grain filling period and harvest index Jupateco 73 had the greatest GCA effect. Jupateco 73's GCA effect on harvest index was not different from Huacamayo "S". Huacamayo "S" had a superior GCA effect for plant height and kernel weight. Its GCA effect on plant height was not significantly different from Siete Cerros 66. For kernel weight, Huacamayo "S" was only significantly different from Torim 73.

Specific combining ability effects are presented for only those characters where significant mean square values were detected and are given in Table 19. The cross Kavkaz-Siete Cerros 66 had the highest SCA effect for heading date (3.54), plant height (6.54), grain yield (11.42) and kernels per spike (14.48). For tillers per plant the cross with the superior SCA effect was Kavkaz-Huacamayo "S" (2.81). Weique Red Mace-Jupateco 73 had the greater SCA effect on harvest index (7.69).

Observed mean square values of combining ability analysis for eight characters in winter x spring F2's are given in Table 20. General combining ability associated with winter parents was highly significant for the eight characters considered in this population. This was also true for harvest index (Table 21). General combining ability due to spring parents was highly significant for seven characters and significaly different for one (tillers per plant). No significant difference was observed for harvest index (Table 21). Significant SCA mean square values were noted for plant height (Table 20), such differences were highly significant for harvest index (Table 21).

General combining ability effects associated with individual winter and spring parents for each character are reported in Table 22. Weique

Table 19. Estimates of specific combining ability effects for those agronomic characters that had significant SCA differences in the analysis of variance from winter x spring wheat F1's grown at Hyslop Farm, 1977-78.

Cross	Heading Date	Plant Height	Tillers Per Plant	Grain Yield	Harvest Index	Kernels Per Spike
Kavkaz-Inia 66	1.25	-3.22	-1.67	-6.19	-4.86	-5.81
Kavkaz-Siete Cerros 66	3.54	6.54	1.83	11.42	6.65	14.48
Kavkaz-Torim 73	-3.40	-5.53	-3.57	-12.73	-3.96	-11.65
Kavkaz-Jupateco 73	-1.17	-2.38	.62	-2.43	-1.13	-3.74
Kavkaz-Huacamayo "S"	-.20	4.59	2.81	9.94	3.33	6.73
Roussalka-Inia 66	-2.13	1.34	.70	-.34	-2.19	-2.59
Roussalka-Siete Cerros 66	-.62	-.95	-.56	1.17	2.37	1.25
Roussalka-Torim 73	.53	-2.20	.73	-.88	1.42	-1.40
Roussalka-Jupateco 73	2.42	2.15	-1.04	.09	-.53	4.65
Roussalka-Huacamayo "S"	-.20	-.04	.19	-.04	-1.08	-1.88
Yamhill-Inia 66	-.36	-1.69	.80	2.20	.36	2.48
Yamhill-Siete Cerros 66	-2.51	-1.93	-1.19	-2.89	-1.47	-.50
Yamhill-Torim 73	.24	1.38	1.04	4.60	2.84	5.03
Yamhill-Jupateco 73	2.55	2.36	.40	3.46	.61	2.27
Yamhill-Huacamayo "S"	.10	-.16	-1.02	-7.35	-2.31	-9.26
Hyslop-Inia 66	.62	1.81	.47	6.02	6.64	5.70
Hyslop-Siete Cerros 66	-.38	.23	.27	-5.09	-3.14	-7.00
Hyslop-Torim 73	1.42	.82	2.10	6.65	2.49	4.18
Hyslop-Jupateco 73	-3.00	.82	-.87	-5.22	-6.64	-6.23
Hyslop-Huacamayo "S"	1.36	-3.71	1.97	-2.35	.72	3.29
W. R. Mace-Inia 66	.64	1.74	-.27	-1.67	.09	.14
W. R. Mace-Siete Cerros 66	.00	-3.58	-.33	-4.58	-4.37	-8.20
W. R. Mace-Torim 73	1.22	5.52	-.30	2.36	-2.75	3.85
W. R. Mace-Jupateco 73	-.79	-2.99	.93	4.11	7.69	3.08
W. R. Mace-Huacamayo "S"	-1.03	-.70	.01	-.18	-.66	1.15
S.E.*	1.01	1.64	.84	3.01	2.08	2.34

*Standard error of the difference between two effects

Table 20. Observed mean square values for general combining ability on winter (GCA-winters) and spring parents (GCA-springs) and specific combining ability (SCA) for eight agronomic characters measured in 25 winter x spring wheat F2's grown at Hyslop Farm, 1977-78.

Source of Variation	df	Heading Date	Maturity Date	Filling Period	Plant Height	Tillers Per Plant	Grain Yield	100 Kernel Weight	Kernels Per Spike
Within WXS F2's	24	232.58**	35.11**	99.81**	184.36**	4.97**	61.34**	.234**	113.96**
GCA-winters	4	265.89**	29.23**	123.27**	157.86**	4.16**	34.76**	.153**	106.13**
GCA-springs	4	77.86**	17.99**	19.43**	74.44**	1.44*	33.94**	.144**	33.57**
SCA	16	1.28	1.36	2.11	11.05*	.47	5.84	.014	7.80
Error	72	.96	1.36	2.15	6.11	.42	5.26	.011	4.94

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

Table 21. Observed mean square values for general combining ability on winter (GCA-winters) and spring parents (GCA-springs) and specific combining ability (SCA) for Harvest Index measured in 25 winter x spring wheat F2's grown at Hyslop Farm, 1977-78.

Source of Variation	df	Harvest Index
Within WXS F2's	24	21.64**
GCA-winters	4	43.08**
GCA-springs	4	4.95
SCA	16	4.22**
Error	49	1.84

**Significant at the 1% probability level.

Table 22. Estimates of general combining ability effects of winter and spring wheat parents for nine agronomic characters from 25 winter x spring F2's grown at Hyslop Farm, 1977-78.

Parent	Heading Date	Maturity Date	Filling Period	Plant Height	Tillers Per Plant	Grain Yield	Harvest Index	100 Kernel Weight	Kernels Per Spike
Winters									
Kavkaz	-3.72 c*	-1.43 b	2.49 b	4.34 a	-1.24 c	-4.38 b	-3.62 d	.29 a	-7.24 c
Roussalka	-10.74 d	-3.45 c	7.29 a	-6.55 c	-.15 b	-.46 a	3.98 a	-.01 b	-.34 b
Yamhill	6.18 a	1.66 a	-4.52 d	7.21 a	-.24 b	1.66 a	1.10 ab	-.06 bc	4.41 a
Hyslop	1.80 b	.76 a	-1.03 c	-2.42 b	1.26 a	1.01 a	.56 bc	-.19 c	-.39 b
W.R. Mace	6.49 a	2.46 a	-4.22 cd	-2.57 b	.35 ab	2.17 a	-2.01 cd	-.03 b	3.57 a
Springs									
Inia 66	-3.81 d	-1.75 c	1.87 a	-.66 bc	-.74 c	-1.30 c	.83 a	.03 bc	-.22 b
Siete Cerros 66	4.58 a	2.42 a	-1.96 b	4.91 a	.45 ab	3.20 a	-.44 a	.09 ab	2.99 a
Torim 73	.33 c	-.16 bc	-.46 b	-4.75 d	-.10 bc	-1.13 bc	1.24 a	-.22 d	1.13 a
Jupateco 73	-4.16 d	-1.89 c	2.27 a	2.24 c	-.23 bc	-2.99 c	-.52 a	-.12 cd	-4.07 c
Huacamayo "S"	3.06 b	1.38 ab	-1.68 b	2.73 ab	.59 a	2.23 ab	-1.12 a	.21 a	.18 ab

*Duncan's new multiple range test. Effects with the same letter are not significantly different at the 5% probability level.

Red Mace was the winter parent with the highest GCA effect for heading date, maturity date and grain yield. For heading date the Weique Red Mace GCA effect was significantly different from Hyslop, Kavkaz and Roussalka. Weique Red Mace's GCA effect for maturity date was significantly different from Kavkaz and Roussalka. For grain yield the Weique Red Mace GCA effect was significantly different only from Kavkaz. Roussalka had the highest GCA effect for grain filling period and harvest index. For harvest index it was not significantly different from the Yamhill GCA effect. Yamhill had the largest GCA effect for plant height and kernels per spike. For plant height it was not significantly different from Kavkaz nor was it significantly different from Weique Red Mace for kernels per spike. Hyslop had the greatest GCA contribution for tillers per plant. It was not significantly different from Weique Red Mace, however. Kavkaz had the largest and significant GCA effects for kernel weight.

For the spring parents Siete Cerros 66 was again the best contributor to heading and maturity date, plant height, grain yield and kernels per spike. Siete Cerros 66 was not significantly different from Huacamayo "S" for maturity date, plant height and grain yield. There was also no significant difference between Siete Cerros 66 and Torim 73 and Huacamayo "S" for kernels per spike. Jupateco 73's GCA effect was the highest for grain filling period; however, it was not significantly different from Inia 66. For tillers per plant and kernel weight Huacamayo "S" GCA effects were the highest but were not significantly different from Siete Cerros 66.

Specific combining ability effects of the crosses Hyslop-Inia 66 and Kavkaz-Huacamayo "S" were the highest for plant height (Table 23). Roussalka-Jupateco 73 had the largest SCA effect for harvest index.

Observed mean square values of combining ability analyses for eight agronomic characters measured in winter x winter F1's are presented in Table 24. Highly significant GCA values were detected for heading date, maturity date, grain filling period, plant height and kernels per spike. This was also true for harvest index (Table 25). Specific combining ability mean squares were significant only for heading date.

Individual GCA effects indicated that Weique Red Mace had the highest significant effect for heading and maturity date (Table 26). For grain filling period, Roussalka was the highest being significantly different from the other winter parents. Kavkaz's GCA effect was high and significantly different for plant height. For harvest index Hyslop had the highest and significant GCA effect. A high and significant GCA effect was observed for Yamhill for kernels per spike. As previously noted no significant differences were detected for tillers per plant, kernel weight and grain yield.

The cross Weique Red Mace-Kavkaz had the highest SCA effect for heading date, with Weique Red Mace-Yamhill being second (Table 27).

In Study II, the winter parents generally had higher GCA mean square estimates and larger combining ability estimates for most characters than the spring parents. This was true in both F1 (Tables 16 and 17) and F2 (Tables 20 and 21) generations. Those winter and spring parents which had the highest GCA effect in the F1 generation also were those which were superior in the F2 generation. The exceptions to this were heading date and plant height for the winter parents and

Table 23. Estimates of specific combining ability effects for those agronomic characters that had significant SCA differences in the analysis of variance from winter x spring wheat F2's grown at Hyslop Farm, 1977-78.

Cross	Plant Height	Harvest Index
Kavkaz-Inia 66	-7.42	-.92
Kavkaz-Siete Cerros 66	1.70	.84
Kavkaz-Torim 73	1.23	.28
Kavkaz-Jupateco 73	-.52	-2.63
Kavkaz-Huacamayo "S"	5.00	2.43
Roussalka-Inia 66	1.84	-2.44
Roussalka-Siete Cerros 66	.57	.52
Roussalka-Torim 73	-.39	-1.87
Roussalka-Jupateco 73	-1.33	3.73
Roussalka-Huacamayo "S"	-.66	.09
Yamhill-Inia 66	-2.60	1.64
Yamhill-Siete Cerros 66	.40	-1.10
Yamhill-Torim 73	.27	1.05
Yamhill-Jupateco 73	-.09	-.58
Yamhill-Huacamayo "S"	2.03	-1.00
Hyslop-Inia 66	5.20	.31
Hyslop-Siete Cerros 66	-1.17	-.44
Hyslop-Torim 73	-2.62	2.28
Hyslop-Jupateco 73	.48	-2.43
Hyslop-Huacamayo "S"	-1.86	.27
W. R. Mace-Inia 66	2.99	1.43
W. R. Mace-Siete Cerros 66	-1.49	.12
W. R. Mace-Torim 73	1.53	-1.73
W. R. Mace-Jupateco 73	1.49	1.91
W. R. Mace-Huacamayo "S"	-4.49	-1.72
S.E.*	1.75	1.35

*Standard error of the difference between two effects.

Table 24. Observed mean square values for general combining ability (GCA) and specific combining ability (SCA) for eight agronomic characters measured in 10 winter x winter wheat F1's grown at Hyslop Farm, 1977-78.

Source of Variation	df	Heading Date	Maturity Date	Filling Period	Plant Height	Tillers Per Plant	Grain Yield	100 Kernel Weight	Kernels Per Spike
Within WXW F1's	9	262.08**	77.17**	61.75**	137.97**	6.18**	79.30**	.069*	126.18**
GCA	4	131.59**	41.53**	31.37**	69.49**	.71	17.99	.022	50.45**
SCA	5	5.41**	1.50	2.72	6.50	2.21	21.29	.014	16.41
Error	27	1.33	1.34	2.45	6.88	1.52	19.04	.022	6.49

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

Table 25. Observed mean square values for general combining ability (GCA) and specific combining ability (SCA) for Harvest Index in 10 winter x winter wheat F1's grown at Hyslop Farm, 1977-78.

Source of Variation	df	Harvest Index
Within WXW F1's	9	26.20**
GCA	4	27.27**
SCA	5	1.77
Error	19	3.05

**Significant at the 1% probability level.

Table 26. Estimates of general combining ability effects of winter wheat parents for nine agronomic characters from 10 winter x winter F1's grown at Hyslop Farm, 1977-78.

Parent	Heading Date	Maturity Date	Filling Period	Plant Height	Tillers Per Plant	Grain Yield	Harvest Index	100 Kernel Weight	Kernels Per Spike
Kavkaz	-.23 c*	-.88 d	-.66 c	7.01 a	-.06 a	-1.29 a	-2.21 d	.05 a	-2.31 c
Roussalka	-10.96 d	-5.84 e	5.12 a	-4.25 d	-.58 a	-2.78 a	2.06 b	-.04 a	-1.56 c
Yamhill	3.70 b	2.81 b	-.90 c	2.90 b	-.28 a	3.79 a	.30 c	.08	6.23 a
Hyslop	.18 c	.39 c	.23 b	-3.58 d	.21 a	.44 a	3.61 a	-.13	1.81 b
W. R. Mace	7.31 a	3.52 a	-3.79 d	-2.08 c	.70 a	-.17 a	-3.76 e	.04 a	-4.17 d

*Duncan's new multiple range test. Effects with the same letter are not significantly different at the 5% probability level.

Table 27. Estimate of specific combining ability effects for heading date from 10 winter x winter wheat F1's grown at Hyslop Farm, 1977-78.

Cross	Heading Date
Roussalka-Kavkaz	.17
Yamhill-Kavkaz	.47
Hyslop-Kavkaz	-2.92
W. R. Mace-Kavkaz	2.28
Yamhill-Roussalka	.78
Hyslop-Roussalka	.05
W. R. Mace-Roussalka	-1.00
Hyslop-Yamhill	-2.70
W. R. Mace-Yamhill	1.42
S.E. $(S_{ij}-S_{ik})$*	.94
S.E. $(S_{ij}-S_{kl})$**	.82

*Standard error of the difference between two effects where $i \neq j, k; j \neq k$.

**Standard error of the difference between two effects where $i \neq j, k, l; j \neq k, l; k \neq l$.

plant height and tillers per plant for the spring parents.

Comparing GCA effects of winter parents in winter x spring and winter x winter crosses indicates that the same parent in both types of crosses had the highest effect for maturity date, grain filling period, plant height, kernel weight and kernels per spike.

Study III

Observed mean square values of combining ability analysis for the agronomic characters measured in winter x spring F2's are given in Table 28. Highly significant GCA due to winter parents was noted for the nine characters. General combining ability associated with spring parents was highly significant for five characters (maturity date, plant height, tillers per plant, grain yield and kernel weight) and significant at a lower probability (P = 0.05) for heading date and harvest index. There were highly significant SCA detected for plant height and kernel weight only.

Of the winter parents, Yamhill had the highest GCA effect for heading date and plant height (Table 29). For heading date it was significantly different from Roussalka and Kavkaz. Yamhill was not significantly different from Kavkaz's GCA effect for plant height. Weique Red Mace had the greatest GCA effect on maturity date being significantly different from Roussalka and Kavkaz. Roussalka's GCA effects were superior for grain filling period being significantly different from Kavkaz, Yamhill and Hyslop. For harvest index, Roussalka had a significantly different effect when compared to Yamhill and Weique Red Mace. The greatest contribution for tillers per plant and grain

Table 28. Observed mean square values for general combining ability of winter (GCA-winters) and spring parents (GCA-springs) and specific combining ability (SCA) for nine agronomic characters measured in 25 winter x spring wheat F2's grown at CIANO, 1977-78.

Source of Variation	df	Heading Date	Maturity Date	Filling Period	Plant Height	Tillers Per Plant	Grain Yield	Harvest Index	100 Kernel Weight	Kernels Per Spike
Within WXS F2's	24	21.61**	15.73**	10.23*	262.86*	37.40**	166.71**	44.56*	.3922*	70.76*
GCA-winters	4	21.69**	16.06**	9.23**	194.97**	36.86**	104.43**	35.30**	.2959**	49.58**
GCA-springs	4	3.51*	5.92**	1.97	134.83**	8.43**	63.42**	18.84*	.1424**	15.57
SCA	16	1.79	.41	1.04	16.13**	2.69	20.54	3.18	.0364**	10.24
Error	72	1.36	.48	1.17	4.10	1.76	13.27	5.77	.0122	9.09

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

Table 29. Estimates of general combining ability effects of winter and spring wheat parents for nine agronomic characters from 25 winter x spring F2's grown at CIANO, 1977-78.

Parent	Heading Date	Maturity Date	Filling Period	Plant Height	Tillers Per Plant	Grain Yield	Harvest Index	100 Kernel Weight	Kernels Per Spike
<u>Winters</u>									
Kavkaz	-.30 b*	-2.19 b	-1.80 c	5.29 a	-3.63 c	-3.03 b	1.21 ab	.25 a	3.34 a
Roussalka	-3.37 c	-1.64 b	1.82 a	-8.21 c	-1.87 c	-2.63 b	2.65 a	.15 ab	-.46 ab
Yamhill	2.12 a	1.53 a	-.48 bc	7.13 a	1.64 ab	-1.29 b	-1.84 bc	-.39 d	-1.40 ab
Hyslop	1.09 ab	.72 a	-.26 bc	-1.46 b	3.09 a	8.04 a	1.65 ab	-.04 c	2.82 a
W.R. Mace	.46 ab	1.59 a	.74 ab	-2.77 b	.75 b	-1.04 b	-3.69 c	.05 c	-4.28 b
<u>Springs</u>									
Inia 66	-1.11 b	-1.04 c	.18 a	3.18 a	-1.08 b	.04 ab	1.15 ab	.13 ab	1.29 a
Siete Cerros 66	.26 ab	1.68 a	1.00 a	-1.39 b	-.74 b	-2.95 b	-1.53 b	-.08 cd	-1.34 a
Torim 73	-.08 ab	-.48 bc	-.29 a	-8.45 c	.12 ab	-2.30 b	.21 ab	-.21 d	-.77 a
Jupateco 73	-.28 ab	.61 c	-.22 a	2.24 a	2.18 a	6.01 a	2.45 a	-.04 bc	2.43 a
Huacamayo "S"	1.20 a	.47 b	-.64 a	4.39 a	-.51 b	-.78 b	-2.31 b	.21 a	-1.58 a

*Duncan's new multiple range test. Effects with the same letter are not significantly different at the 5% probability level.

yield was provided by Hyslop. For tillers per plant Hyslop was significantly different from three other parents (Weique Red Mace, Roussalka and Kavkaz) and for yield it was significantly different from the other cultivars. Kavkaz's GCA effects were the highest and significantly different for kernel weight when compared to Yamhill, Hyslop and Weique Red Mace and for kernels per spike when compared to Weique Red Mace.

Of the spring parents, Huacamayo "S" had a superior GCA effect for heading date, plant height and kernel weight (Table 29). Its GCA effect on heading date was significantly different from Inia 66. For plant height the Huacamayo "S" GCA effect differed significantly from Siete Cerros 66 and Torim 73. The Huacamayo "S" GCA effect on kernel weight was not significantly different from Inia 66. The Siete Cerros 66 GCA effect was significantly different for maturity date. For tillers per plant, grain yield and harvest index the highest GCA effect was contributed by Jupateco 73. For tillers per plant the Jupateco 73 GCA effect was significantly different from the other spring cultivars except Torim 73. For grain yield the Jupateco 73 GCA effect differed significantly from Huacamayo "S", Torim 73 and Siete Cerros 66. The Jupateco 73 GCA effect on harvest index differed significantly from Siete Cerros 66 and Huacamayo "S".

Only those characters which had a significant SCA were analyzed for the individual effect of each cross. In this case they were plant height and kernel weight (Table 30). The specific combining ability effect of Yamhill-Siete Cerros 66 was the highest for plant height (7.79). For kernel weight, the cross Yamhill-Torim 73 had the largest effect, followed by Yamhill-Siete Cerros 66 (.26 and .21, respectively).

Table 30. Estimates of specific combining ability effects for those agronomic characters that had significant SCA differences in the analysis of variance from winter x spring wheat F2's grown at CIANO, 1977-78.

Cross	Plant Height	100 Kernel Weight
Kavkaz-Inia 66	1.41	.01
Kavkaz-Siete Cerros 66	-3.12	-.33
Kavkaz-Torim 73	-1.76	-.06
Kavkaz-Jupateco 73	3.18	.18
Kavkaz-Huacamayo "S"	.30	.18
Roussalka-Inia 66	-2.23	-.04
Roussalka-Siete Cerros 66	1.38	.10
Roussalka-Torim 73	-.04	-.14
Roussalka-Jupateco 73	.51	-.09
Roussalka-Huacamayo "S"	.40	.14
Yamhill-Inia 66	-2.34	-.16
Yamhill-Siete Cerros 66	7.79	.21
Yamhill-Torim 73	.29	.26
Yamhill-Jupateco 73	-7.18	-.30
Yamhill-Huacamayo "S"	1.46	-.01
Hyslop-Inia 66	.37	.03
Hyslop-Siete Cerros 66	-4.00	.08
Hyslop-Torim 73	-1.12	-.01
Hyslop-Jupateco 73	.46	.09
Hyslop-Huacamayo "S"	4.31	-.18
W. R. Mace-Inia 66	2.83	.17
W. R. Mace-Siete Cerros 66	-2.03	-.07
W. R. Mace-Torim 73	2.63	-.06
W. R. Mace-Jupateco 73	3.05	.12
W. R. Mace-Huacamayo "S"	-6.43	-.14
S.E.*	1.43	.08

*Standard error of the difference between two effects.

Observed mean square values from combining ability analyses for nine agronomic characters in spring x spring F1's are reported in Table 31. General combining ability mean squares were found with highly significant differences for heading and maturity date, grain filling period, plant height, kernel weight and kernels per spike. A significant difference for grain yield was also found but at a lower probability level. There was a highly significant SCA mean square for heading date and significant difference at lower probability for grain filling period and kernel weight.

When the individual combining ability effects were evaluated, Huacamayo "S" had the highest GCA effect being significantly different for heading date, for plant height with exception of Siete Cerros 66 and kernel weight except when compared to Jupateco 73 and Inia 66 (Table 32). Siete Cerros 66 had significantly larger GCA effects on maturity date, grain filling period, grain yield and kernels per spike. It was also higher, but not significantly different for tillers per plant.

Individual crosses SCA effects for heading date, grain filling period and kernel weight are listed in Table 33. Siete Cerros 66-Huacamayo "S" had the highest SCA effect for heading date (2.40). For grain filling period, the greatest effect was found in the cross Inia 66-Siete Cerros 66 (1.54). Inia 66-Huacamayo "S" had the highest SCA effect for kernel weight (.16) closely followed by Inia 66-Siete Cerros 66 (.12).

As observed in Study I (Table 13) and Study II (Tables 16, 17, 20 and 21), the winter parents generally had the higher GCA mean square estimates for most characters. Again in Study III (Table 28) a greater

Table 31. Observed mean square values for general combining ability (GCA) and specific combining ability (SCA) for nine agronomic characters measured in 10 spring x spring wheat F1's grown at CIANO, 1977-78.

Source of Variation	df	Heading Date	Maturity Date	Filling Period	Plant Height	Tillers Per Plant	Grain Yield	Harvest Index	100 Kernel Weight	Kernels Per Spike
Within SXS F1's	9	19.58**	17.40**	14.60**	146.90**	9.74**	76.38**	9.79**	.2633**	80.10**
GCA	4	5.75**	8.34**	4.96**	78.68**	4.75	35.50*	1.84	.1115**	35.76**
SCA	5	4.22**	1.16	2.61*	3.12	.58	5.95	2.64	.0289*	7.43
Error	27	.92	1.06	.76	2.95	1.77	10.06	1.80	.0094	4.31

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

Table 32. Estimates of general combining ability effects of spring wheat parents for nine agronomic characters from 10 spring x spring F1's grown at CIANO, 1977-78.

Parent	Heading Date	Maturity Date	Filling Period	Plant Height	Tillers Per Plant	Grain Yield	Harvest Index	100 Kernel Weight	Kernels Per Spike
Inia 66	-1.74 d*	-2.11 e	-.37 c	.72 c	-.72 a	-2.14 c	1.16 a	.05 a	-1.46 b
Siete Cerros 66	.53 b	2.35 a	1.83 a	2.66 ab	1.48 a	5.31 a	-.04 a	-.19 b	6.10 a
Torim 73	.47 b	.62 b	.16 b	-9.01 d	.07 a	-2.56 c	.01 a	-.17 b	-2.41 c
Jupateco 73	-1.02 c	-.88 d	.15 b	2.39 b	.87 a	1.67 b	-.09 a	-.05 a	-1.01 b
Huacamayo "S"	1.76 a	.01 c	-1.76 d	3.23 a	-1.69 a	-2.28 c	-1.04 a	.28 a	-1.21 b

*Duncan's new multiple range test. Effects with the same letter are not significantly different at the 5% probability level.

Table 33. Estimates of specific combining ability effects for heading date, filling period and 100 kernel weight from 10 spring x spring wheat F1's grown at CIANO, 1977-78.

Cross	Heading Date	Filling Period	100 Kernel Weight
Inia 66-Siete Cerros 66	-2.69	1.54	.12
Inia 66-Torim 73	1.27	-1.60	-.11
Inia 66-Jupateco 73	1.79	-1.23	-.17
Inia 66-Huacamayo "S"	-.37	1.28	.16
Siete Cerros 66-Torim 73	.67	-.43	.04
Siete Cerros 66-Jupateco 73	-.38	.36	.08
Siete Cerros 66-Huacamayo "S"	2.40	-1.47	-.23
Torim 73-Jupateco 73	-.84	1.35	.05
Torim 73-Huacamayo "S"	-1.28	.67	.03
Jupateco 73-Huacamayo "S"	-.75	-.48	.05
S.E. $(S_{ij}-S_{ik})$*	.78	.71	.08
S.E. $(S_{ij}-S_{kl})$**	.55	.50	.06

*Standard error of the difference between two effects where $i \neq j, k; j \neq k$.

**Standard error of the difference between two effects where $i \neq j, k, l; j \neq k, l; k \neq l$.

mean square estimate of GCA was noted for the winter parents for all the characters.

When comparing the GCA effects of spring parents in winter x spring and spring x spring crosses, the same parent had the highest value in both types of crosses for heading and maturity date, grain filling period, plant height and kernel weight.

