5-1973

Evaluation of Yield, Yield Components and Other Agronomic Characteristics in Mixtures of Wheat and Barley

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EVALUATION OF YIELD, YIELD COMPONENTS AND OTHER AGRONOMIC CHARACTERISTICS IN MIXTURES OF WHEAT AND BARLEY

by

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A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Plant Science

Approved:

UTAH STATE UNIVERSITY
Logan, Utah

1973

ACKNOWLEDGMENTS

I would like to express my sincere appreciation to all who have contributed to make this thesis possible. The Agency for International Development (AID) and the Bolivian Government provided the funds for my studies in the United States. Invaluable cooperation was given by Dr. R. S. Albrechtsen, without whose help this paper could never have been completed. Drs. W. G. Dewey, D. R. McAllister, and O. S. Cannon were most helpful during the entire work. Grateful acknowledgment is also expressed to Dr. D. V. Sisson for assistance in analyzing the data.

I would also like to express my appreciation to my mother and brothers for the constant encouragement and help they have given me during the writing of this thesis.

Hugo Villarroel-Arispe

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ABSTRACT

Evaluation of Yield, Yield Components and Other Agronomic Characteristics in Mixtures of Wheat and Barley

by

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Utah State University, 1973

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Inia 66 and Siete Cerros wheat varieties, and Steveland and Woodvale barley varieties were grown in mixtures and in pure stands for two years in irrigated nurseries at Logan. These four varieties were also grown the first year in a dryland nursery at Blue Creek. Another set of four varieties was used the second year in the dryland nursery. These four varieties as well as the first set, were tested in seven combinations, with the following percentages of one barley and one wheat variety: 100:0, 90:10, 75:25, 50:50, 25:75, 10:90, and 0:100.

Grain yield of mixtures was higher than that of the mid-component value in most cases and was higher than that of the best component in a few cases. Only a few of the observed differences were statistically significant.

All mixtures had significantly lower test weight than that of the best component. Ninety percent of the mixtures were significantly lower in test weight than the mid-component value.

Tillering of both wheat varieties consistently decreased as the percentage of wheat in the seeded mixture decreased. Conversely, tillering in barley increased as the percentage of barley in the seeded mixture decreased.

Most of the mixtures showed an excess of barley in the harvested crop, compared to that in the seeded mixture. These excesses were usually greatest around the 50:50 mixture level.

A consistent pattern of slight increase in kernel weight of barley was observed as the amount of barley decreased in the seeded mixture. Wheat showed the reverse situation. None of these differences were statistically significant.

Inter-relationships among yield components were evaluated by simple correlation coefficients. The correlations were subdivided into direct and indirect effects by the use of path coefficient analyses. Correlation coefficients and path coefficients showed consistent changes as the percentage of crop mixtures changed. Coefficients of determination for both wheat and barley decreased as the percentage of that crop in the seeded mixture was decreased.

(103 pages)

INTRODUCTION

The commercial possibilities of heterogeneous populations produced by mixing different genotypes, different varieties and even different crops have received increased attention in recent years. Among the possible advantages of such populations are: (1) greater grain yield through more efficient use of the environment, (2) greater stability in yield over different environments and (3) lower incidence of diseases.

So far, however, the presence of mixtures in cereals and other crop seeds is usually considered a problem not only to plant breeders and producers of "pure seeds," but also to commercial interests. These admixtures are troublesome, especially when comprised of crops belonging to the same or closely related species. It is well established that admixtures of barley and/or oats within a wheat crop lessen the milling, flour and baking quality of the wheat. Such mixtures are not objectionable if the resulting crop is to be used for animal feed, and may possibly be advantageous in some instances. Frankel (1950) wrote:

> "From the early days of plant breeding, uniformity has been sought after with great determination. For this there are many reasons--technical, commercial, historical, psychological, aesthetic, etc.,--. It seems to me that the 'purity concept' has not only been carried to unnecessary lengths but that it may be altogether inimical to the attainment of highest production."

He added that strict purity is commonly an illusion and is concerned with characters which are readily seen, but are often of little significance.

A knowledge of the effects of mixtures on grain yield and other agronomic characteristics will be helpful in understanding the possible value of crop mixtures. An understanding of relationships among the components of the mixture when grown under different environments will also be helpful in assessing such mixtures.

The specific objectives of this study were: (1) to evaluate the effects of crop mixtures upon grain yield and yield components (tillering, kernel number per head and kernel size); (2) to determine the effect of mixtures upon lodging resistance in barley; (3) to learn the possible differential response of mixtures to different environmental conditions (dryland and irrigated); and (4) to study the nature of survival in competitive mixtures.

REVIEW OF LITERATURE

Many studies on competition between cereal plants have been reported. Most of these studies were conducted primarily to evaluate the yield of mixtures, yield stability, and the incidence of diseases when grown in different or changing environments.

Genotype and Varietal Mixtures

Numerous examples are present in the literature reporting that mixtures of different genotypes or varieties, within self-pollinated crops, produce higher seed yields than do homogeneous cultivars.

Clay and Allard (1969), concluded that barley varietal mixtures tended to yield slightly more than the mean of their components. They also concluded that the advantage of the mixtures increased as environmental heterogeneity increased.

Increased yields of oat cultivar mixtures, grown under stress environments, were reported by Frey and Maldonado (1967). This increase in seed yield was attributed to the fact that in mixtures, plants that were not damaged by adverse environmental conditions increased their productivity by utilizing nutrients and moisture which the damaged plants could no longer use. When damage occurred in homogeneous cultivars, however, there were no undamaged plants to utilize the unused nutrients and moisture.

Frey and Maldonado (1967) pointed out that there was no association between relative yield and the number of cultivars included in the mixtures.

Smith (1937), studying competition between plants of the same crop and variety, showed that stand irregularities occurring in mechanically sown fields were usually adequately compensated by differences in tillering, growth, and yield of the individual plants.

Jensen (1965) reported that composites of oat genotypes, when compared with the means of their component lines, over an 8-year period, showed composite yields to be 3.2 percent higher than the mean of the component lines. A 5-line oat multiline yielded 7.3 percent higher than the mean of its component lines.

Suneson (1949) pointed out that the relative yield of a variety does not necessarily determine its ability to survive in competition with other varieties.

Clay and Allard (1969) found some evidence that shattering was reduced when shattering types were mixed with non-shattering varieties, thus enhancing yield.

Harlan and Martini (1938), studying natural selection in mixtures of barley varieties, observed that the number of plants of a given variety present in a harvested mixture depended upon the number rather than the weight of seeds sown. The percentage survival of seedlings in competition was also considered as an important feature.

Laude and Swanson (1942) concluded that changes in varietal ratios of mixtures were brought about by competition among plants, resulting in the survival of a larger proportion of the better adapted variety than of the less well-adapted. These survival differences were enhanced by the production of more seeds in the surviving plants of the better adapted variety.

Grafius (1956b), working with oats and barley, suggested that cultivars differed in their inherent sensitivities to high temperatures. The degree of effect upon productivity depended upon whether the high-temperature period coincided with a temperature sensitive stage of plant growth. This highly thermal-changing environment is another case in which mixed crops would likely be advantageous.

Crop Mixtures

Several authors have studied competition between varietal mixtures of cereals, but very little is known about the response of different cereal crops grown in mixed populations.

Klages (1936), utilizing various oat and barley mixtures, found that the percentage of barley in the harvested crop was greater than the percentage planted. The difference between the percentage planted and that harvested was greatest in the mixture of 25 percent barley, in which case the proportion of barley harvested exceeded that planted by 27.5 percent. Further increases in the percentage of barley in the planted mixture resulted in a gradual decline in the difference between proportion planted and proportion harvested.

Seed yield of the various combinations of the two crops studied by Klages (1936), did not show great differences. However, the highest grain yield was obtained when the mixture contained 25 percent barley. Grain yield of this mixture was higher than that of the best component, which was the oat variety.

Pavlychenko (1937), studying barley and wheat in competition with wild oats, reported losses in seed yield of barley and wheat. Mutual competition between plants was given as the explanation for such losses. Both barley and wheat suffered considerably from competition with wild oats. Barley, however, was much more successful in competing with wild oats towards maturity.

Simmonds (1962) stated that uniformity of maturity is clearly imperative in fields of grain that are to be machine-harvested. He stated that though uniformity of grain quality is generally demanded, there are instances in which it is quite unnecessary. He cited maize and barley destined to be used for stock feed as examples which need not be grown in strictly pure stands. Likewise, Simmonds proposed that wheat to be used for livestock feed could well be grown in standard mixtures with either barley or oats.

Yield Components

Grafius (1956a, 1964) pointed out that in oats and barley, respectively, the complex trait, yield, has three components: number of heads per unit area (X), average number of kernels per head (Y), and average kernel weight (Z). When multiplied together, XYZ = W, make up the volume or yield. Final yield is considered a ratio or a product represented geometrically by a rectangular parallelepiped with the edges representing a percentage of the population mean. No yield changes can be made without changing one or more of the components.

Grafius (1959) suggested that the correlation between the edges X, Y, and Z was either small or zero. He, therefore, suggested that there were no genes for yield itself, but only for yield components.

In another study, Grafius and Wiebe (1959) concluded that it was better to concentrate on improving one edge at a time when the expected genetic gain for the other two was low. They suggested that it might be better to select for two or even three edges at one time if the expected genetic gain was high for this many components.

Yeh (1967) reported no significant differences in grain yield for oats when seeded at four different rates. This constancy in grain yield was due primarily to the counterbalance of two components, namely, the increase in panicles per unit area and the decrease in seeds per panicle. The other component, seed weight, was not affected.

Correlation and Path Coefficient Analysis

A path coefficient is described by Dewey and Lu (1959) as a standardized partial regression coefficient. As such, it measures the direct influence of one variable upon another and permits the break-down of the correlation coefficient into components of direct and indirect effects.

Yeh (1967) utilized simple correlation and path coefficient analyses to study the interrelationship of yield components in oats. He reported that panicles per unit area and seeds per panicle had the greatest direct effect upon yield. These components also showed significant effect indirectly through the other components. Seed weight had little effect upon grain yield, either directly or indirectly, through the other components.

Fonseca and Patterson (1968), using path coefficient analyses, concluded that yield components were highly correlated with grain yield in winter wheat. Each of the components had large direct effects on grain yield, and also important indirect effects, resulting from negative correlations among yield components.

Using correlation and path coefficients, Bhamonchant and Patterson (1964) studied the association of some morphological characters and lodging resistance in oats. Diameter of culm, height, and length of flag leaf sheath were the characters most highly related to lodging resistance.

MATERIALS AND METHODS

Four yield test experiments were conducted during the 1971 and 1972 seasons. Dryland nurseries were grown on the Utah State University Experimental Farm at Blue Creek both years. Irrigated nurseries were grown on the Evans farm in 1971 and on the Greenville farm in 1972. Both farms are located at Logan.

Mixtures involving two Mexican wheat varieties, Inia 66 and Siete Cerros, with two varieties of barley, Steveland and Woodvale, were compounded in seven different proportions as presented in Table 1. These varieties were utilized in the irrigated nurseries both years and in the 1971 dryland nursery. Make-up of mixtures was based on weight. The four varieties were also planted in pure stands. In the 1972 Blue Creek nursery the wheat varieties used were Bannock and Red River 68; the barley varieties were Caribou and Gem. The varieties used in 1972 were better adapted to dryland conditions than those used in the previous year.

Varietal Descriptions

Following is an agronomic description of the varieties used in the study.

Wheat

Inia 66 is a stiff-strawed Mexican semi-dwarf, hard red spring variety. It is white-chaffed, bearded and has medium sized kernels.

Table 1. Proportions of components of seeded mixtures.

Percentage by weight		Irrigated Percentage in number**		Dryland (1972)* Percentage in number	
Barley (%)	Wheat (%)	Barley (%)	Wheat (%)	Barley (%)	Wheat (%)
		Steveland -	Inia 66	Caribou -	Bannock
100	0	100.0	0.0	100.0	0.0
90	10	91.0	9.0	90.4	9.6
75	25	72.1	28.8	79.8	20.2
50	50	45.8	54.1	47.1	52.9
25	75	25.2	74.8	28.2	71.8
10	90	7.8	92.2	9.0	91.0
0	100	0.0	100.0	0.0	100.0
		Steveland-Siete Cerros		Caribou-Red River 68	
100	0	100.0	0.0	100.0	0.0
90	10	87.9	12.0	89.6	10.4
75	25	75.0	25.0	76.9	23.1
50	50	49.7	50.3	51.2	48.8
25	75	20.6	79.4	23.6	76.4
10	90	8.1	91.9	10.3	89.7
0	100	0.0	100.0	0.0	100.0
		Woodvale -	Inia 66	Gem -	Bannock
100	0	100.0	0.0	100.0	0.0
90	10	89.8	10.1	90.6	9.4
75	25	78.7	21.3	78.4	21.6
50	50	47.3	52.6	47.5	52.5
25	75	22.6	87.4	25.9	74.1
10	90	6.6	93.4	9.7	90.3
0	100	0.0	100.0	0.0	100.0
		Woodvale-Siete Cerros		Gem - Red River 68	
100	0	100.0	0.0	100.0	0.0
90	10	87.5	12.5	88.7	11.3
75	25	64.9	35.1	82.5	17.5
50	50	50.2	49.8	56.0	44.0
25	75	15.3	84.7	23.0	77.0
10	90	7.7	92.3	8.6	91.4
0	100	0.0	100.0	0.0	100.0

*Steveland, Woodvale, Inia 66 and Siete Cerros were the varieties used on dryland at Blue Creek in 1971.

**Percentages in number were taken on 25g samples.

It is grown primarily under irrigation or on drylands with better-than-average moisture. It is early-maturing with medium yielding capacity.

Siete Cerros is a hard white Mexican semi-dwarf with stiff straw. It is bearded and brown chaffed, has small kernels and high yielding capacity. It is best adapted under conditions of irrigation and high fertility. It matures 6 to 8 days later than Inia 66.

Bannock is a white chaffed, bearded semi-dwarf variety with moderately stiff straw, medium yield and good test weight. It is a hard red spring wheat with medium kernel size and early maturity.

Red River 68 is a semi-dwarf, hard red spring wheat with medium kernel size and intermediate maturity. It is adapted to both irrigated and dryland conditions.

Barley

Steveland is a rough-awned, six-row variety with short straw and moderately good lodging resistance. It yields well and is adapted to areas with medium moisture and fertility. It is an early maturing variety with medium kernel size.