Combined Analysis from Study I and II

Combined analysis of combining ability for the two years involving eight agronomic characters from winter x spring F1's grown at Hyslop Farm is presented in Table 34. All mean squares were highly significant within F1's, Years x within F1's interaction and GCA associated with both winter and spring parents. A highly significant interaction of Years x GCA due to winter parents was detected for most of the characters. Plant height was the exception. Most of the characters reflected a highly significant interaction of Years x GCA associated with spring parents with the exception of maturity date, tillers per plant and grain yield. These were significant at a lower probability level. Specific combining ability was highly significant for most characters with grain filling period being significantly different at lower probability level. A highly significant interaction of Years x SCA resulted for most characters studied. The exception was plant height where no significant differences were detected. In Table 35 a similar pattern can be seen for harvest index. Highly significant differences were noted for all the sources of variation except the interaction of Years x SCA which was significant at a lower probability level and the interaction of Years x GCA due to

Table 34. Observed mean square values for eight agronomic characters for winter x spring wheat F1's from two years combined analysis. Hyslop Farm, 1976-77 and 1977-78.

Source of Variation	df	Heading Date	Maturity Oate	Filling Period	Plant Height	Tillers Per Plant	Grain Yield	100 Kernel Weight	Kernels Per Spike
Within WXS F1's	24	309.68**	31.08**	160.73**	561.73**	18.94**	455.03**	.7595**	596.15**
Years X Within F1's	24	28.28**	6.39**	27.69**	24.64**	9.09**	138.90**	.2093**	110.40**
GCA-Winter Parents	4	276.63**	26.73**	134.61**	567.31**	13.60**	337.23**	.8814**	648.10**
Years X GCA-Winter Parents	4	22.18**	1.64**	17.92**	1.63	3.60**	76.76**	.1950**	29.47**
GCA-Spring Parents	4	177.36**	14.55**	96.65**	198.89**	7.94**	179.13**	.1465**	84.28**
Years X GCA-Spring Parents	4	10.89**	2.07*	10.59**	12.93**	2.12*	28.66*	.0341**	46.40**
SCA	16	2.74**	1.34**	2.46*	19.09**	1.72**	41.56**	.0284**	40.49**
Years X SCA	16	2.39**	1.47**	3.26**	5.61	1.98**	25.78**	.0215**	22.44**
Error	144	.59	.60	1.25	1.68	.73	9.11	.0094	4.63

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

Table 35. Observed mean square values for Harvest Index in winter x spring wheat Fl's from two years combined analysis. Hyslop Farm, 1976-77 and 1977-78.

Source of Variation	df	Harvest Index
Within WXS Fl's	24	75.32**
Years X Within Fl's	24	15.67**
GCA-Winter Parents	4	128.68**
Years X GCA-Winter Parents	4	1.84
GCA-Spring Parents	4	20.86**
Years X GCA-Spring Parents	4	14.72**
SCA	16	19.22**
Years X SCA	16	7.62*
Error	48	2.67

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

winter parents where no significant difference was found. With the significant interactions observed for most characters measured, no attempt was made to further partition out the GCA and SCA effects when the years were combined.

Combined Analysis from Study II and III

In Tables 36 and 37 are presented the analysis for nine agronomic characters from winter x spring F2's when two locations are combined. All the mean square values for within winter x spring F2's, Locations x within F2's interaction, GCA-associated with winter parents and specific combining ability were different at either the 5% or 1% level of probability. Locations x GCA interaction due to winter parents was highly significant for all the characters except plant height. Mean square values for GCA associated with the spring parents were also highly significant except for kernels per spike. The interactions of Locations x specific combining ability were significant for every trait with the exception of grain filling period. No significant difference was detected for harvest index for either Location x GCA associated with spring parent or Locations x SCA interaction (Table 37). With the significant interactions observed for most characters measured no attempt was made to further partition out the GCA and SCA effects when the locations were combined.

Table 36. Observed mean square values for eight agronomic characters for winter x spring wheat F2's from two locations combined analysis. Hyslop Farm, 1977-78 and CIANO, 1977-78.

Source of Variation	df	Heading Date	Maturity Date	Filling Period	Plant Height	Tillers Per Plant	Grain Yield	100 Kernel Weight	Kernels Per Spike
Within WXS F2's	24	181.77**	45.22**	62.57**	378.01**	28.08**	111.64**	.4947**	42.58**
Locations X Within F2's	24	72.42**	5.62**	47.48**	69.22**	14.30**	116.41**	.1311**	142.14**
GCA-Winter Parents	4	213.01**	42.39**	76.35**	349.94**	31.20**	92.21**	.3491**	19.56**
Locations X GCA-Winter Parents	4	74.57**	2.90**	56.15**	2.89	9.81**	46.98**	.1000**	136.15**
GCA-Spring Parents	4	53.45**	21.66**	9.55**	152.40**	4.49**	15.40**	.2569**	5.40
Locations X GCA-Spring Parents	4	27.92**	2.25**	11.85**	56.87**	5.47**	81.96**	.0297**	43.75**
SCA	16	1.53**	.95*	2.11**	16.17**	1.60**	14.96**	.0342**	9.73**
Locations X SCA	16	1.55**	.82*	1.04	11.01**	1.56**	11.41**	.0158**	8.31**
Error	144	.58	.46	.83	2.55	.54	4.63	.0058	3.51

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

Table 37. Observed mean square values for Harvest Index in winter x spring wheat F2's from two locations combined analysis. Hyslop Farm, 1977-78 and CIANO, 1977-78.

Source of Variation	df	Harvest Index
Within WXS F2's	24	38.62**
Locations X Within F2's	24	14.46**
GCA-Winter Parents	4	69.82**
Locations X GCA-Winter Parents	4	20.18**
GCA-Spring Parents	4	15.18**
Locations X GCA-Spring Parents	4	4.03
SCA	16	7.71*
Locations X SCA	16	4.79
Error	48	3.50

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

Association and Interrelationship Among Agronomic Characters

Correlation Coefficients

Study II

To measure possible relationships between agronomic traits, correlation coefficients were computed. Eight agronomic characters were considered for each of the 25 winter x spring crosses grown at Hyslop Farm, 1977-78. They are presented in Table 38 through 42. When the yield components, tillers per plant and kernels per spike are considered they provide consistent positive and significant correlation values with grain yield. The exception was the cross Roussalka-Inia 66 where kernels per spike was not significantly correlated with grain yield. The other component of yield, kernel weight, had significant correlations in 20 of the 25 crosses. This correlation was consistent for crosses where the winter parents, Roussalka or Yamhill, were present. Plant height was positively and significantly associated with grain yield in 18 crosses. This association was consistent in crosses where Yamhill or Weique Red Mace were present. Four crosses had a positive and significant correlation for heading date and grain yield (Kavkaz-Siete Cerros 66, Yamhill-Inia 66, Hyslop-Siete Cerros 66 and Hyslop-Jupateco 73). Maturity date was positive and significantly correlated in 13 crosses. This association was consistent when the spring parents, Jupateco 73 or Torim 73, were present in the cross; however, only one cross with Torim 73 did not show this trend. Three crosses showed significant association of grain filling period and grain yield. Two of them were positive (Roussalka-Torim 73, Roussalka-Huacamayo "S") and one negative (Kavkaz-Siete Cerros 66).

Table 38. Associations among eight agronomic characters for F1, F2 and both backcrosses on five winter x spring wheat crosses grown at Hyslop Farm, 1977-78.

	CROSS				
	KVZ-INIA	KVZ-7C	KVZ-TRM	KVZ-JUP	KVZ-HUAC
GRAIN YIELD VS					
Tillers Per Plant	.7660**	.8549**	.8618**	.8262**	.9646**
Kernel Weight	.4825	.4522	-.2354	.6038*	.5012*
Kernels Per Spike	.8407**	.6439**	.7861**	.4721	.8488**
Plant Height	.4806	.8075**	.0322	.6289**	.6438**
Heading Date	.4579	.6390**	.1696	.2159	-.2117
Maturity Date	.1772	.1850	.7212**	.5470*	.5265*
Filling Period	-.3756	-.5558*	.3435	.0408	.3861
TILLERS PER PLANT VS					
Kernel Weight	.1895	.4852	-.4878	.4062	.4596
Kernels Per Spike	.3866	.2064	.5969*	.0528	.7419**
Plant Height	.1323	.7850**	-.1734	.4058	.7413**
Heading Date	.0698	.5321*	.1648	.0236	-.0466
Maturity Date	.4841	.0148	.6543**	.2427	.4148
Filling Period	.0745	-.4901	.3109	.0819	.2115
KERNEL WEIGHT VS					
Kernels Per Spike	.2549	-.1227	-.5616*	-.0911	.2479
Plant Height	.3817	.5628*	.4370	.6904**	.1888
Heading Date	.3489	.4596	-.0903	.2851	-.1055
Maturity Date	-.1399	-.1363	.0061	.3870	.6764**
Filling Period	-.3654	-.4521	.0709	-.0882	.3677
KERNELS PER SPIKE VS					
Plant Height	.5135*	.3699	-.1272	.1707	.4838
Heading Date	.4791	.4492	.0935	.1410	-.2978
Maturity Date	-.0918	.3142	.4200	.6081*	.4703
Filling Period	-.4729	-.3547	.1951	.1328	.4288
PLANT HEIGHT VS					
Heading Date	.5496*	.8315**	.6975*	.7848**	.4146
Maturity Date	-.0733	-.2814	-.1835	.1634	-.1079
Filling Period	-.5332*	-.8239**	-.6331**	-.6249**	-.3654
HEADING DATE VS					
Maturity Date	-.0907	-.3014	-.0479	-.0510	-.3462
Filling Period	-.9579**	.9831**	-.7596**	-.9061**	-.9177**
MATURITY DATE VS					
Filling Period	.3727	.4707	.6853**	.4687	.6904**

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

KVZ = Kavkaz
INIA = Inia 66
7C = Siete Cerros 66
TRM = Torim 73
JUP = Jupateco 73
HUAC = Huacamayo "S"

Table 39. Associations among eight agronomic characters for F1, F2 and both backcrosses on five winter x spring wheat crosses grown at Hyslop Farm, 1977-78.

	CROSS				
	RSK-INIA	RSK-7C	RSK-TRM	RSK-JUP	RSK-HUAC
GRAIN YIELD VS					
Tillers Per Plant	.8232**	.6888**	.7333**	.5955*	.7707**
Kernel Weight	.8073**	.8998**	.7936**	.8797**	.6447**
Kernels Per Spike	.4929	.7772**	.6597**	.7986**	.8063**
Plant Height	.7750**	.3288	.1322	.2981	.3165
Heading Date	.0044	-.0031	-.4457	-.1293	-.1137
Maturity Date	.4299	-.2033	.2974	.6241**	.3835
Filling Period	.2652	-.1429	.5868*	.4569	.5851*
TILLERS PER PLANT VS					
Kernel Weight	.6445**	.5746*	.3473	.2932	.3375
Kernels Per Spike	-.0478	.0992	.1346	.0592	.2966
Plant Height	.5588*	.6301**	.0517	.2675	.2453
Heading Date	.0431	-.1543	-.3584	-.7540**	-.2979
Maturity Oate	.4076	-.2885	.1444	.5097*	-.0523
Filling Period	.2055	-.0876	.3752	.8048**	.2341
KERNEL WEIGHT VS					
Kernels Per Spike	.2624	.6917**	.4363	.7540**	.4477
Plant Height	.7095**	.1072	.3177	.1314	.5751*
Heading Date	.1652	.1978	-.3872	.1433	-.4906
Maturity Date	.0893	-.2333	.2690	.6343**	.4465
Filling Period	-.0023	-.3189	.5206*	.2831	.6829**
KERNELS PER SPIKE VS					
Plant Height	.4082	-.0473	.0100	.2053	.0776
Heading Date	-.0524	.0777	-.2454	.3004	.1420
Maturity Date	.3004	.0473	.2005	.3770	.5800*
Filling Period	.2014	-.2059	.3606	.0225	.5704*
PLANT HEIGHT VS					
Heading Date	-.0463	-.3586	-.5510*	-.2628	-.4906
Maturity Date	.0077	-.3346	-.6600**	-.2238	-.3459
Filling Period	.1110	.0366	-.3230	.0436	.0665
HEADING DATE VS					
Maturity Date	-.1345	.0935	.3431	-.2564	.6146*
Filling Period	-.8591**	-.7024**	.2857	-.8179**	-.2465
MATURITY DATE VS					
Filling Period	.6063*	.6430**	.8021**	.7657**	.6130*

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

RSK = Roussalka
INIA = Inia 66
7C = Siete Cerros 66
TRM = Torim 73
JUP = Jupateco 73
HUAC = Huacamayo "S"

Table 40. Associations among eight agronomic characters for F1, F2 and both backcrosses on five winter x spring wheat crosses grown at Hyslop Farm, 1977-78.

	CROSS				
	YMH-INIA	YMH-7C	YMH-TRM	YMH-JUP	YMH-HUAC
GRAIN YIELD VS					
Tillers Per Plant	.5780*	.9181**	.8050**	.8858**	.5166*
Kernel Weight	.7154**	.7001**	.8278**	.9091**	.7861**
Kernels Per Spike	.7835**	.7960**	.9129**	.7830**	.8173**
Plant Height	.6823**	.7612**	.7086**	.8451**	.8335**
Heading Date	.6099*	-.0926	.3981	.4254	-.0554
Maturity Date	.5892*	.5537*	.7196**	.7504**	.3548
Filling Period	-.4667	.2848	-.0910	-.0486	.2330
TILLERS PER PLANT VS					
Kernel Weight	.2494	.5270*	.5444*	.6899**	.2823
Kernels Per Spike	.0078	.5648*	.5260*	.4315	.0256
Plant Height	.1443	.5695*	.4850	.6000*	.3719
Heading Date	.1189	-.2643	.1917	.1834	-.3172
Maturity Date	.3876	.5745*	.6483**	.7504**	-.2282
Filling Period	.0384	.4459	.1156	.2307	.2348
KERNEL WEIGHT VS					
Kernels Per Spike	.4901	.4889	.7523**	.8090**	.5260*
Plant Height	.6628**	.9176**	.6695**	.9409**	.6318**
Heading Date	.4406	.2126	.6016*	.6276**	-.4604
Maturity Date	.5652*	.7151**	.8322**	.7450**	.2908
Filling Period	-.2748	.0710	-.2724	-.2853	-.1427
KERNELS PER SPIKE VS					
Plant Height	.6405**	.6709**	.6914**	.8158**	.7620**
Heading Date	.6326**	-.0908	.3700	.5881*	.3946
Maturity Date	.3472	.2850	.5590*	.5005*	.5912*
Filling Period	-.6074*	.1851	-.1422	-.3838	-.1427
PLANT HEIGHT VS					
Heading Date	.7065**	.1790	.7116**	.7331**	.1428
Maturity Date	.3172	.5926*	.5294*	.6978**	.2838
Filling Period	-.7125**	.0564	-.5627*	-.4349	-.0177
HEADING DATE VS					
Maturity Date	.6122*	-.1051	.5439*	.4995*	.4009
Filling Period	-.9299**	-.9318**	-.8963**	-.8598**	-.8952**
MATURITY DATE VS					
Filling Period	-.2784	.4590	-.1155	.0129	.0493

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

YMH = Yamhill
INIA = Inia 66
7C = Siete Cerros 66
TRM = Torim 73
JUP = Jupateco 73
HUAC = Huacamayo "S"

Table 41. Associations among eight agronomic characters for F1, F2 and both backcrosses on five winter x spring wheat crosses grown at Hyslop Farm, 1977-78.

	CROSS				
	HYS-INIA	HYS-7C	HYS-TRM	HYS-JUP	HYS-HUAC
GRAIN YIELD VS					
Tillers Per Plant	.8622**	.8066**	.8955**	.7136**	.7245**
Kernel Weight	.2902	.6698**	.8511**	.5097*	.6862**
Kernels Per Spike	.8329**	.7786**	.7395**	.8590**	.6239**
Plant Height	.7030**	.4795	.5751*	.6315**	.6276**
Heading Date	.2819	.5396*	.1957	.7208**	.0486
Maturity Date	.1702	.3736	.7289**	.9058**	.5350*
Filling Period	-.2632	-.4052	.0853	-.4016	.2621
TILLERS PER PLANT VS					
Kernel Weight	-.0097	.4520	.7361**	.2521	.3432
Kernels Per Spike	.4925	.3620	.4209	.3378	.0076
Plant Height	.7116**	.4865*	.6091*	.5370*	.1317
Heading Date	.4046	.3847	-.0112	.3586	.1533
Maturity Date	.3707	.1128	.6661**	.5982*	.6818**
Filling Period	-.3318	-.3408	.2841	-.1093	.2249
KERNEL WEIGHT VS					
Kernels Per Spike	.2369	.2979	.5215*	.2415	.3027
Plant Height	.1797	.5732*	.6815**	.6390**	.6700**
Heading Date	-.1364	.4194	.0292	.2353	-.4855
Maturity Date	-.0350	.3927	.7476**	.4778	.1403
Filling Period	.1446	-.2804	.2735	-.0194	.6610**
KERNELS PER SPIKE VS					
Plant Height	.5161*	.1556	.2006	.3532	.5998*
Heading Date	.1377	.4692	.6109*	.2353	.2481
Maturity Date	-.0881	.3605	.5446*	.8180**	.1740
Filling Period	-.1910	-.3403	-.4404	-.5360*	-.1904
PLANT HEIGHT VS					
Heading Date	.5525*	-.2795	.2071	.3615	-.3922
Maturity Date	.2576	.2943	.7495**	.5895*	-.0208
Filling Period	-.5437*	.3748	.0813	-.1185	.4539
HEADING DATE VS					
Maturity Date	.5518*	.1275	.3878	.6997**	.5420*
Filling Period	-.9528**	-.9421**	-.9265**	-.8989**	-.8647**
MATURITY DATE VS					
Filling Period	-.2726	.2125	-.0124	-.3158	-.0466

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

HYS = Hyslop
INIA = Inia 66
7C = Siete Cerros 66
TRM = Torim 73
JUP = Jupateco 73
HUAC = Huacamayo "S"

Table 42. Associations among eight agronomic characters for F1, F2 and both backcrosses on five winter x spring wheat crosses grown at Hyslop Farm, 1977-78.

	CROSS				
	WRM-INIA	WRM-7C	WRM-TRM	WRM-JUP	WRM-HUAC
GRAIN YIELD VS					
Tillers Per Plant	.8370**	.8237**	.9429**	.9211**	.8452**
Kernel Weight	.5837*	.6716**	.9038**	.8177**	.4265
Kernels Per Spike	.5203*	.5478*	.7074**	.7891**	.9328**
Plant Height	.6483**	.8897**	.8570**	.5991*	.6805**
Heading Date	.2479	-.1643	-.0336	.2108	-.2490
Maturity Date	.4084	.3895	.5167*	.5289*	-.2060
Filling Period	-.1354	.3687	.3340	.0033	.2414
TILLERS PER PLANT VS					
Kernel Weight	.6271**	.4480	.8510**	.7867**	.1065
Kernels Per Spike	.0045	.0763	.4737	.5770*	.6548**
Plant Height	.2714	.7369**	.7397**	.7013**	.4306
Heading Date	.5082*	.0633	.0931	.2671	-.2163
Maturity Date	.6634**	.5790*	.6186*	.5033*	-.2928
Filling Period	-.3185	.1959	.2292	-.0826	.1513
KERNEL WEIGHT VS					
Kernels Per Spike	-.1331	.1343	.6147*	.3638	.3513
Plant Height	.5112*	.7032**	.8707**	.5389*	.6130*
Heading Date	.6689**	.4069	.2623	.6023*	.1723
Maturity Date	.7570**	.4666	.7472**	.7857**	.4483
Filling Period	-.4999*	-.2498	.0852	-.3683	-.0106
KERNELS PER SPIKE VS					
Plant Height	.6355**	.3857	.7951**	.3565	.6696**
Heading Date	-.4421	-.7509**	-.2978	-.2586	-.2773
Maturity Date	-.4001	-.2464	.0457	.1276	-.2367
Filling Period	.3399	.7458**	.4068	.4004	.2651
PLANT HEIGHT VS					
Heading Date	.1269	.0155	.0444	.1360	-.2473
Maturity Date	.0274	.3556	.4036	.1787	-.0727
Filling Period	-.1828	.1471	.1704	-.0825	.3071
HEADING DATE VS					
Maturity Date	.7795**	.4961	.6622**	.6975**	.8449**
Filling Period	-.9410**	-.9154**	-.9066**	-.9277**	-.9614**
MATURITY DATE VS					
Filling Period	-.5383*	-.1046	-.2842	-.3497	-.6652**

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

WRM = Weique Red Mace
INIA = Inia 66
7C = Siete Cerros 66
TRM = Torim 73
JUP = Jupateco 73
HUAC = Huacamayo "S"

Tillers per plant was positively and significantly associated with kernel weight in ten crosses. Twelve crosses also showed a significant positive association of tillers per plant and plant height. In four of these crosses Hyslop was the winter parent. Tillers per plant was positively and significantly associated with maturity date in 12 out of the 25 crosses.

Kernel weight and kernels per spike were significantly correlated in nine crosses in a positive manner and a negative association was observed in one cross (Kavkaz-Torim 73). Another significant association was kernel weight with plant height. It was positive in 18 crosses. This association was consistent when the winter parents, Yamhill or Weique Red Mace, were present in the cross. Kernel weight and maturity date were positive and significantly associated in nine crosses.

Significant and positive association of kernels per spike with plant height was observed in eleven crosses. In five of these crosses Yamhill was present as the winter parent.

Another frequent association was heading date with grain filling period: 22 crosses expressed a significant negative association and one cross expressed a positive association (Kavkaz-Siete Cerros 66). Roussalka-Torim 73 and Roussalka-Huacamayo "S" were the only crosses where no significant association was observed.

Study III

Correlation coefficents among nine agronomic characters considered for each of the 25 winter x spring crosses grown at CIANO, 1977-78 are listed in Tables 43 through 47. Fewer significant correlations among the characters were noted in this study than in Study II. Even so, the characters with the greatest association with grain yield were again kernels per spike and tillers per plant. Seventeen crosses expressed positive and significant correlation of kernels per spike with grain yield. Four of these crosses shared the same winter parent, Yamhill. The five crosses where Weique Red Mace was present also reflected this association between tillers per plant and grain yield. The five crosses that shared Hyslop as a common winter parent showed this trend. Four of the crosses where Roussalka was present also had similar associations between tiller number and grain yield. Harvest index was positive and significantly associated with grain yield in nine crosses. A positive and significant association between plant height and grain yield was observed in seven crosses. Five of these crosses shared Hyslop as a common winter parent. Kernel weight was positive and significantly associated with grain yield in only five crosses. In the crosses Roussalka-Siete Cerros 66 and Hyslop-Huacamayo "S", this association was negative. Heading and maturity date were also positive and significantly associated with grain yield in six and four crosses. Significant negative association was found between filling period and grain yield in three crosses (Yamhill-Torim 73, Hyslop-Inia 66 and Hyslop-Jupateco 73). The cross Roussalka-Siete Cerros 66 showed a significant positive association between grain filling period and grain yield.

Nine crosses showed a positive and significant association of tillers per plant and plant height. Five of these crosses shared Hyslop as a common winter parent. A significant negative association was found between tiller number and plant height in Kavkaz-Jupateco 73.

Table 43. Association among nine agronomic characters for spring parents, F2's and backcrosses to spring parents from five winter x spring wheat crosses grown at CIANO, 1977-78.

	CROSS				
	KVZ-INIA	KVZ-7C	KVZ-TRM	KVZ-JUP	KVZ-HUAC
GRAIN YIELD VS					
Tillers Per Plant	.7896**	.4781	.2974	.3232	.3439
Kernel Weight	.5490	.0332	.0844	.3868	.5840*
Kernels Per Spike	.6905*	.5376	.9287**	.6821*	.2427
Plant Height	.2399	-.1976	.3582	-.1292	.3762
Harvest Index	.6139*	.4293	.3697	.5384	.1991
Heading Date	.2167	-.1586	.3077	-.1853	.3313
Maturity Date	.1195	.1654	.4722	-.0058	.3448
Filling Period	-.2530	.1910	.0287	.2059	-.3119
TILLERS PER PLANT VS					
Kernel Weight	.2389	-.4474	-.7180**	-.6426*	.2432
Kernels Per Spike	.1429	-.2850	.1983	-.4323	-.7865**
Plant Height	-.0599	-.0600	-.1338	-.8588**	-.1115
Harvest Index	-.4378	-.1943	-.0272	.2183	-.4337
Heading Date	-.0900	-.1043	-.0376	-.7145**	-.0594
Maturity Date	-.1230	.0552	.2007	-.5039	.0214
Filling Period	.0584	.1094	.3433	.6882*	.0923
KERNEL WEIGHT VS					
Kernels Per Spike	.3463	-.1347	.1303	.7558**	-.1085
Plant Height	.5570	.4959	.4412	.7082**	.7867**
Harvest Index	.0590	-.1355	-.0124	.1889	-.3625
Heading Date	.5114	.5183	.2427	.5154	.5042
Maturity Date	.3302	.4477	.2151	.3047	.5013
Filling Period	-.5773*	-.4450	-.1887	-.5121	-.4850
KERNELS PER SPIKE VS					
Plant Height	.3341	.5447	.3193	.4960	.1407
Harvest Index	.5975*	.8115**	.4585	.2955	.6905*
Heading Date	.3521	-.4664	.2904	.3291	.1460
Maturity Date	.2786	-.2569	.3469	.4032	.0664
Filling Period	-.3533	.4529	-.1055	-.2820	-.1747
PLANT HEIGHT VS					
Harvest Index	-.4378	-.7401**	-.4276	-.3645	-.4537
Heading Date	.9471**	.8649**	.8989**	.8946**	.8449**
Maturity Date	.7629**	.3564	.8330**	.5417	.7560**
Filling Period	-.9662**	-.8180**	-.6498*	-.8940**	-.8493**
HARVEST INDEX VS					
Heading Date	-.4687	-.5719	-.3666	-.4901	-.4950
Maturity Date	-.4543	-.2569	-.2455	.0078	-.4617
Filling Period	.4329	.5347	.3914	.5961	-.8493**
HEADING DATE VS					
Maturity Date	.9001**	.2584	.8845**	.6823*	.9346**
Filling Period	-.9551**	-.9802**	-.7796**	-.9623**	.9879**
MATURITY DATE					
Filling Period	-.7315**	-.0644	-.3973	-.4621	-.8681**

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

KVZ = Kavkaz
INIA = Inia 66
7C = Siete Cerros 66
TRM = Torim 73
JUP = Jupateco 73
HUAC = Huacamayo "S"

Table 44. Association among nine agronomic characters for spring parents, F2's and backcrosses to spring parents from five winter x spring wheat crosses grown at CIANO, 1977-78.

	CROSS				
	RSK-INIA	RSK-7C	RSK-TRM	RSK-JUP	RSK-HUAC
GRAIN YIELD VS					
Tillers Per Plant	.6270*	.8703**	.6703*	.8369**	.3524
Kernel Weight	-.1439	-.7482**	.1031	.1363	.2606
Kernels Per Spike	.4864	.8254**	.5522	.5480	.8432**
Plant Height	.2004	.1773	.2025	.4710	.3499
Harvest Index	.1300	.5767*	.4489	.6044*	.7366**
Heading Date	-.1770	-.6479*	.1189	-.3937	-.3339
Maturity Date	-.2033	-.4376	.2679	-.3676	.0454
Filling Period	.0734	.5810*	.1011	.3666	.4314
TILLERS PER PLANT VS					
Kernel Weight	-.6297*	-.7901**	-.1607	.1837	.1040
Kernels Per Spike	-.3112	.5515	.2191	.0882	-.1264
Plant Height	.3511	-.1747	.2166	.3306	.0395
Harvest Index	-.5045	.2391	-.2423	.3584	-.0848
Heading Date	.4809	-.4024	.4108	-.3915	-.2937
Maturity Date	.3357	-.0539	.4651	-.3530	-.1314
Filling Period	-.4638	.4685	-.2889	.3804	.3012
KERNEL WEIGHT VS					
Kernels Per Spike	.2227	-.7911**	.0841	-.4834	-.0525
Plant Height	-.0207	.2008	.5444	.1668	.0235
Harvest Index	.2748	-.4071	-.0253	-.1955	-.0036
Heading Date	-.4998	.6501*	.2351	-.3374	-.5641
Maturity Date	-.2974	-.0395	.2296	-.0926	-.3225
Filling Period	.5450	-.8195**	-.2161	.4923	.5849*
KERNELS PER SPIKE VS					
Plant Height	-.1860	.2820	-.0981	.2331	.3287
Harvest Index	.7580**	.7585**	.9077**	.6588*	.8587**
Heading Date	-.6637*	-.8437**	-.3503	-.0390	-.0631
Maturity Date	-.6002*	-.4615	-.2106	-.1685	.1885
Filling Period	.4729	.8100**	.5043	-.0694	.1512
PLANT HEIGHT VS					
Harvest Index	-.6259*	.3604	-.4403	-.1355	-.0295
Heading Date	.6847*	-.2298	.8259**	.3055	.4183
Maturity Date	.6203*	-.5850*	.8527**	.5053	.4860
Filling Period	-.4864	-.0063	-.6949*	-.1083	-.3010
HARVEST INDEX VS					
Heading Date	-.8558**	-.8495**	-.6409*	-.7163**	-.2643
Maturity Date	.7944**	-.6986*	-.5467	-.7689**	-.2186
Filling Period	.5847*	.7000*	.6988*	.5867*	.2128
HEADING DATE VS					
Maturity Date	.8547**	.6236*	.9660**	.9147**	.6973*
Filling Period	-.7731**	-.9224**	-.9336**	-.9462**	-.9353**
MATURITY DATE VS					
Filling Period	-.3315	-.2732	-.8093**	-.7347**	-.4002

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

RSK = Roussalka
INIA = Inia 66
7C = Siete Cerros 66
TRM = Torim 73
JUP = Jupateco 73
HUAC = Huacamayo "S"

Table 45. Association among nine agronomic characters for spring parents, F2's and backcrosses to spring parents from five winter x spring wheat crosses grown at CIANO, 1977-78.

	CROSS				
	YMH-INIA	YMH-7C	YMH-TRM	YMH-JUP	YMH-HUAC
GRAIN YIELD VS					
Tillers Per Plant	.6464*	.3576	.8199**	.3320	.4458
Kernel Weight	.5089	.1415	.5464	.8678**	.4356
Kernels Per Spike	.9192**	.7714**	.7425**	.8912**	.4638
Plant Height	-.0215	-.1325	.7987**	.0829	-.0654
Harvest Index	.5921*	.7898**	.1243	.6986*	.3163
Heading Date	.1459	-.4404	.6863*	-.3815	-.0954
Maturity Date	.2317	-.1977	.6224*	-.3747	-.1268
Filling Period	.0041	.4739	-.6569*	.3302	.0554
TILLERS PER PLANT VS					
Kernel Weight	-.2613	-.0631	.2078	.0169	-.3025
Kernels Per Spike	.3865	-.2325	.2661	-.0735	-.3856
Plant Height	.6262*	.1829	.7965**	.3256	.2651
Harvest Index	-.1444	-.0730	-.2688	-.2030	-.5634
Heading Date	.7208**	-.1564	.5917*	-.1359	.2904
Maturity Date	.7178**	.0663	.5285	.0340	.5650
Filling Period	-.6034*	.1939	-.5926*	.2414	-.0379
KERNEL WEIGHT VS					
Kernels Per Spike	.5949*	-.1364	.4552	.8096**	.1544
Plant Height	-.6284*	.5834*	.4553	-.0885	-.8123**
Harvest Index	.7469**	-.1134	-.0462	.6848*	.7099**
Heading Date	-.5830*	-.1010	.4369	-.5432	-.7515**
Maturity Date	-.3853	-.2684	.4710	-.4347	-.7330**
Filling Period	.7734**	.0678	-.2667	.5430	.6312*
KERNELS PER SPIKE VS					
Plant Height	-.2796	-.4238	.4489	.0003	.2607
Harvest Index	.8080**	.8897**	.5985*	.8266**	.5559
Heading Date	-.0481	.2766	.5068	-.2222	.1262
Maturity Date	-.0065	-.1246	.4349	-.3594	-.2681
Filling Period	.1007	.2972	-.5351	.0878	-.3921
PLANT HEIGHT VS					
Harvest Index	-.7397**	-.5029	-.3500	-.0350	-.5844*
Heading Date	.8566**	.4816	.9296**	.6459*	.9272**
Maturity Date	.8508**	.3800	.8665**	.7041*	.7729**
Filling Period	-.7202**	-.4890	-.8422**	-.5073	-.8750**
HARVEST INDEX VS					
Heading Date	-.5644	-.5940	-.3398	-.2341	-.6315*
Maturity Date	-.5355	-.4106	-.4003	-.3361	-.8166**
Filling Period	.5111	.6130*	.1388	.1241	.3873
HEADING DATE VS					
Maturity Date	.9538**	.8891**	.9638**	.8837**	.8572**
Filling Period	-.8984**	-.9966**	-.8418**	-.9381**	-.9264**
MATURITY DATE VS					
Filling Period	-.7249**	-.8481**	-.6673*	-.6669*	-.6001*

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

YMH = Yamhill
INIA = Inia 66
7C = Siete Cerros 66
TRM = Torim 73
JUP = Jupateco 73
HUAC = Huacamayo "S"

Table 46. Association among nine agronomic characters for spring parents, F2's and backcrosses to spring parents from five winter x spring wheat crosses grown at CIANO, 1977-78.

	CROSS				
	HYS-INIA	HYS-7C	HYS-TRM	HYS-JUP	HYS-HUAC
GRAIN YIELD VS					
Tillers Per Plant	.6128*	.8473**	.9595**	.8504**	.7757**
Kernel Weight	-.3358	.3973	.5966*	.0841	-.6844*
Kernels Per Spike	.4237	.5005	.8743**	.6519*	.6850*
Plant Height	.8374**	.7785**	.8699**	.6300*	.7312**
Harvest Index	-.4109	-.0429	.0909	.1182	.1121
Heading Date	.7388**	.2886	.6678*	.7121**	.4842
Maturity Date	.7488**	.2900	.6953*	.5626	.5417
Filling Period	-.5886*	-.2325	-.4954	-.7529**	-.3608
TILLERS PER PLANT VS					
Kernel Weight	-.7017**	.3962	.4961	-.2191	-.8391**
Kernels Per Spike	-.4454	.0558	.6926*	.1722	.1065
Plant Height	.5962*	.8275**	.9179**	.6450*	.7403**
Harvest Index	-.5826*	-.3191	-.0467	-.3554	-.4584
Heading Date	.4127	.3020	.7279**	.7976**	.7806**
Maturity Date	.6367*	.3869	.6834*	.7162**	.7948**
Filling Period	-.0585	-.1876	-.6640*	-.7644**	-.6933*
KERNEL WEIGHT VS					
Kernels Per Spike	.3397	-.3309	.4611	.3210	-.2773
Plant Height	-.3537	.7224**	.3690	-.1014	-.7057*
Harvest Index	.5244	-.2126	.3084	.4374	.3789
Heading Date	-.4010	.4510	.0959	-.0570	-.7875**
Maturity Date	-.4387	.4301	.2317	-.1310	-.7911**
Filling Period	.2798	-.3992	.1482	-.0185	.7028*
KERNELS PER SPIKE VS					
Plant Height	.2451	-.0328	.6651*	.2560	.3204
Harvest Index	.2096	.4561	.2390	.7437**	.6814*
Heading Date	.3893	-.1324	.5885*	.1941	-.0773
Maturity Date	.1242	-.2079	.6735*	.0301	.0024
Filling Period	-.6448*	.0700	-.3356	-.3182	.1735
PLANT HEIGHT VS					
Harvest Index	-.7094**	-.2035	-.3053	-.3815	-.4161
Heading Date	.8831**	.3950	.8344**	.8359**	.7364**
Maturity Date	.9244**	.4132	.8106**	.8963**	.8050**
Filling Period	-.6682*	-.3203	-.7159**	-.6677*	-.5733
HARVEST INDEX VS					
Heading Date	-.6367*	-.7922**	-.4145	-.4074	.7235**
Maturity Date	-.7172**	-.7896**	-.3788	-.5205	-.6670*
Filling Period	.4184	.6526*	.3953	.2488	.7248**
HEADING DATE VS					
Maturity Date	.9337**	.8460**	.9583**	.9228**	.9675**
Filling Period	-.8966**	-.9332**	-.8799**	-.9356**	-.9432**
MATURITY DATE					
Filling Period	-.6788*	-.5986*	-.7074*	-.7274**	-.8286**

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

HYS = Hyslop
INIA = Inia 66
7C = Siete Cerros
TRM = Torim 73
JUP = Jupateco 73
HUAC = Huacamayo "S"

Table 47. Association among nine agronomic characters for spring parents, F2's and backcrosses to spring parents from five winter x spring wheat crosses grown at CIANO, 1977-78.

	CROSS				
	WRM-INIA	WRM-7C	WRM-TRM	WRM-JUP	WRM-HUAC
GRAIN YIELD VS					
Tillers Per Plant	.5791*	.8778**	.5003	.8417**	.2276
Kernel Weight	.3548	-.3003	.6936*	-.4029	.1961
Kernels Per Spike	.7563**	.8370**	.7087**	.7764**	.7473**
Plant Height	.5482	.5613	.7164**	-.1403	-.0299
Harvest Index	-.1666	.4155	.2100	.6984*	.6199*
Heading Date	.6175*	-.1122	.5611	-.2101	.0933
Maturity Date	.6935*	-.0230	.5222	-.1841	-.1942
Filling Period	-.4147	.3705	-.5112	.1706	-.3096
TILLERS PER PLANT VS					
Kernel Weight	-.2527	-.3478	.2098	-.5509	-.5538
Kernels Per Spike	.0096	.5685	-.1934	.3672	-.4432
Plant Height	.1295	.5234	.6943*	-.2365	-.2801
Harvest Index	-.4537	.1985	-.6519*	.2970	-.4604
Heading Date	.5707	-.1712	.6939*	-.1632	.1816
Maturity Date	.6137*	-.0451	.6467*	.0369	.4910
Filling Period	-.4362	.3596	-.6310*	.2698	.1402
KERNEL WEIGHT VS					
Kernels Per Spike	.2783	-.5750	.3839	-.3638	.3846
Plant Height	.3348	.3772	.6828*	.5024	.3967
Harvest Index	.2006	-.5721	.0784	-.3843	.4164
Heading Date	.1369	.5200	.3588	.6761*	-.1177
Maturity Date	.1251	.6023*	.4194	.3331	-.5597
Filling Period	-.1475	-.7668**	-.2139	-.7468**	-.3637
KERNELS PER SPIKE VS					
Plant Height	.5487	.2243	.1727	-.0693	.0654
Harvest Index	.1127	.6953*	.7971**	.9401**	.8763**
Heading Date	.2818	-.2605	.0788	.6761*	.0048
Maturity Date	.3643	-.2593	.0397	-.4087	-.4164
Filling Period	-.0965	.5528	-.1162	.2170	-.3637
PLANT HEIGHT VS					
Harvest Index	-.4403	-.3692	-.3639	-.2915	-.2393
Heading Date	.6221*	.3393	.8434**	.6296*	.2988
Maturity Date	.6532*	.4864	.8522**	.3188	.1228
Filling Period	-.5062	-.4607	-.6795*	-.6889**	-.3552
HARVEST INDEX VS					
Heading Date	-.7509**	-.5426	-.4770	.7853**	-.3010
Maturity Date	-.7487**	-.6273*	.4750	-.5579	-.7028*
Filling Period	.6884*	.7940**	.3936	.1346	-.1376
HEADING DATE VS					
Maturity Date	.9846**	.7662**	.9418**	.7853**	.7985**
Filling Period	-.9407**	-.7648**	-.8962**	-.8813**	-.8572**
MATURITY DATE					
Filling Period	-.8669**	-.6708*	-.6950*	-.3995	-.3746

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

WRM = Weique Red Mace
INIA = Inia 66
7C = Siete Cerros 66
TRM = Torim 73
JUP = Jupateco 73
HUAC = Huacamayo "S"

Another negative association noted in six crosses was between tillers per plant and kernel weight.

Kernels per spike and harvest index were positive and significantly associated in 18 crosses. Five of these crosses had Roussalka and four had Weique Red Mace as a winter parent.

Plant height and heading date showed a consistent positive correlation in 18 crosses. Some of these crosses shared a common winter parent: five crosses with Kavkaz, four crosses with Yamhill and four crosses with Hyslop. Five crosses expressed a significant negative association for plant height with harvest index.

All the crosses showed a negative and significant association of heading date and grain filling period. The same trend was found in Study II. Maturity date and grain filling period also showed a positive and significant association in 17 crosses.

Path-Coefficient Analysis

To provide a better understanding of associations between the agronomic characters and grain yield, correlation coefficients were partitioned into direct and indirect effects using path-coefficient analysis.

Study II

In Tables 48 to 52 the correlation coefficients are partitioned into the direct and indirect effects of six characters on grain yield. Heading date had no or very little direct effect on grain yield. Where significant correlation values were observed, the main effects were via indirect associations. In the cross Kavkaz-Siete Cerros 66, the

Table 48. Direct and indirect effects of six agronomic characters on grain yield of wheat for winter x spring F1's, F2's and reciprocal backcrosses when grown at Hyslop Farm, 1977-78.

Character	CROSS				
	KVZ-INIA	KVZ-7C	KVZ-TRM	KVZ-JUP	KVZ-HUAC
GRAIN YIELD AND HEADING DATE					
Direct effect	.080	-.102	-.014	.030	-.104
Indirect effect via Maturity Date	-.003	-.008	.000	.006	-.016
Indirect effect via Plant Height	.001	.069	.020	-.049	.020
Indirect effect via Tillers Per Plant	.034	.332	.119	-.016	-.032
Indirect effect via Kernel Weight	.078	.102	-.041	.134	-.008
Indirect effect via Kernels Per Spike	.268	.247	.057	.079	-.072
Correlation	.458	.639**	.170	.216	.212
GRAIN YIELD AND MATURITY DATE					
Direct Effect	.032	.026	-.005	-.126	.047
Indirect effect via Heading Date	-.007	.031	-.001	-.002	.036
Indirect effect via Plant Height	-.000	-.023	-.005	.010	-.005
Indirect effect via Tillers Per Plant	.235	.009	.472	.160	.288
Indirect effect via Kernel Weight	-.031	-.030	.003	.182	.048
Indirect effect via Kernels per Spike	-.051	.173	.257	.343	.113
Correlation	.177	.185	.721**	.547*	.527*
GRAIN YIELD AND PLANT HEIGHT					
Direct effect	.002	.083	.028	-.063	.048
Indirect effect via Heading Date	.044	-.085	.010	.023	-.044
Indirect effect via Maturity Date	-.002	-.007	.001	-.021	-.005
Indirect effect via Tillers Per Plant	.064	.489	-.125	.268	.514
Indirect effect via Kernel Weight	.085	.124	.196	.325	.013
Indirect effect via Kernels Per Spike	.287	.203	-.078	.096	.116
Correlation	.481	.408**	.032	.629**	.644**
GRAIN YIELD AND TILLERS PER PLANT					
Direct effect	.486	.623	.721	.661	.695
Indirect effect via Heading Date	.006	-.054	.002	.001	.005
Indirect effect via Maturity Date	.016	.000	-.003	-.031	.020
Indirect effect via Plant Height	.003	.065	-.005	-.026	.036
Indirect effect via Kernel Weight	.042	.107	-.219	.191	.033
Indirect effect via Kernels Per Spike	.216	.113	.366	.030	.178
Correlation	.766**	.855**	.862**	.826**	.965**
GRAIN YIELD AND KERNEL WEIGHT					
Direct effect	.224	.221	.449	.471	.071
Indirect effect via Heading Date	.028	-.047	-.001	.008	.011
Indirect effect via Maturity Date	-.005	-.004	.000	-.049	.032
Indirect effect via Plant Height	.001	.047	.012	-.043	.009
Indirect effect via Tillers Per Plant	.092	.302	-.352	.268	.319
Indirect effect via Kernels Per Spike	.143	-.067	-.344	.051	.060
Correlation	.483	.452	-.235	.604*	.502*
GRAIN YIELD AND KERNELS PER SPIKE					
Direct effect	.560	.550	.612	.563	.240
Indirect effect via Heading Date	.038	-.046	.001	.004	.031
Indirect effect via Maturity Date	-.003	.008	-.002	-.077	.022
Indirect effect via Plant Height	.001	.031	-.004	-.011	.023
Indirect effect via Tillers Per Plant	.188	.129	.430	.035	.515
Indirect effect via Kernel Weight	.057	-.027	-.225	-.043	.018
Correlation	.839**	.644**	.786**	.472	.849**
R^2	.993	.992	.996	.993	.986

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

KVZ = Kavkaz
INIA = Inia 66
7C = Siete Cerros 66
TRM = Torim 73
JUP = Jupateco 73
HUAC = Huacamayo "S"

Table 49. Direct and indirect effects of six agronomic characters on grain yield of wheat for winter x spring F1's, F2's and reciprocal backcrosses when grown at Hyslop Farm, 1977-78.

Character	CROSS				
	RSK-INIA	RSK-7C	RSK-TRM	RSK-JUP	RSK-HUAC
GRAIN YIELD AND HEADING DATE					
Direct effect	-.035	-.000	-.014	.043	-.015
Indirect effect via Maturity Date	-.001	-.044	-.007	.013	.044
Indirect effect via Plant Height	-.003	.001	.037	-.004	-.036
Indirect effect via Tillers Per Plant	.029	-.081	-.187	-.380	-.162
Indirect effect via Kernel Weight	.037	.033	-.180	.058	-.020
Indirect effect via Kernels Per Spike	-.023	.048	.095	.141	.076
Correlation	.004	-.003	-.446	-.129	.114
GRAIN YIELD AND MATURITY DATE					
Direct Effect	.004	-.044	-.021	-.051	.071
Indirect effect via Heading Date	.005	-.000	-.005	-.011	-.009
Indirect effect via Plant Height	.001	.001	.045	-.003	-.026
Indirect effect via Tillers Per Plant	.270	-.151	.075	.257	-.028
Indirect effect via Kernel Weight	.020	-.039	.125	.256	.066
Indirect effect via Kernels per Spike	.131	.029	.078	.177	.310
Correlation	.430	-.203	.297	.624**	.384
GRAIN YIELD AND PLANT HEIGHT					
Direct effect	.066	-.004	-.068	.014	.074
Indirect effect via Heading Date	.002	.000	.008	-.011	.007
Indirect effect via Maturity Date	.000	.015	.013	.011	-.025
Indirect effect via Tillers Per Plant	.370	.329	.027	.135	.133
Indirect effect via Kernel Weight	.160	.018	.148	.053	.085
Indirect effect via Kernels Per Spike	.178	-.029	.004	.096	.042
Correlation	.775**	.329	.132	.298	.317
GRAIN YIELD AND TILLERS PER PLANT					
Direct effect	.662	.522	.521	.505	.543
Indirect effect via Heading Date	-.002	.000	.005	-.033	.005
Indirect effect via Maturity Date	.002	.013	-.003	-.026	-.004
Indirect effect via Plant Height	.037	-.003	-.004	.003	.018
Indirect effect via Kernel Weight	.145	.096	.162	.118	.050
Indirect effect via Kernels Per Spike	-.021	.061	.052	.028	.158
Correlation	.823**	.689**	.733**	.596*	.771**
GRAIN YIELD AND KERNEL WEIGHT					
Direct effect	.225	.167	.465	.403	.148
Indirect effect via Heading Date	-.006	-.000	.005	.006	.002
Indirect effect via Maturity Date	.000	.010	-.006	-.032	.032
Indirect effect via Plant Height	.047	-.000	-.022	.002	.042
Indirect effect via Tillers Per Plant	.427	.300	.181	.148	.183
Indirect effect via Kernels Per Spike	.114	.423	.169	.353	.239
Correlation	.807**	.900**	.794**	.880**	.647**
GRAIN YIELD AND KERNELS PER SPIKE					
Direct effect	.436	.612	.388	.468	.534
Indirect effect via Heading Date	.002	-.000	.003	.013	-.002
Indirect effect via Maturity Date	.001	-.002	-.004	-.019	.041
Indirect effect via Plant Height	.027	.000	-.001	.003	.006
Indirect effect via Tillers Per Plant	-.032	.052	.070	.030	.167
Indirect effect via Kernel Weight	.059	.115	.203	.304	.066
Correlation	.493	.777**	.660**	.799**	.806**
R^2	.994	.993	.998	.995	.997

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

RSK = Roussalka
INIA = Inia 66
7C = Siete Cerros 66
TRM = Torim 73
JUP = Jupateco 73
HUAC = Huacamayo "S"

Table 50. Direct and indirect effects of six agronomic characters on grain yield of wheat for winter x spring F1's, F2's and reciprocal backcrosses when grown at Hyslop Farm, 1977-78.

Character	CROSS YMH-INIA	YMH-7C	YMH-TRM	YMH-JUP	YMH-HUAC
GRAIN YIELD AND HEADING DATE					
Direct effect	.007	.062	.004	-.057	-.042
Indirect effect via Maturity Date	.016	.012	-.030	-.032	-.015
Indirect effect via Plant Height	.026	-.036	.007	.052	-.006
Indirect effect via Tillers Per Plant	.059	-.180	.082	.107	-.128
Indirect effect via Kernel Weight	.108	.085	.134	.159	-.146
Indirect effect via Kernels Per Spike	.394	-.035	.201	.196	.280
Correlation	.610*	-.093	.398	.425	-.055
GRAIN YIELD AND MATURITY DATE					
Direct Effect	.027	-.110	-.055	-.064	-.037
Indirect effect via Heading Date	.005	-.007	.002	-.029	-.017
Indirect effect via Plant Height	.012	-.119	.005	.049	-.011
Indirect effect via Tillers Per Plant	.192	.392	.278	.437	-.092
Indirect effect via Kernel Weight	.138	.287	.186	.189	.092
Indirect effect via Kernels per Spike	.216	.110	.304	.167	.419
Correlation	.589*	.554*	.720**	.750**	.354
GRAIN YIELD AND PLANT HEIGHT					
Direct effect	.036	-.200	.010	.071	-.040
Indirect effect via Heading Date	.005	.011	.003	-.042	-.006
Indirect effect via Maturity Date	.009	-.065	-.029	-.044	-.010
Indirect effect via Tillers Per Plant	.072	.389	.208	.350	.150
Indirect effect via Kernel Weight	.162	.368	.154	.238	.200
Indirect effect via Kernels Per Spike	.399	.259	.363	.273	.546
Correlation	.682**	.761**	.709**	.845**	.834**
GRAIN YIELD AND TILLERS PER PLANT					
Direct effect	.496	.682	.428	.583	.403
Indirect effect via Heading Date	.001	-.016	.001	-.011	.013
Indirect effect via Maturity Date	.010	-.063	-.036	-.048	.008
Indirect effect via Plant Height	.005	-.114	.005	.042	-.015
Indirect effect via Kernel Weight	.061	.211	.121	.175	.090
Indirect effect via Kernels Per Spike	.005	.218	.286	.144	.018
Correlation	.578*	.918**	.805**	.886**	.517*
GRAIN YIELD AND KERNEL WEIGHT					
Direct effect	.244	.401	.223	.254	.316
Indirect effect via Heading Date	.003	.013	.002	-.036	.019
Indirect effect via Maturity Date	.015	-.079	-.046	-.048	-.011
Indirect effect via Plant Height	.024	-.184	.007	.067	-.025
Indirect effect via Tillers Per Plant	.124	.360	.233	.402	.114
Indirect effect via Kernels Per Spike	.305	.189	.408	.271	.373
Correlation	.715**	.700**	.828**	.909**	.786**
GRAIN YIELD AND KERNELS PER SPIKE					
Direct effect	.623	.386	.543	.335	.709
Indirect effect via Heading Date	.005	.006	.002	-.034	-.017
Indirect effect via Maturity Date	.009	-.031	-.031	-.032	-.022
Indirect effect via Plant Height	.022	-.134	.006	.058	-.031
Indirect effect via Tillers Per Plant	.004	.395	.225	.251	.010
Indirect effect via Kernel Weight	.120	.196	.168	.205	.166
Correlation	.784**	.796**	.913**	.783**	.817**
R^2	.994	.995	.993	.995	.992

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

YMH = Yamhill
INIA = Inia 66
7C = Siete Cerros 66
TRM = Torim 73
JUP = Jupateco 73
HUAC = Huacamayo "S"

Table 51. Direct and indirect effects of six agronomic characters on grain yield of wheat for winter x spring F1's, F2's and reciprocal backcrosses when grown at Hyslop Farm, 1977-78.

Character	CROSS HYS-INIA	HYS-7C	HYS-TRM	HYS-JUP	HYS-HUAC
GRAIN YIELD AND HEADING DATE					
Direct effect	.018	-.111	-.093	-.008	-.018
Indirect effect via Maturity Date	-.013	.003	-.029	-.021	-.008
Indirect effect via Plant Height	-.036	.033	.019	.012	-.015
Indirect effect via Tillers Per Plant	.272	.209	-.006	.154	.097
Indirect effect via Kernel Weight	-.027	.155	.006	.055	-.136
Indirect effect via Kernels Per Spike	.067	.250	.299	.528	.129
Correlation	.282	.540*	.196	.721**	.149
GRAIN YIELD AND MATURITY DATE					
Direct Effect	-.023	.023	-.076	-.029	-.015
Indirect effect via Heading Date	.010	-.014	-.036	-.005	-.010
Indirect effect via Plant Height	-.017	-.035	.068	.020	-.001
Indirect effect via Tillers Per Plant	.250	.061	.359	.256	.431
Indirect effect via Kernel Weight	-.007	.145	.147	.111	.039
Indirect effect via Kernels per Spike	-.043	.192	.267	.553	.090
Correlation	.170	.374	.729**	.906**	.535*
GRAIN YIELD AND PLANT HEIGHT					
Direct effect	-.065	-.118	.090	.034	.039
Indirect effect via Heading Date	.010	.031	-.019	-.003	.007
Indirect effect via Maturity Date	-.006	.007	-.057	-.017	.000
Indirect effect via Tillers Per Plant	.479	.265	.328	.230	.083
Indirect effect via Kernel Weight	.035	.212	.134	.149	.188
Indirect effect via Kernels Per Spike	.250	.083	.098	.239	.311
Correlation	.703**	.480	.575*	.632**	.628**
GRAIN YIELD AND TILLERS PER PLANT					
Direct effect	.673	.544	.539	.429	.633
Indirect effect via Heading Date	.007	-.043	.001	-.003	-.003
Indirect effect via Maturity Date	-.009	.003	-.050	-.018	-.010
Indirect effect via Plant Height	-.046	-.058	.055	.018	.005
Indirect effect via Kernel Weight	-.002	.167	.145	.059	.096
Indirect effect via Kernels Per Spike	.239	.193	.206	.228	.004
Correlation	.862**	.807**	.896**	.714**	.725**
GRAIN YIELD AND KERNEL WEIGHT					
Direct effect	.195	.370	.197	.233	.280
Indirect effect via Heading Date	-.003	-.047	-.003	-.002	.009
Indirect effect via Maturity Date	.001	.009	-.056	-.014	-.002
Indirect effect via Plant Height	-.012	.068	.062	.022	.026
Indirect effect via Tillers Per Plant	-.007	.246	.397	.108	.217
Indirect effect via Kernels Per Spike	.115	.159	.255	.163	.157
Correlation	.290	.670**	.851**	.510*	.686**
GRAIN YIELD AND KERNELS PER SPIKE					
Direct effect	.484	.534	.490	.676	.518
Indirect effect via Heading Date	.003	-.052	-.057	-.006	-.004
Indirect effect via Maturity Date	.002	.009	-.041	-.024	-.003
Indirect effect via Plant Height	-.034	-.018	.018	.012	.023
Indirect effect via Tillers Per Plant	.332	.197	.227	.145	.005
Indirect effect via Kernel Weight	.046	.110	.103	.056	.085
Correlation	.833**	.779**	.740**	.859**	.624**
R^2	.995	.994	.990	.994	.988

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

HYS = Hyslop
INIA = Inia 66
7C = Siete Cerros 66
TRM = Torim 73
JUP = Jupateco 73
HUAC = Huacamayo "S"

Table 52. Direct and indirect effects of six agronomic characters on grain yield of wheat for winter x spring F1's, F2's and reciprocal backcrosses when grown at Hyslop Farm, 1977-78.