Woodvale has semi-stiff straw, a semi-club, six row head and smooth awns. It is slightly taller and later than Steveland. It has a high yielding capacity and large kernel size.

Gem is an early-maturing, high-yielding, six-row variety that is grown to some extent on Utah's drylands. It has smooth awns and large kernels.

Caribou is a two-row, early-maturing, white-kerneled barley. It has good yield, straw strength and test weight under dryland conditions. It has medium kernel size.

Experimental Procedures

Mixtures and pure stands were grown both years in four-row plots with rows .30 m (1 foot) apart. Irrigated plots were 3.05 m (10 feet) long and were seeded at the rate of 100 kg/ha (89 lbs/acre). Dryland plots were 3.66 m (12 feet) long and were seeded at the rate of 84 kg/ha (75 lbs/acre). The two center rows of each plot were harvested for yield; 2.44 m (8 feet) on irrigated plots and 3.05 m (10 feet) on dryland plots.

The experimental design used was a 2x2x7 factorial with two varieties of barley and two varieties of wheat. These varieties were tested in seven combinations with the following percentages of one barley and one wheat variety: 100:0, 90:10, 75:25, 50:50, 25:75, 10:90 and 0:100. The plots were set up in the field in a randomized complete block design with four replications.

Dates of seeding at the two 1971 locations, Evans farm and Blue Creek farm, were April 13 and April 6, respectively. The 1972 nurseries, Greenville farm and Blue Creek farm, were planted on April 5 and April 7, respectively.

The irrigated nurseries were fertilized with 168 kg/ha of N (150 lb/acre), applied prior to seeding in 1971 and approximately five weeks after seeding in 1972. The dryland nurseries received 50 kg/ha (45 lbs/acre) of N fertilizer applied approximately five weeks after planting both years.

Collection of Data

At harvest time plant counts were made on a .60 m (2 foot) section of one border row per plot in the Greenville nursery only. Tillers per plant were obtained from these same sections. Harvest dates for the 1971 nurseries, Evans farm and Blue Creek farm, were August 18 and August 2, respectively. The 1972 nurseries, Greenville farm and Blue Creek farm, were harvested on August 5 and July 19, respectively.

Threshing was done with a standard Vogel nursery thresher. Yields of the mixed and pure crops were determined on a plot basis. Twenty-five-gram samples were used to determine the proportion of wheat and barley in the harvested mixtures. These percentages were then compared with corresponding planted mixtures. Wheat and barley kernel counts and weights were also determined from these samples.

Data Analysis

An analysis of variance was computed for all characteristics studied. A completely fixed-effect model was assumed for these analyses. Combined analyses of variance were also made for those characteristics for which data were recorded in two or more nurseries. Data for two missing plots in the 1972 Greenville nursery were estimated by the method presented by Snedecor and Cochran (1971).

The L.S.D. test was used to make individual comparisons between observed means and the appropriate check treatment. Mid-component, best component and expected (or calculated) values are among the checks that were used to make comparisons. Mid-component values are weighted arithmetic means of yields of the components (varieties in this case) making up the mixture, when grown in pure stands. Best component values are yield of the highest yielding variety in the mixture.

The interrelationships among grain yield and its components, as affected by levels of mixtures, were studied by computing simple correlation coefficients. The correlations were further analyzed by the path coefficient method as outlined by Li (1956) and Dewey and Lu (1959). A path coefficient is a standardized partial regression coefficient. It measures the direct effect of an independent variable (yield component) upon the dependent variable (yield) after removal of the influence of all other independent variables included in the analysis.

EXPERIMENTAL RESULTS

Grain Yield

Analysis of individual nurseries

Analysis of variance. A completely fixed-effects model was assumed for the analyses of variance of the yield data. Tables 2 and 3 show that mean squares for levels of mixture were significantly different at the .01 probability level for all four nurseries studied. The second order interaction (W x B x L) did not show statistical significance in any of the nurseries.

Barley varieties showed highly significant differences in the Greenville nursery and differences at the .05 probability level in the Evans nursery. No statistical differences between barley varieties were found at Blue Creek either year.

Inia 66 and Siete Cerros showed highly significant differences in yielding capacity in the 1971 Blue Creek and the Greenville nurseries. No statistical differences were observed between wheat varieties in the Evans or the 1972 Blue Creek nurseries.

A significant (.05 level) interaction effect between wheat and barley (W x B) was observed only in the Greenville nursery. The Greenville nursery was the only location at which a significant (.01 probability level) B x L interaction was observed.

Even though the two wheat varieties showed similar yielding capacities in the Evans and 1972 Blue Creek nurseries, they showed significant (.01 probability level) W x L interactions in these

Table 2. Mean squares for grain yield of two barley and two wheat varieties grown in different mixtures and in pure stands at three locations.

Source of variation	d. f.	Mean squares Evans 1971	Blue Creek 1971	Greenville 1972
Reps	3	19,692.0*	14,508.6**	27,180.5
Barley (B)	1	40,386.0*	43.8	175,143.2**
Wheat (W)	1	8,366.3	28,544.1**	126,968.2**
Level (L)	6	123,460.9**	7,562.6**	167,139.5**
W x B	1	5,076.0	4,425.1	40,927.5*
B x L	6	7,627.5	2,238.0	37,118.5**
W x L	6	27,329.7**	2,670.9	13,200.4
W x B x L	6	3,892.4	2,622.9	14,081.3
Error	81	7,203.3	2,302.4	9,699.5
Total	111	15,046.9		

*Significant at the .05 probability level.
**Significant at the .01 probability level.

Table 3. Mean squares for grain yield of two barley and two wheat varieties grown in different mixtures and in pure stands in the 1972 Blue Creek nursery.

Source of variation	d.f.	M.S.	F.
Reps	3	22,047.5	7.54**
Barley (B)	1	91.1	.03
Wheat (W)	1	2,386.5	.82
Level (L)	6	17,944.3	6.13**
W x B	1	3,076.5	1.05
B x L	6	5,409.1	1.85
W x L	6	4,796.4	16.40**
W x B x L	6	1,871.2	.64
Error	81	2,925.0	
Total	111	4,403.2	

*Significant at the .05 probability level.

**Significant at the .01 probability level.

nurseries. No significant W x L interaction was observed in the Greenville or the 1971 Blue Creek nurseries.

Mean comparisons. Tables 4, 5 and 6 show grain yield of Steveland and Woodvale barleys and Inia 66 and Siete Cerros wheats when grown in pure stands and in five combinations of mixtures. The same data are shown graphically in Figures 1, 2 and 3. The L.S.D. test was utilized to make individual comparisons between observed yields of mixtures and mid-component values and also between mixture yields and best component values. The same test was used to compare varietal yields.

Steveland and Woodvale barley varieties showed similar relative grain yielding protential at the Evans and Blue Creek farms in 1971. Steveland yielded significantly higher than Woodvale in the Greenville nursery. This difference is not readily explainable, since in many previous tests Woodvale has normally given yields as high or higher than those of Steveland.

Siete Cerros yielded significantly (.05 level) higher than Inia 66 in the Evans and Greenville nurseries grown under irrigation. These same varieties grown on dryland at Blue Creek in 1971, did not differ significantly in yield.

Yields of pure stands of barley were higher than those for pure stands of wheat in all comparisons, although some of these differences were not statistically significant. In general, the superiority of the barleys was greater when grown under irrigation than when grown under dryland conditions.

Individual comparisons among the different admixtures are more difficult to make because of inherent differences in yielding ability

Table 4. Grain yields (kg/ha) of two barley and two wheat varieties grown in different mixtures and in pure stands in the Evans nursery.

	Mixture seeded (%)		Grain yield in kg/ha		
Entry number	Barley	Wheat	Mixture	Mid-component	Best component
			Steveland - Inia 66		
1	100	0	5,974.0	5,974.0	5,974.0
2	90	10	5,940.3	5,762.8	5,974.0
3	75	25	5,607.3	5,445.9	5,974.0
4	50	50	5,927.9**	4,917.8	5,974.0
5	25	75	5,338.2**	4,389.7	5,974.0
6	10	90	4,419.9	4,072.8	5,974.0
7	0	100	3,861.6	3,861.6	3,861.6
			Steveland - Siete Cerros		
8	100	0	5,974.0	5,974.0	5,974.0
9	90	10	6,233.0	5,836.2	5,974.0
10	75	25	6,085.0	5,629.6	5,974.0
11	50	50	5,186.9	5,285.2	5,974.0
12	25	75	5,244.0	4,940.9	5,974.0
13	10	90	5,197.0	4,734.2	5,974.0
14	0	100	4,596.5	4,596.5	4,596.5
			Woodvale - Inia 66		
15	100	0	5,775.5	5,775.5	5,775.5
16	90	10	5,869.7	5,584.1	5,775.5
17	75	25	4,867.3	5,297.0	5,775.5
18	50	50	5,866.3**	4,818.6	5,775.5
19	25	75	5,028.8*	4,340.1	5,775.5
20	10	90	4,645.3	4,053.0	5,775.5
21	0	100	3,861.6	3,861.6	3,861.6
			Woodvale - Siete Cerros		
22	100	0	5,775.5	5,775.5	5,775.5
23	90	10	5,476.1	5,657.6	5,775.5
24	75	25	5,180.1	5,480.8	5,775.5
25	50	50	4,662.1	5,186.0	5,775.5
26	25	75	5,493.0	4,891.2	5,775.5
27	10	90	4,911.0	4,714.4	5,775.5
28	0	100	4,596.5	4,596.5	4,596.5

*Significant at the .05 level in comparison with mid-component.
**Significant at the .01 level in comparison with mid-component.
L.S.D. at the .05 level = 642.4
L.S.D. at the .01 level = 852.0

Table 5. Grain yields (kg/ha) of two barley and two wheat varieties grown in different mixtures and in pure stands in the 1971 Blue Creek nursery.

	Mixture seeded (%)		Grain yield in kg/ha		
Entry number	Barley	Wheat	Mixture	Mid-component	Best component
			Steveland -	Inia 66	
1	100	0	1,642.8	1,642.8	1,642.8
2	90	10	1,340.1	1,620.6	1,642.8
3	75	25	1,501.6	1,587.3	1,642.8
4	50	50	1,700.7	1,538.8	1,642.8
5	25	75	1,843.3*	1,476.3*	1,642.8
6	10	90	1,606.5	1,443.0	1,642.8
7	0	100	1,420.8	1,420.8	1,420.8
			Steveland -	Siete Cerros	
8	100	0	1,642.8	1,642.8	1,642.8
9	90	10	1,254.0	1,596.1	1,642.8
10	75	25	1,267.4	1,526.1	1,642.8
11	50	50	1,603.8	1,409.4	1,642.8
12	25	75	1,202.9	1,292.7	1,642.8
13	10	90	1,235.2	1,222.7	1,642.8
14	0	100	1,176.0	1,176.0	1,176.0
			Woodvale -	Inia 66	
15	100	0	1,614.6	1,614.6	1,614.6
16	90	10	1,493.5	1,595.2	1,614.6
17	75	25	1,326.6	1,566.2	1,614.6
18	50	50	1,663.0	1,517.7	1,614.6
19	25	75	1,447.7	1,469.2	1,614.6
20	10	90	1,665.7	1,440.2	1,614.6
21	0	100	1,420.8	1,420.8	1,420.8
			Woodvale -	Siete Cerros	
22	100	0	1,614.6	1,614.6	1,614.6
23	90	10	1,587.7	1,570.7	1,614.6
24	75	25	1,332.0	1,505.0	1,614.6
25	50	50	1,353.6	1,395.3	1,614.6
26	25	75	1,472.0	1,285.6	1,614.6
27	10	90	1,364.3	1,219.9	1,614.6
28	0	100	1,176.0	1,176.0	1,176.0

*Significant at the .05 level in comparison with mid-component.
**Significant at the .01 level in comparison with mid-component.
L.S.D. at the .05 level = 363.2
L.S.D. at the .01 level = 481.7

Table 6. Grain yields (kg/ha) of two barley and two wheat varieties grown in different mixtures and in pure stands in the Greenville nursery.

	Mixture seeded (%)		Grain yield in kg/ha		
Entry number	Barley	Wheat	Mixture	Mid-component	Best component
			Steveland - Inia 66		
1	100	0	6,703.9	6,703.9	6,703.9
2	90	10	6,697.1	6,395.3	6,703.9
3	75	25	5,617.4	5,932.4	6,703.9
4	50	50	5,879.8	5,160.8	6,703.9
5	25	75	4,436.7	4,389.2	6,703.9
6	10	90	4,265.2	3,926.3	6,703.9
7	0	100	3,617.7	3,617.7	3,617.7
			Steveland - Siete Cerros		
8	100	0	6,703.9	6,703.9	6,703.9
9	90	10	5,471.1*	6,473.6	6,703.9
10	75	25	6,029.5	6,128.3	6,703.9
11	50	50	5,639.3	5,552.6	6,703.9
12	25	75	5,144.8	4,977.0	6,703.9
13	10	90	4,929.5	4,631.6	6,703.9
14	0	100	4,401.4	4,401.4	4,401.4
			Woodvale - Inia 66		
15	100	0	4,795.0	4,795.0	4,795.0
16	90	10	4,848.8	4,677.3	4,795.0
17	75	25	5,207.0	4,500.7	4,795.0
18	50	50	4,875.7	4,206.4	4,795.0
19	25	75	4,218.1	3,912.0	4,795.0
20	10	90	3,861.6	3,735.4	4,795.0
21	0	100	3,617.7	3,617.7	3,617.7
			Woodvale - Siete Cerros		
22	100	0	4,795.0	4,795.0	4,795.0
23	90	10	6,026.1**++	4,755.6	4,795.0
24	75	25	5,672.9**+	4,696.6	4,795.0
25	50	50	5,410.5*	4,598.2	4,795.0
26	25	75	4,848.8	4,499.8	4,795.0
27	10	90	5,240.7*	4,440.8	4,795.0
28	0	100	4,401.4	4,401.4	4,401.4

*Significant at the .05 level in comparison with mid-component.
**Significant at the .01 level in comparison with mid-component.
+Significant at the .05 level in comparison with best component.
++Significant at the .01 level in comparison with best component.
L.S.D. at the .05 level = 745.5
L.S.D. at the .10 level = 988.7

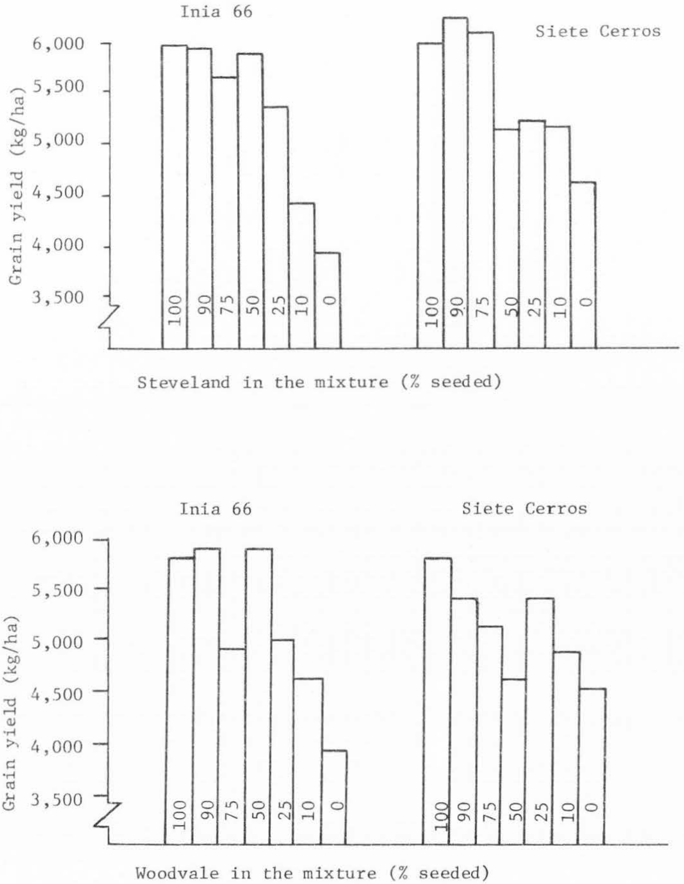


Figure 1. Average grain yield of Steveland and Woodvale grown in pure stands and intermixed with Inia 66 and Siete Cerros in the Evans nursery.

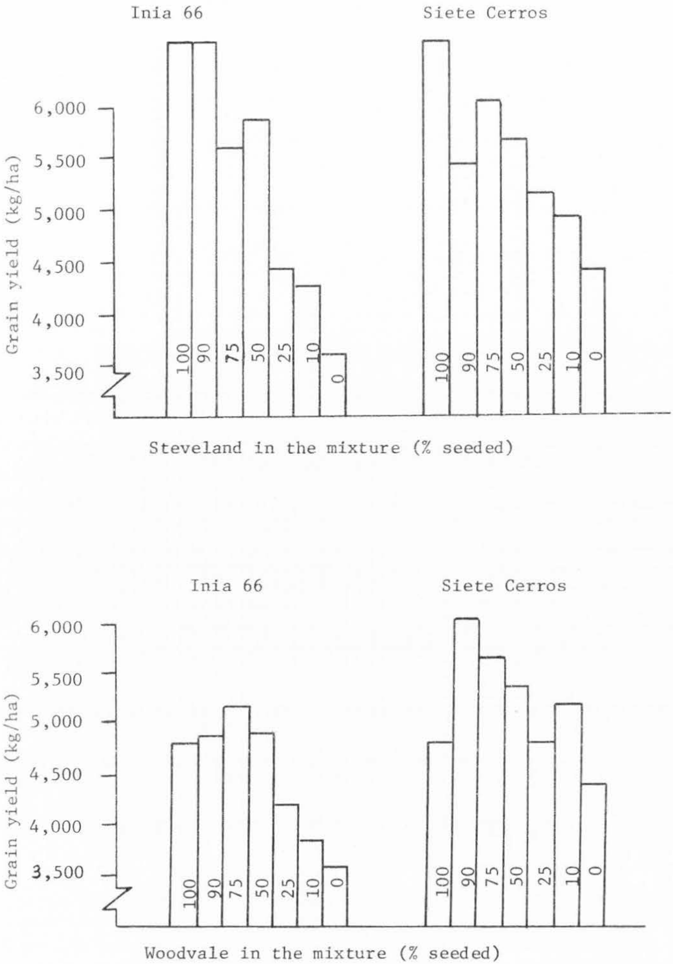


Figure 2. Average grain yield of Steveland and Woodvale grown in pure stands and intermixed with Inia 66 and Siete Cerros in the Greenville nursery.

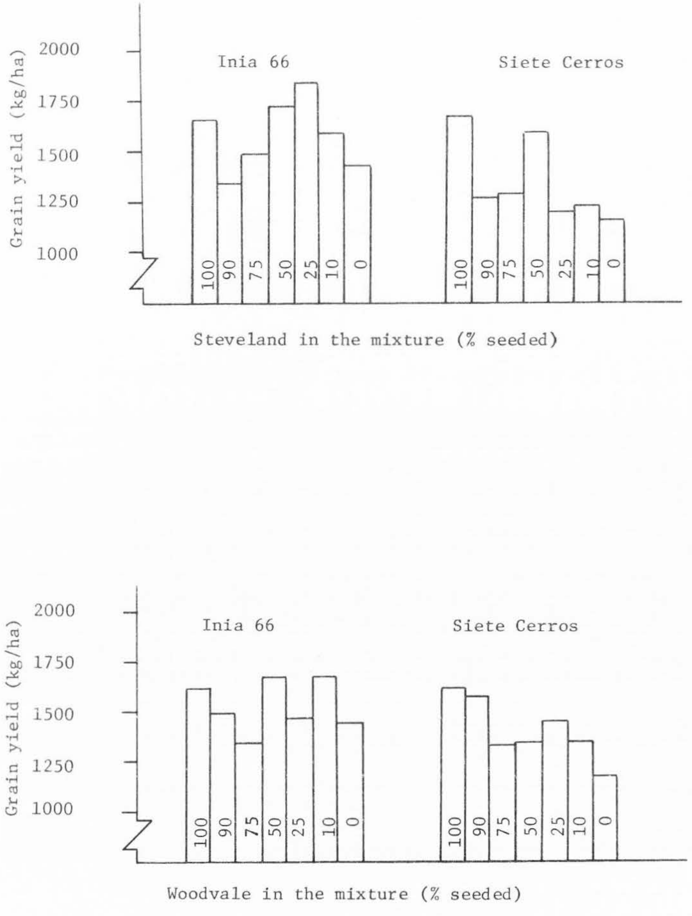


Figure 3. Average grain yield of Steveland and Woodvale grown in pure stands and intermixed with Inia 66 and Siete Cerros in the 1971 Blue Creek nursery.

of the varieties used in the mixtures. The absence of a standard check to which comparisons can be made is another problem.

Clay and Allard (1969) in a similar study conducted at different locations in California used Duncan's new multiple-range test to make mean comparisons. Grain yield of the mixtures was compared to that of the mid-component and/or the best component.

In the Evans nursery, 15 of the 20 mixtures yielded more than their respective calculated mid-component, but only four of the differences were statistically significant (Table 4). None of the mixtures yielded significantly less than the mid-component value.

Four of the mixtures, entries 9, 10, 16, and 18, had yields higher than those of the best component, but none of these differences were statistically significant.

Table 5 shows that half of the admixtures yielded more than the mid-component value in the 1971 Blue Creek nursery. Only one of these differences was statistically significant. None of the mixtures yielded significantly less than the mid-component value. Four of these mixtures were superior to their respective best component, but none of these differences were statistically significant.

Seventeen of the 20 mixtures grown in the Greenville nursery yielded more than the mid-component value (Table 6). Yield of mixtures 25 and 27 exceeded that of their respective mid-component value at the .05 probability level. Mixtures 23 and 24 exceeded their mid-component value in yield at the .01 probability level. In fact, yields of these two mixtures were significantly higher than that of their common best yielding component, Woodvale. However, these results are interpreted with caution, since the yield of Woodvale in this nursery was far below its normal level, relative to other varieties in the study. Roy (1960) is the only study cited by Clay and Allard (1969) in which a mixture has been found to yield significantly higher than its better or best component.

Of the three mixtures that yielded less than the mid-component value, the difference was statistically significant for only one mixture, 90 percent Steveland and 10 percent Siete Cerros.

Table 7 gives mean yield, mid-component and best component yields of each mixture in the 1972 Blue Creek nursery. The same data are shown graphically in Figure 4.

Sixteen of the 20 mixtures studied yielded more than their respective mid-components (Table 7). Ten of the 20 mixtures yielded more than their best components. Entry 23 (90 percent Gem-10 percent Red River 68) showed statistical significance (.05 probability level) in advantage of the mixture over both the mid-component and the best component values. None of the other differences were statistically significant. The above results are in agreement with those reported by Simmonds (1962), Patterson et al. (1963), Clay and Allard (1969), and Klages (1936).

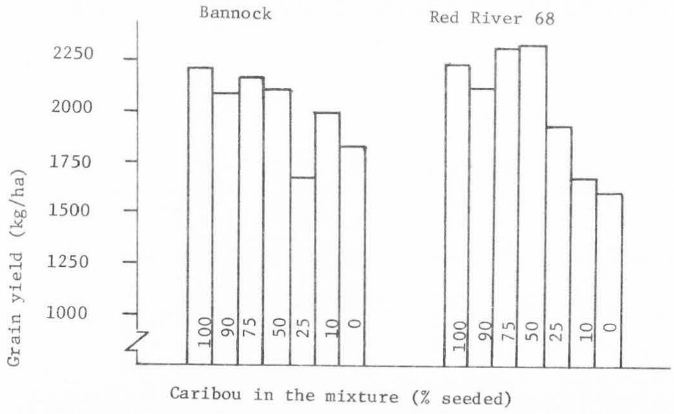
Analysis of combined nurseries

The same varieties were grown in three of the four nurseries. A combined analysis of variance for grain yield on this group of varieties is shown in Table 8. Locations showed highly significant differences. This was not surprising, since the environmental conditions

Table 7. Grain yields (kg/ha) of two barley and two wheat varieties grown in different mixtures and in pure stands in the 1972 Blue Creek nursery.

	Mixture seeded (%)		Grain yield in kg/ha		
Entry number	Barley	Wheat	Mixture	Mid-component	Best component
			Caribou - Bannock		
1	100	0	2,189.1	2,189.1	2,189.1
2	90	10	2,064.0	2,152.9	2,189.1
3	75	25	2,184.4	2,098.6	2,189.1
4	50	50	2,105.7	2,008.2	2,189.1
5	25	75	1,667.1	1,917.7	2,189.1
6	10	90	1,917.3	1,863.4	2,189.1
7	0	100	1,827.2	1,827.2	1,827.2
			Caribou - Red River 68		
8	100	0	2,189.1	2,189.1	2,189.1
9	90	10	2,100.3	2,130.7	2,189.1
10	75	25	2,260.4	2,043.1	2,189.1
11	50	50	2,263.1	1,897.2	2,189.1
12	25	75	1,901.2	1,751.2	2,189.1
13	10	90	1,680.5	1,663.6	2,189.1
14	0	100	1,605.2	1,605.2	1,605.2
			Gem - Bannock		
15	100	0	1,949.6	1,949.6	1,949.6
16	90	10	2,109.7	1,937.4	1,949.6
17	75	25	2,099.0	1,919.0	1,949.6
18	50	50	2,085.5	1,888.4	1,949.6
19	25	75	2,173.0	1,857.8	1,949.6
20	10	90	2,035.7	1,839.4	1,949.6
21	0	100	1,827.2	1,827.2	1,827.2
			Gem - Red River 68		
22	100	0	1,949.6	1,949.6	1,949.6
23	90	10	2,425.9*+	1,915.2	1,949.6
24	75	25	1,893.1	1,863.5	1,949.6
25	50	50	2,132.6	1,777.4	1,949.6
26	25	75	1,983.2	1,691.3	1,949.6
27	10	90	1,551.3	1,639.6	1,949.6
28	0	100	1,605.2	1,605.2	1,605.2

*Significant at the .05 level in comparison with mid-component.
+Significant at the .05 level in comparison with best component.
L.S.D. at the .05 level 409.4
L.S.D. at the .01 level 543.0



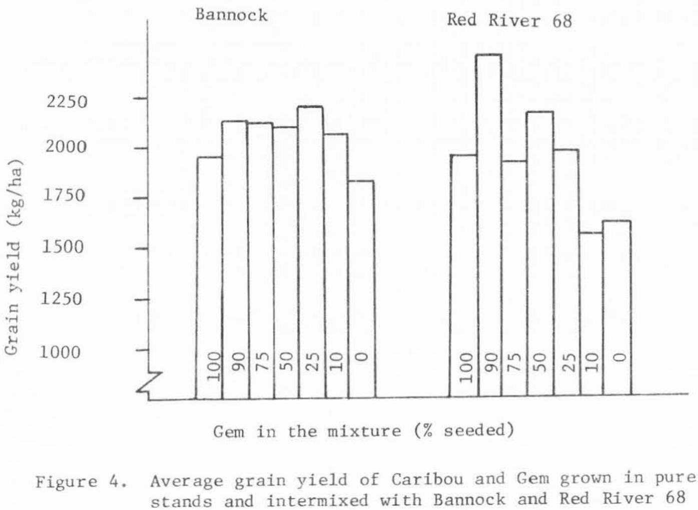


Figure 4. Average grain yield of Caribou and Gem grown in pure stands and intermixed with Bannock and Red River 68 in the 1972 Blue Creek nursery.

Table 8. Mean squares and F values for a combined analysis of grain yield of two barley and two wheat varieties grown in different mixtures and in pure stands in the Evans, the 1971 Blue Creek and the Greenville nurseries.

Source of variation	d.f.	M.S.	F
Locations (Loc)	2	9,336,858.0	458.48**
Reps/Loc	9	20,460.4	3.20**
Barley (B)	1	125,164.4	19.55**
Wheat (W)	1	25,917.9	4.05*
Level (L)	6	211,981.1	33.11**
W x B	1	13,012.7	2.03
B x L	6	18,060.5	2.82*
W x L	6	18,241.8	2.85*
W x B x L	6	3,546.7	.55
Loc x B	2	45,189.3	7.06**
Loc x W	2	68,980.4	10.78**
Loc x L	12	43,091.0	6.73**
Loc x W x B	2	18,708.0	2.92
Loc x B x L	12	14,461.8	2.26*
Loc x W x L	12	12,479.6	1.95*
Loc x W x B x L	12	8,524.9	1.33
Error	243	6,401.8	
Total	335	69,543.3	

*Significant at the .05 probability level.
**Significant at the .01 probability level.

under which the nurseries were grown were quite different. The 1971 Blue Creek nursery was grown under dryland conditions, while the Evans and the Greenville nurseries were favored by irrigation. Replications within locations were significantly different at the .01 probability level.