Character	WRM-INIA	WRM-7C	WRM-TRM	WRM-JUP	WRM-HUAC
			CROSS		
GRAIN YIELD AND HEADING DATE					
Direct effect	-.038	.064	-.038	.023	-.030
Indirect effect via Maturity Date	.016	-.025	-.120	-.022	-.005
Indirect effect via Plant Height	.003	.001	-.006	-.007	.008
Indirect effect via Tillers Per Plant	.356	.042	.060	.116	-.098
Indirect effect via Kernel Weight	.143	.116	.132	.214	.035
Indirect effect via Kernels Per Spike	-.232	-.361	-.061	-.113	-.138
Correlation	.248	-.164	-.034	.211	-.249
GRAIN YIELD AND MATURITY DATE					
Direct Effect	.020	-.050	-.182	-.031	-.005
Indirect effect via Heading Date	-.029	.032	-.025	.016	-.025
Indirect effect via Plant Height	.001	.013	-.057	-.009	.003
Indirect effect via Tillers Per Plant	.465	.381	.394	.219	-.132
Indirect effect via Kernel Weight	.162	.133	.378	.279	.091
Indirect effect via Kernels per Spike	-.210	-.119	.009	.056	-.137
Correlation	.408	.390	.517*	.529*	-.206
GRAIN YIELD AND PLANT HEIGHT					
Direct effect	.020	.037	-.142	-.050	-.034
Indirect effect via Heading Date	-.005	.001	-.002	.003	.007
Indirect effect via Maturity Date	.001	-.018	-.073	-.006	.000
Indirect effect via Tillers Per Plant	.190	.485	.471	.305	.194
Indirect effect via Kernel Weight	.109	.200	.439	.191	.125
Indirect effect via Kernels Per Spike	.333	.186	.163	.156	.388
Correlation	.648**	.890**	.857**	.599*	.681**
GRAIN YIELD AND TILLERS PER PLANT					
Direct effect	.701	.658	.637	.435	.451
Indirect effect via Heading Date	-.019	.004	-.004	.006	.006
Indirect effect via Maturity Date	.013	-.029	-.113	-.016	.002
Indirect effect via Plant Height	.005	.027	-.105	-.035	-.015
Indirect effect via Kernel Weight	.134	.127	.429	.279	.022
Indirect effect via Kernels Per Spike	.002	.037	.097	.252	.380
Correlation	.837**	.824**	.943**	.921**	.845**
GRAIN YIELD AND KERNEL WEIGHT					
Direct effect	.214	.284	.505	.354	.203
Indirect effect via Heading Date	-.025	.026	-.010	.014	-.005
Indirect effect via Maturity Date	.015	-.023	-.136	-.025	-.002
Indirect effect via Plant Height	.010	.026	-.124	-.027	-.021
Indirect effect via Tillers Per Plant	.440	.295	.542	.342	.048
Indirect effect via Kernels Per Spike	-.070	.065	.126	.159	.204
Correlation	.583*	.672**	.904**	.818**	.427
GRAIN YIELD AND KERNELS PER SPIKE					
Direct effect	.525	.481	.205	.437	.579
Indirect effect via Heading Date	-.017	-.048	.011	-.006	.008
Indirect effect via Maturity Date	-.008	.012	-.008	-.004	.001
Indirect effect via Plant Height	.012	.014	-.113	-.018	-.023
Indirect effect via Tillers Per Plant	.003	.050	.302	.251	.295
Indirect effect via Kernel Weight	-.029	.038	.310	.129	.071
Correlation	.520*	.548*	.707**	.789**	.933**
R^2	.996	.998	.987	.993	.993

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

WRM = Weique Red Mace
INIA = Inia 66
7C = Siete Cerros 66
TRM = Torim 73
JUP = Jupateco 73
HUAC = Huacamayo "S"

large indirect effect was via tillers per plant and kernels per spike which accounted for the significant correlation value (.639) between grain yield and heading date. This was also true for the cross Hyslop-Siete Cerros 66. For Yamhill-Inia 66 and Hyslop-Jupateco 73, the large indirect effect of kernels per spike was responsible for the significant correlation value between grain yield and heading date.

When the association between grain yield and maturity date is considered, a similar result appears as with heading date. Where significant correlation values were noted, the main contributing effects were via indirect association through either tillers per plant or kernels per spike or both. The indirect effect of kernel weight was also important in some crosses such as Roussalka-Jupateco 73, Yamhill-Siete Cerros 66, Weique Red Mace-Torim 73 and Weique Red Mace-Jupateco 73.

Plant height and grain yield were significantly associated in several crosses. As with heading and maturity date, the direct effect on grain yield by plant height was very small or negative. Indirect associations of either tillers per plant, kernel weight, kernels per spike or a combination of the above were responsible for the significant association between grain yield with plant height. In the cross Kavkaz-Siete Cerros 66 the indirect effect of tillers per plant determined the significant correlation (.408) between grain yield and plant height. This was also true for the crosses Kavkaz-Huacamayo "S", Roussalka-Inia 66, Hyslop-Inia 66, Hyslop-Torim 73 and Weique Red Mace-Jupateco 73. Indirect effects via tillers per plant and kernel weight determined almost completely the association between plant height and grain yield in the crosses Kavkaz-Jupateco 73 and Weique Red Mace-Torim 73 (.629 and

.857, respectively). Kernels per spike was the primary indirect effect that resulted in a significant correlation of grain yield with plant height for the crosses Yamhill-Inia 66, Yamhill-Huacamayo "S", Weique Red Mace-Inia 66 and Weique Red Mace-Huacamayo "S". The indirect influences of tillers per plant, kernel weight and kernels per spike contributed to the significant associations of plant height and grain yield for the crosses Yamhill-Siete Cerros 66 and Yamhill-Jupateco 73. For the crosses Yamhill-Torim 73 and Hyslop-Jupateco 73 the total correlation of plant height with grain yield resulted from the indirect effects of tillers per plant and kernels per spike. For Weique Red Mace-Huacamayo "S" kernels per spike was the most important indirect effect that contributed to significant correlation between grain yield and plant height.

When the association between grain yield and tillers per plant was considered, most of the significant correlations were the result of the large direct effect of tillers per plant. This direct effect alone was responsible for significant correlations between grain yield and tillers per plant in the crosses Roussalka-Siete Cerros 66, Roussalka-Jupateco 73, Yamhill-Inia 66, Yamhill-Huacamayo "S" and Hyslop-Huacamayo "S". Indirect effects via either kernel weight or kernels per spike or both made up the total correlation in some crosses. In Kavkaz-Inia 66 the direct effect of tillers per plant (.486) and the indirect effect via kernels per spike (.216) determined almost the total correlation with grain yield (.766). The same was true for the crosses Kavkaz-Huacamayo "S", Roussalka-Huacamayo "S", Hyslop-Inia 66, Hyslop-Jupateco 73 and Weique Red Mace-Huacamayo "S". In the cross Kavkaz-Siete Cerros 66 the direct effect (.623) of tillers per plant plus the indirect effects of kernel weight (.107) and kernels per spike (.113) determined the total significant correlation between grain yield and tillers per plant (.855). The same was observed for the crosses Yamhill-Siete Cerros 66, Yamhill-Torim 73, Yamhill-Jupateco 73, Hyslop-Siete Cerros 66, Hyslop-Torim 73 and Weique Red Mace-Jupateco 73. The cross Kavkaz-Jupateco 73 had a significant correlation between grain yield and tillers per plant (.826). This was primarily due to the direct influence of tillers per plant (.661) and the indirect effect of kernel weight (.191). This trend was noted also for Roussalka-Inia 66, Roussalka-Torim 73, Weique Red Mace-Inia 66, Weique Red Mace-Siete Cerros 66 and Weique Red Mace-Torim 73 crosses. In three crosses a negative indirect influence of kernel weight or kernels per spike was observed. Kavkaz-Torim 73 had a negative indirect effect via kernel weight (-.219). Even so, the total correlation of tillers per plant with grain yield was significant due to the high direct effect of tillers per plant (.721) and the indirect effect via kernels per spike (.366). The other two crosses with negative indirect effects through kernel weight (Hyslop-Inia 66) and kernels per spike (Roussalka-Inia 66) were of a small magnitude which did not offset the large direct effect of tillers per plant. Thus the correlation values were significant and positive.

Kernel weight had a positive direct effect on grain yield. Its direct effect was not as high as for tillers per plant. Whenever significant correlation values were observed they were made by the direct effect of kernel weight and indirect effect of either tillers per plant or kernels per spike or both. In the cross Kavkaz-Jupateco 73 the significant total correlation (.604) was determined by the direct effect of kernel weight (.471) plus the indirect effect of tillers per plant (.268). The same was true for the crosses Kavkaz-Huacamayo "S", Weique Red Mace-Inia 66 and Weique Red Mace-Siete Cerros 66. In some crosses the indirect effect of both tillers per plant and kernels per spike were important, i.e. crosses where Roussalka, Yamhill or Hyslop (except Hyslop-Inia 66 cross) were involved as a winter parent and the Weique Red Mace-Torim 73 and Weique Red Mace-Jupateco 73 crosses.

When the association between grain yield and kernels per spike was considered, similar results appeared as with tillers per plant and kernel weight. Where significant correlation values were noted, they were due to the direct effect of kernels per spike or were the result of the indirect effects of either tillers per plant or kernel weight or both. In the crosses Hyslop-Huacamayo "S", Weique Red Mace-Inia 66 and Weique Red Mace-Siete Cerros 66 the significant correlation was caused by the direct effect of kernels per spike on grain yield. In the cross Kavkaz-Inia 66 the significant correlation (.839) between grain yield and kernels per spike was determined by the direct effect of kernels per spike (.560) and the indirect effect of tillers per plant (.188). The same was true for the crosses Kavkaz-Siete Cerros 66, Kavkaz-Huacamayo "S", Roussalka-Huacamayo "S", Yamhill-Inia 66, Hyslop-Inia 66, Hyslop-Jupateco 73 and Weique Red Mace-Huacamayo "S". A negative indirect effect was noted in the cross Kavkaz-Torim 73 (-.225) through kernels per spike. However, the correlation between grain yield and kernels per spike was significant (.786) due to the high direct effect of kernels per spike (.612) and the indirect effect of tillers per plant

(.430). In the cross Roussalka-Siete Cerros 66 the direct effect of kernels per spike (.612) on grain yield was important and together with the indirect effect of kernel weight (.115) gave a significant correlation (.777) between grain yield and kernels per spike. The same trend was noted for the crosses Roussalka-Torim 73, Roussalka-Jupateco 73, Yamhill-Inia 66, and Yamhill-Huacamayo "S". The direct effect of kernels per spike plus the indirect effects of tillers per plant and kernel weight were important in crosses such as Yamhill-Torim 73, Yamhill-Jupateco 73, Hyslop-Siete Cerros 66, Hyslop-Torim 73, Weique Red Mace-Torim 73 and Weique Red Mace-Jupateco 73.

Direct and indirect associations via heading date, maturity date and plant height with grain yield were of very small magnitude or negative. When a significant correlation of these characters with grain yield was observed it was the result of the indirect effect of the yield components (tillers per plant, kernel weight and kernels per spike). These yield components showed a high direct and indirect effect contributing to significant correlations.

In all crosses the coefficient of determination (R^2) was greater than 98 percent indicating that nearly all the total variation for grain yield was explained by the six agronomic characters studied.

Study III

Direct and indirect associations of seven agronomic characters with grain yield for the 25 winter x spring crosses are given in Tables 53 to 57. Several crosses showed a greater direct effect of heading date on grain yield than in Study II. When significant associations between grain yield and heading date were observed they were the result

Table 53. Direct and indirect effects of seven agronomic characters on grain yield of wheat for the spring parent, winter x spring F2 and backcross to spring parent when grown at CIANO, 1977-78.

Character	CROSS				
	KVZ-INIA	KVZ-7C	KVZ-TRM	KVZ-JUP	KVZ-HUAC
GRAIN YIELD AND HEADING DATE					
Direct effect	-.051	.037	-.000	.185	-.004
Indirect effect via Maturity Date	.017	-.008	-.032	-.030	.078
Indirect effect via Plant Height	.032	.067	-.001	-.138	.099
Indirect effect via Tillers Per Plant	-.059	-.107	-.021	-.626	-.070
Indirect effect via Harvest Index	-.012	.006	.012	-.037	-.103
Indirect effect via Kernel Weight	.111	.298	.091	.202	.178
Indirect effect via Kernels Per Spike	.279	-.452	.260	.259	.153
Correlation	.217	-.159	.308	-.185	.331
GRAIN YIELD AND MATURITY DATE					
Direct effect	.019	-.032	-.037	-.044	.084
Indirect effect via Heading Date	-.046	.010	-.000	.126	-.004
Indirect effect via Plant Height	.026	.028	-.001	-.083	.089
Indirect effect via Tillers Per Plant	-.081	.056	.111	-.442	.025
Indirect effect via Harvest Index	-.012	.003	.008	.001	-.096
Indirect effect via Kernel Weight	.072	.258	.081	.119	.177
Indirect effect via Kernels Per Spike	.142	-.156	.311	.317	.069
Correlation	.120	.165	.472	-.006	.345
GRAIN YIELD AND PLANT HEIGHT					
Direct effect	.034	.077	-.002	-.154	.117
Indirect effect via Heading Date	-.048	.032	-.000	.165	-.003
Indirect effect via Maturity Date	.014	-.012	-.031	-.024	.063
Indirect effect via Tillers Per Plant	-.039	-.061	-.074	-.752	-.132
Indirect effect via Harvest Index	-.011	.008	.014	-.028	-.094
Indirect effect via Kernel Weight	.121	.285	.165	.277	.278
Indirect effect via Kernels Per Spike	.170	-.528	.286	.326	.147
Correlation	.240	-.198	.358	-.129	.376
GRAIN YIELD AND TILLERS PER PLANT					
Direct effect	.653	1.020	.654	.876	1.181
Indirect effect via Heading Date	.005	-.004	.000	-.132	.000
Indirect effect via Maturity Date	-.002	-.002	-.007	.022	.002
Indirect effect via Plant Height	-.002	-.005	.000	.132	-.013
Indirect effect via Harvest Index	.011	.002	.001	.017	-.090
Indirect effect via Kernel Weight	.052	-.258	-.268	-.252	.086
Indirect effect via Kernels Per Spike	.073	-.276	.018	-.340	-.822
Correlation	.789**	.478	.297	.323	.344
GRAIN YIELD AND HARVEST INDEX					
Direct effect	.025	-.010	-.031	.076	.207
Indirect effect via Heading Date	.024	-.021	.000	-.091	.002
Indirect effect via Maturity Date	-.008	.008	.009	-.000	-.039
Indirect effect via Plant Height	-.015	-.057	.001	.056	-.053
Indirect effect via Tillers Per Plant	.271	-.198	-.015	.191	-.512
Indirect effect via Kernel Weight	.013	-.078	-.005	.074	-.128
Indirect effect via Kernels Per Spike	.304	.786	.411	.233	.722
Correlation	.614*	.429	.370	.538	.199
GRAIN YIELD AND KERNEL WEIGHT					
Direct effect	.216	.575	.374	.392	.353
Indirect effect via Heading Date	-.026	.019	-.000	.095	-.002
Indirect effect via Maturity Date	.006	-.014	-.008	-.013	.042
Indirect effect via Plant Height	.019	.038	-.001	-.109	.092
Indirect effect via Tillers Per Plant	.156	-.456	-.398	-.563	.287
Indirect effect via Harvest Index	.002	.001	.000	.014	-.075
Indirect effect via Kernels Per Spike	.176	-.131	.117	.571	-.113
Correlation	.549	.033	.084	.387	.584*
GRAIN YIELD AND KERNELS PER SPIKE					
Direct effect	.508	.969	.897	.787	1.046
Indirect effect via Heading Date	-.018	-.017	-.000	.061	-.001
Indirect effect via Maturity Date	.005	.005	-.013	-.018	.006
Indirect effect via Plant Height	.011	-.042	-.001	-.076	.017
Indirect effect via Tillers Per Plant	.094	-.291	.011	-.379	-.929
Indirect effect via Harvest Index	.015	-.008	-.014	.022	.143
Indirect effect via Kernel Weight	.075	-.078	.049	.284	-.036
Correlation	.691*	.537	.929**	.682*	.243
R^2	.999	.996	.999	.997	.979

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

KVZ = Kavkaz
INIA = Inia 66
7C = Siete Cerros 66
TRM = Torim 73
JUP = Jupateco 73
HUAC = Huacamayo "S"

Table 54. Direct and indirect effects of seven agronomic characters on grain yield of wheat for the spring parent, winter x spring F2 and backcross to spring parent when grown at CIANO, 1977-78.

Character	CROSS RSK-INIA	RSK-7C	RSK-TRM	RSK-JUP	RSK-HUAC
GRAIN YIELD AND HEADING DATE					
Direct effect	.058	-.086	.034	.142	-.100
Indirect effect via Maturity Date	.023	.052	-.168	-.103	.059
Indirect effect via Plant Height	-.068	.008	-.000	.027	.035
Indirect effect via Tillers Per Plant	.551	-.386	.375	-.272	-.121
Indirect effect via Harvest Index	-.009	.031	.160	-.060	-.030
Indirect effect via Kernel Weight	-.219	.520	.046	-.107	-.128
Indirect effect via Kernels Per Spike	-.514	-.786	-.329	-.022	-.048
Correlation	-.177	-.548*	.119	-.394	-.334
GRAIN YIELD AND MATURITY DATE					
Direct effect	.027	.083	-.174	-.113	.084
Indirect effect via Heading Date	.050	-.053	.033	.130	-.069
Indirect effect via Plant Height	-.062	.021	-.000	.044	.040
Indirect effect via Tillers Per Plant	.385	-.052	.425	-.243	-.054
Indirect effect via Harvest Index	-.008	.025	.137	-.064	-.025
Indirect effect via Kernel Weight	-.130	-.032	.045	-.029	-.073
Indirect effect via Kernels Per Spike	-.465	-.430	-.198	-.093	.143
Correlation	-.203	-.438	.268	-.368	.045
GRAIN YIELD AND PLANT HEIGHT					
Direct effect	-.099	-.037	-.001	.087	.083
Indirect effect via Heading Date	.040	.020	.028	.043	-.042
Indirect effect via Maturity Date	.017	-.048	-.149	-.057	.041
Indirect effect via Tillers Per Plant	.403	-.168	.198	.227	.016
Indirect effect via Harvest Index	-.006	-.013	.110	-.011	-.003
Indirect effect via Kernel Weight	-.009	.161	.107	.053	.005
Indirect effect via Kernels Per Spike	-.144	.263	-.092	.129	.250
Correlation	.200	.177	.203	.471	.380
GRAIN YIELD AND TILLERS PER PLANT					
Direct effect	1.147	.960	.914	.688	.413
Indirect effect via Heading Date	.028	.035	.014	-.056	.029
Indirect effect via Maturity Date	.009	-.005	-.081	.040	-.011
Indirect effect via Plant Height	-.035	.006	-.000	.029	.003
Indirect effect via Harvest Index	-.005	-.009	.061	.030	-.010
Indirect effect via Kernel Weight	-.276	-.632	-.032	.058	.024
Indirect effect via Kernels Per Spike	-.241	.514	-.206	.049	-.096
Correlation	.627*	.873**	.570*	.837**	.352
GRAIN YIELD AND HARVEST INDEX					
Direct effect	.010	-.036	-.250	.083	.115
Indirect effect via Heading Date	-.050	.073	-.022	-.102	.026
Indirect effect via Maturity Date	-.021	-.058	.095	.087	-.018
Indirect effect via Plant Height	.062	-.013	.000	-.012	-.002
Indirect effect via Tillers Per Plant	-.579	.230	-.221	.247	-.035
Indirect effect via Kernel Weight	.120	-.325	-.005	-.061	-.001
Indirect effect via Kernels Per Spike	.587	.707	.852	.363	.652
Correlation	.130	.577*	.449	.604*	.737**
GRAIN YIELD AND KERNEL WEIGHT					
Direct effect	.438	.799	.197	.316	.227
Indirect effect via Heading Date	-.029	-.056	.008	-.048	.056
Indirect effect via Maturity Date	-.008	-.003	-.040	.010	-.027
Indirect effect via Plant Height	.002	-.007	-.000	.015	.002
Indirect effect via Tillers Per Plant	-.722	-.759	-.147	.126	.043
Indirect effect via Harvest Index	.003	.015	.006	-.016	-.000
Indirect effect via Kernels Per Spike	.172	-.737	.079	-.267	-.040
Correlation	-.144	-.748**	.103	.136	.261
GRAIN YIELD AND KERNELS PER SPIKE					
Direct effect	.774	.932	.938	.552	.759
Indirect effect via Heading Date	-.038	.072	-.012	-.006	.006
Indirect effect via Maturity Date	-.016	-.038	.037	.019	.016
Indirect effect via Plant Height	.019	-.010	.000	.020	.027
Indirect effect via Tillers Per Plant	-.357	.530	-.200	.061	-.052
Indirect effect via Harvest Index	.008	-.028	-.227	.055	.099
Indirect effect via Kernel Weight	.098	-.632	.017	-.153	-.012
Correlation	.486	.826**	.552	.548	.843**
R^2	.998	.998	.996	.997	.995

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

RSK = Roussalka
INIA = Inia 66
7C = Siete Cerros 66
TRM = Torim 73
JUP = Jupateco 73
HUAC = Huacamayo "S"

Table 55. Direct and indirect effects of seven agronomic characters on grain yield of wheat for the spring parent, winter x spring F2 and backcross to spring parent when grown at CIANO, 1977-78.

Character	CROSS				
	YMH-INIA	YMH-7C	YMH-TRM	YMH-JUP	YMH-HUAC
GRAIN YIELD AND HEADING DATE					
Direct effect	.207	-.195	-.009	.246	.105
Indirect effect via Maturity Date	.275	.110	.054	-.147	-.030
Indirect effect via Plant Height	.076	.014	-.120	-.033	-.169
Indirect effect via Tillers Per Plant	.435	-.085	.434	-.058	.267
Indirect effect via Harvest Index	-.002	-.003	-.007	-.014	.033
Indirect effect via Kernel Weight	-.274	-.030	.094	-.274	-.402
Indirect effect via Kernels Per Spike	-.021	-.251	.241	-.102	.100
Correlation	.146	-.440	.687*	-.382	-.095
GRAIN YIELD AND MATURITY DATE					
Direct effect	-.288	.124	.056	-.166	-.034
Indirect effect via Heading Date	.197	-.174	-.009	.217	.090
Indirect effect via Plant Height	.076	.011	-.112	-.036	-.141
Indirect effect via Tillers Per Plant	.431	.036	.387	.014	.520
Indirect effect via Harvest Index	-.002	-.002	-.008	-.020	.042
Indirect effect via Kernel Weight	-.181	-.080	.101	-.219	-.392
Indirect effect via Kernels Per Spike	-.003	-.113	-.207	-.165	-.212
Correlation	.232	-.198	.622*	-.375	-.127
GRAIN YIELD AND PLANT HEIGHT					
Direct effect	.089	.029	-.129	-.051	-.182
Indirect effect via Heading Date	.177	.094	-.008	.159	.097
Indirect effect via Maturity Date	-.245	.047	.049	-.117	-.027
Indirect effect via Tillers Per Plant	.378	.099	.584	.138	.244
Indirect effect via Harvest Index	-.003	-.003	-.007	-.002	.031
Indirect effect via Kernel Weight	-.295	.173	.098	-.045	-.435
Indirect effect via Kernels Per Spike	-.122	-.285	.213	.000	.206
Correlation	-.022	-.133	.799**	.083	.065
GRAIN YIELD AND TILLERS PER PLANT					
Direct effect	.603	.544	.733	.425	.920
Indirect effect via Heading Date	.149	.031	-.005	-.033	.031
Indirect effect via Maturity Date	-.207	.008	.030	-.006	-.019
Indirect effect via Plant Height	.056	.005	-.103	-.016	-.048
Indirect effect via Harvest Index	-.001	-.000	-.006	-.012	.029
Indirect effect via Kernel Weight	-.123	-.019	.045	.009	-.162
Indirect effect via Kernels Per Spike	.169	-.211	.126	-.034	-.305
Correlation	.647*	.358	.820**	.332	.446
GRAIN YIELD AND HARVEST INDEX					
Direct effect	.004	.005	.021	.059	-.052
Indirect effect via Heading Date	-.117	.116	.003	-.058	-.066
Indirect effect via Maturity Date	.154	-.051	-.022	.056	.028
Indirect effect via Plant Height	-.066	-.015	.045	.002	.106
Indirect effect via Tillers Per Plant	-.087	-.040	-.197	-.086	-.518
Indirect effect via Kernel Weight	.350	-.034	-.010	.345	.380
Indirect effect via Kernels Per Spike	.353	.807	.284	.380	.439
Correlation	.592*	.790**	.124	.699*	.316
GRAIN YIELD AND KERNEL WEIGHT					
Direct effect	.469	.297	.215	.504	.535
Indirect effect via Heading Date	-.120	.020	-.004	-.134	-.079
Indirect effect via Maturity Date	.111	-.033	.026	.072	.025
Indirect effect via Plant Height	-.056	.017	-.059	.005	.148
Indirect effect via Tillers Per Plant	-.158	-.034	.152	.007	-.278
Indirect effect via Harvest Index	.003	-.001	-.001	.040	-.037
Indirect effect via Kernels Per Spike	.260	-.124	.216	.373	.122
Correlation	.509	.142	.546	.868**	.436
GRAIN YIELD AND KERNELS PER SPIKE					
Direct effect	.436	.907	.475	.460	.790
Indirect effect via Heading Date	-.010	.054	-.005	-.055	.013
Indirect effect via Maturity Date	.002	-.015	.024	.060	.009
Indirect effect via Plant Height	-.025	-.012	-.058	.000	-.047
Indirect effect via Tillers Per Plant	.233	-.126	.195	-.031	-.355
Indirect effect via Harvest Index	.004	.005	.013	.049	-.029
Indirect effect via Kernel Weight	.279	-.041	.098	.408	.083
Correlation	.919**	.771**	.743**	.891**	.464
R^2	.993	.998	.999	.994	.999

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

YMH = Yamhill
INIA = Inia 66
7C = Siete Cerros 66
TRM = Torim 73
JUP = Jupateco 73
HUAC = Huacamayo "S"

Table 56. Direct and indirect effects of seven agronomic characters on grain yield of wheat for the spring parent, winter x spring F2 and backcross to spring parent when grown at CIANO, 1977-78.