The two barley varieties differed at the .01 probability level and the two wheat varieties differed at the .05 level when compared over the three nurseries.

Levels at which the wheat and barley varieties were mixed is the only source of variation that consistently showed highly significant differences on an individual location basis and also when pooled across locations. Significant interaction between varieties of wheat and barley was not observed. The interactions W x B x L, Loc x W x B and Loc x W x B x L showed no significant effects.

First order interactions (B x L) and W x L) and second order interactions (Loc x B x L and Loc x W x L) were all significant at the .05 probability level.

The other first order interactions which involved the location factor (Loc x B, Loc x W, and Loc x L) were all statistically significant at the .01 probability level. These interactions were likely inflated by large differences between locations as a result of different moisture levels and different seasons.

Test Weight

Analysis of variance

The analysis of variance for test weight data is shown in Table 9. All main effects (barley, wheat and level) and the interactions B x L and W x L were highly significant (.01 level). The second order interaction W x B x L was statistically significant at the .05 probability level. Interaction between the two crops (W x B) was non-existent.

Mean comparisons

Table 10 gives test weight for the barley and wheat varieties grown in pure stands and when intermixed. This same information is shown graphically in Figure 5. As would be expected on the basis of inherent test weight differences between wheat and barley, test weights of the various mixtures increased in all instances as the proportion of barley in the admixture decreased.

When grown in pure stands, Steveland was slightly higher in test weight than Woodvale. This difference was significant at the .05 probability level. Inia 66 and Siete Cerros showed no significant difference in test weight when grown in pure stands.

Without exception, test weight of the mixtures was lower than that of their respective mid-component or best component value. Sixteen of the comparisons with the mid-component value showed differences that were significant at the .01 probability level, and two additional ones showed significance at the .05 level. The remaining two admixtures (entries 2 and 23) were not statistically different from their respective mid-component test weight.

Table 9. Analysis of variance for test weight of two barley and two wheat varieties grown in different mixtures and in pure stands in the Greenville nursery.

Source of variation	d.f.	M.S.	F
Reps	3	.938	1.17
Barley (B)	1	11.765	14.72**
Wheat (W)	1	11.379	14.24**
Level (L)	6	418.418	523.68**
W x B	1	.043	.05
B x L	6	3.928	4.92**
W x L	6	2.989	3.74**
W x B x L	6	1.796	2.25*
Error	81	.799	
Total	111	23.907	

*Significant at the .05 probability level.
**Significant at the .01 probability level.

Table 10. Test weight (kg/hl) of two barley and two wheat varieties grown in different mixtures and in pure stands in the Greenville nursery.

	Mixture seeded (%)		Test weight in kg/hl		
Entry number	Barley	Wheat	Mixture	Mid-component	Best component
			Steveland - Inia 66		
1	100	0	67.73	67.73	67.73
2	90	10	67.93 ++	69.32	83.58
3	75	25	68.45**++	71.69	83.58
4	50	50	70.06**++	75.66	83.58
5	25	75	73.60**++	79.62	83.58
6	10	90	75.71**++	82.00	83.58
7	0	100	83.58	83.58	83.58
			Steveland - Siete Cerros		
8	100	0	67.73	67.73	67.73
9	90	10	66.52**++	69.32	83.66
10	75	25	69.42**++	71.71	83.66
11	50	50	70.70**++	75.70	83.66
12	25	75	75.05**++	79.68	83.66
13	10	90	80.12* ++	82.07	83.66
14	0	100	83.66	83.66	83.66
			Woodvale - Inia 66		
15	100	0	65.64	65.64	65.64
16	90	10	65.32* ++	67.43	83.58
17	75	25	65.32**++	70.13	83.58
18	50	50	69.90**++	74.61	83.58
19	25	75	73.84**++	79.10	83.58
20	10	90	78.02**++	81.79	83.58
21	0	100	83.58	83.58	83.58
			Woodvale - Siete Cerros		
22	100	0	65.64	65.64	65.64
23	90	10	66.60 ++	67.44	83.66
24	75	25	67.08**++	70.15	83.66
25	50	50	69.58**++	74.65	83.66
26	25	75	74.97**++	79.16	83.66
27	10	90	79.47**++	81.86	83.66
28	0	100	83.66	83.66	83.66

*Significant at the .05 level in comparison with mid-component.
**Significant at the .01 level in comparison with mid-component.
+Significant at the .05 level in comparison with best component.
++Significant at the .01 level in comparison with best component.
L.S.D. at the .05 level = 1.62.
L.S.D. at the .01 level = 2.15.

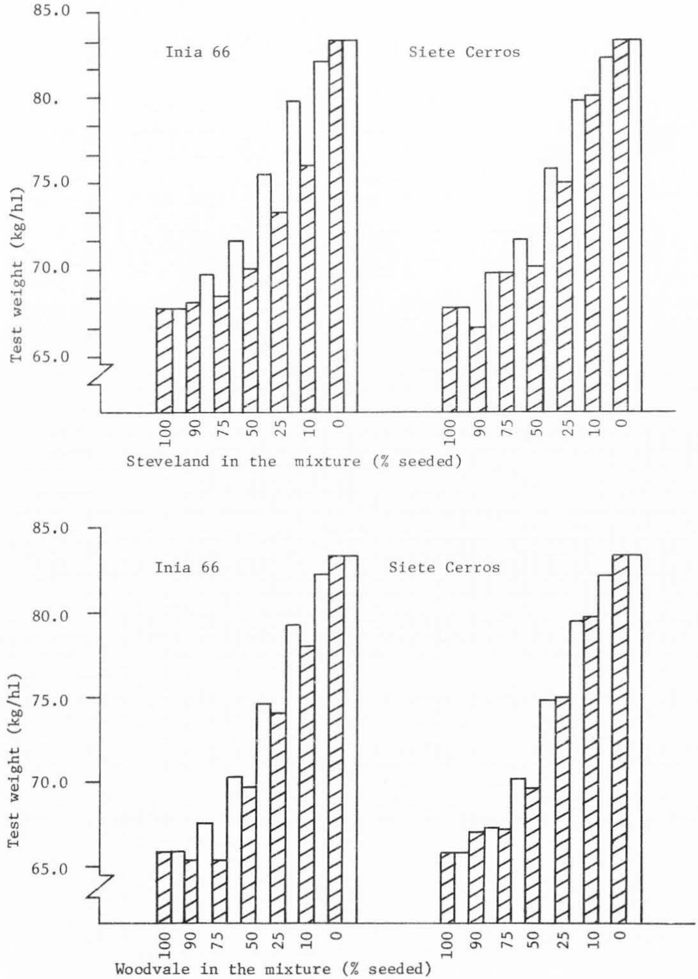


Figure 5. Effect of blending upon test weight (kg/hl) of two barley and two wheat varieties grown in pure stands and intermixed in the Greenville nursery.

Without exception, test weight of the mixtures was significantly lower than that of their respective best component at the .01 probability level. The lowest test weights were approximately 8.0 percent lower than those of their respective mid-component and 17.5 percent lower than those of their best component. This lowering of test weight in mixtures, relative to that of the mid-component weight may be a disadvantage in a commercial cropping situation.

Number of Plants per .60 m Section

Analyses of variance

Analyses of variance for number of barley and wheat plants per .60 m (2 foot) section of row in the Greenville nursery are shown in Table 11.

Both barley and wheat varieties, when compared among themselves, showed significant differences at the .01 probability level for number of plants per .60 m section. These differences were likely due to differences in seed size among varieties. Seed for planting was packaged by weight. Thus, varieties with small kernel size had more seeds per package than did varieties with a larger kernel size.

Levels of mixture was also significant at the .01 probability level for both barley and wheat. These differences were created by the treatments imposed in the form of mixtures. No statistical significances were observed for any of the interaction effects for either crop (Table 11).

Table 11. Analyses of variance for number of barley and wheat plants per .60 m section of row in the Greenville nursery.

Source of variation	d.f.	Barley M.S.	Barley F	Wheat M.S.	Wheat F
Reps	3	17.89	1.44	40.17	2.57
Barley (B)	1	468.22	37.77**	72.32	4.62
Wheat (W)	1	3.94	.32	295.75	18.91**
Level (L)	6	3,951.45	318.77**	5,242.04	335.12**
W x B	1	7.51	.60	.57	.04
B x L	6	61.58	4.97	19.30	1.23
W x L	6	9.54	.77	35.85	2.29
W x B x L	6	9.57	.77	13.26	.85
Error	81	12.40		15.64	
Total	111	231.80			

*Significant at the .05 probability level.
**Significant at the .01 probability level.

Mean comparisons

The observed mean number of plants per .60 m section of barley and wheat were compared to expected or calculated values. Expected number of plants for a given variety in a mixture was calculated from information on number of observed plants of that variety in pure stands and by extending this to the percentage of that variety present in the mixture. Total expected values are weighted arithmetic means of number of plants per .60 m section of the components making up the mixture when grown in pure stands.

L.S.D. values for total number of plants (barley plus wheat) per .60 m section was calculated using a pooled variance of wheat and barley.

Average number of observed and expected barley, wheat and total plants per .60 m section of row in the Greenville nursery are shown in Table 12.

Table 12. Average number of observed and expected barley, wheat and total plants per .60 m section of row in the Greenville nursery.

Entry number	Barley Observed	Barley Expected	Wheat Observed	Wheat Expected	Total Observed	Total Expected
			Steveland - Inia 66			
1	45.50	45.50	0.00	0.00	45.50	45.50
2	40.00	40.95	3.75	4.22	43.75	45.17
3	32.25	34.12	11.50	10.56	43.75	44.68
4	22.25	22.75	18.50	21.12	40.75	43.87
5	12.25	11.38	31.00	31.69	43.25	43.07
6	4.75	4.55	36.00	38.02	40.75	42.57
7	0.00	0.00	42.25	42.25	42.25	42.25
			Steveland - Siete Cerros			
8	45.50	45.50	0.00	0.00	45.50	45.50
9	38.75	40.95	2.50	4.80	41.25	45.75
10	30.25	34.12	11.25	12.00	41.50	46.12
11	21.50	22.75	21.00	24.00	42.50	46.75
12	11.00	11.38	36.50	36.00	47.50	47.38
13	2.75	4.55	45.50	43.20	48.25	47.75
14	0.00	0.00	48.00	48.00	48.00	48.00
			Woodvale - Inia 66			
15	35.50	35.50	0.00	0.00	35.50	35.50
16	32.50	31.95	3.00	4.22	35.50	36.17
17	23.75	26.62	13.00	10.56	36.75	37.18
18	19.25	17.75	22.75	21.12	42.00	38.97
19	8.50	8.87	32.00	31.69	40.50	40.56
20	4.25	3.55	40.25	38.02	44.50	41.57
21	0.00	0.00	42.25	42.25	42.25	42.25
			Woodvale - Siete Cerros			
22	35.50	35.50	0.00	0.00	35.50	35.50
23	29.50	31.95	6.75	4.80	36.25	36.75
24	30.00	26.62	11.75	12.00	41.75	38.62
25	16.75	17.75	29.50	24.00	46.25	41.75
26	8.75	8.87	37.25	36.00	46.00	44.87
27	4.25	3.55	43.75	43.20	48.00	46.75
28	0.00	0.00	48.00	48.00	48.00	48.00
L.S.D. at the .05 level =		4.96	5.56		5.19	
L.S.D. at the .01 level =		6.58	7.38		6.82	

Thirteen of 20 entries where barley was sown mixed with either Inia 66 or Siete Cerros, showed fewer plants than was expected from percentages (by weight) planted. Even though some of these differences were as large as 12.8 percent (entries 10, 17 and 24), none of the differences were statistically significant.

Nine of the 20 mixtures showed fewer wheat plants per .60 m section of row than was expected. No statistically significant differences between observed and expected numbers were present for plant stands as affected by levels of mixture.

Figures 6 and 7 show a wide range of variation in total number of plants per .60 m section for the four varieties when grown in pure stands. Barley counts ranged from 35.5 plants per .60 m section for Woodvale to 45.5 plants for Steveland. Inia 66 and Siete Cerros averaged 42.2 and 48.0 plants, respectively. In general, Steveland had fewer than the expected number of plants per .60 m section in mixtures with both wheat varieties (Figure 6). Woodvale, on the other hand, showed more than the expected number of plants (Figure 7). Larger differences, with respect to the theoretical line, were usually observed when mixtures were compounded in equal parts. However, none of the differences noted between the observed and expected wheat, barley or total number of plants were statistically significant (Table 12).

Tillering

Analyses of variance

Table 13 contains analyses of variance for tillering of wheat, barley and mixtures in the Greenville nursery. Replications showed no significance in either the barley or the wheat. Mixture level showed

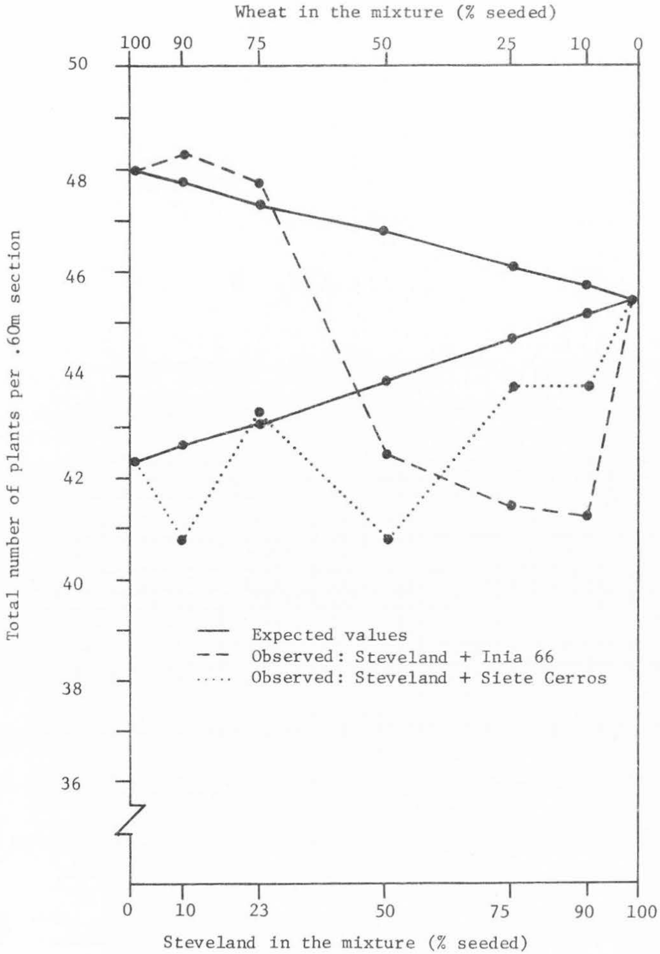


Figure 6. Total number of plants, barley (Steveland) and wheat in a .60m section in the Greenville nursery.

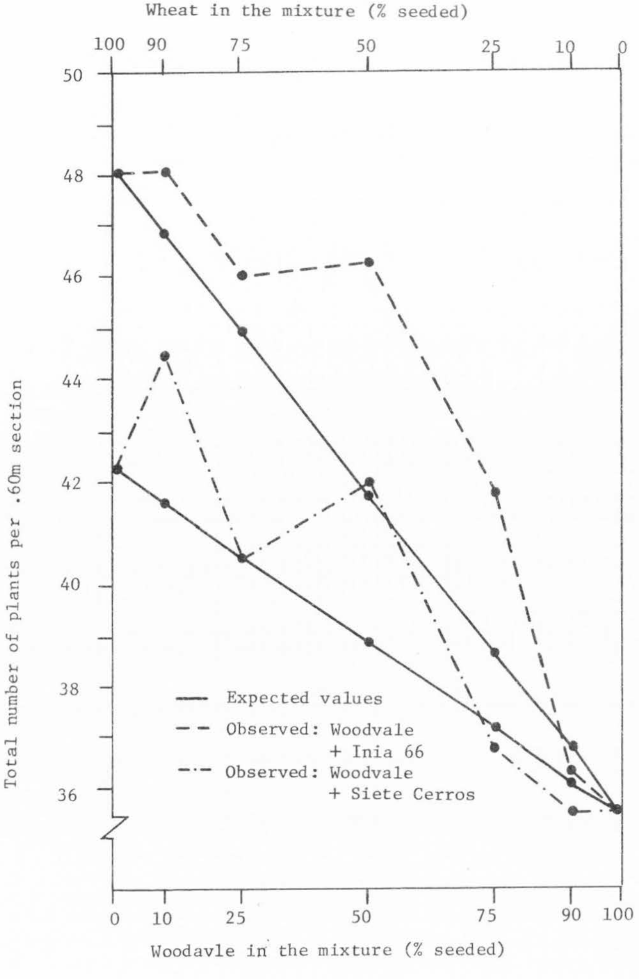


Figure 7. Total number of plants, barley (Woodvale) and wheat in a .60m section in the Greenville nursery.

Table 13. Analyses of variance for tillering of two barley and two wheat varieties grown in different mixtures and in pure stands in the Greenville nursery.

		Barley		Wheat	
Source of variation	d.f.	M.S.	F	M.S.	F
Reps	3	.214	.44	.037	.95
Barley (B)	1	4.108	8.45**	.008	.20
Wheat (W)	1	.084	.17	.337	8.64**
Level (L)	6	15.768	32.44**	4.608	118.15**
W x B	1	.006	.01	.027	.69
B x L	6	.360	.74	.017	.44
W x L	6	.109	.18	.015	.38
W x B x L	6	.311	.64	.034	.87
Error	81	.486		.039	
Total	111	1.293		.285	

*Significant at the .05 probability level.
**Significant at the .01 probability level.

highly significant differences in both barley and wheat. The 'level' source of variation is inflated as a result of including the pure stand entries among the analyses of mixture levels. Thus, mean squares for the main effect, levels, and those for all interactions involving levels should be interpreted with this in mind. This inflation is evidenced by the fact that the L.S.D. test used to make individual comparisons failed to show significant differences between level means after the F-test in the analysis of variance had shown highly significant differences between levels. None of the first order (W x B, B x L, and W x L) or the second order (W x B x L) interactions showed significant F values.

Mean comparisons

Table 14 shows the average number of tillers per plant of barley and wheat plants in pure stands and in mixtures. Steveland and Woodvale showed no significant difference in tillers per plant. Likewise, Inia 66 and Siete Cerros were not statistically different in average number of tillers per plant.

In 15 of the 20 mixtures, the barley varieties had higher tiller number than either Steveland or Woodvale grown in pure stands. Only one of these differences (entry 6) was statistically significant at the .05 probability level.

Steveland, when mixed in 10 percent proportion with Inia 66 and Siete Cerros (entries 6 and 13) had 44.0 and 38.2 percent more tillers per plant than when grown in pure stand. Woodvale mixed in 25 and 10 percent proportions with Inia 66 and Siete Cerros, respectively (entries 19 and 27) produced 22.2 percent and 38.4 percent more tillers per plant than Woodvale when grown alone. In all cases, tillering of both wheat varieties decreased when grown intermixed with either barley variety, compared to the same variety grown in pure stand.

Ten percent mixtures of Inia 66 and Siete Cerros with Steveland (entries 2 and 9) showed tillering reductions that were significant at the .01 probability level. Inia 66 in 10 percent proportion with Woodvale (entry 16) also showed a highly significant (.01 level) reduction in tillering. In entries 3, 18, and 23, tillering in the wheat was significantly (.05 level) reduced from that in pure stand. The advantage in tillering from growing straight wheat compared to the mixtures was 29.5 percent in entries 2 and 16 and 38.0 and 21.9 percent in entries 9 and 23, respectively.

Table 14. Average tillering (tillers per plant) of two barley and two wheat varieties grown in different mixtures and in pure stands in the Greenville nursery.

Entry number	Mixture seeded (%)		Average tillers per plant	
	Barley	Wheat	Barley	Wheat
		Steveland - Inia 66		
1	100	0	2.41	0.00
2	90	10	2.38	1.19**
3	75	25	2.20	1.32*
4	50	50	2.78	1.62
5	25	75	3.00	1.40
6	10	90	3.47*	1.61
7	0	100	0.00	1.66
		Steveland - Siete Cerros		
8	100	0	2.41	0.00
9	90	10	2.23	1.08**
10	75	25	2.76	1.26
11	50	50	2.81	1.23
12	25	75	3.19	1.36
13	10	90	3.33	1.38
14	0	100	0.00	1.49
		Woodvale - Inia 66		
15	100	0	2.16	0.00
16	90	10	2.16	1.19**
17	75	25	2.20	1.41
18	50	50	2.33	1.25*
19	25	75	2.64	1.44
20	10	90	2.18	1.51
21	0	100	0.00	1.66
		Woodvale - Siete Cerros		
22	100	0	2.16	0.00
23	90	10	2.25	1.13
24	75	25	2.07	1.23
25	50	50	2.38	1.28
26	25	75	2.16	1.33
27	10	90	2.99	1.44
28	0	100	0.00	1.49

*Significant at the .05 probability level.
**Significant at the .01 probability level.

L.S.D. at the .05 level =	.98	.28
L.S.D. at the .01 level =	1.30	.37

In general, both barley varieties showed a consistent increase in tillering as the amount of wheat in the mixture increased. Conversely, the wheat varieties showed a steady decrease in tillering as the amount of barley increased in the mixture.

Kernel Number per Head

Analyses of variance

Significant differences were noted, at the .01 probability level, for kernel number per head between Steveland and Woodvale (Table 15). Likewise, Inia 66 and Siete Cerros differed significantly at the .01 probability level.

Table 15. Analyses of variance for barley and wheat kernel number per head in the Greenville nursery.

		Barley		Wheat	
Source of variation	d.f.	M.S.	F	M.S.	F
Reps	3	51.34	3.17*	75.87	4.00*
Barley (B)	1	1,335.84	82.39**	1.63	.09
Wheat (W)	1	25.54	1.57	1,015.15	55.53**
Level (L)	6	4,067.48	280.86**	2,907.92	153.40**
W x B	1	.86	.05	9.82	.52
B x L	6	112.72	6.95**	30.27	1.60
W x L	6	16.78	1.03	54.37	2.87*
B x W x L	6	10.50	.65	11.36	.60
Error	81	16.21		18.96	
Total	111	252.92		187.51	

*Significant at the .05 probability level.
**Significant at the .01 probability level.

Mixture levels strongly influenced kernel number per head. Differences were significant at the .01 probability level in both the barley and the wheat. However, this line from the analysis of variance table and all interactions involving the 'level' source of variation should be interpreted with caution, since these factors were inflated as described in the section on tillering. The interaction between barley and level (B x L) was also significant at the .01 probability level. None of the other interactions were statistically significant.

Mean comparisons

Average barley and wheat kernel number per head, grown in mixtures, was compared to that of the same variety grown in pure stand (Table 16). Steveland consistently produced more kernels per head when grown in mixtures with wheat than when grown in pure stand. Five of the mixtures showed significant differences at the .01 probability level and the other five were significant at the .05 level.

Both wheat varieties, and Woodvale barley, were usually reduced in kernel number per head when grown in mixtures, compared to that found in pure stands. Only one of these reductions (entry 17) was statistically significant (.05 probability level) for Woodvale.

Inia 66 and Siete Cerros consistently had fewer kernels per head when grown in mixtures than when grown in pure stand, with a single exception (entry 27). Entries 2, 3, 9 and 17 showed significant differences at the .01 probability level; entry 24 showed significance at the .05 level. The remaining differences were not statistically significant.

Table 16. Average kernel number per head of two barley and two wheat varieties grown in different mixtures and in pure stands in the Greenville nursery.

Entry number	Mixture seeded (%)		Kernels per head	
	Barley	Wheat	Barley	Wheat
		Steveland - Inia 66		
1	100	0	31.50	0.00
2	90	10	38.34*	26.88**
3	75	25	41.33**	27.37**
4	50	50	42.38**	31.04
5	25	75	38.29*	32.21
6	10	90	40.50**	32.92
7	0	100	0.00	35.96
		Steveland - Siete Cerros		
8	100	0	31.50	0.00
9	90	10	38.21*	31.54**
10	75	25	39.50**	40.79
11	50	50	37.29*	38.71
12	25	75	38.46*	39.32
13	10	90	39.46**	41.12
14	0	100	0.00	41.17
		Woodvale - Inia 66		
15	100	0	48.66	0.00
16	90	10	48.46	33.83
17	75	25	41.62*	26.54**
18	50	50	49.54	32.29
19	25	75	45.70	32.67
20	10	90	45.46	30.92
21	0	100	0.00	35.96
		Woodvale - Siete Cerros		
22	100	0	48.66	0.00
23	90	10	45.21	35.17
24	75	25	46.88	33.29*
25	50	50	44.79	37.34
26	25	75	43.92	40.21
27	10	90	44.54	43.04
28	0	100	0.00	41.17

*Significant at the .05 probability level.
**Significant at the .01 probability level.

L.S.D. of the .05 level =	5.66	6.12
L.S.D. at the .01 level =	7.51	8.12

Inia 66 wheat had an average decrease of 9.63 kernels per head (23.4 percent) in entry 9. Steveland barley showed an average increase of 10.88 kernels per head (34.5 percent) in entry 4.

Weight of Kernels per Head

Analyses of variance

Analyses of variance for barley and wheat kernel weight per head in the Greenville nursery are shown in Table 17. Replications, varieties (barley and wheat) and mixture levels all showed significant differences. However, the 'level' source of variation and all interactions involving levels should be interpreted with caution, since these factors were inflated as described in the section on tillering. Crop by level interactions were significant for both barley and wheat, B x L at the .01 probability level and W x L at the .05 level. This suggests that barley varieties were influenced more than wheat varieties by different levels of the other crop in the mixture. None of the other interactions were significant.

Mean comparisons

Average barley and wheat kernel weight (g) per head observed for all treatments in the Greenville nursery are shown in Table 18. Kernel weight per head (head size) of barley and wheat varieties grown in mixtures were compared with those of the same variety grown in pure stand.

Head size of Steveland increased as the proportion of this variety decreased in the seeded mixture (Figure 8). Even though a 23.9 percent increase in head size was observed in entry 4, this difference was not

Table 17. Analyses of variance for barley and wheat kernel weight per head in the Greenville nursery.

		Barley		Wheat	
Source of variation	d.f.	M.S.	F	M.S.	F
Reps	3	7.41	4.86**	6.40	7.27**
Barley (B)	1	440.75	288.64**	.03	.03
Wheat (W)	1	5.28	3.46	19.12	21.71**
Level (L)	6	405.51	265.56**	185.69	210.77**
W x B	1	.76	.50	.58	.65
B x L	6	17.20	11.26**	1.23	1.39
W x L	6	2.12	1.38	2.08	2.36*
W x B x L	6	.47	.31	.54	.62
Error	81	1.53		.88	
Total	111			11.24	

*Significant at the .05 probability level.
**Significant at the .01 probability level.

statistically significant because of large random variation that was present.

Woodvale, Inia 66 and Siete Cerros all showed a generally slight decrease in head size as the amount of the considered variety decreased in the seeded mixture. However, none of these differences were statistically significant. Similar trends were observed in kernel number per head (Table 16).

Kernel Weight

Analyses of individual irrigated nurseries

Analyses of variance. Table 19 shows analyses of variance for kernel weight of barley entries in the Evans and the Greenville nurseries. The 'level' source of variation in these analyses is inflated as

Table 18. Average kernel weight (g) per head of two barley and two wheat varieties grown in different mixtures and in pure stands in the Greenville nursery.