Character	CROSS				
	HYS-INIA	HYS-7C	HYS-TRM	HYS-JUP	HYS-HUAC
GRAIN YIELD AND HEADING DATE					
Direct effect	-.002	.018	-.236	-.001	.261
Indirect effect via Maturity Date	-.106	-.024	.107	-.084	-.172
Indirect effect via Plant Height	.137	.003	.050	.082	.061
Indirect effect via Tillers Per Plant	.429	.206	.474	.646	.714
Indirect effect via Harvest Index	.011	.021	.016	-.010	-.053
Indirect effect via Kernel Weight	-.051	.140	.006	-.006	-.279
Indirect effect via Kernels Per Spike	.321	-.076	.252	.085	-.048
Correlation	.739**	.289	.668*	.712**	.484
GRAIN YIELD AND MATURITY DATE					
Direct effect	-.113	-.028	.111	-.091	-.178
Indirect effect via Heading Date	-.002	.015	-.226	-.001	.252
Indirect effect via Plant Height	.143	.003	.049	.088	.067
Indirect effect via Tillers Per Plant	.662	.265	.445	.580	.727
Indirect effect via Harvest Index	.012	.021	.014	-.012	-.049
Indirect effect via Kernel Weight	-.056	.133	.015	-.014	-.280
Indirect effect via Kernels Per Spike	.102	-.119	.288	.013	.002
Correlation	.749**	.290	.695*	.563	.542
GRAIN YIELD AND PLANT HEIGHT					
Direct effect	.155	.007	.060	.098	.083
Indirect effect via Heading Date	-.002	.007	-.197	-.001	.192
Indirect effect via Maturity Date	-.105	-.012	.090	-.082	-.143
Indirect effect via Tillers Per Plant	.620	.566	.598	.523	.678
Indirect effect via Harvest Index	.012	.006	.011	-.009	-.030
Indirect effect via Kernel Weight	-.045	.223	.023	-.011	-.250
Indirect effect via Kernels Per Spike	.202	-.019	.284	.112	.202
Correlation	.837**	.779**	.870**	.630*	.731**
GRAIN YIELD AND TILLERS PER PLANT					
Direct effect	1.039	.684	.651	.810	.915
Indirect effect via Heading Date	-.001	.005	-.172	-.001	.203
Indirect effect via Maturity Date	-.072	-.011	.076	-.065	-.141
Indirect effect via Plant Height	.092	.006	.055	.063	.062
Indirect effect via Harvest Index	.010	.009	.001	-.008	-.034
Indirect effect via Kernel Weight	-.089	.123	.031	-.024	-.297
Indirect effect via Kernels Per Spike	-.367	.032	.296	.075	.067
Correlation	.613*	.847**	.940**	.850**	.776**
GRAIN YIELD AND HARVEST INDEX					
Direct effect	-.017	-.027	-.037	.024	.073
Indirect effect via Heading Date	.001	-.014	.098	.000	-.189
Indirect effect via Maturity Date	.081	.022	-.042	.047	.119
Indirect effect via Plant Height	-.110	-.001	-.018	-.037	-.035
Indirect effect via Tillers Per Plant	-.605	-.218	-.031	-.288	-.420
Indirect effect via Kernel Weight	.067	-.066	.019	.047	.134
Indirect effect via Kernels Per Spike	.173	.252	.102	.326	.429
Correlation	-.411	-.043	.091	.118	.112
GRAIN YIELD AND KERNEL WEIGHT					
Direct effect	.127	.309	.063	.109	.354
Indirect effect via Heading Date	.001	.008	-.023	.000	-.205
Indirect effect via Maturity Date	.050	-.012	.026	.012	.141
Indirect effect via Plant Height	-.055	.005	.022	-.010	-.059
Indirect effect via Tillers Per Plant	-.729	.271	.323	-.178	-.768
Indirect effect via Harvest Index	-.009	.006	-.012	.010	.028
Indirect effect via Kernels per Spike	.280	-.190	.197	.141	-.175
Correlation	-.336	.397	.597*	.084	-.684*
GRAIN YIELD AND KERNELS PER SPIKE					
Direct effect	.824	.574	.427	.438	.630
Indirect effect via Heading Date	-.001	-.002	-.139	-.000	-.020
Indirect effect via Maturity Date	-.014	.006	.075	-.003	-.000
Indirect effect via Plant Height	.038	-.000	.040	.025	.027
Indirect effect via Tillers Per Plant	-.463	.038	.451	.140	.098
Indirect effect via Harvest Index	-.004	-.012	-.009	.018	.050
Indirect effect via Kernel Weight	.043	-.102	.029	.035	-.098
Correlation	.424	.501	.874**	.652*	.685*
R^2	.994	.993	.991	.996	.998

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

HYS = Hyslop
INIA = Inia 66
7C = Siete Cerros 66
TRM = Torim 73
JUP = Jupateco 73
HUAC = Huacamayo "S"

Table 57. Direct and indirect effects of seven agronomic characters on grain yield of wheat for the spring parent, winter x spring F2 and backcross to spring parent when grown at CIANO, 1977-78.

Character	CROSS WRM-INIA	WRM-7C	WRM-TRM	WRM-JUP	WRM-HUAC
GRAIN YIELD AND HEADING DATE					
Direct effect	.123	.030	.045	.048	.100
Indirect effect via Maturity Date	-.126	-.019	-.022	-.069	-.189
Indirect effect via Plant Height	-.029	-.025	-.087	-.026	.016
Indirect effect via Tillers Per Plant	.375	-.110	.411	-.126	.154
Indirect effect via Harvest Index	.031	.023	.012	-.007	.026
Indirect effect via Kernel Weight	.048	.175	.125	.165	-.019
Indirect effect via Kernels Per Spike	.196	-.186	.057	-.196	.005
Correlation	.618*	-.112	.561	.210	.093
GRAIN YIELD AND MATURITY DATE					
Direct effect	-.128	-.024	-.003	-.087	-.236
Indirect effect via Heading Date	.121	.023	.042	.038	.080
Indirect effect via Plant Height	-.030	-.036	-.088	-.013	.007
Indirect effect via Tillers Per Plant	.403	-.029	.383	.029	.417
Indirect effect via Harvest Index	.031	.026	.012	-.007	.060
Indirect effect via Kernel Weight	.044	.202	.146	.081	-.091
Indirect effect via Kernels Per Spike	.253	-.185	.029	-.224	-.431
Correlation	.694*	-.023	.522	-.184	-.194
GRAIN YIELD AND PLANT HEIGHT					
Direct effect	-.046	-.074	-.104	-.041	.055
Indirect effect via Heading Date	.076	.010	.038	.030	.030
Indirect effect via Maturity Date	-.083	-.012	-.002	-.028	-.029
Indirect effect via Tillers Per Plant	.085	.335	.412	.183	-.238
Indirect effect via Harvest Index	.018	.016	.010	-.004	.021
Indirect effect via Kernel Weight	.117	.127	.238	.123	.064
Indirect effect via Kernels Per Spike	.381	.160	.125	-.038	.068
Correlation	.548	.561	.717**	-.140	-.030
GRAIN YIELD AND TILLERS PER PLANT					
Direct effect	.657	.640	.593	.773	.850
Indirect effect via Heading Date	.070	-.005	.031	-.008	.018
Indirect effect via Maturity Date	-.078	.001	-.002	-.003	-.116
Indirect effect via Plant Height	-.006	-.039	-.072	.010	-.015
Indirect effect via Harvest Index	.019	-.008	.017	.004	.040
Indirect effect via Kernel Weight	-.089	-.117	.073	-.135	-.090
Indirect effect via Kernels Per Spike	.007	.405	-.140	.201	-.458
Correlation	.579*	.878**	.500	.842**	.228
GRAIN YIELD AND HARVEST INDEX					
Direct effect	-.041	-.042	-.026	.013	-.086
Indirect effect via Heading Date	-.092	-.016	-.022	-.026	-.030
Indirect effect via Maturity Date	.096	.015	.001	.049	.166
Indirect effect via Plant Height	.020	.027	.038	.012	-.013
Indirect effect via Tillers Per Plant	-.298	.127	-.386	.230	-.391
Indirect effect via Kernel Weight	.070	-.192	.027	-.094	.068
Indirect effect via Kernels Per Spike	.078	.496	.578	.516	.906
Correlation	.167	.416	.210	.598*	.520*
GRAIN YIELD AND KERNEL WEIGHT					
Direct effect	.350	.336	.349	.245	.162
Indirect effect via Heading Date	.017	.015	.016	.032	-.011
Indirect effect via Maturity Date	-.016	-.015	-.001	-.029	.132
Indirect effect via Plant Height	-.015	-.028	-.071	-.021	.022
Indirect effect via Tillers Per Plant	-.166	-.223	.124	-.426	-.471
Indirect effect via Harvest Index	-.008	.024	-.002	-.005	-.036
Indirect effect via Kernels Per Spike	.193	-.410	.278	-.199	.398
Correlation	.355	-.300	.694*	-.403	.196
GRAIN YIELD AND KERNELS PER SPIKE					
Direct effect	.694	.713	.725	.548	1.034
Indirect effect via Heading Date	.035	-.008	.004	-.017	.001
Indirect effect via Maturity Date	-.047	.006	-.000	.036	.098
Indirect effect via Plant Height	-.025	-.017	-.018	.003	.004
Indirect effect via Tillers Per Plant	.006	.364	-.115	.284	-.377
Indirect effect via Harvest Index	-.005	-.029	-.021	.012	-.075
Indirect effect via Kernel Weight	.098	-.193	.134	-.089	.063
Correlation	.756**	.837**	.709**	.776**	.747**
R^2	.998	.996	.996	.998	.998

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

WRM = Weique Red Mace
INIA = Inia 66
7C = Siete Cerros 66
TRM = Torim 73
JUP = Jupateco 73
HUAC = Huacamayo "S"

of indirect effects. In the cross Yamhill-Torim 73 the large indirect effects of tillers per plant (.434) and kernels per spike (.241) determined the total significant correlation (.687) between grain yield and heading date. This trend was also noted for the crosses Hyslop-Inia 66, Hyslop Torim 73, Hyslop-Jupateco 73 and Weique Red Mace-Inia 66. A significant negative association between grain yield and heading date (-.648) was primarily due to the negative indirect effects of tillers per plant (-.386) and kernels per spike (-.786) for the cross Roussalka-Siete Cerros 66. For this cross kernel weight had a high indirect effect (.520) but it was canceled out by the negative indirect effects of other characters previously noted.

Maturity date, as in Study II had little or no direct effect on grain yield. In the cross Yamhill-Torim 73, the significant association between maturity date and grain yield (.622) was mainly due to the indirect effects of tillers per plant (.387), kernel weight (.101) and kernels per spike (.207). In the cross Hyslop-Inia 66 the indirect effects of tillers per plant (.662), kernels per spike (.102) and plant height (.143) were responsible for the significant association of maturity date and grain yield. The significant correlation between grain yield and maturity date (.695) in the cross Hyslop-Torim 73 resulted from the direct effect of maturity date (.111) plus the indirect effects of tillers per plant (.445) and kernels per spike (.288) on grain yield. In the Weique Red Mace-Inia 66 cross, the indirect effects of tillers per plant (.403), kernels per spike (.253) and heading date (.121) were mainly responsible for the significant correlation between grain yield and maturity date (.694).

When the associations between grain yield and plant height were considered, usually the direct effect was of a small magnitude or negative. However, an indirect effect of plant height on grain yield (.155) was noted in the cross Hyslop-Inia 66. This cross also included greater indirect effects through tillers per plant (.620) and kernels per spike (.202) resulting in a significant correlation between grain yield with plant height (.837). For the Yamhill-Torim 73 cross the indirect effects of tillers per plant (.584) and kernels per spike (.213) were important in determining the signficant correlation between grain yield and plant height (.799). The same trend was noted in the crosses Hyslop-Torim 73, Hyslop-Jupateco 73 and Hyslop-Huacamayo "S". In Hyslop-Siete Cerros 66 and Weique Red Mace-Torim 73, important indirect effects via tillers per plant and kernel weight were observed that contributed to the significant association between grain yield and plant height.

Tillers per plant again had the highest direct effect on grain yield. In the cross Kavkaz-Inia 66, the high direct effect (.653) was responsible for almost all the total correlation between tillers per plant and grain yield (.789). The same was true for the crosses Roussalka-Inia 66, Roussalka-Torim 73, Roussalka-Jupateco 73, Hyslop-Jupateco 73 and Weique Red Mace-Inia 66. In the cross Roussalka-Siete Cerros 66 a significant association between grain yield and tillers per plant was observed (.873). It was made up by the high direct effect of tillers per plant (.960) and the indirect effect of kernels per spike (.514). These overcame the negative indirect effect of kernel weight (-.632). A similar trend was noted in the crosses Yamhill-Inia 66, Hyslop-Huacamayo "S", Weique Red Mace-Siete Cerros 66 and Weique Red

Mace-Jupateco 73. The important direct effect of tillers per plant and the indirect effect of kernels per spike were responsible for the significant association of grain yield and tillers per plant for the crosses Yamhill-Torim 73 and Hyslop-Torim 73 (.820 and .940, respectively). In the cross Hyslop-Siete Cerros 66 the direct effect of tillers per plant (.684) and the indirect effect of kernel weight (.123) were responsible for the significant association between grain yield and tillers per plant (.847).

When the association between harvest index and grain yield was considered, the direct effects were of small magnitude or negative in most of the crosses. Where significant associations were noted, they resulted from the indirect effects of either tillers per plant, kernel weight, kernels per spike or a combination of them. Roussalka-Huacamayo "S" was the only cross where the direct effect of harvest index (.115) on grain yield coupled with the indirect effect of kernels per spike (.652) was important in determining the total significant correlation between harvest index and grain yield (.737). In the cross Kavkaz-Inia 66, the significant association between harvest index and grain yield (.614) resulted from the important indirect effects of tillers per plant (.271) and kernels per spike (.304). The same was true for the crosses Roussalka-Siete Cerros 66, Roussalka-Jupateco 73 and Weique Red Mace-Jupateco 73. The indirect effect of kernels per spike was responsible for the significant association between harvest index and grain yield in the crosses Yamhill-Siete Cerros 66 and Weique Red Mace-Huacamayo "S". These indirect effects offset the negative indirect effects of the other characters and resulted in a significant correlation between grain yield and harvest index. In the cross Yamhill-Jupateco 73, the significant correlation between grain yield and harvest index (.699) was determined by the indirect effects of kernel weight (.345) and kernels per spike (.380).

Kernel weight had, as previously noted in Study II, a high direct effect on grain yield. Due to the negative indirect effects of the other characters associated with grain yield, the total correlations were reduced and only six crosses reflected a signficant association of grain yield and kernel weight. In the crosses Roussalka-Siete Cerros 66 and Hyslop-Huacamayo "S", a significant negative association between grain yield and kernel weight was observed. The positive direct effects of kernel weight were surpassed by the high and negative indirect effects of tillers per plant and kernels per spike on grain yield. In the cross Kavkaz-Huacamayo "S", the direct effect of kernel weight (.353) was important together with the indirect effect of tillers per spike (.287) to determine a significant association between grain yield and kernel weight (.584). In the cross, Yamhill-Huacamayo "S", the significant association between grain yield and kernel weight (.868) was mainly the result of the direct effect of kernel weight (.504) and the indirect effect via kernels per spike (.373). The total significant correlation of grain yield with kernel weight (.694) in the cross Weique Red Mace-Torim 73 was caused by the direct effect of kernel weight (.349) plus the indirect effects of tillers per plant (.124) and kernels per spike (.278). However, in the cross Hyslop-Torim 73 the indirect effects of tillers per plant (.323) and kernels per spike (.197) mainly contributed to a significant correlation between grain yield and kernel weight (.597).

Kernels per spike had a high contribution to grain yield with large direct effects in all the crosses. In the cross Kavkaz-Inia 66, the direct effect of kernels per spike (.508) mainly determined the significant correlation of grain yield and kernels per spike (.691). The same can be stated for the crosses Kavkaz-Torim 73, Roussalka-Huacamayo "S", Yamhill-Siete Cerros 66, Hyslop-Huacamayo "S", Weique Red Mace-Inia 66, and Weique Red Mace-Huacamayo "S". The significant association of grain yield with kernels per spike (.682) on Kavkaz-Jupateco 73 was caused by the direct effect of kernels per spike (.787) and the indirect effect of kernel weight (.284) that overcame the negative indirect effect of tillers per plant (-.379). The same was true for the crosses Yamhill-Jupateco 73 and Weique Red Mace-Torim 73. In the cross Roussalka-Siete Cerros 66, the direct effect of kernels per spike on grain yield (.932) and the indirect effect through tillers per plant (.530) determined the total significant association between grain yield and kernels per spike (.826) overcoming the high negative indirect effect of kernel weight (-.632). The same trend was observed in the crosses Weique Red Mace-Siete Cerros 66 and Weique Red Mace-Jupateco 73. The important direct effect of kernels per spike (.436) and indirect effects of tillers per plant (.233) and kernel weight (.279) determined the significant association of grain yield with kernels per spike (.919) in the cross Yamhill-Inia 66. The same was true in the cross Yamhill-Torim 73. In the cross Hyslop-Torim 73 and Hyslop-Jupateco 73 the direct effect of kernels per spike together with the indirect effects of tillers per plant determined the significant correlation between grain yield and kernels per spike (.874 and .652, respectively).

As noted in Study II, whenever a significant association of heading date, maturity date, plant height and harvest index with grain yield was observed, it was the result of the indirect effects of the yield components (tillers per plant, kernel weight and kernels per spike). These yield components were then responsible for grain yield in either a direct or indirect manner in all the crosses evaluated.

The coefficients of determination (R^2) were greater than 99% for all crosses indicating that the characters considered explained nearly all the total variation for grain yield.

Tillers per plant and kernels per spike were the two yield components with the greatest direct effect on grain yield in both studies.

DISCUSSION

The major factor influencing the development of superior crop cultivars is the availability of usable genetic diversity. In wheat, questions regarding the possible exhaustion of such variability are being raised. This concern is reflected in possible grain yield plateaus which seem to have been reached with recently released high yielding cultivars. In order to avoid this problem additional genetic variation is being sought by combining two different gene pools through the systematic hybridization of winter x spring wheat cultivars. However, information is lacking on the nature of gene action making up this genetic variability and the association and interrelationship among yield components and grain yield resulting from such crosses. An understanding of the nature of inheritance and possible yield component compensation must be developed if the genetic variation from the winter x spring wheat crosses is to be capitalized upon by plant breeders.

In this investigation the total genetic variation of winter x spring crosses was determined when the resulting progeny and parents were grown at two locations. The total genetic variation was partitioned into the relative gene action for nine agronomic characters through parent-progeny regression and combining ability analysis for winter x winter, spring x spring and winter x spring crosses. Also, the association and interrelationship among selected agronomic characters and grain yield were studied in the winter x spring crosses using correlation and path-coefficient analysis. By knowing how much genetic variability is available, the nature of the gene action contributing to this variation and the possible relationship between the traits influencing grain yield, the breeders can better plan their breeding strategies.

Total Genetic Variation

This investigation was conducted in two environmentally diverse locations. These included the Hyslop Agronomy Farm, which is in an area where the major wheat production is of the winter type and the Northwest Agricultural Research Center (CIANO) near Ciudad Obregon, Sonora, Mexico, where spring type wheats are fall sown. Therefore, it was possible to assess if selected populations representing winter x spring crosses would be of equal importance in generating usable genetic variation for both the winter and spring wheat breeders.

The two locations were compared in terms of the total genetic variability generated by the winter x spring crosses. A larger estimate for the total genetic variation for grain yield was observed at the CIANO location, suggesting that the improvement of spring cultivars might benefit more through winter x spring crossing. However, caution must be exercised in this statement since the sample size was smaller at this location. Also, breeders of self pollinated crops can only use that portion of the total genetic variation which is due to genes which behave in an additive manner. Frequently the true genetic worth of a population may be masked or over-estimated in early generations due to the non-additive gene action if only the total genetic variation is considered.

Nature of the Genetic Variation

Parent-offspring Regression

Parent-offspring regression provides an estimate of the additive genetic variation for a specific character. In the winter x winter crosses, additive gene action in contrast to the non-additive portion made the greater contribution to the total genetic variation for eight agronomic characters (heading date, maturity date, grain filling period, plant height, harvest index, kernel weight, kernels per spike and grain yield). This was not the case for tillers per plant, however. These data are in general agreement with reports of the nature of the genetic variation in winter wheat by Kronstad and Foote (1964), Edwards, et al. (1976) and Abi-Antoun (1977). The one exception was tillers per plant where these workers also found larger additive gene action influencing this character. Results from this study are in agreement with the findings of Petpisit (1980) where tillers per plant were largely influenced by non-additive gene action. The explanation for this disagreement could be in the selection of the winter parents used in this investigation as there was no significant differences for tillers per plant for parents nor for the F1's (Appendix Tables 7 and 12).

Parent-offspring regression estimates for spring x spring crosses suggested that additive gene action appeared to be most important in the expression of eight agronomic characters (heading date, maturity date, grain filling period, plant height, tillers per plant, kernel weight, kernels per spike and grain yield) with harvest index being the one exception. Similar findings in spring wheat were reported by Maya de Leon (1975) and Walton (1972).

Selection in early generations could be achieved with success for most of the characters studied in winter x winter and spring x spring crosses since additive gene action seems to be responsible for variation in most of the agronomic characters studied.

In winter x spring crosses estimates of the total genetic variation at both locations were associated with a large additive gene action estimate for heading date, maturity date, grain filling period, plant height, harvest index and kernel weight at both locations. These results are in agreement with the findings of Firat (1978) who analyzed the genetic variation resulting from winter x spring crosses; however, he used only two winter wheat growing locations. Progress could be made through selection in early generations (F2 perhaps) for those characters following a conventional program of selfing. However, due to the lower estimates, selection for tillers per plant, kernels per spike and grain yield should be delayed until later generations. Such a delay would permit a reduction of the non-additive gene action which is masking the effect of the additive portion controlling these characters.

Combining Ability

Combining ability also provides an opportunity to study the nature of gene action for a particular character in a population of selected genotypes. Those characters that respond to additive gene action are determined in terms of significant mean square values associated with general combining ability (GCA). Deviations from the additive scheme are noted by significant mean square values for specific combining ability (SCA). Furthermore, combining ability effects can be partitioned into the relative contribution of an individual parent for each trait. Thus it might be possible, based on the individual combining ability effects of the parents for a specific character, to predict which parental combinations would provide the highest frequency of desireable segregates. This would be especially helpful in the case of quantitatively inherited characters like grain yield.

In winter x winter crosses the combining ability analysis suggested the predominance of additive gene action controlling the expression of heading date, maturity date, grain filling period, plant height, harvest index and kernels per spike. Some influence of non-additive gene action was also noted for heading date. This observation is in agreement with the findings of Bitzer and Fu (1972) in winter wheat. The failure to detect significant differences for GCA or SCA in grain yield, tillers per plant or kernel weight was due to the winter x winter F1's which did not differ significantly for these traits (Appendix Table 12) in spite of the fact that the winter parents were significantly different for kernel weight and grain yield (Appendix Table 7).

When the individual GCA effects contributed by each parent were determined the following winter parents would be selected to improve specific traits. Kavkaz would contribute to taller progeny and to heavier kernel weight. If early heading and maturity dates along with long grain filling period and short stature are desireable, Roussalka might be a valuable parent. Yamhill made a greater contribution to grain yield and number of kernels per spike. Hyslop contributed to harvest index. Crosses involving Weique Red Mace had later heading and maturity dates and progeny with a short grain filling period and a high number of tillers per plant.

In spring x spring crosses, combining ability analysis indicated that additive gene action had a greater effect on heading and maturity date, grain filling period, plant height, kernel weight, kernels per spike and grain yield. Non-additive gene action was also important in heading date, grain filling period and kernel weight. These observations are in agreement with the findings of Walton (1971) in spring wheat except he did not detect significant differences for SCA for kernel weight. Maya de Leon (1975) did find a significant SCA for kernel weight in spring wheat which agrees with the present investigation. The failure to detect significant differences for GCA and SCA in tillers per plant and harvest index could be in part attributed to the lack of variability for these two traits in the spring x spring F1's (Appendix Table 13). The cross with the highest mean was significantly different only from the cross with the lowest value of tillers per plant. For harvest index the spring parents did not differ significantly and the F1 cross with the highest value was significantly different only from two other crosses.

The spring parents in the spring x spring crosses can be categorized by their individual GCA effect and subsequent contribution to their progeny as follows. Inia 66 produced the earliest progeny in heading and maturity dates with a high harvest index. Siete Cerros 66 produced later maturing progeny with a longer grain filling period, higher number of tillers per plant, larger number of kernels per spike and a high grain yield. Torim 73 was categorized by producing the shorter stature offspring. Progeny where Jupateco 73 was involved were categorized by having an early heading date. Huacamayo "S" contributed to late heading date with a short grain filling period and tall plants with heavy kernels.

General combining ability estimates in the winter x spring crosses indicated that additive gene action appeared to be most important for the nine agronomic characters studied. For all the characters greater mean squares were associated with GCA due to winter parents at both locations, except grain filling period in Study I, tillers per plant and grain yield in Study II when compared to the spring parents. This suggests that the winter parents in general had a greater effect than the spring parents when the two gene pools are combined at both locations. A point of interest that should be investigated further is if reciprocal crosses produce the same results observed in this investigation. Due to the experimental analysis the winter cultivar was used as the female in this investigation.

Specific combining ability in winter x spring crosses seems to be important for some characters. Combining ability analysis indicated that SCA is important at the Hyslop site for heading date, plant height, harvest index, kernel weight, tillers per plant, kernels per spike and grain yield. At the CIANO location plant height and kernel weight were influenced by SCA. High heterosis values over the mid-parent and winter parent were reported for the same population (Brajcich, 1980) thus confirming the presence of non-additive gene action for plant height, kernel weight, tillers per plant, kernels per spike and grain yield. The findings of Mihaljev (1976) also are in agreement with the results of the present investigation for kernel weight. Selection for these agronomic characters may not be effective in early generations due to the masking effect of the non-additive gene action which is unavailable to the breeder of self-pollinating species.

As a result of their individual GCA effects, the winter parents in the winter x spring crosses when both locations are considered can be categorized by the contribution made to their progeny as follows. Kavkaz crosses were taller with heavier kernels. Roussalka passed on to its progeny early heading and maturity date with a long grain filling period, short stature and high harvest index. Yamhill was noted for contributing late heading and maturity dates with short grain filling periods. The progeny resulting from the crosses involving Yamhill were also tall with a high number of kernels per spike. Yamhill also influenced the resulting progeny in a positive way for grain yield. Hyslop's major contribution was for tillers per plant. Hyslop also had a large effect on grain yield in the F2 populations but not in the F1's. Weique Red Mace at the winter wheat location had a large influence on late heading date and short grain filling period, a high number of kernels per spike and high grain yield.

For the spring parents, Inia 66 was characterized by producing progeny with early heading and maturity dates resulting in a long grain filling period. The major contribution of Siete Cerros 66 was late heading and maturity with a short grain filling period. At the winter wheat location, Siete Cerros 66 also contributed to plant height, number of tillers and grain yield. The progeny where Torim 73 was the spring parent were early in heading with short stature. Jupateco 73 produced progeny with early heading and maturity dates and a long grain filling period at the winter wheat location. At the spring wheat location

Jupateco 73 was characterized by producing progeny with early heading date, high number of tillers per plant and kernels per spike, high harvest index and the largest influence on grain yield. Huacamayo "S" contributed mainly to late heading date, early maturity, short grain filling period and taller progeny. At the winter location it had a high effect on number of tillers per plant, number of kernels per spike, kernel weight and grain yield. At the spring wheat location Huacamayo "S" also contributed to kernel weight.

Plant height was the only character that showed a consistent significant difference for SCA effects at both locations and for both the F1 and F2 generations. This may be why it has been difficult to obtain a uniform line for plant height after three or four generations of selfing in winter x spring crosses at Oregon State University and at the International Maize and Wheat Improvement Center where winter x spring crosses are emphasized. Non-additive gene action had an important effect on the winter x spring crosses suggesting that selection for plant height should be delayed until five or more generations of selfing. This is in contrast to most findings regarding winter x winter or spring x spring crosses.