Entry number	Mixture seeded (%)		Kernel weight (g) per head	
	Barley	Wheat	Barley	Wheat
	Steveland - Inia 66			
1	100	0	1.63	0.00
2	90	10	1.72	1.10
3	75	25	1.94	1.19
4	50	50	2.02	1.42
5	25	75	1.83	1.41
6	10	90	1.95	1.43
7	0	100	0.00	1.66
	Steveland - Siete Cerros			
8	100	0	1.63	0.00
9	90	10	1.80	1.35
10	75	25	1.91	1.57
11	50	50	1.76	1.54
12	25	75	1.82	1.57
13	10	90	1.90	1.66
14	0	100	0.00	1.63
	Woodvale - Inia 66			
15	100	0	2.78	0.00
16	90	10	2.75	1.25
17	75	25	2.54	1.12
18	50	50	2.83	1.42
19	25	75	2.50	1.46
20	10	90	2.57	1.41
21	0	100	0.00	1.66
	Woodvale - Siete Cerros			
22	100	0	2.78	0.00
23	90	10	2.52	1.37
24	75	25	2.60	1.24
25	50	50	2.43	1.48
26	25	75	2.45	1.63
27	10	90	2.50	1.76
28	0	100	0.00	1.63
L.S.D. at the .05 level =			1.74	1.32
L.S.D. at the .01 level =			2.31	1.75

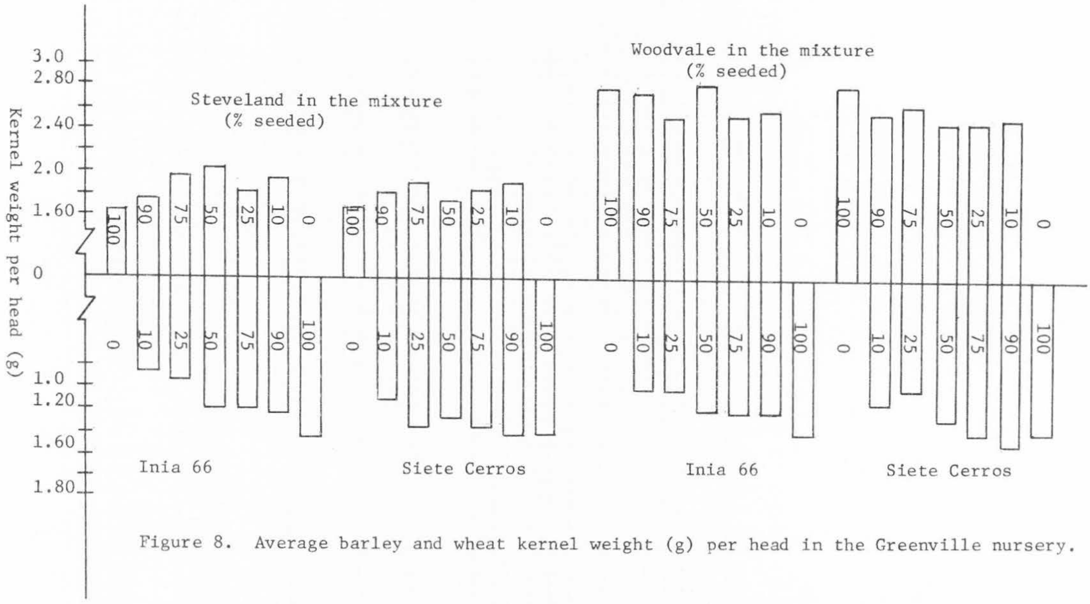


Figure 8. Average barley and wheat kernel weight (g) per head in the Greenville nursery.

Table 19. Analyses of variance for kernel weight of two barley varieties in the Evans and the Greenville nurseries.

		Evans		Greenville	
Source of variation	d.f.	M.S.	F	M.S.	F
Reps	3	.20	2.16	.03	1.33
Barley (B)	1	4.99	54.28**	1.51	62.75**
Wheat (W)	1	.70	7.66**	.01	.80
Level (L)	6	6.48	70.42**	5.85	243.62**
W x B	1	.76	8.23**	.02	.62
B x L	6	.48	5.22**	.07	2.75*
W x L	6	.39	4.23**	.03	1.33
W x B x L	6	.41	4.44**	.03	1.33
Error	81	.09		.02	
Total	111	.55		.36	

*Significant at the .05 probability level.
**Significant at the .01 probability level.

described in the section on tillering. Because of this inflation, mean squares for the main effect, levels, and those for all interactions involving levels should be interpreted with this in mind.

In the Evans nursery, kernel weight variability was significant at the .01 probability level for all main effects (barley, wheat and levels) and for all interactions. Replications was the only factor that did not show dignificant differences.

In the Greenville nursery the factors, barley and levels of mixtures, were the only main effects that showed significant differences, both at the .01 probability level. A significant (.05 level) interaction effect between barley and levels of mixture (B x L) was observed. No other statistically significant interaction response was observed in the two nurseries even though the same varieties were used and experimental conditions were near the same both years (Table 19).

Table 20 contains analyses of variance for kernel weight of wheat entries in the Evans and the Greenville nurseries.

Table 20. Analyses of variance for kernel weight of two wheat varieties in the Evans and the Greenville nurseries.

		Evans		Greenville	
Source of variation	d.f.	M.S.	F	M.S.	F
Reps	3	.92	.67	.06	1.48
Barley (B)	1	.22	7.00**	.00	.00
Wheat (W)	1	1.22	39.35**	.53	13.20**
Level (L)	6	3.41	109.90	3.94	98.42**
W x B	1	.01	.35	.01	.35
B x L	6	.03	1.06	.00	.05
W x L	6	.08	2.68*	.05	1.25
W x B x L	6	.06	1.93	.02	.50
Error	81	.03		.04	
Total	111	.23		.25	

*Significant at the .05 probability level.
**Significant at the .01 probability level.

The main effects, barley, wheat, and levels, were all significant at the .01 probability level in the Evans nursery. The only interaction showing a significant effect in this nursery was that between wheat and levels of mixture (W x L).

In the Greenville nursery, only wheat and levels of mixture showed significance, both at the .01 probability level. None of the interactions were statistically significant.

Mean comparisons. Average kernel weights of Steveland and Woodvale barleys grown in pure stands and when intermixed in five different percentages with Inia 66 and Siete Cerros wheats are shown in Table 21. No statistically significant differences in kernel weight were observed among any entries in either the Evans or the Greenville nursery. This lack of statistical significance was attributed to the large error mean square, which in turn inflated the L.S.D. value used to test for significance.

Although no statistically significant differences in kernel weight were observed in either nursery, Table 21 shows a rather consistent pattern of slight increase in barley kernel weight as the amount of barley decreased in the seeded mixture in the Evans nursery. There appeared to be a slight trend in the opposite direction in the Greenville nursery.

Average kernel weights of Inia 66 and Siete Cerros wheats grown in pure stands and intermixed in five different percentages with Steveland and Woodvale barleys are shown in Table 22.

Kernel weight showed no statistically significant difference among any of the mixtures in either the Evans or the Greenville nursery. However, a very consistent pattern of decrease in kernel weight was observed as the proportion of wheat decreased in the sown mixture. This pattern held true in both nurseries.

Analyses of combined irrigated nurseries

Analyses of variance. Table 23 shows mean squares and F ratios for combined analyses of variance on kernel weight of the two barley and

Table 21. Weight (g) of 1,000 kernels of Steveland and Woodvale barleys when intermixed with Inia 66 and Siete Cerros wheats in the Evans and the Greenville nurseries.

	Mixture seeded (%)		Barley kernel weight (g)	
Entry number	Barley	Wheat	Evans	Greenville
		Steveland - Inia 66		
1	100	0	44.00	45.00
2	90	10	44.02	45.45
3	75	25	44.22	45.00
4	50	50	43.07	46.88
5	25	75	43.50	46.58
6	10	90	44.95	47.48
7	0	100	0.00	0.00
		Steveland - Siete Cerros		
8	100	0	44.00	45.00
9	90	10	43.42	44.85
10	75	25	43.62	46.05
11	50	50	43.47	45.70
12	25	75	44.07	46.78
13	10	90	43.92	47.62
14	0	100	0.00	0.00
		Woodvale - Inia 66		
15	100	0	54.77	53.05
16	90	10	54.32	51.88
17	75	25	53.45	54.32
18	50	50	52.70	54.30
19	25	75	52.27	54.42
20	10	90	53.35	54.68
21	0	100	0.00	0.00
		Woodvale - Siete Cerros		
22	100	0	54.77	53.05
23	90	10	53.12	52.75
24	75	25	54.37	51.50
25	50	50	53.20	53.45
26	25	75	53.92	53.20
27	10	90	54.42	54.06
28	0	100	0.00	0.00
L.S.D. at the .05 level =			13.49	6.89
L.S.D. at the .01 level =			17.89	9.14

Table 22. Weight (g) of 1,000 kernels of Inia 66 and Siete Cerros wheats when intermixed with Steveland and Woodvale barleys in the Evans and the Greenville nurseries.

	Mixture seeded (%)		Wheat kernel weight (g)	
Entry number	Barley	Wheat	Evans	Greenville
	Steveland - Inia 66			
1	100	0	0.00	0.00
2	90	10	41.62	39.90
3	75	25	41.25	40.27
4	50	50	42.57	41.30
5	25	75	43.90	42.20
6	10	90	43.60	42.80
7	0	100	44.17	44.22
	Steveland - Siete Cerros			
8	100	0	0.00	0.00
9	90	10	34.70	37.68
10	75	25	34.50	37.78
11	50	50	36.55	37.15
12	25	75	37.27	39.78
13	10	90	37.72	39.20
14	0	100	38.30	39.35
	Woodvale - Inia 66			
15	100	0	0.00	0.00
16	90	10	38.10	38.87
17	75	25	36.30	40.12
18	50	50	40.40	41.68
19	25	75	42.75	43.90
20	10	90	40.02	43.22
21	0	100	44.17	44.22
	Woodvale - Siete Cerros			
22	100	0	0.00	0.00
23	90	10	33.82	36.92
24	75	25	36.17	36.90
25	50	50	35.20	37.88
26	25	75	36.40	39.28
27	10	90	37.20	38.70
28	0	100	38.30	39.35
L.S.D. at the .05 level =			7.82	8.85
L.S.D. at the .01 level =			10.36	11.74

Table 23. Mean squares and F ratios for a combined analysis of kernel weight of two barley and two wheat varieties grown in different mixtures and in pure stands in the Evans and the Greenville nurseries.

		Barley		Wheat	
Source of variation	d.f.	M.S.	F	M.S.	F
Loc	1	.000074	1.28	.000379	6.53*
Reps/Loc	6	.000115	1.98	.000040	.69
Barley (B)	1	.005993	17.12**	.000113	1.95
Wheat (W)	1	.000452	7.79**	.001677	28.91**
Level (L)	6	.012250	211.21**	.007293	125.74**
W x B	1	.000491	8.46**	.000000	0.00
B x L	6	.000433	7.46**	.000014	.24
W x L	6	.000310	5.34**	.000081	1.40
W x B x L	6	.000319	5.50**	.000064	1.10
Loc x B	1	.000508	8.76**	.000105	1.81
Loc x W	1	.000265	4.57**	.000071	1.22
Loc x L	6	.000076	1.31	.000051	.88
Loc x W x B	1	.000280	4.83**	.000025	.43
Loc x B	6	.000112	1.93	.000020	.34
Loc x W x L	6	.000110	1.90	.000053	.91
Loc x W x B x L	6	.000122	2.10	.000016	.28
Error	162	.000058		.000035	
Total	223	.000451		.000241	

*Significant at the .05 probability level.
**Significant at the .01 probability level.

two wheat varieties grown in different mixtures and in pure stands. Data from the Evans and the Greenville nurseries were pooled and evaluated in a combined analysis.

Interpretation of mean squares for the main effect, level, and those for all interactions involving levels should be done with caution since the level source of variation is inflated as described in the section on tillering.

In the barley analysis of variance, all main effects, barley, wheat and levels of mixture, were significant at the .01 probability level. Highly significant (.01 level) first order interactions were observed between wheat and barley (W x B), barley and level (B x L), wheat and level (W x L), locations and barley (Loc x B) and locations and wheat (Loc x W). The second order interaction (Loc x W x B) was also significant at the .01 probability level. None of the remaining interactions, locations or replications within location (Reps/Loc) were significant.

In the wheat analysis of variance the main effects, wheat and levels, showed highly significant values. Locations showed significance at the .05 probability level. There were no significant interactions in the wheat analyses (Table 23).

Mean comparisons. Average kernel weight (g) of two barley and two wheat varieties in pure stands and in various mixture combinations are given in Table 24. These means are averages of the data given in Tables 21 and 22.

No statistically significant differences in kernel weight were observed in either barley or wheat when mixtures were compared. Even though no statistically significant differences in kernel weight were

Table 24. Average weight (g) of 1,000 kernels of two barley and two wheat varieties grown in different mixtures and in pure stands in the Evans and the Greenville nurseries.

Entry number	Mixture seeded (%)		Kernel weight (g)	
	Barley	Wheat	Barley	Wheat
		Steveland - Inia 66		
1	100	0	44.50	0.00
2	90	10	44.74	40.76
3	75	25	44.61	43.56
4	50	50	44.98	43.82
5	25	75	45.04	43.05
6	10	90	46.21	43.20
7	0	100	0.00	44.20
		Steveland - Siete Cerros		
8	100	0	44.50	0.00
9	90	10	44.14	36.19
10	75	25	44.82	36.14
11	50	50	44.59	36.85
12	25	75	45.42	38.52
13	10	90	45.78	38.46
14	0	100	0.00	38.82
		Woodvale - Inia 66		
15	100	0	53.91	0.00
16	90	10	53.10	38.48
17	75	25	53.89	38.21
18	50	50	53.50	41.04
19	25	75	53.35	43.32
20	10	90	54.01	43.62
21	0	100	0.00	44.20
		Woodvale - Siete Cerros		
22	100	0	53.91	0.00
23	90	10	52.94	35.38
24	75	25	52.94	36.53
25	50	50	53.32	36.54
26	25	75	53.56	37.84
27	10	90	54.25	37.95
28	0	100	0.00	38.82
L.S.D. at the .05 level =			5.38	4.18

observed, barley showed a consistent pattern of slight increase in kernel weight as the amount of barley in the sown mixture decreased. Conversely, wheat showed a very consistent pattern of decreasing kernel weight as the amount of wheat decreased in the seeded mixture.

Analyses of variance for the 1972 dryland nursery

Table 25 gives analyses of variance for kernel weight of two barley and two wheat varieties in the 1972 Blue Creek nursery.

Table 25. Analyses of variance for kernel weight of two wheat and two barley varieties grown in different mixtures and in pure stands in the 1972 Blue Creek nursery.

		Barley		Wheat	
Source of variation	d.f.	M.S.	F	M.S.	F
Reps	3	.023	.53	.047	1.38
Barley (B)	1	.267	6.21*	.092	2.70
Wheat (W)	1	.000	.00	.007	.20
Level (L)	6	4.611	107.23**	2.258	66.41**
W x B	1	.009	.21	.106	3.12
B x L	6	.024	.56	.022	.65
W x L	6	.026	.60	.029	.85
W x B x L	6	.053	1.23	.050	1.47
Error	81	.043		.034	
Total	111	.289			

*Significant at the .05 probability level.
**Significant at the .01 probability level.

Mean squares for the main effect, level, and those for all interactions involving levels should be interpreted with caution, since the level source of variation is inflated as described in the section on tillering.

Mixture levels were significantly different at the .01 probability level for both barley and wheat. The main effect, barley, in the barley analysis of variance, was the only other source showing any significant (.05 probability level) difference. None of the other main effects or interaction effects in either the wheat or barley analyses were statistically significant.