Specific combining ability of winter x spring crosses was important for grain yield at the winter wheat location. The cross, Kavkaz-Siete Cerros 66 produced the highest grain yield (Appendix Table 8). A subsequent inbreeding depression was noted from F1 (45.07 gm) to F2 (23.54 gm) generation for this cross (Appendix Tables 8 and 9), confirming the widely accepted thought that non-additive gene action provides a measure of potential hybrid vigor. Wheat breeders working on hybrid F1 production may wish to look at winter x spring crosses as means of maximizing grain yield by capitalizing on the total genetic variation available in this type of cross.

Prediction of Superior Crosses Based on General Combining Ability Effects

With the additional genetic variability made available through winter x spring crosses the question of the most efficient use of this variation is raised. Petpisit (1980), when comparing several methods of predicting which parental combination would provide the greatest frequency of desired segregates, found individual parental GCA effects to be important. It is interesting to make such an evaluation in this study of the winter and spring parents. In Table 18 the individual GCA effects for nine characters involving the parents are estimated from the F1 crosses grown at Hyslop Agronomy Farm, 1977-78. The subsequent performance of the same crosses grown as F2's at the same site and during the same year is provided in Appendix Table 9. When considering grain yield per se it can be seen that Weique Red Mace (4.56) and Yamhill (1.81) had the highest individual GCA effects of the winter parents. For the spring parents Siete Cerros 66 (6.52) followed closely by Huacamayo "S" (5.43) had high individual GCA effects. If the relative individual GCA effects associated with the parents can be used to predict superior segregating populations, the winter x spring cross, Weique Red Mace-Siete Cerros 66, should be promising. In Appendix Table 9 it can be observed that it resulted in the highest F2 mean value (30.41 gm) of the 25 crosses. The cross of Weique Red Mace-Huacamayo "S" was somewhat lower (23.36 gm) being slightly above the overall mean of all the crosses.

When considering Yamhill with the same two spring parents, Huacamayo "S" and Siete Cerros 66, they ranked third (26.56 gm) and fourth (26.26 gm), respectively. Similar trends were found for the other characters measured. For example the same four crosses noted above had the highest individual GCA effects and their subsequent F2 population means were the highest for heading date, maturity date and kernels per spike. Roussalka and Jupateco 73 had the largest individual GCA effects for grain filling period and harvest index. The F2 means of these crosses were also the highest in comparison with the other crosses. Plant height which is generally regarded as being qualitatively inherited reflected a similar pattern. The winter parents Kavkaz and Yamhill had the highest individual GCA effect for plant height and with the spring parents Siete Cerros 66 and Huacamayo "S" resulted in the tallest F2 mean values. For tillers per plant the highest individual GCA effects corresponded to Hyslop and Siete Cerros 66 followed closely by Huacamayo "S". The cross with the highest mean for tillers per plant was Hyslop-Huacamayo "S" and Hyslop-Siete Cerros 66 ranked fifth for the same character. Thus, it would appear that GCA effect of individual parents may be a useful guide in predicting which parental lines will provide the superior progeny in later generations.

Genotype-Environment Interaction

Genotype-environment interactions are important for parents and progeny evaluation as they influence the association between the genotype and phenotype especially in quantitatively inherited characters. Relevant information as to these interactions also can help in deciding on the number of locations and/or years that have to be considered in selection for certain traits. In the present investigation significant interactions were found for Years-winter x spring F1's and Locations-winter x spring F2's for all the nine agronomic characters studied. These interactions were partitioned for Years-GCA due to winter parents, Years-GCA due to spring parents, Years-SCA, Locations-GCA due to winter parents, Locations-GCA due to spring parents and Locations-SCA. All the interactions were significant for the characters studied except Years-GCA due to winter parents for plant height and harvest index, Years-SCA for plant height, Locations-GCA due to winter parents for plant height, Locations-GCA due to spring parents for harvest index and Locations-SCA for grain filling period and harvest index. These findings are in agreement with those reported over different locations by Jordaan and Laubscher (1968) for grain yield in spring wheat and by Daaloul (1974) in winter wheat for plant height, number of tillers, kernel weight, kernels per spike and grain yield. The failure of general and specific combining ability effects to be consistent in different environments could be associated with the genotype-environment interaction for the agronomic characters measured in winter x spring crosses. This genotype-environment interaction also prevented any attempt to combine the relative combining ability estimates for the populations and for individual parental effects over locations in this study. It will be necessary to determine the combining ability estimates for each location separately if the results are to be meaningful. However, over years in spite of the fact that there was a significant Years-GCA interaction for the parents the relative ranking of the individual GCA effects of the parents was consistent. Therefore, when predicting the relative performance of the resulting progeny a consistent response would be expected.

Association and Interrelationship Among Agronomic Characters

Correlation coefficients between the seven agronomic characters for the winter x spring crosses grown at Hyslop Farm indicated that improvement was possible for grain yield through selection of either tillers per plant, or kernels per spike and, to a lesser extent, kernel weight or a combination of the three. The associations among the yield components, whenever significant, were positive. Only one cross, Kavkaz-Torim 73, resulted in a negative association between kernel weight and kernels per spike. This investigation did not detect a negative association of kernel weight and kernels per spike as was reported by Firat (1978) in winter x spring crosses at Hyslop Farm. However, since simple phenotypic correlations can be misleading, the correlation coefficients were partitioned into direct and indirect effect between grain yield with heading date, maturity date, plant height, tillers per plant, kernel weight and kernels per spike. When significant correlations were found they involved either a direct or indirect association of the three major components of yield (tillers per plant, kernel weight and kernels per spike).

Correlation coefficients obtained at CIANO suggested that for most of the winter x spring crosses improvement could be made for grain yield by selecting for either tillers per plant or kernels per spike. Negative associations among some of the yield components indicated that some limitations using the component approach for grain yield could be present at this location. A compromise between the yield components may be necessary if effective selection for increased grain yield is to be achieved. The path coefficient analysis indicated that correlation coefficients can be misleading. Two crosses, Kavkaz-Siete Cerros 66 and Yamhill-Huacamayo "S", showed non-significant association of grain yield with any of the other characters measured. When these associations were considered in terms of direct and indirect effects for the yield components (tillers per plant, kernel weight and kernels per spike) a different result was noted. The high direct effect on grain yield was cancelled by the indirect effect via the other characters which were negative or very low and thus a low total correlation was found. Two crosses resulted in significant negative association between grain yield and kernel weight. For example, Roussalka-Siete Cerros 66 had a high positive direct effect for kernel weight and grain yield but this value was cancelled out by the high negative indirect effect of tillers per plant and kernels per spike. As with the Hyslop Farm site, the significant correlation of grain yield with heading date, maturity date, plant height and harvest index resulted from the indirect effect of the yield components at CIANO.

Of the three yield components considered, tillers per plant and kernels per spike produced the greater direct effect on grain yield with kernel weight exerting a lesser effect. It would be anticipated that as grain yield was increased, several biological activities involving the sink-source relationship could result in indirect negative associations. This would cancel any further gain unless greater efficiency in the metabolism of the plant could be achieved.

Another major factor which could influence the effectiveness of selection for grain yield would be yield component compensation as would be the case if there were a negative association between kernel weight and kernels per spike. Thus, if the breeder were using the component approach and emphasizing one component, the advance in increasing grain yield might be negated by such a negative association with other components. The results for the winter x spring crosses path-coefficient analysis suggested that the major components influencing grain yield were tillers per plant, kernels per spike and to a lesser degree, kernel weight. These components had a large direct effect on grain yield with little or no indirect effect via the other character measured. Therefore, for the winter x spring populations used in this investigation, progress could be made by selecting for the components of grain yield initially. The large additive genetic variance associated with the characters studied would confirm that such progress would be possible.

In summary it would appear that winter x spring crosses are equally important to both spring and winter wheat breeders since new genetic variability is being introduced to each breeding program. Of the total genetic variability the additive gene action seems to be important in controlling the expression of all the characters studied at both locations. Non-additive gene action was important for plant height (at both locations), harvest index (at the winter location), and kernel weight (at the spring location). At the spring location, greater total genetic variability was detected for grain yield, tillers per plant and kernel weight, suggesting that spring wheat breeders have a better chance to increase grain yield but due to the compensation effects of the yield components at this site, selection for grain yield would not be that successful. On the other hand, the winter wheat location had less genetic variability for those characters but higher genetic variability for kernels per spike. However, no compensatory effect was observed indicating that selection through the yield components would improve grain yield.

SUMMARY AND CONCLUSIONS

The objectives of this investigation were as follows: 1) to determine the total amount of genetic variability that can be obtained when winter and spring gene pools are combined; 2) to assess the potential of such crosses for the improvement of both winter and spring wheats when the experimental populations were grown at both winter and spring wheat growing locations; 3) to estimate the nature of gene action controlling specific traits in progeny from winter x spring crosses when compared to similar populations resulting from winter x winter and spring x spring crosses; 4) to determine if the relative general combining ability estimates contributed by individual cultivars for specific traits can be used to predict their performance as parents; 5) to determine the possible association and interrelationship among selected agronomic characters and grain yield in winter x spring crosses when grown in winter and spring environments.

Five winter and five spring cultivars were crossed to obtain 25 winter x spring, 10 winter x winter and 10 spring x spring F1's and 25 winter x spring F2's. The winter x spring F1's were backcrossed to both winter and spring parents. Three studies were conducted, two at Hyslop Farm, Corvallis, Oregon during two crop seasons (1976-77 and 1977-78) and one at Northwest Agricultural Research Center (CIANO) located near Ciudad Obregon, Sonora in the Northwest part of Mexico.

The parents plus the winter x spring F1's were planted for two growing seasons at Hyslop Farm. In the second season the winter x winter F1's, winter x spring F2's and both sets of backcrosses were included.

At CIANO, the spring parents, winter x spring F1's and F2's plus backcrosses to spring parents and spring x spring F1's were planted. At this location a maximum number of days to heading was established for winter x spring crosses to avoid unadapted late progeny.

Data were collected on an individual plant basis for heading date, maturity date, grain filling period, plant height, harvest index, tillers per plant, 100 kernel weight, kernels per spike and grain yield. Analyses of variance were performed on all the characters studied to determine if their were significant differences among the crosses and generations. Mean values for each generation were computed using Duncan's new multiple range test.

The genetic variance generated by each winter x spring cross at both locations was compared by subtracting the phenotypic variance of non-segregating populations from the F2 populations. Parent-progeny regression and combining ability analyses were used to estimate the types of gene action involved in the winter x spring, winter x winter and spring x spring crosses. Genotype-environment interactions were examined for winter x spring crosses. Correlation coefficients and path-coefficient analyses were used to determine associations and interrelationships among selected agronomic characters in winter x spring crosses at both locations.

Based on the results of this investigation, the following conclusions were drawn:

1. More total genetic variability was detected for maturity date, plant height, tillers per plant, kernel weight and grain yield in the winter x spring crosses when grown at the spring wheat location.

2. Additive gene action estimates were high for the nine agronomic characters studied in winter x spring, winter x winter and spring x spring crosses.
3. Non-additive gene action played an important role in the winter x spring crosses especially when planted at the winter location. This was observed from the specific combining ability estimates obtained in the F1 and inbreeding depression values observed in the F2 generation.
4. Several years and/or locations should be used when analyzing winter x spring crosses to minimize the effects of their differential responses to the environment which influenced both additive and non-additive gene action estimates.
5. From the mean square values, the winter parents appeared to have a greater effect on the nine agronomic characters studied when compared to the spring parents in winter x spring crosses.
6. Parents which contributed the most to grain yield in the winter x spring crosses were not always the most important in the winter x winter or spring x spring crosses.
7. Individual GCA effects from F1's are a useful aid in predicting which winter x spring parental combinations would result in the most promising F2 populations for all the traits measured.
8. Due to significant location-general combining ability interaction it will be necessary to determine combining ability estimates for a potential parent grown at the specific site where the breeding work is to be done.

9. At the Hyslop site, grain yield in winter x spring crosses correlated significantly with tillers per plant, kernel weight and kernels per spike. Also, positive correlations were noted among these three yield components.
10. At CIANO grain yield correlated significantly in winter x spring crosses with tillers per plant and kernels per spike. Negative associations were observed among the three yield components studied for the same crosses.
11. The three components of yield had high direct and indirect effects in the expression of grain yield in winter x spring crosses at both locations. The yield component, kernel weight, had the least effect at both experimental sites.
12. Heading date, maturity date, plant height and harvest index had very low direct and indirect effects on grain yield in winter x spring crosses.
13. Winter x spring crosses offer additional sources of genetic variability for all the traits measured in this study. Also, it appears that a large percentage of this genetic variability is due to additive gene action which is important to the breeders of a self-pollinated species like wheat.

LITERATURE CITED

Abi-Antoun, M. 1977. Compensating effects and gene action estimates for the components of grain yield in winter wheat (Triticum aestivum L. em Thell). Ph.D. Thesis. Oregon State University, Corvallis.

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

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

Alexander, W. L. 1980. An evaluation of methods to select superior parents utilizing tester crosses to predict progeny performance in winter wheat (Triticum aestivum L.). Ph.D. Thesis. Oregon State University, Corvallis.

Allard, R. W. 1956. Estimation of prepotency from lima bean diallel cross. Agronomy Journal 48:537-543.

Anand, S. C., H. S. Aulakh and S. K. Sharma. 1972. Association among yield components in dwarf wheats. Indian J. Agric. Sci. 42:935-938.

Bhatt, G. M. 1971. Heterotic performance and combining ability in a diallel cross among spring wheats (Triticum aestivum L.). Aust. J. Agr. Res. 22:359-368.

Bhatt, G. M. 1973 (a). Diallel analysis and cross prediction in common bread wheats. Aust. J. Agr. Res. 24:169-178.

Bhatt, G. M. 1973 (b). Significance of path-coefficient analysis in determining the nature of character association. Euphytica 22: 338-343.

Bhatia, C. R. 1975. Criteria for early generation selection in wheat breeding programmes for improving protein productivity. Euphytica 24:789-794.

Bhullar, G. S., K. S. Gill and A. Bhatia. 1979. Combining ability over successive generations in diallel crosses of bread wheat. Cereal Res. Comm. 7:207-213.

Bitzer, M. J., F. L. Patterson and W. E. Nyquist. 1971. Hybrid vigor and gene action in six parent diallel cross of soft winter wheat. Can. J. Genet. Cytol. 13:131-137.

Bitzer, M. J. and S. H. Fu. 1972. Heterosis and combining ability in southern soft red winter wheats. Crop Sci. 12:35-37.

Brajcich, P. 1980. Estimates of heterosis for five agronomic traits in selected winter x spring and winter x winter wheat crosses (Triticum aestivum L. em Thell). M. S. Thesis. Oregon State University, Corvallis.

Brown, C. M., R. O. Wiebel and R. O. Seif. 1966. Heterosis and combining ability in common winter wheat. Crop Sci. 6:382-383.

Comstock, R. E. and H. F. Robinson. 1952. Estimation of average degree of dominance. Heterosis, P.P. 464-516. Iowa State College Press, Ames, Iowa.

Daaloul, A. 1974. Genetic and environmental factors influencing the effectiveness of early generation selection in a diallel cross involving four winter wheat cultivars (Triticum aestivum Vill., Host). Ph.D. Thesis. Oregon State University, Corvallis.

Das, P. K. 1972. Studies on selection for yield in wheat. An application of genotypic and phenotypic correlations, path-coefficient analysis and discriminant functions. J. Agric. Sci. Camb. 79: 447-453.

Dewey, D. R. and K. H. Lu. 1959. A correlation and path-coefficient analysis of crested wheatgrass seed production. Agronomy Journal 51:515-518.

Edwards, L. H., H. Ketata and E. L. Smith. 1976. Gene action of heading date, plant height and other characters in two winter wheat crosses. Crop Sci. 16:257-277.

Firat, A. E. 1978. Inheritance and association of earliness and grain yield in four winter x spring wheat crosses (Triticum aestivum L. em Thell). M.S. Thesis. Oregon State University, Corvallis.

Fischer, R. A. and Z. Kertesz. 1976. Harvest index in spaced populations and grain weight in microplots as indicators of yielding ability in spring wheat. Crop Sci. 16:55-59.

Frey, K. L. and T. Horner. 1957. Heritability in standard units. Agronomy Journal 49:59-62.

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

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

Griffing, B. 1956. Concepts of general and specific combining ability in relation to diallel crossing system. Aust. J. Biol. Sci. 9: 463-493.

Gyawali, K. K., C. O. Qualset and W. T. Yamazaki. 1968. Estimates of heterosis and combining ability in winter wheat. Crop Sci. 8: 322-324.

Hsu, P. and P. D. Walton. 1970. The inheritance of morphological and agronomic characters in spring wheat. Euphytica 19:54-60.

Jatasra, D. S. and R. S. Paroda. 1978. Use of F2 generation for combining ability in wheat. Cereal Res. Comm. 6:265-271.

Jatasra, D. S. and R. S. Paroda. 1979. An 8x8 diallel analysis for plant height in bread wheat. Indian J. Agric. Sci. 49:904-914.

Jordaan, J. P. and F. X. Laubscher. 1968. The repeatability of breeding values for eleven wheat varieties estimated over generations. In proceedings of the Third International Wheat Genetics Symposium . Australia Academy of Science, Camberra. p. 146-420.

Kempthorne, O. 1959. An Introduction to Genetical Statistics. John Wiley & Sons. New York. 545 pp.

Khan, A. W., N. U. Khan and D. C. Beohar. 1972. Estimates of genetic variability and correlation coefficients of some biometric characters in rain fed wheat (T. aestivum L.). Indian J. Agric. Sci. 42:557-561.

Kronstad, W. E. 1963. Combining ability and gene action estimates and the association of the components of yield in winter wheat crosses. Ph.D. Thesis. Oregon State University, Corvallis.

Kronstad, W. E. and W. H. Foote. 1964. General and specific combining ability estimates in winter wheat (Triticum aestivum Vill., Host). Crop Sci. 4:616-619.

Leffel, R. C. and W. D. Hanson. 1961. Early generation testing of diallel crosses of soybean. Crop Sci. 1:169-175.

Li, C. C. 1956. The concept of path coefficient and its impact on population genetics. Biometrics 12:190-210.

Lupton, F. G. H. 1965. Studies in breeding of self-pollinating cereals. 5. Use of the incomplete diallel in wheat breeding. Euphytica 14: 331-352.

Matzinger, D. F., G. F. Sprague and C. C. Cockerham. 1959. Diallel crosses of maize in experiment repeated over locations and years. Agronomy Journal 51:346-350.

Maya de Leon, J. L. 1975. Combining ability and associations of agronomic traits involving three sources of dwarfism in wheat (Triticum aestivum L. em Thell). Ph.D. Thesis. Oregon State University, Corvallis.

Mihaljev, I. 1976. Expression of heterosis and combining ability in a diallel wheat cross. Proc. Seventh Cong. of Eucarpia. pp. 327-329.

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

Parodi, C. P. and F. L. Patterson. 1973. A comparison of genetic behavior in a six-parent diallel cross of winter wheat grown under northern and southern hemisphere environments. In the Fourth Wheat Genetic Symposium, Missouri. pp. 569-575.

Petpisit, V. 1980. Progeny test for predicting grain yield and selected agronomic traits in single, three-way and double crosses in wheat (Triticum aestivum L. em Thell). Ph.D. Thesis. Oregon State University, Corvallis.

Rasmusson, D. C. and R. Q. Cannel. 1970. Selection for grain yield and components of yield in barley. Crop Sci. 10:51-54.

Rojas, B. A. and G. F. Sprague. 1952. A comparison of variance components in corn yield trial: III. General and specific combining ability and their interaction with locations and years. Agronomy Journal 44:462-466.

Snedecor, G. W. and W. C. Cochran. 1967. Statistical Methods. Iowa State University Press. Ames, Iowa.

Sprague, G. F. and L. A. Tatum. 1942. General vs. specific combining ability in single crosses of corn. J. Amer. Soc. Agron. 34:923-932.

Sidwell, R. J., E. L. Smith and R. W. McNew. 1976. Inheritance and interrelationships of grain yield and selected yield-related traits in a hard red winter wheat cross. Crop Sci. 16:650-654.

Singh, S. P., M. S. Shrivastava and S. V. Valamker. 1970. Variability and correlation coefficients for grain yield and other quantitative characters in Triticum durum desf. Indian J. Agri. Sci. 40:1042-1045.

Virk, D. S., H. S. Aulakh and H. S. Pooni. 1977. A path coefficient analysis of grain yield in three bread wheat crosses. Cereal Res. Comm. 5:31-39.

Walton, P. D. 1971. Heterosis in spring wheat. Crop Sci. 11:422-424.

Walton. P. D. 1972. Quantitative inheritance of yield and associated factors in spring wheat. Euphytica 21:553-556.

Wright, S. 1921. Correlation and causation. J. Agric. Res. 20:557-585.

APPENDIX

Appendix Table 1. Pedigree and description of cultivars.

KAVKAZ

Lutescens 314-h-147/Bezostaja 1. A hard red common winter wheat cultivar released by Russia in 1971. Large spikes, cylindrical, white and awnless. Early, tall with high yield potential, poor tillering, large seed with good milling and baking qualities.

ROUSSALKA

Was-Nibay/Sterling B x C54. A hard red common winter wheat variety from Bulgaria, resulted from a cross of Italian and Indian germ plasm. Semidwarf, awned, mid-dense spike, high yielding, early, low tillering potential and medium kernel weight. Resistant to leaf rust (*Puccinia recondita*) and moderately susceptible to stripe rust (*Puccinia striiformis*).

YAMHILL

Heines VII/Redmon (Alba). A soft white common winter wheat cultivar released by Oregon State University in 1969. Late maturity, medium height, high yielding and awnless. Good milling and baking qualities, resistant to stripe rust and powdery mildew (*Erysiphe graminis f. sp. tritici*). Large fertile spikes and medium to large kernels.

HYSLOP

Nord Desprez/Pullman Selection 101^2. A soft white common winter wheat cultivar released by Oregon State University in 1970. Semi-dwarf, awned, mid-dense spike and high yielding. Resistant to stripe rust and common bunt (*Tilletia caries* and *T. foetida*), moderately resistant to powdery mildew, leaf rust and septoria (*Septoria tritici*). Medium early, large head size, medium kernel weight and good milling and baking quality.

WEIQUE RED MACE

Wheat variety/Rye IB/IR substitution x Hybrid 46. A fixed line resulting from a cross made in the USA of German and British germ plasm. A hard red winter wheat with cylindrical spike, white and awnless. Late maturity, semidwarf with profuse tillering, resistant to shattering and lodging.

INIA 66

Lerma Rojo S-64 x Sonora F-64. A hard red common spring wheat cultivar released by Mexico in 1966. Early maturity, semidwarf, with white awned fusiform spikes and resistant to shattering. Medium size kernel. Resistant to stem rust (*Puccinia graminis f. sp. tritici*) and susceptible to leaf rust. High yield potential and wide adaptation with excellent milling and baking qualities.

SIETE CERROS 66

(Frontana x Kenya 58-Newthatch/Norin 10-Baart)Gabo 55. A hard white common spring wheat cultivar released by Mexico in 1966. Mid-season maturity, semidwarf, with brown awns, oblong to clavate spike and resistant to shattering. Small to medium size kernel. Widely adapted and excellent yield potential, resistant to leaf, stem and stripe rust but is currently susceptible to all three rusts in Mexico. Poor bread-making quality.

TORIM 73

Bluebird x Inia 66. A hard white common spring wheat cultivar released by Mexico in 1973. Midseason maturity, dwarf with white

Appendix Table 1. - continued

awned fusiform spike, resistant to shattering. Small to medium size kernel. High yield potenital and resistant to stem rust and moderately resistant to leaf rust. Good baking qualities.

JUPATECO 73

12300 x Lerma Rojo S-64-8156/Norteño M-67. A hard red common spring wheat cultivar released by Mexico in 1973. Midseason maturity, semi-dwarf, with white, awned, fusiform spike, resistant to shattering. Small to medium size kernel. High yield potential with resistance to stem and leaf rust. Good baking qualities.

HUACAMAYO "S"

Yecora 70 x Sonora 64-NY5207.85/Ciano 67 "S"-7Cerros 66 X Gaboto. A hard red common spring wheat, fixed line from Mexico. Midseason maturity, semidwarf with good straw strength. White, awned fusiform spike, resistant to shattering. Resistant to stripe, stem and leaf rust. High yield potential and profuse tillering.

Appendix Table 2. Summary of climatic data on a per month basis for Hyslop Farm growing seasons 1976-77 and 1977-78 and CIANO during the 1977-78 growing season.

Location and Growing Season	Month	Precipitation (mm)	Temperature °C		
			Max	Min	Mean
Hyslop 1976-77	October	31.8	19.1	5.1	12.1
	November	36.1	13.1	3.4	8.3
	December	37.3	6.4	-0.4	3.1
	January	24.4	7.1	-2.3	2.4
	February	75.4	12.5	1.4	7.0
	March	129.3	11.4	1.4	6.4
	April	25.9	17.1	3.1	10.2
	May	87.1	16.5	5.3	10.9
	June	28.7	23.6	8.7	16.2
	July	3.1	26.0	9.5	17.8
	Total	479.1			
Hyslop 1977-78	October	65.5	17.8	6.6	12.2
	November	206.0	10.7	3.2	6.9
	December	280.2	9.4	3.8	6.6
	January	186.4	8.1	2.9	5.5
	February	108.7	10.9	4.4	7.7
	March	54.6	15.1	4.7	9.9
	April	25.5	14.3	5.7	10.0
	May	91.7	17.6	7.1	12.3
	June	23.9	23.9	10.6	17.3
	July	7.4	27.1	11.5	19.3
	Total	1,149.9			
CIANO 1977-78	November	0.3	22.4	14.4	18.4
	December	0.0	28.4	11.5	20.0
	January	0.5	25.3	9.6	17.5
	February	6.7	25.2	8.2	16.7
	March	15.9	28.4	12.3	20.4
	April	0.0	30.9	10.7	20.8
	Total	23.4			

Appendix Table 3. Path coefficient equations for Study II. Hyslop Farm, 1977-78.

$$r_{21} = P_{21} + r_{23}P_{31} + r_{24}P_{41} + r_{25}P_{51} + r_{26}P_{61} + r_{27}P_{71}$$
$$r_{31} = P_{31} + r_{23}P_{21} + r_{34}P_{41} + r_{35}P_{51} + r_{36}P_{61} + r_{37}P_{71}$$
$$r_{41} = P_{41} + r_{24}P_{21} + r_{34}P_{31} + r_{45}P_{51} + r_{46}P_{61} + r_{47}P_{71}$$
$$r_{51} = P_{51} + r_{25}P_{21} + r_{35}P_{31} + r_{45}P_{41} + r_{56}P_{61} + r_{57}P_{71}$$
$$r_{61} = P_{61} + r_{26}P_{21} + r_{36}P_{31} + r_{46}P_{41} + r_{56}P_{51} + r_{67}P_{71}$$

The variation in yield accounted for the above association was calculated by the formula:

$$R^2 = P_{21}r_{21} + P_{31}r_{31} + P_{41}r_{41} + P_{51}r_{51} + P_{61}r_{61}$$

1 = Grain Yield
2 = Heading Date
3 = Maturity Date
4 = Plant Height
5 = Tillers per Plant
6 = Kernel Weight
7 = Kernels per Spike

r = correlation coefficient
P = path coefficient
R^2 = coefficient of determination

Appendix Table 4. Path coefficient equations for Study III. CIANO, 1977-78.

$$r_{21} = P_{21} + r_{23}P_{31} + r_{24}P_{41} + r_{25}P_{51} + r_{26}P_{61} + r_{27}P_{71} + r_{28}P_{81}$$
$$r_{31} = P_{31} + r_{23}P_{21} + r_{34}P_{41} + r_{35}P_{51} + r_{36}P_{61} + r_{37}P_{71} + r_{38}P_{81}$$
$$r_{41} = P_{41} + r_{24}P_{21} + r_{34}P_{31} + r_{45}P_{51} + r_{46}P_{61} + r_{47}P_{71} + r_{48}P_{81}$$
$$r_{51} = P_{51} + r_{25}P_{21} + r_{35}P_{31} + r_{45}P_{41} + r_{56}P_{61} + r_{57}P_{71} + r_{58}P_{81}$$
$$r_{61} = P_{61} + r_{26}P_{21} + r_{36}P_{31} + r_{46}P_{41} + r_{56}P_{51} + r_{67}P_{71} + r_{68}P_{81}$$
$$r_{71} = P_{71} + r_{27}P_{21} + r_{37}P_{31} + r_{47}P_{41} + r_{57}P_{51} + r_{67}P_{61} + r_{78}P_{81}$$
$$r_{81} = P_{81} + r_{28}P_{21} + r_{38}P_{31} + r_{48}P_{41} + r_{58}P_{51} + r_{68}P_{61} + r_{78}P_{71}$$

The variation in yield accounted for the above association was calculated by the formula:

$$R^2 = P_{21}r_{21} + P_{31}r_{31} + P_{41}r_{41} + P_{51}r_{51} + P_{61}r_{61} + P_{71}r_{71} + P_{81}r_{81}$$

1 = Grain Yield
2 = Heading Date
3 = Maturity Date
4 = Plant Height
5 = Tillers per Plant
6 = Harvest Index
7 = Kernel Weight
8 = Kernels per Spike

r = correlation coefficient

P = path coefficient

R^2 = coefficient of determination

Appendix Table 5. Mean values for nine agronomic characters measured in winter and spring wheat parents grown at Hyslop Farm, 1976-77.