Mean comparisons for the 1972
dryland nursery

Table 26 shows average weight (g) of 1,000 kernels of the two barley and two wheat varieties grown in pure stands and in various mixture combinations in the 1972 Blue Creek nursery.

Kernel weight showed no statistically significant differences for either barley or wheat when comparisons were made between seed grown in pure stands and that grown in the various mixtures. Though not statistically significant, the wheat showed a very consistent increase in kernel weight as the amount of barley in the seeded mixture was decreased. No such definite trend was observable in the barley.

Table 26. Weight (g) of 1,000 kernels of two barley and two wheat varieties grown in different mixtures and in pure stands in the 1972 Blue Creek nursery.

Entry number	Mixture seeded (%)		Kernel weight (g)	
	Barley	Wheat	Barley	Wheat
		Caribou - Bannock		
1	100	0	43.80	0.00
2	90	10	44.27	31.27
3	75	25	45.00	30.60
4	50	50	46.15	32.35
5	25	75	44.10	25.25
6	10	90	45.62	33.40
7	0	100	0.00	32.75
		Caribou - Red River 68		
8	100	0	43.80	0.00
9	90	10	45.82	28.85
10	75	25	44.75	27.72
11	50	50	43.95	27.80
12	25	75	43.10	31.12
13	10	90	43.92	32.30
14	0	100	0.00	32.67
		Gem - Bannock		
15	100	0	47.90	0.00
16	90	10	47.07	30.45
17	75	25	46.50	29.45
18	50	50	46.30	29.47
19	25	75	46.22	30.67
20	10	90	47.12	32.62
21	0	100	0.00	32.07
		Gem - Red River 68		
22	100	0	47.90	0.00
23	90	10	46.82	31.12
24	75	25	47.37	31.62
25	50	50	46.22	31.47
26	25	75	46.65	30.85
27	10	90	46.00	34.07
28	0	100	0.00	32.65
L.S.D. at the .05 level =			9.22	8.20
L.S.D. at the .01 level =			12.23	10.88

Composition of Seeded and Harvested Crop

Analyses of individual irrigated nurseries

Analyses of variance. Analyses of variance for barley harvested from the Evans and the Greenville nurseries are given in Table 27. The main effects, barley and mixture levels were significant at the .01 probability level in both nurseries. Wheat in the mixture also showed a significant influence upon performance of the barley in the Greenville nursery.

Table 27. Analyses of variance for the proportion (weight) of harvested barley kernels in the Evans and the Greenville nurseries.

		Evans		Greenville	
Source of variation	d.f.	M.S.	F	M.S.	F
Reps	3	5.23	.20	30.96	1.77
Barley (B)	1	1,776.48	52.43**	262.85	15.01**
Wheat (W)	1	68.08	2.59	176.30	10.10**
Level (L)	6	23,653.06	900.96**	24,705.19	1,415.53**
W x B	1	112.40	4.28*	2.45	.14
B x L	6	268.99	10.25**	60.13	3.44**
W x L	6	45.77	1.74	24.76	1.42
W x B x L	6	151.83	5.78**	8.08	.46
Error	81	26.25		17.45	
Total	111	1,337.09		1,357.99	

*Significant at the .05 probability level.
**Significant at the .01 probability level.

Barley and levels (B x L) showed a highly significant interaction effect in both nurseries. A significant interaction effect at the .05 probability level between wheat and barley (W x B), was also observed in the Evans nursery. The second order interaction (W x B x L) was statistically significant at the .01 probability level, only in the Evans nursery. No statistical significance was observed for any of the other interactions, at either location.

Analyses of variance for wheat are not presented, because they are identical to those presented for barley. This occurred since analyses of variance were run using data on a percentage basis. Therefore, for a certain increase in percentage of barley in the harvested crop, there was a corresponding equal decrease in percentage of wheat.

Mean comparisons. Percentage of barley in the harvested crop and the amount by which this percentage exceeded the proportion seeded are given in Table 28 for the Evans and the Greenville nurseries.

Percentage of barley harvested exceeded that planted for all mixtures in both nurseries. All except one (entry 23 in the Greenville nursery) of these differences were statistically significant, 36 at the .01 probability level and three at the .05 level.

The differences in harvested percentages over the sown percentages in the Evans nursery ranged from 5.4 to 49.5 (entry 26). Differences in the Greenville nursery ranged from 4.0 to 25.7 percent (Table 28). The greatest increases in percentage of barley in the harvested crop occurred in the 50:50 mixture of Steveland and Inia 66 (Greenville nursery) and in the 75:25 mixture of Woodvale and Siete Cerros (Evans nursery).

Differences in percentage of harvested mixtures compared to planted mixtures are illustrated in Figures 9 and 10. These figures show that, in general, the greatest deviations from the "mixture seeded" line are usually around the 50:50 mixtures.

Table 28. Changes in proportion (weight) of the components of seeded and harvested mixtures in the Evans and the Greenville nurseries.

Entry number	Mixture seeded (%) Barley	Mixture seeded (%) Wheat	Barley in harvested crop (%) Evans	Barley in harvested crop (%) Greenville	Excess of barley (%) Evans	Excess of barley (%) Greenville
			Steveland - Inia 66			
1	100	0	100.0	100.0	0.0	0.0
2	90	10	97.8	96.3	7.8**	6.3**
3	75	25	93.1	89.0	18.1**	14.0**
4	50	50	74.4	75.7	24.4**	25.7**
5	25	75	51.9	44.9	26.9**	19.9**
6	10	90	24.0	22.0	14.0**	12.0**
7	0	100	0.0	0.0	0.0	0.0
			Steveland - Siete Cerros			
8	100	0	100.0	100.0	0.0	0.0
9	90	10	97.9	95.2	7.9**	5.2*
10	75	25	90.5	87.1	15.5**	12.1**
11	50	50	79.4	70.8	29.4**	20.8**
12	25	75	54.8	37.1	29.8**	12.1**
13	10	90	15.4	18.1	5.4*	8.1**
14	0	100	0.0	0.0	0.0	0.0
			Woodvale - Inia 66			
15	100	0	100.0	100.0	0.0	0.0
16	90	10	99.1	94.9	9.1**	4.9*
17	75	25	96.5	87.9	21.5**	12.9**
18	50	50	86.7	64.0	36.7**	14.0**
19	25	75	62.6	39.5	37.6**	14.5**
20	10	90	31.2	18.2	21.2**	8.2**
21	0	100	0.0	0.0	0.0	0.0
			Woodvale - Siete Cerros			
22	100	0	100.0	100.0	0.0	0.0
23	90	10	99.3	94.0	9.3**	4.0
24	75	25	97.3	81.4	22.3**	6.4**
25	50	50	79.5	60.2	29.5**	10.2**
26	25	75	74.5	34.5	49.5**	9.5**
27	10	90	50.6	18.8	40.6**	8.8**
28	0	100	0.0	0.0	0.0	0.0

*Significant at the .05 probability level.
**Significant at the .01 probability level.

L.S.D. at the .05 level =	5.10	4.15
L.S.D. at the .01 level =	6.76	5.51

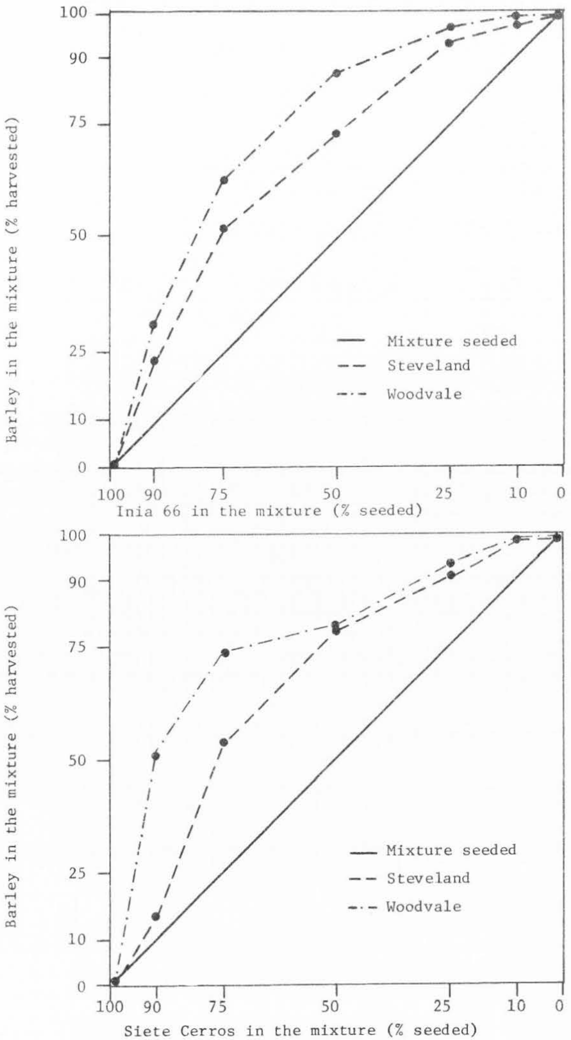


Figure 9. Percentage of barley in seeded and harvested mixtures of Steveland - Inia 66, Woodvale - Inia 66, Steveland - Siete Cerros and Woodvale - Siete Cerros in the Evans nursery.

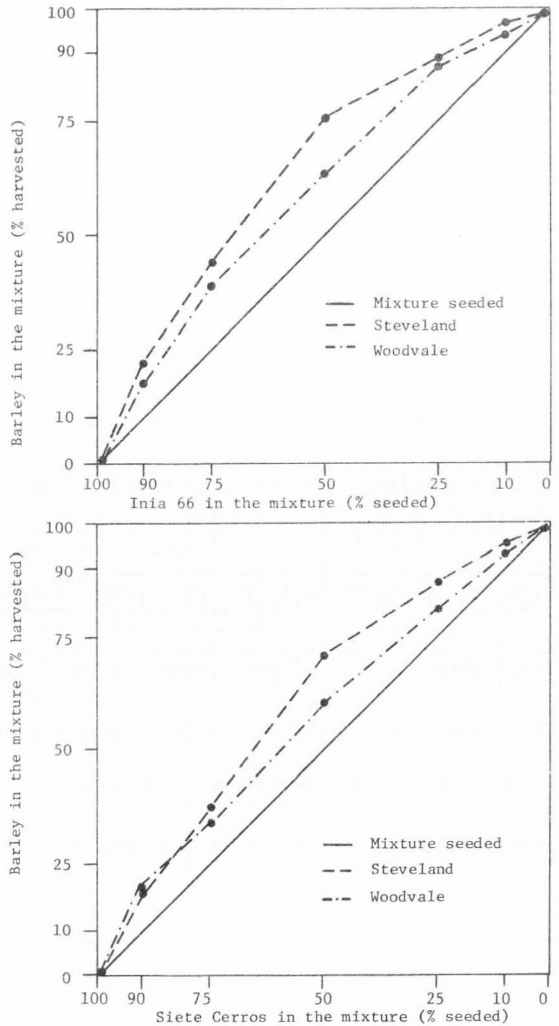


Figure 10. Percentage of barley in seeded and harvested mixtures of Steveland - Inia 66, Woodvale - Inia 66, Steveland - Siete Cerros and Woodvale - Siete Cerros in the Greenville nursery.

Similar results were reported by Klages (1936). He reported 27.5 and 26.9 percent excesses of barley in the harvested crop over percentages seeded when 25 and 50 percent, respectively, of barley was used in the seeded mixture. Woodvale when intermixed with both wheat varieties, Inia 66 and Siete Cerros, showed greatest total deviations from the "mixture seeded" line in the Evans nursery (Figure 9) whereas, Steveland showed greater total deviations in the Greenville nursery (Figure 10). These observed deviations were generally greater in the 1971 nursery.

The discussion of mean comparisons presented for barley also stand true for wheat, in a reverse relationship. Wheat proportions were decreased exactly the same amount that barley was increased in the respective mixtures.

Analysis of combined irrigated nurseries

Analysis of variance. Table 29 gives mean squares and F ratios for a combined analysis of variance for proportions of components, by weight, of harvested mixtures grown in 1971 and 1972.

Locations, barley and levels main effects were significant at the .01 probability level. Even though both nurseries were grown on irrigated land, changes in proportion of barley and wheat in the harvested crops were different in the two nurseries. These different responses were likely due to different environmental conditions under which the two nurseries were grown.

A significant interaction effect, at the .01 probability level, was observed between barley and mixture levels (B x L). Likewise Loc x B, Loc x W and Loc x L first order interactions were significant

Table 29. Analysis of variance for the proportion (weight) of components of harvested mixtures in the combined Evans and Greenville nurseries.

Source of variation	d.f.	M.S.	F
Location (loc)	1	3,670.3	168.36**
Reps/Loc	6	18.1	.83
Barley (B)	1	218.2	10.01**
Wheat (W)	1	12.6	.58
Level (L)	6	47,863.2	2,195.56**
W x B	1	74.0	3.39
B x L	6	143.4	6.58**
W x L	6	21.9	1.00
W x B x L	6	97.9	4.49
Loc x B	1	1,421.2	65.19**
Loc x W	1	231.7	10.63**
Loc x L	6	495.1	22.71**
Loc x W x B	1	40.8	1.87
Loc x B x L	6	185.7	8.52**
Loc x W x L	6	48.6	2.23*
Loc x W x B x L	6	62.0	2.84*
Error	162	21.8	
Total	223	1,358.0	

*Significant at the .05 probability level.
**Significant at the .01 probability level.

at the .01 probability level. All except one (Loc x W x B) of the second and third order interactions showed significance.

The combined analysis for changes in proportions of seeded and harvested wheat are identical to those reported for barley (Table 29). Since these data were recorded on a percentage basis, a change in percentage of one component necessitated a corresponding opposite change in percentage of the other component.

Mean comparisons. Table 30 shows percentages of barley and wheat seeded and harvested from mixtures grown in the Evans and the Greenville nurseries. Excess of barley in the harvested crop is also shown. All values are averages for the two locations.

Without exception, the proportion of barley harvested was significantly greater than the proportion seeded. These differences were all statistically significant at the .01 probability level.

Steveland showed its greatest excess in the harvested crop when mixed in equal proportions (50:50) with both wheat varieties (entries 4 and 11). Woodvale had the greatest excess when it made up only 25 percent of the mixture with both wheat varieties (entries 19 and 26).

Analyses of variance for the 1972 dryland nursery

Table 31 gives analyses of variance for percentage (by weight) of harvested barley and wheat in the 1972 Blue Creek nursery.