Parents	Heading Date	Maturity Date	Filling Period	Plant Height (cm)	Tillers Per Plant	Grain Yield (gm)	Harvest Index %	100 Kernel Weight (gm)	Kernels Per Spike
<u>Winters</u>									
Kavkaz	145.93 d*	196.33 bc	50.40 a	108.91 a	15.96 bc	46.70 ab	33.83 b	5.01 ab	58.29 a
Roussalka	130.48 e	185.33 d	54.93 a	85.93 d	13.15 c	29.37 c	38.33 ab	5.05 a	44.08 b
Yamhill	157.58 a	199.13 ab	41.55 c	99.14 b	17.29 b	43.23 b	34.33 b	4.27 c	58.47 a
Hyslop	148.48 c	193.58 c	45.13 b	92.71 c	21.41 a	57.20 a	40.89 a	4.34 c	61.40 a
W. R. Mace	153.80 d	200.05 a	46.23 b	87.75 d	17.52 b	42.22 b	26.83 c	4.77 b	50.44 b
Average	147.25	194.88	47.64	94.89	17.07	43.74	34.84	4.69	54.54
<u>Springs</u>									
Inia 66	120.70 c	187.88 b	67.18 a	92.90 c	14.73 b	30.99 b	39.13 a	4.80 a	30.99 b
Siete Cerros 66	134.03 a	189.85 ab	55.83 b	97.73 b	16.85 ab	37.50 b	34.82 b	3.92 c	37.50 b
Torim 73	128.85 b	187.53 b	58.68 b	80.52 d	17.57 ab	33.19 b	38.64 a	4.30 b	33.19 b
Jupateco 73	119.80 c	189.75 ab	69.98 a	93.22 c	14.44 b	29.41 b	36.45 a	4.05 bc	29.41 b
Huacamayo "S"	133.43 a	191.80 a	58.38 b	102.63 a	18.80 a	56.61 a	40.48 a	4.91 a	56.61 a
Average	127.36	189.36	62.00	93.40	16.48	37.54	37.90	4.40	51.44

*Duncan's new multiple range test. Means with the same letter are not significantly different at the 5% probability level.

Appendix Table 6. Mean values for nine agronomic characters measured in 25 F1 crosses of winter x spring wheat grown at Hyslop Farm, 1976-77.

Cross	Heading Date	Maturity Date	Filling Period	Plant Height (cm)	Tillers Per Plant	Grain Yield (gm)	Harvest Index %	100 Kernel Weight (gm)	Kernels Per Spike
Kavkaz-Inia 66	131.08 j-l*	190.60 a-d	59.53 abc	111.41 ef	15.01 cd	37.35 h	32.89 fg	5.90 b	42.25 gh
Kavkaz-Siete Cerros 66	137.70 ef	191.58 ab	53.88 e-h	116.00 cd	17.66 a-d	42.74 e-h	25.48 h	5.83 b	41.74 h
Kavkaz-Torim 73	132.85 ij	189.73 a-e	56.88 b-e	106.70 g-j	16.30 bcd	42.09 fgh	35.79 c-g	5.63 bcd	45.81 fgh
Kavkaz-Jupateco 73	131.60 jk	190.55 a-d	58.95 abc	112.78 de	18.45 a-d	45.75 d-h	32.92 fg	5.91 b	42.09 gh
Kavkaz-Huacamayo "S"	136.35 fg	190.75 abc	55.13 d-g	123.75 a	16.09 bcd	54.37 b-f	32.89 fg	6.56 a	51.27 ef
Roussalka-Inia 66	125.60 n	186.58 e	60.95 a	97.64 lm	14.42 d	38.30 gh	42.04 abc	5.29 d-g	50.37 efg
Roussalka-Siete Cerros 66	133.73 hi	190.98 abc	57.25 a-e	99.64 kl	16.17 bcd	46.32 d-h	42.18 ab	5.19 e-h	55.30 de
Roussalka-Torim 73	129.45 lm	189.40 b-e	59.95 ab	87.00 o	15.85 bcd	41.17 fgh	43.94 a	4.97 ghi	52.06 e
Roussalka-Jupateco 73	128.15 m	187.30 de	59.15 abc	95.45 mn	15.69 bcd	41.04 fgh	42.84 ab	5.12 e-i	51.60 e
Roussalka-Huacamayo "S"	130.95 kl	187.88 cde	56.95 b-e	103.08 jk	14.79 d	46.57 d-h	39.90 a-e	5.34 def	58.92 b-e
Yamhill-Inia 66	134.85 gh	191.73 ab	56.93 b-e	108.11 f-i	16.82 a-d	55.03 b-f	39.90 a-e	5.09 e-i	63.78 a-d
Yamhill-Siete Cerros 66	145.88 a	192.88 ab	47.03 k	118.12 bc	17.78 a-d	59.25 a-d	35.36 d-g	4.82 ij	68.90 a
Yamhill-Torim 73	139.83 cd	191.13 abc	51.30 hij	108.45 e-h	16.44 bcd	54.81 b-f	41.10 a-d	5.00 f-i	66.57 ab
Yamhill-Jupateco 73	139.48 de	191.93 ab	52.45 g-j	117.14 bcd	15.89 bcd	52.18 b-f	38.33 a-f	5.00 f-i	65.94 ab
Yamhill-Huacamayo "S"	143.15 b	192.43 ab	49.30 j-k	120.76 ab	16.52 a-d	53.62 b-f	34.57 efg	5.19 e-h	62.66 a-d
Hyslop-Inia 66	131.80 jk	189.85 a-d	58.10 a-d	150.06 hij	19.73 ab	51.06 b-g	40.05 a-e	5.09 e-i	51.05 ef
Hyslop-Siete Cerros 66	140.78 cd	190.13 a-d	49.35 j-k	104.74 hij	19.54 ab	44.26 e-h	31.76 g	4.93 hij	46.19 fgh
Hyslop-Torim 73	136.40 fg	192.48 ab	56.08 cf	93.43 n	19.60 ab	49.81 c-h	41.78 abc	4.61 j	55.16 de
Hyslop-Jupateco 73	134.18 hi	190.90 abc	56.73 bf	99.60 kl	19.50 ab	41.63 f-h	36.82 b-g	4.64 j	46.10 fgh
Hyslop-Huacamayo "S"	139.88 cd	193.10 a	53.23 f-i	103.78 jk	20.86 a	59.40 a-d	39.07 a-e	5.02 f-i	56.86 c-e
W. R. Mace-Inia 66	131.30 jk	189.45 b-e	58.13 a-d	110.69 efg	17.51 a-d	66.30 ab	40.08 a-e	5.79 bc	65.60 abc
W. R. Mace-Siete Cerros 66	141.50 bc	192.10 ab	50.63 ij	108.24 e-i	19.31 abc	70.54 a	34.76 d-g	5.44 cde	66.46 ab
W. R. Mace-Torim 73	134.80 gh	191.33 ab	56.53 b-f	105.75 hij	17.22 a-d	60.75 abc	41.00 a-d	5.29 d-g	67.11 ab
W. R. Mace-Jupateco 73	134.28 hi	190.98 abc	56.70 b-f	108.19 f-i	15.54 bcd	56.24 b-e	40.23 a-e	5.31 d-g	69.07 a
W. R. Mace-Huacamayo "S"	140.53 cd	192.28 ab	51.75 g-j	107.43 f-j	17.85 a-d	62.98 abc	37.09 b-g	5.30 d-g	66.80 ab
Average	135.44	190.72	55.28	106.92	17.22	50.94	37.71	5.25	56.39

*Duncan's new multiple range test. Means with the same letter are not significantly different at the 5% probability level.

Appendix Table 7. Mean values for nine agronomic characters measured in winter and spring wheat parents grown at Hyslop Farm, 1977-78.

Parents	Heading Date	Maturity Date	Filling Period	Plant Height (cm)	Tillers Per Plant	Grain Yield (gm)	Harvest Index %	100 Kernel Weight (gm)	Kernels Per Spike
Winters									
Kavkaz	142.21 c*	181.59 b	39.38 b	110.24 a	12.82 a	27.92 a	28.24 a	4.60 a	46.82 b
Roussalka	117.33 d	171.39 c	54.05 a	84.30 d	13.29 a	20.80 b	33.15 a	4.08 b	37.81 c
Yamhill	149.77 b	186.41 b	36.65 b	100.62 b	13.32 a	29.91 a	30.91 a	4.42 a	50.29 b
Hyslop	149.07 b	186.15 a	37.09 b	91.69 c	14.67 a	32.48 a	31.06 a	3.91 b	56.10 a
W. R. Mace	156.62 a	194.47 a	37.84 b	83.01 d	12.07 a	17.63 c	18.81 b	4.50 a	32.20 d
Average	143.00	184.00	41.00	93.97	13.23	25.75	28.43	4.30	44.64
Springs									
Inia 66	109.29 c	173.10 b	63.84 c	82.21 b	7.86 b	10.50 bc	35.65 a	3.54 b	36.26 a
Siete Cerros 66	122.72 a	180.96 a	58.21 b	89.25 a	8.16 b	11.95 b	31.91 a	3.23 bc	42.31 a
Torim 73	117.88 b	173.71 b	55.83 b	73.76 c	9.58 ab	12.01 b	34.29 a	3.13 c	37.85 a
Jupateco 73	107.25 c	172.94 b	65.70 a	79.10 b	7.36 c	7.98 c	30.28 a	3.09 c	35.74 a
Huacamayo "S"	124.35 a	179.91 a	54.57 b	89.88 a	10.56 a	19.94 a	33.82 a	4.00 a	46.41 a
Average	116.30	175.92	59.62	82.84	8.70	12.84	33.19	3.40	39.71

*Duncan's new multiple range test. Means with the same letter are not significantly different at the 5% probability level.

Appendix Table 8. Mean values for nine agronomic characters measured in 25 F1 crosses of winter x spring wheat grown at Hyslop Farm, 1977-78.

Cross	Heading Date	Maturity Date	Filling Period	Plant Height (cm)	Tillers Per Plant	Grain Yield (gm)	Harvest Index %	100 Kernel Weight (gm)	Kernels Per Spike
Kavkaz-Inia 66	123.28 hij*	173.05 g	49.77 e-h	104.64 d-g	8.47 bc	15.09 fg	24.35 j	4.71 a-d	35.96 j
Kavkaz-Siete Cerros 66	135.69 ab	179.75 abc	44.06 hi	120.35 a	15.33 a	45.07 a	35.27 b-h	4.57 a-d	64.65 ab
Kavkaz-Torim 73	121.22 ijk	174.14 efg	52.93 c-f	97.96 fgh	8.22 c	12.48 g	25.18 ij	4.95 a	31.09 j
Kavkaz-Jupateco 73	119.22 jk	175.47 d-g	56.26 b-e	102.72 efg	12.51 abc	20.51 efg	30.12 e-j	4.80 abc	34.10 j
Kavkaz-Huacamayo "S"	129.16 c-g	179.41 a-d	50.25 efg	118.66 ab	15.92 a	42.50 ab	30.95 e-j	4.98 a	53.38 b-h
Roussalka-Inia 66	109.11 n	173.33 fg	64.22 a	93.19 h	11.74 abc	24.51 efg	36.82 a-e	4.50 a-d	46.80 hi
Roussalka-Siete Cerros 66	120.74 ijk	174.08 fg	53.34 c-f	96.54 gh	13.84 a	38.40 abc	40.79 ab	4.77 a-d	59.04 a-g
Roussalka-Torim 73	114.15 lm	175.84 c-g	61.69 ab	85.29 i	13.42 a	27.90 b-f	40.36 abc	4.28 cd	48.96 f-h
Roussalka-Jupateco 73	112.01 mn	173.59 fg	61.58 ab	91.25 hi	11.75 abc	26.60 c-f	40.52 abc	4.54 a-d	50.11 e-h
Roussalka-Huacamayo "S"	118.37 kl	175.39 d-g	57.02 bcd	98.03 fgh	14.20 a	36.10 a-e	36.34 a-f	4.84 ab	52.39 d-h
Yamhill-Inia 66	127.84 e-h	176.07 c-f	48.24 f-i	105.93 c-f	11.49 abc	29.93 b-e	34.98 b-h	4.33 bcd	60.35 a-f
Yamhill-Siete Cerros 66	135.81 a	181.57 a	45.75 ghi	111.65 bcd	12.86 abc	37.22 abc	32.56 d-h	4.35 bcd	65.77 a
Yamhill-Torim 73	130.82 b-f	179.25 a-d	48.43 f-i	104.64 d-g	13.38 a	36.27 a-d	37.39 a-d	4.24 d	63.87 abc
Yamhill-Jupateco 73	129.10 c-g	178.96 a-d	49.85 e-h	107.23 cde	12.84 abc	32.86 a-e	37.27 a-e	4.50 a-d	56.21 a-h
Yamhill-Huacamayo "S"	135.63 ab	178.17 a-e	42.54 i	113.68 abc	12.64 abc	31.67 a-e	30.72 e-j	4.64 a-d	53.49 b-h
Hyslop-Inia 66	124.87 g-i	176.35 c-g	51.48 c-g	97.30 gh	12.71 abc	31.28 a-e	39.63 a-d	4.48 a-d	52.97 c-h
Hyslop-Siete Cerros 66	133.99 abc	179.79 a-c	45.80 ghi	101.68 efg	15.87 a	32.55 a-e	29.22 f-j	4.24 d	48.59 gh
Hyslop-Torim 73	128.05 d-h	178.84 a-d	50.80 d-g	91.95 hi	15.99 a	35.85 a-e	35.41 b-g	4.22 d	52.34 d-h
Hyslop-Jupateco 73	119.60 jk	177.37 b-f	57.77 abc	93.56 h	13.12 ab	21.71 d-g	28.39 g-j	4.48 a-d	37.03 ij
Hyslop-Huacamayo "S"	132.94 a-d	179.70 abc	46.77 f-i	98.00 fgh	13.24 a	34.20 a-e	32.12 e-i	4.46 a-d	55.36 a-h
W. R. Mace-Inia 66	126.36 f-h	175.95 c-g	49.59 e-h	103.60 d-g	11.55 abc	28.81 b-f	33.29 c-h	4.50 a-d	55.96 a-h
W. R. Mace-Siete Cerros 66	135.84 a	181.22 ab	45.38 ghi	104.24 d-g	14.85 a	38.28 abc	28.24 hij	4.54 a-d	56.02 a-h
W. R. Mace-Torim 73	129.32 c-g	178.91 a-d	49.59 e-h	103.02 efg	13.17 ab	36.78 abc	30.38 e-j	4.47 a-d	60.64 a-e
W. R. Mace-Jupateco 73	123.28 hij	178.91 a-d	55.64 b-e	96.13 gh	14.50 a	36.26 a-d	42.93 a	4.52 a-d	54.97 a-h
W. R. Mace-Huacamayo "S"	132.02 a-e	179.70 abc	47.64 f-i	107.38 cde	14.80 a	41.59 ab	30.95 e-j	4.56 a-d	61.86 a-d
Average	125.93	177.39	51.46	101.94	13.14	31.78	33.76	4.54	52.47

Duncan's new multiple range test. Means with the same letter are not significantly different at the 5% probability level.

Appendix Table 9. Mean values for nine agronomic characters measured in 25 F2 crosses of winter x spring wheat grown at Hyslop Farm, 1977-78.

Cross	Heading Oate	Maturity Date	Filling Period	Plant Height (cm)	Tillers Per Plant	Grain Yield (gm)	Harvest Index %	100 Kernel Weight (gm)	Kernels Per Spike
Kavkaz-Inia 66	121.98 klm*	174.24 h-k	52.26 bcd	92.50 d-g	9.80 e	15.02 gh	27.43 ghi	4.43 bc	34.18 g
Kavkaz-Siete Cerros 66	126.32 ij	178.85 c-f	52.53 bcd	107.19 ab	11.76 b-e	23.54 a-f	27.92 ghi	4.58 ab	44.03 cf
Kavkaz-Torim 73	123.55 jkl	176.05 e-i	52.50 bcd	97.06 cde	11.76 b-e	18.10 e-h	29.04 e-h	4.23 b-f	38.03 fg
Kavkaz-Jupateco 73	120.28 mn	173.81 ijk	53.53 bc	97.82 cde	9.93 e	14.43 h	24.37 i	4.38 b-d	33.33 g
Kavkaz-Huacamayo "S"	126.48 hij	178.52 c-f	52.03 bcd	108.31 a	11.08 cde	23.21 a-f	28.83 f-i	4.93 a	42.26 ef
Roussalka-Inia 66	112.70 o	172.89 jk	60.18 a	90.86 e-h	11.19 cde	20.58 b-h	33.50 b-f	4.22 b-f	43.27 c-f
Roussalka-Siete Cerros 66	121.10 lm	174.70 g-k	53.60 bc	95.16 cde	12.41 a-d	25.84 a-e	35.19 ab	4.31 bcd	48.35 a-e
Roussalka-Torim 73	117.98 n	176.71 d-i	58.74 a	84.54 h	11.97 b-e	22.11 b-g	34.48 a-d	4.09 c-g	45.01 b-e
Roussalka-Jupateco 73	112.10 o	171.70 k	59.60 a	86.11 gh	11.01 cde	19.23 c-h	38.32 a	4.02 d-g	42.89 def
Roussalka-Huacamayo "S"	119.63 mn	175.36 f-j	55.73 ab	91.75 d-h	12.62 a-d	16.38 fgh	34.08 a-e	4.45 bc	46.83 a-e
Yamhill-Inia 66	128.34 ghi	177.08 d-i	48.74 c-f	100.19 a-d	10.93 de	23.80 a-f	34.71 abc	4.11 c-g	52.60 ab
Yamhill-Siete Cerros 66	139.91 a	183.11 a	43.20 h	108.76 a	11.27 cde	26.26 a-d	30.76 b-h	4.30 b-e	50.84 abc
Yamhill-Torim 73	133.38 de	178.77 c-f	45.38 e-h	98.97 b-e	11.99 b-e	25.54 a-e	34.53 a-d	3.94 efg	53.57 a
Yamhill-Jupateco 73	130.59 efg	178.38 c-g	47.78 d-h	101.15 abc	12.02 b-e	22.27 b-g	31.14 b-g	4.03 d-g	45.55 b-e
Yamhill-Huacamayo "S"	135.89 bcd	179.61 a-e	43.71 gh	108.21 a	12.56 a-d	26.56 a-c	30.04 d-h	4.43 bc	47.52 a-e
Hyslop-Inia 66	124.97 jk	176.91 d-i	51.94 bcd	98.35 cde	12.91 a-d	25.02 a-e	32.84 b-f	4.17 c-f	46.84 a-e
Hyslop-Siete Cerros 66	134.65 cd	181.14 abc	46.50 e-g	97.55 cde	12.95 a-d	26.12 a-d	30.82 b-h	4.08 c-g	49.05 a-e
Hyslop-Torim 73	129.71 fgh	177.47 c-i	47.76 d-h	86.44 fgh	13.26 abc	23.63 a-f	35.22 ab	3.81 g	46.75 a-e
Hyslop-Jupateco 73	124.19 jkl	176.05 e-i	51.86 bcd	92.05 d-g	12.85 a-d	18.66 d-h	28.75 f-i	3.89 fg	37.13 fg
Hyslop-Huacamayo "S"	132.67 def	180.88 a-d	48.21 d-g	94.67 c-f	14.28 a	27.77 ab	30.85 b-h	4.22 b-f	46.32 a-e
W. R. Mace-Inia 66	130.15 efg	178.76 c-f	47.61 d-h	95.99 cde	11.46 cde	25.22 a-e	31.39 b-g	4.35 bcd	50.00 a-d
W. R. Mace-Siete Cerros 66	138.13 ab	182.91 ab	44.78 fgh	97.08 cde	13.84 ab	30.41 a	28.81 f-i	4.33 bcd	50.73 abc
W. R. Mace-Torim 73	134.27 d	178.85 c-f	44.58 fgh	90.44 e-h	11.04 cde	22.37 b-g	28.64 f-i	3.95 efg	50.36 a-d
W. R. Mace-Jupateco 73	129.26 ghi	179.25 b-e	50.00 b-e	92.91 c-g	13.01 a-d	26.88 abc	30.52 b-h	4.22 b-f	48.81 a-e
W. R. Mace-Huacamayo "S"	137.84 abc	181.16 abc	43.33 gh	91.90 d-h	12.34 a-d	23.36 a-f	26.29 hi	4.13 c-g	46.00 a-e
Average	127.44	177.73	50.24	96.24	11.99	23.23	31.14	4.22	45.61

*Duncan's new multiple range test. Means with the same letter are not significantly different at the 5% probability level.

Appendix Table 10. Mean values for nine agronomic characters measured in 25 backcrosses to winter wheat parents grown at Hyslop Farm, 1977-78.

Cross	Heading Date	Maturity Date	Filling Period	Plant Height (cm)	Tillers Per Plant	Grain Yield (gm)	Harvest Index %	100 Kernel Weight (gm)	Kernels Per Spike
Kavkaz-Inia 66	128.80 hi*	174.48 ghi	45.68 d-g	111.29 a	11.25 de	22.03 abc	26.58 i-l	4.40 bcd	44.24 e-i
Kavkaz-Siete Cerros 66	130.89 gh	179.46 c-f	48.56 cd	111.23 a	13.10 a-d	30.48 ab	27.96 h-l	4.67 ab	49.99 b-f
Kavkaz-Torim 73	129.33 hi	176.91 fgh	47.58 d	109.79 ab	11.96 a-e	20.73 bc	23.82 l	4.45 a-d	38.41 i
Kavkaz-Jupateco 73	128.05 i	175.16 ghi	47.10 de	108.71 ab	10.75 e	18.74 c	26.43 i-l	4.48 a-d	38.58 hi
Kavkaz-Huacamayo "S"	131.16 gh	179.46 c-f	48.30 cd	108.09 ab	10.81 e	21.58 abc	24.66 kl	4.93 a	39.03 ghi
Roussalka-Inia 66	114.88 l	173.16 i	58.28 a	88.31 gh	11.79 b-e	22.20 abc	34.50 bcd	4.43 bcd	43.11 f-i
Roussalka-Siete Cerros 66	120.57 j	173.39 hi	52.82 bc	92.57 efg	11.97 a-e	23.18 abc	35.66 abc	4.29 b-e	44.79 e-i
Roussalka-Torim 73	115.94 kl	174.99 ghi	59.04 a	85.96 h	12.37 a-e	24.71 abc	37.70 ab	4.30 b-e	45.99 e-i
Roussalka-Jupateco 73	114.86 l	171.76 i	56.97 ab	87.27 gh	11.15 de	21.77 abc	39.14 a	4.36 bcd	43.07 f-i
Roussalka-Huacamayo "S"	117.35 k	171.98 i	54.63 ab	91.99 e-h	12.55 a-e	22.73 abc	32.52 c-g	4.24 b-e	42.89 f-i
Yamhill-Inia 66	137.48 e-f	180.45 b-e	42.97 e-h	106.74 ab	12.01 a-e	30.69 ab	32.88 c-f	4.33 b-e	59.05 a
Yamhill-Siete Cerros 66	144.15 ab	183.81 ab	39.67 hi	112.91 a	11.43 cde	30.48 ab	30.46 d-i	4.48 a-d	57.57 ab
Yamhill-Torim 73	140.18 cd	180.77 b-e	40.59 hi	103.29 bc	12.67 a-e	31.09 ab	33.60 bcd	4.31 b-e	56.65 ab
Yamhill-Jupateco 73	138.82 de	180.89 b-e	42.07 f-i	107.90 ab	11.88 b-e	28.96 abc	31.58 c-h	4.35 bcd	55.29 a-d
Yamhill-Huacamayo "S"	143.22 ab	182.60 a-d	39.39 hi	111.17 a	12.00 a-e	29.57 ab	29.10 e-j	4.42 bcd	55.12 a-d
Hyslop-Inia 66	132.62 g	179.20 def	46.58 def	99.82 cd	14.70 a	30.97 ab	32.17 c-h	4.19 b-e	50.30 a-f
Hyslop-Siete Cerros 66	139.18 de	182.02 a-d	42.84 e-h	96.40 def	14.10 abc	30.11 ab	28.84 f-j	4.17 cde	50.90 a-f
Hyslop-Torim 73	138.35 de	179.56 c-f	41.21 ghi	89.38 gh	14.01 abc	28.36 abc	32.50 c-g	3.84 e	52.19 a-e
Hyslop-Jupateco 73	135.28 f	181.69 bcd	46.41 def	92.64 efg	14.06 abc	29.08 abc	32.96 c-f	4.07 de	50.70 a-f
Hyslop-Huacamayo "S"	139.70 de	182.47 a-d	42.78 e-h	92.51 efg	13.77 a-d	31.00 ab	33.10 cde	4.05 de	56.33 abc
W. R. Mace-Inia 66	142.52 bc	183.07 abc	40.55 hi	96.79 cde	13.15 a-d	27.04 abc	26.60 i-l	4.65 abc	44.01 e-i
W. R. Mace-Siete Cerros 66	145.68 a	185.61 a	39.94 hi	99.83 cd	14.32 ab	30.57 ab	25.01 jkl	4.49 a-d	47.22 d-h
W. R. Mace-Torim 73	144.87 ab	183.11 abc	38.24 i	90.94 fgh	11.50 cde	23.23 abc	25.64 jkl	4.20 b-e	47.69 c-g
W. R. Mace-Jupateco 73	142.97 b	177.55 efg	42.18 f-i	92.27 e-h	13.77 a-d	31.81 a	28.50 g-k	4.67 ab	49.13 b-f
W. R. Mace-Huacamayo "S"	145.60 a	179.21 def	38.88 hi	98.24 cd	11.88 b-e	25.06 abc	26.78 i-l	4.49 a-d	47.02 d-i
Average	133.70	179.42	45.73	99.44	12.51	26.65	30.35	4.37	48.37

*Duncan's new multiple range test. Means with the same letter are not significantly different at the 5% probability level.

Appendix Table 11. Mean values for nine agronomic characters measured in 25 backcrosses to spring wheat parents grown at Hyslop Farm, 1977-78.

Cross	Heading Date	Maturity Date	Filling Period	Plant Height (cm)	Tillers Per Plant	Grain Yield (gm)	Harvest Index %	100 Kernel Weight (gm)	Kernels Per Spike
Kavkaz-Inia 66	114.24 i*	174.66 ghi	60.42 a-d	94.20 cde	10.46 abc	15.24 d	31.48 d-h	4.07 c-f	35.90 h
Kavkaz-Siete Cerros 66	121.94 def	180.77 abc	58.84 b-g	98.74 abc	10.13 abc	23.58 a-d	35.29 a-e	4.23 a-e	54.97 ab
Kavkaz-Torim 73	121.09 d-g	177.69 c-h	56.60 b-i	85.68 fgh	12.94 ab	20.49 bcd	32.52 c-h	3.85 e-j	41.06 e-h
Kavkaz-Jupateco 73	114.63 i	175.06 f-i	60.44 a-d	88.80 d-g	9.95 bc	15.01 d	32.93 b-h	3.97 d-i	37.77 fgh
Kavkaz-Huacamayo "S"	124.44 cd	179.63 a-e	55.20 c-j	104.49 a	11.46 abc	25.72 ab	31.57 d-h	4.64 a	47.73 b-e
Roussalka-Inia 66	109.63 j	175.41 e-i	65.28 a	85.60 fgh	10.47 abc	19.12 bcd	36.60 abc	4.07 c-f	44.76 d-g
Roussalka-Siete Cerros 66	119.23 fg	178.90 b-g	59.67 a-d	92.18 c-f	10.60 abc	19.94 bcd	35.51 a-d	3.92 d-i	47.48 b-e
Roussalka-Torim 73	117.99 gh	178.99 b-f	61.00 abc	78.74 i	12.32 abc	20.48 bcd	37.07 ab	3.76 f-j	44.10 d-g
Roussalka-Jupateco 73	110.93 j	172.96 i	62.03 ab	84.82 ghi	11.93 abc	18.74 bcd	36.89 ab	3.88 e-j	40.33 e-h
Roussalka-Huacamayo "S"	122.59 c-f	177.41 c-h	54.82 d-k	89.54 d-g	12.01 abc	23.54 a-d	31.50 d-h	4.44 abc	41.44 e-h
Yamhill-Inia 66	121.21 d-g	176.50 c-i	55.34 c-j	95.19 cd	12.01 abc	23.01 a-d	33.96 a-h	3.98 d-h	48.16 b-e
Yamhill-Siete Cerros 66	130.28 a	183.80 a	53.53 e-k	103.04 ab	11.77 abc	25.42 abc	30.42 ghi	4.02 c-h	53.10 abc
Yamhill-Torim 73	123.25 cde	176.42 d-i	53.17 g-k	89.53 d-g	11.56 abc	21.21 bcd	37.21 a	3.83 e-j	47.58 b-e
Yamhill-Jupateco 73	119.29 fg	175.35 e-i	56.07 b-j	92.53 c-f	10.78 abc	17.28 bcd	32.17 d-h	3.57 ij	44.98 d-g
Yamhill-Huacamayo "S"	130.26 a	179.25 b-f	48.99 k	104.22 ab	12.72 ab	24.88 abc	30.58 ghi	4.58 ab	42.21 d-h
Hyslop-Inia 66	119.30 fg	176.54 c-i	57.24 b-h	92.26 c-f	10.51 abc	20.58 bcd	34.87 a-f	4.18 b-e	46.58 cde
Hyslop-Siete Cerros 66	126.06 bc	180.57 a-d	54.51 d-k	97.80 abc	12.22 abc	19.92 bcd	27.28 i	3.65 g-j	40.58 d-g
Hyslop-Torim 73	122.33 def	175.77 e-i	53.44 f-k	81.10 hi	11.96 abc	17.66 bcd	30.81 f-i	3.53 j	41.97 e-h
Hyslop-Jupateco 73	115.42 hi	174.61 hi	59.19 b-f	88.27 d-g	11.64 abc	15.64 cd	30.57 ghi	3.62 hij	37.03 gh
Hyslop-Huacamayo "S"	128.52 ab	179.22 b-f	50.70 jk	94.00 cde	12.40 abc	25.49 ab	31.01 f-i	4.32 a-d	47.72 b-e
W. R. Mace-Inia 66	120.23 efg	175.72 e-i	55.49 c-j	93.55 cde	11.22 abc	23.54 a-d	34.36 a-g	4.08 c-f	50.40 a-d
W. R. Mace-Siete Cerros 66	129.34 ab	181.99 ab	52.64 h-k	97.35 bc	13.26 a	30.82 a	33.16 a-h	4.04 c-g	57.30 a
W. R. Mace-Torim 73	124.04 cd	176.52 c-i	52.48 h-k	84.29 ghi	9.48 c	17.11 bcd	31.29 e-h	3.65 g-j	48.93 b-e
W. R. Mace-Jupateco 73	118.08 g	177.55 c-h	59.47 a-e	87.83 efg	11.28 abc	20.91 bcd	34.94 a-f	3.72 f-j	48.99 b-e
W. R. Mace-Huacamayo "S"	128.40 ab	179.21 b-f	50.81 ijk	97.46 abc	12.26 abc	24.04 a-d	30.00 hi	4.25 a-e	45.52 c-f
Average	121.31	177.62	56.29	92.05	11.49	21.17	32.96	3.99	45.74

*Duncan's new multiple range test. Means with the same letter are not significantly different at the 5% probability level.

Appendix Table 12. Mean values for nine agronomic characters measured in 10 F1 crosses of winter x winter wheat grown at Hyslop Farm, 1977-78.

Cross	Heading Date	Maturity Date	Filling Period	Plant Height (cm)	Tillers Per Plant	Grain Yield (gm)	Harvest Index %	100 Kernel Weight (gm)	Kernels Per Spike
Rousssalka-Kavkaz	130.15 e*	175.36 d	45.22 a	105.95 abc	12.70 a	27.37 a	27.71 bcd	4.58 a	47.29 c
Yamhill-Kavkaz	145.10 c	184.25 ab	39.14 b	114.57 a	12.67 a	38.92 a	28.51 bcd	4.84 a	63.20 a
Hyslop-Kavkaz	138.20 d	180.70 bc	42.50 ab	108.33 abc	15.14 a	35.34 a	30.60 abc	4.61 a	50.23 c
W. R. Mace-Kavkaz	150.54 a	185.37 a	34.83 c	109.36 ab	13.00 a	30.28 a	24.19 d	4.69 a	49.03 c
Yamhill-Roussalka	134.69 d	180.29 c	45.60 a	105.56 abc	13.89 a	39.07 a	32.98 ab	4.74 a	59.25 ab
Hyslop Roussalka	130.43 e	176.50 d	46.08 a	93.68 d	12.48 a	32.09 a	35.66 a	4.55 a	56.13 abc
W. R. Mace-Roussalka	136.52 d	178.65 cd	42.13 ab	99.26 cd	12.88 a	28.92 a	27.47 bcd	4.58 a	49.34 c
Hyslop-Yamhill	146.50 bc	184.83 a	38.33 bc	103.95 bc	11.54 a	31.39 a	32.27 ab	4.40 a	61.44 a
W. R. Mace-Yamhill	149.48 ab	187.39 a	37.91 bc	101.82 bcd	14.74 a	37.78 a	24.77 cd	4.81 a	51.49 bc
W. R. Mace-Hyslop	150.08 ab	187.48 a	37.45 bc	100.51 bcd	15.15 a	38.29 a	29.94 a-d	4.60 a	54.32 abc
Average	141.17	182.08	40.92	104.30		33.95	29.41	4.64	54.17

*Duncan's new multiple range test. Means with the same letter are not significantly different at the 5% probability level.

Appendix Table 13. Mean values for nine agronomic characters measured in five spring parents and 10 F1 crosses of spring x spring wheat grown at CIANO, 1977-78.

Spring Parents	Heading Date	Maturity Date	Filling Period	Plant Height (cm)	Tillers Per Plant	Grain Yield (gm)	Harvest Index %	100 Kernel Weight (gm)	Kernels Per Spike
Inia 66	72.90 d*	123.10 c	50.20 bc	80.69 b	15.25 b	30.46 b	43.22 a	4.16 b	47.94 b
Siete Cerros 66	80.74 a	132.97 a	52.23 a	80.17 b	18.61 c	35.22 ab	38.36 a	3.42 d	55.06 a
Torim 73	75.43 bc	124.03 c	48.61 c	58.82 c	14.26 c	21.63 c	39.38 a	3.55 d	42.59 c
Jupateco 73	74.13 cd	126.49 b	52.36 a	83.51 a	20.10 a	39.80 a	40.73 a	3.95 c	49.97 b
Huacamayo "S"	76.52 b	127.31 b	50.79 ab	81.33 b	15.57 c	33.05 b	39.34 a	4.46 a	46.91 bc
Average	75.94	126.78	50.84	76.90	16.76	32.03	40.21	3.91	48.57
SXS F1's									
Inia 66-Siete Cerros 66	72.02 c	127.76 bc	55.74 a	80.95 ab	17.49 ab	38.62 ab	44.48 a	4.10 cd	54.71 ab
Inia 66-Torim 73	75.91 b	126.84 bc	50.93 c	68.17 c	14.81 ab	29.05 b	42.16 ab	3.89 d	50.41 abc
Inia 66-Jupateco 73	74.95 bc	126.24 c	51.29 c	77.77 b	16.08 ab	29.89 b	40.58 ab	4.06 cd	45.77 c
Inia 66-Huacamayo "S"	75.57 b	127.46 bc	51.89 bc	82.42 ab	13.81 b	29.32 b	40.40 ab	4.61 a	45.82 c
Siete Cerros 66-Torim 73	77.58 ab	131.88 a	54.30 ab	69.62 c	17.11 ab	33.60 ab	39.87 b	3.80 d	51.78 abc
Siete Cerros 66-Jupateco 73	75.04 b	130.10 ab	55.07 a	83.60 a	18.90 a	42.44 a	40.07 ab	4.06 cd	55.94 ab
Siete Cerros 66-Huacamayo "S"	80.60 a	131.93 a	51.34 c	80.98 ab	15.30 ab	34.58 ab	39.58 b	3.98 cd	56.98 a
Torim 73-Jupateco 73	74.70 bc	129.09 abc	54.39 ab	70.93 c	17.23 ab	33.19 ab	42.71 ab	4.05 cd	46.69 c
Torim 73-Huacamayo "S"	76.87 b	128.68 abc	51.81 bc	71.42 c	15.42 ab	29.78 b	39.97 ab	4.26 bc	45.00 c
Jupateco 73 - Huacamayo "S"	75.91 b	126.56 c	50.65 c	82.04 ab	14.75 ab	32.79 ab	41.25 ab	4.50 ab	49.66 bc
Average	75.92	128.65	52.73	76.79	16.09	33.33	41.11	4.13	50.28

*Duncan's new multiple range test. Means with the same letter are not significantly different at the 5% probability level.

Appendix Table 14. Mean values for nine agronomic characters measured in 25 winter x spring F2 wheat crosses grown at CIANO, 1977-78.

Cross	Heading Date	Maturity Date	Filling Period	Plant Height (cm)	Tillers Per Plant	Grain Yield (gm)	Harvest Index %	100 Kernel Weight (gm)	Kernels Per Spike
Kavkaz-Inia 66	87.26 de*	129.56 i	42.30 def	100.36 ab	14.39 hi	32.67 b-e	35.59 abc	4.33 abc	52.50 a-d
Kavkaz-Siete Cerros 66	89.74 a-d	133.05 b-f	43.18 a-f	91.26 d-g	16.10 f-i	28.72 de	33.13 a-d	3.76 e-i	47.64 a-f
Kavkaz-Torim 73	86.65 def	129.85 hi	43.21 a-f	85.56 g-j	14.11 i	29.50 de	37.18 abc	3.92 d-h	53.50 abc
Kavkaz-Jupateco 73	88.15 a-e	129.03 i	40.88 f	101.19 a	15.60 ghi	36.16 b-e	36.17 abc	4.33 abc	53.56 ab
Kavkaz-Huacamayo "S"	89.83 a-d	131.27 e-i	41.44 ef	100.46 ab	14.68 hi	33.12 b-e	33.77 a-d	4.58 a	49.57 a-d
Roussalka-Inia 66	83.30 f	129.67 i	46.37 a	83.22 hij	16.38 f-i	31.58 b-e	37.66 ab	4.18 bcd	46.15 a-f
Roussalka-Siete Cerros 66	86.99 de	133.08 b-f	46.09 abc	82.26 ij	16.05 f-i	32.00 b-e	36.29 abc	4.11 d-e	48.57 a-e
Roussalka-Torim 73	84.73 ef	130.72 ghi	45.99 a-d	73.78 h	17.10 e-i	29.57 de	36.69 abc	3.74 e-i	46.49 a-f
Roussalka-Jupateco 73	84.74 ef	131.16 e-i	46.42 a	85.02 g-j	19.35 b-g	38.28 b-e	37.07 abc	3.96 c-h	50.02 a-d
Roussalka-Huacamayo "S"	86.53 def	130.88 f-i	44.22 a-f	87.06 e-i	14.84 ghi	30.71 de	35.33 abc	4.44 ab	46.54 a-f
Yamhill-Inia 66	89.42 a-d	133.53 a-d	44.11 a-f	98.45 abc	20.63 b-f	37.59 b-e	31.93 a-d	3.52 i	50.18 a-d
Yamhill-Siete Cerros 66	90.14 a-d	135.45 ab	45.31 a-d	104.01 a	20.58 b-f	32.15 b-e	29.04 cd	3.68 ghi	42.38 def
Yamhill-Torim 73	90.27 a-d	133.48 a-e	43.22 a-f	89.45 e-h	21.54 a-e	37.98 b-e	33.46 a-d	3.60 hi	48.38 a-f
Yamhill-Jupateco 73	91.98 a	134.54 abc	42.56 b-f	92.67 c-e	21.15 b-e	29.70 de	35.60 abc	3.21 j	43.08 c-f
Yamhill-Huacamayo "S"	91.93 a	134.34 abc	42.41 c-f	103.46 a	17.33 e-i	31.44 cde	30.55 bcd	3.75 e-i	49.03 a-e
Hyslop-Inia 66	87.86 cde	131.93 d-h	44.07 a-f	92.57 c-f	18.69 b-h	38.33 b-e	37.01 abc	4.06 b-f	50.68 a-d
Hyslop-Siete Cerros 66	89.94 a-d	134.63 abc	44.69 a-e	83.63 hij	18.69 b-h	36.14 b-e	32.61 a-d	3.90 d-h	49.57 a-d
Hyslop-Torim 73	89.43 a-d	133.10 b-f	43.67 a-f	79.45 jh	22.19 abc	39.95 bcd	36.38 abc	3.68 ghi	48.89 a-e
Hyslop-Jupateco 73	89.85 a-d	132.64 c-g	42.79 a-f	91.72 c-g	25.79 a	57.04 a	39.88 a	3.95 c-h	56.41 a
Hyslop-Huacamayo "S"	91.52 abc	135.01 ab	43.49 a-f	97.72 a-d	23.15 ab	44.04 bc	32.19 a-d	3.93 d-h	48.61 a-e
W. R. Mace-Inia 66	89.77 a-d	133.80 a-d	44.04 a-f	93.72 b-e	17.57 d-i	35.33 b-e	33.38 a-d	4.28 a-d	46.97 a-f
W. R. Mace-Siete Cerros 66	87.65 cde	135.88 a	45.73 a-d	84.29 hij	17.92 c-i	31.57 b-e	31.09 bcd	3.83 e-i	45.21 b-f
W. R. Mace-Torim 73	91.67 ab	134.14 a-d	42.46 c-f	81.89 ij	18.72 b-h	26.80 e	27.15 d	3.71 f-i	38.73 ef
W. R. Mace-Jupateco 73	87.04 de	133.27 b-e	46.23 ab	93.00 c-e	22.07 a-d	44.17 b	33.33 a-d	4.26 b-f	49.14 a-d
W. R. Mace-Huacamayo "S"	89.32 a-d	134.56 abc	45.24 a-d	85.67 f-j	20.52 b-f	32.08 b-e	26.39 d	4.05 c-g	38.38 f
Average	88.63	132.74	44.11	90.47	18.61	35.06	33.95	3.95	48.02

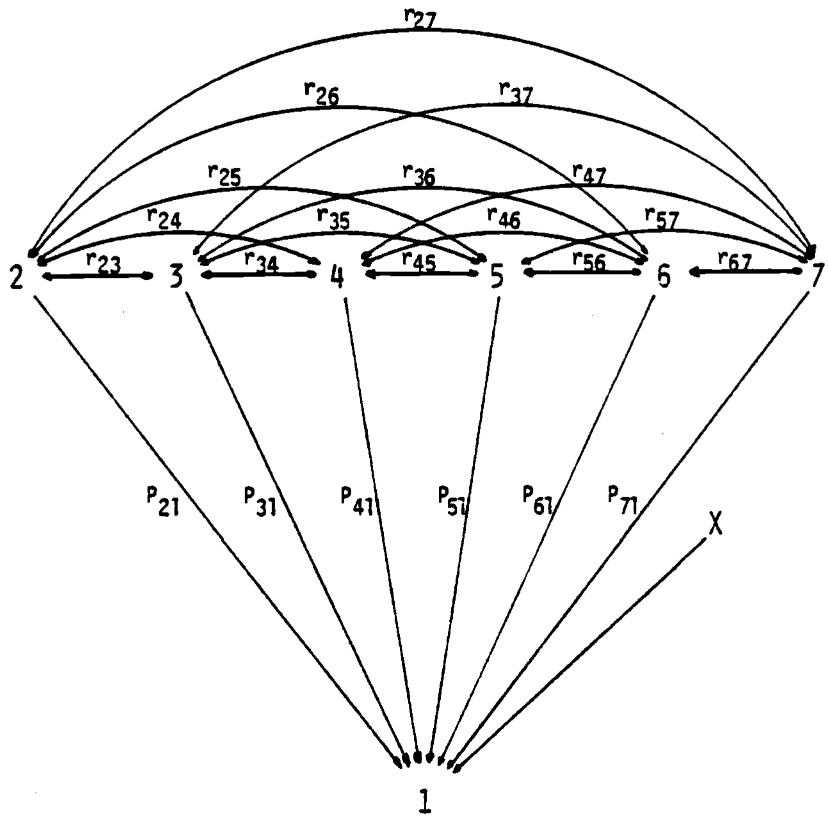
*Duncan's new multiple range test. Means with the same letter are not significantly different at the 5% probability level.

Appendix Table 15. Mean values for nine agronomic characters measured in 25 backcrosses to spring wheat parents grown at CIANO, 1977-78.

Cross	Heading Date	Maturity Date	Filling Period	Plant Height (cm)	Tillers Per Plant	Grain Yield (gm)	Harvest Index %	100 Kernel Weight (gm)	Kernels Per Spike
Kavkaz-Inia 66	79.50 jk*	127.76 l	48.28 abc	87.31 abc	13.60 j	30.71 de	39.47 a-d	4.31 abc	52.18 a-d
Kavkaz-Siete Cerros 66	85.14 d-h	133.38 b	48.24 abc	86.94 abc	15.32 e-j	31.44 de	34.92 e-h	3.78 gh	54.06 ab
Kavkaz-Torim 73	81.34 ij	128.94 jkl	47.61 a-d	71.38 fg	14.79 f-j	28.72 e	38.89 a-e	3.84 fgh	50.60 a-d
Kavkaz-Jupateco 73	81.12 ijk	128.62 kl	47.25 a-e	95.04 ab	15.36 e-j	37.68 a-d	40.20 abc	4.31 abc	56.84 a
Kavkaz-Huacamayo "S"	85.50 c-h	129.83 h-k	44.33 fg	92.48 abc	13.73 j	31.59 de	37.54 b-g	4.48 a	51.78 a-d
Roussalka-Inia 66	78.32 k	128.44 kl	50.13 a	79.09 de	15.88 e-j	31.88 de	43.12 a	4.18 cde	48.10 bcd
Roussalka-Siete Cerros 66	84.43 fgh	132.52 c-f	48.09 abc	78.77 def	16.54 d-j	34.15 cde	38.22 b-f	3.95 efg	52.62 a-d
Roussalka-Torim 73	79.70 jk	128.23 kl	48.53 abc	65.96 g	16.23 d-j	30.03 de	40.74 ab	3.72 ghi	49.71 a-d
Roussalka-Jupateco 73	79.72 jk	128.99 jkl	49.28 ab	86.93 abc	20.22 abc	43.17 a	38.91 a-e	4.15 cde	51.02 a-d
Roussalka-Huacamayo "S"	83.26 ghi	130.56 g-j	47.30 a-e	81.44 cde	14.39 g-j	30.29 de	37.52 b-g	4.54 a	46.58 cd
Yamhill-Inia 66	84.56 e-h	131.69 c-h	47.13 b-f	93.14 abc	17.11 c-h	33.35 de	35.85 d-h	3.95 efg	48.33 bcd
Yamhill-Siete Cerros 66	89.21 ab	135.46 a	46.25 c-g	88.36 abc	18.22 b-e	30.48 de	32.29 h	3.53 i	47.67 bcd
Yamhill-Torim 73	87.85 a-d	133.01 bcd	45.16 d-g	77.15 def	17.42 b-g	33.43 de	37.38 b-g	3.71 ghi	51.84 a-d
Yamhill-Jupateco 73	86.99 a-f	133.34 bc	46.35 c-g	92.29 abc	21.41 a	42.58 ab	37.34 b-g	3.84 fgh	52.10 a-d
Yamhill-Huacamayo "S"	87.61 a-e	131.17 d-i	43.57 g	92.95 abc	15.67 e-j	33.78 de	34.42 fgh	4.29 a-d	50.51 a-d
Hyslop-Inia 66	83.42 ghi	129.58 i-l	46.15 c-g	87.77 abc	15.54 e-j	33.18 de	39.87 a-d	4.21 bcd	51.26 a-d
Hyslop-Siete Cerros 66	88.60 abc	135.02 ab	46.42 b-f	83.32 bcd	17.78 b-f	34.92 b-e	34.06 fgh	3.80 gh	51.52 a-d
Hyslop-Torim 73	85.58 c-h	131.86 cg	46.28 c-g	68.65 g	17.17 c-g	30.23 de	38.68 b-e	3.65 hi	48.36 bcd
Hyslop-Jupateco 73	83.68 ghi	130.89 e-j	47.21 a-e	89.08 abc	19.10 a-d	41.86 abc	41.00 ab	4.08 def	53.92 abc
Hyslop-Huacamayo "S"	88.16 a-d	132.66 c-f	44.49 efg	90.64 abc	17.14 c-h	34.57 cde	33.90 gh	4.29 a-d	46.99 bcd
W. R. Mace-Inia 66	82.81 hi	130.15 g-k	47.34 a-e	95.76 a	16.19 d-j	37.37 a-d	38.17 b-f	4.47 ab	51.65 a-d
W. R. Mace-Siete Cerros 66	89.71 a	136.43 a	46.71 b-f	82.74 cd	16.94 d-i	33.44 de	33.57 gh	3.71 ghi	53.12 abc
W. R. Mace-Torim 73	88.53 abc	133.33 bc	44.80 d-g	75.66 ef	16.51 d-j	30.97 de	36.11 c-h	3.79 gh	49.86 a-d
W. R. Mace-Jupateco 73	85.17 d-h	132.82 cde	47.65 a-d	94.80 ab	20.35 ab	41.85 abc	36.29 c-h	4.13 cde	49.97 a-d
W. R. Mace-Huacamayo "S"	86.10 b-g	130.75 f-j	44.65 efg	92.27 abc	14.06 ij	28.97 e	32.85 h	4.52 a	45.70 d
Average	84.64	131.42	46.78	85.20	16.67	34.03	37.25	4.05	50.65

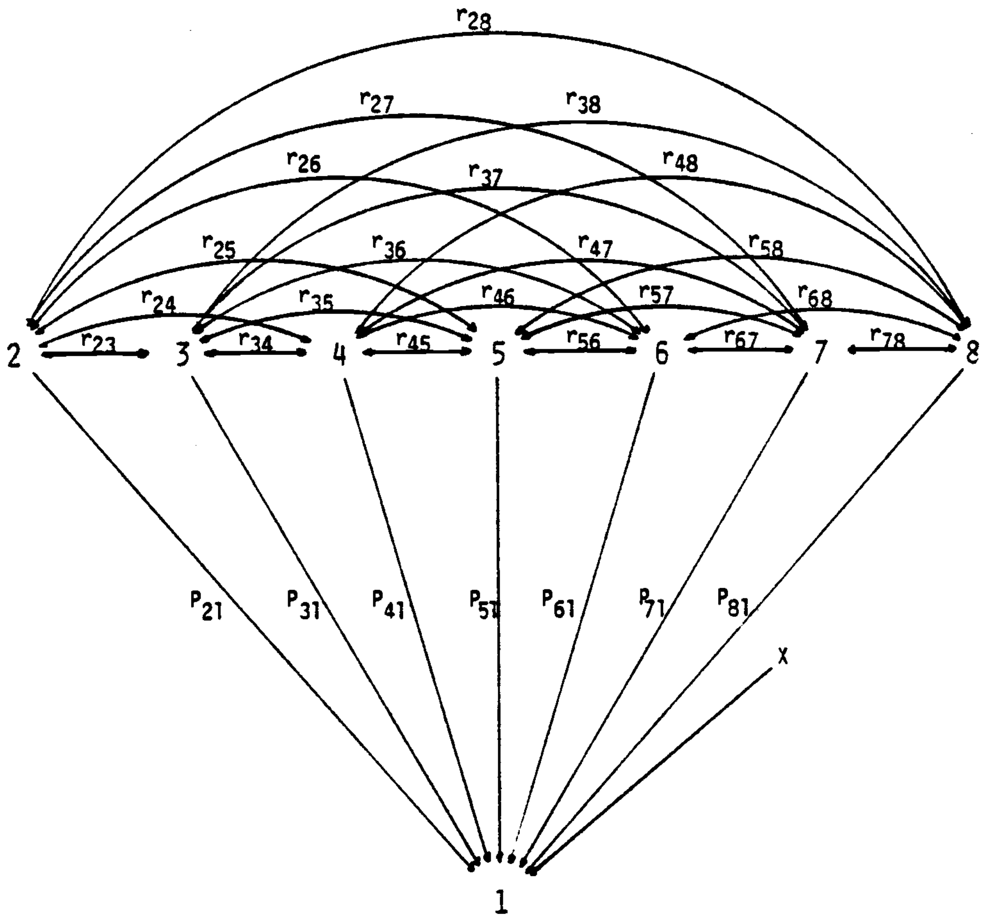
*Duncan's new multiple range test. Means with the same letter are not significantly different at the 5% probability level.

Appendix Figure 1. Path diagram and association of the agronomic characters considered in Study II. Hyslop Farm, 1977-78.



1 = Grain Yield
2 = Heading Date
3 = Maturity Date
4 = Plant Height
5 = Tillers Per Plant
6 = Kernel Weight
7 = Kernels Per Spike
P = Path-coefficient
X = Residual Factor
r = Correlation coefficient between any two of the independent variables (2 - 7)

Appendix Figure 2. Path diagram and association of the agronomic characters considered in Study III. CIANO, 1977-78.



1 = Grain Yield
2 = Heading Date
3 = Maturity Date
4 = Plant Height
5 = Tillers Per Plant
6 = Harvest Index
7 = Kernel Weight
8 = Kernels Per Spike
P = Path-coefficient
X = Residual

r = correlation coefficient between any two of the independent variables (2 - 8).