Main effects of barley and levels of mixture were statistically significant at the .01 probability level in both analyses. The significance of barley in both analyses indicates different responses of the two barley varieties and a significant influence of barley upon performance of the wheats in combination with it.

The wheat in both analyses of variance, showed significance at the .05 probability level. Neither the first nor the second order interactions were statistically significant.

Mean comparisons for the 1972 dryland nursery

Changes in the proportions, by weight, of components of seeded and harvested mixtures of barley and wheat in the 1972 Blue Creek nursery

Table 30. Changes in proportion (weight) of the components of seeded and harvested mixtures for the combined Evans and Greenville nurseries.

Entry number	Mixture seeded (%) Barley	Wheat	Harvested crop (%) Barley	Wheat	Excess of barley in the harvested crop (%)
			Steveland - Inia 66		
1	100	0	100.00	0.00	0.00
2	90	10	97.04	2.96	7.04**
3	75	25	91.06	8.94	16.06**
4	50	50	75.07	24.93	25.07**
5	25	75	48.41	51.59	23.41**
6	10	90	22.99	77.01	12.99**
7	0	100	0.00	100.00	0.00
			Steveland - Siete Cerros		
8	100	0	100.0	0.00	0.00
9	90	10	96.60	3.40	6.60**
10	75	25	88.81	11.19	13.81**
11	50	50	75.10	24.90	25.10**
12	25	75	45.94	54.06	20.94**
13	10	90	16.75	83.24	6.75**
14	0	100	0.00	100.00	0.00
			Woodvale - Inia 66		
15	100	0	100.00	0.00	0.00
16	90	10	97.01	2.99	7.01**
17	75	25	92.21	7.79	17.21**
18	50	50	75.38	24.62	25.38**
19	25	75	51.06	48.94	26.06**
20	10	90	24.68	75.32	14.68**
21	0	100	0.00	100.00	0.00
			Woodvale - Siete Cerros		
22	100	0	100.00	0.00	0.00
23	90	10	96.62	3.38	6.62**
24	75	25	89.37	10.63	14.37**
25	50	50	69.85	30.15	19.85**
26	25	75	54.51	45.49	29.51**
27	10	90	34.71	65.29	24.71**
28	0	100	0.00	100.00	0.00

**Significant at the .01 probability level.
L.S.D. at the .05 level = 3.23
L.S.D. at the .01 level = 4.25

Table 31. Analyses of variance for percentage (weight) of harvested barley and wheat kernels in the 1972 Blue Creek nursery.

		Barley		Wheat	
Source of variation	d.f.	M.S.	F	M.S.	F
Reps	3	129.76	2.10	129.76	2.10
Barley (B)	1	587.43	9.52**	587.45	9.52**
Wheat (W)	1	296.01	4.80*	296.01	4.80*
Level (L)	6	24,080.26	390.37**	24,080.26	390.37**
W x B	1	64.30	1.04	64.30	1.04
B x L	6	116.93	1.90	116.93	1.90
W x L	6	131.11	2.12	131.11	2.12
W x B x L	6	25.91	.42	25.91	.42
Error	81	61.68		61.68	
Total	111	1,373.50		1,373.50	

*Significant at the .05 probability level.
**Significant at the .01 probability level.

are given in Table 32. The last column of the table shows the excess of barley in the harvested crop over the percentage seeded. A consistent increase in the barley component was evident for all mixtures. This may be accounted for by differences in growth habit of the two crops. The barley varieties developed a heavy vegetative growth early and maintained this competitive advantage throughout the growing season.

In entry 12 there was a 23.5 percent excess of Caribou. This difference was significant at the .01 probability level. Caribou also showed significant differences at the .05 probability level in entries 4, 10, and 13.

There was a 15.0 percent excess of harvested Gem in entry 25. This difference was significant at the .01 probability level. Entry 26 showed an excess in percent of Gem harvested that was significant at

Table 32. Changes in proportion (weight) of the components of seeded and harvested mixtures in the 1972 Blue Creek nursery.

Entry number	Mixture seeded (%) Barley	Wheat	Harvested crop (%) Barley	Wheat	Excess of barley in the harvested crop (%)
			Caribou - Bannock		
1	100	0	100.00	0.00	0.00
2	90	10	95.01	4.98	5.01
3	75	25	82.41	17.59	7.41
4	50	50	60.98	39.02	10.98*
5	25	75	27.81	72.19	2.81
6	10	90	15.52	84.48	5.52
7	0	100	0.00	100.00	0.00
			Caribou - Red River 68		
8	100	0	100.00	0.00	0.00
9	90	10	95.47	4.53	5.47
10	75	25	86.86	13.14	11.86*
11	50	50	55.31	19.69	5.31
12	25	75	48.53	51.47	23.53**
13	10	90	21.99	78.01	11.99*
14	0	100	0.00	100.00	0.00
			Gem - Bannock		
15	100	0	100.00	0.00	0.00
16	90	10	94.56	5.44	4.56
17	75	25	83.83	16.17	8.83
18	50	50	54.64	45.38	4.64
19	25	75	30.65	69.35	5.65
20	10	90	14.65	85.35	4.65
21	0	100	0.00	100.00	0.00
			Gem - Red River 68		
22	100	0	100.00	0.00	0.00
23	90	10	92.29	7.70	2.29
24	75	25	77.49	22.51	2.49
25	50	50	65.04	34.96	15.04**
26	25	75	36.71	63.29	11.71*
27	10	90	18.95	81.03	8.95
28	0	100	0.00	100.00	0.00

*Significant at the .05 probability level.
**Significant at the .01 probability level.

L.S.D. at the .05 level =	9.28	9.28
L.S.D. at the .01 level =	13.27	13.27

the .05 probability level. None of the other differences were statistically significant. Relationships for proportions of barley and wheat in seeded and harvested mixtures are shown diagramatically in Figure 11.

The proportion of wheat in the harvested mixtures was reduced by the same amount as the excess shown by the barley varieties in each mixture. Consequently, the discussion of barley presented above is applicable to the wheat also, with a reversal in proportions harvested.

Path Coefficient Analyses

Correlation coefficients between seed yield and four of its components were subdivided into their direct and indirect effects using path coefficient analyses.

In the path diagrams, correlation coefficients are represented by double-headed arrows, indicating mutual association. Path coefficients are represented by single-headed arrows representing direct influence of the yield components upon seed yield. Residual variation or variation in grain yield not explained by the model is represented by Z.

In the discussion of yield and yield components, the terms "kernel size" and "kernel weight" are considered synonymous and are used interchangeably throughout the following discussion. The terms "head size" and "number of kernels per head" are also considered synonymous and used interchangeably.

First a discussion of changes in each component as influenced by changing the proportions of barley and wheat in the sown mixture will be presented. Second, the direct and indirect effects of yield components upon grain yield within the same mixture level will be discussed.

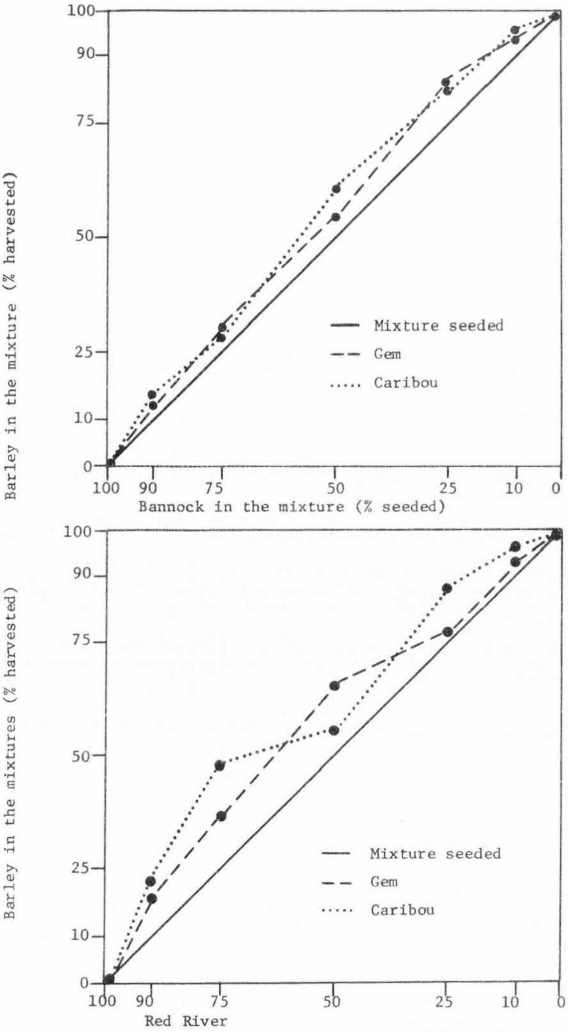


Figure 11. Percentage of barley in seeded and harvested mixtures of Caribou-Bannock, Gem-Bannock, Caribou-Red River 68 and Gem-Red River 68 in the mixture (% seeded) in the 1972 Blue Creek Nursery.

Barley

Numerical breakdown of the correlation coefficients between barley yield and its components in three mixtures are shown in Table 33. The same data are shown graphically in Figures 12, 13, and 14.

The direct effect of plant population (X_1) upon grain yield (Y) changed from a small positive value to a progressively larger negative value as the proportion of barley in the seeded mixture decreased. Calculated phenotypic values for the direct effect of plant population were .074, -.155, and -.366 for barley when it made up 100, 50 and 10 percent, respectively of the sown mixture. Correlation coefficients went from a significantly (.05 probability level) positive value of .487 for pure barley to .292 for 50 percent barley and to a negative value of -.202 where the mixture contained only 10 percent barley. This trend was similar to that for direct effect of plant population described above.

The direct effect of tillering (X_2) upon grain yield showed some inconsistency in sign between different mixtures. However, all direct effects and all correlation coefficients had steady decreases in size as the proportion of barley in the seeded mixture decreased. Correlation coefficients for straight barley and when mixed 50:50 with wheat were significant at the .05 probability level.

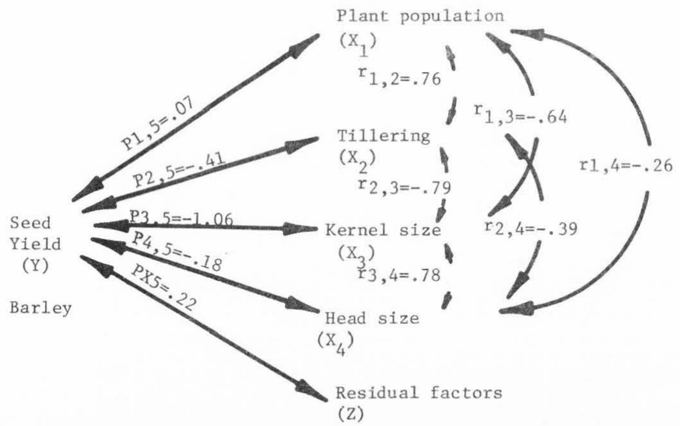
The direct effect of kernel size (X_3) upon grain yield went up from -1.059, when barley was grown in pure stand, to .176 when it made up only 10 percent of the seeded mixture. There was a consistent change from negative to positive with decreasing proportions of barley in the mixture. The same pattern was observed for the correlation

Table 33. Path coefficient analysis of the influence of four components upon barley yield, when grown in pure stand, in mixture of 50 percent barley and 50 percent wheat, and in mixture of 10 percent barley and 90 percent wheat, in the Greenville nursery.

Type of influence and association		Phenotypic values		
		100:0	50:50	10:90
Plant population vs. seed yield				
Direct effect	$P_{1,5}$	0.074	-.155	-.363
Indirect, via tillering	$r_{1,2}P_{2,5}$	-0.310	.175	.141
Indirect, via kernel size	$r_{1,3}P_{3,5}$	0.676	.267	.010
Indirect, via head size	$r_{1,4}P_{4,5}$	0.048	.005	.010
Total correlation	$r_{1,5}$	0.487*	.292	-.202
Tillering vs. seed yield				
Direct effect	$P_{2,5}$	-0.410	.231	.166
Indirect, via plant population	$r_{1,2}P_{1,5}$	0.056	-.117	-.308
Indirect, via kernel size	$r_{2,3}P_{3,5}$	0.834	.290	-.027
Indirect, via head size	$r_{2,4}P_{4,5}$	0.072	.019	-.057
Total correlation	$r_{2,5}$	0.553*	.423*	-.225
Kernel size vs. seed yield				
Direct effect	$P_{3,5}$	-1.059	-.469	.176
Indirect, via plant population	$r_{1,3}P_{1,5}$	-0.047	.088	-.021
Indirect, via tillering	$r_{2,3}P_{2,5}$	0.323	-.143	-.025
Indirect, via head size	$r_{3,4}P_{4,5}$	0.144	-.035	.092
Total correlation	$r_{3,5}$	-0.927**	-.559*	.222
Head size vs. seed yield				
Direct effect	$P_{4,5}$	-0.186	-.054	.189
Indirect, via plant population	$r_{1,4}P_{1,5}$	-0.019	.015	-.019
Indirect, via tillering	$r_{2,4}P_{2,5}$	0.159	-.081	-.050
Indirect, via kernel size	$r_{3,4}P_{3,5}$	-0.821	-.306	.086
Total correlation	$r_{4,5}$	-0.866**	-.426*	.206
Coefficient of determination		0.951	.337	.114

*Correlation coefficient must exceed .426 to be significant at the .05 level.

**Correlation coefficient must exceed .574 to be significant at the .01 level.



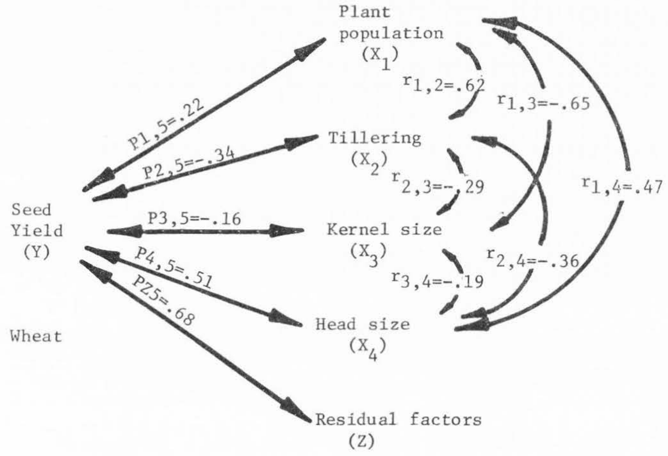


Figure 12. Path coefficient diagrams of the influence of four components upon seed yield of barley and wheat grown in pure stands.

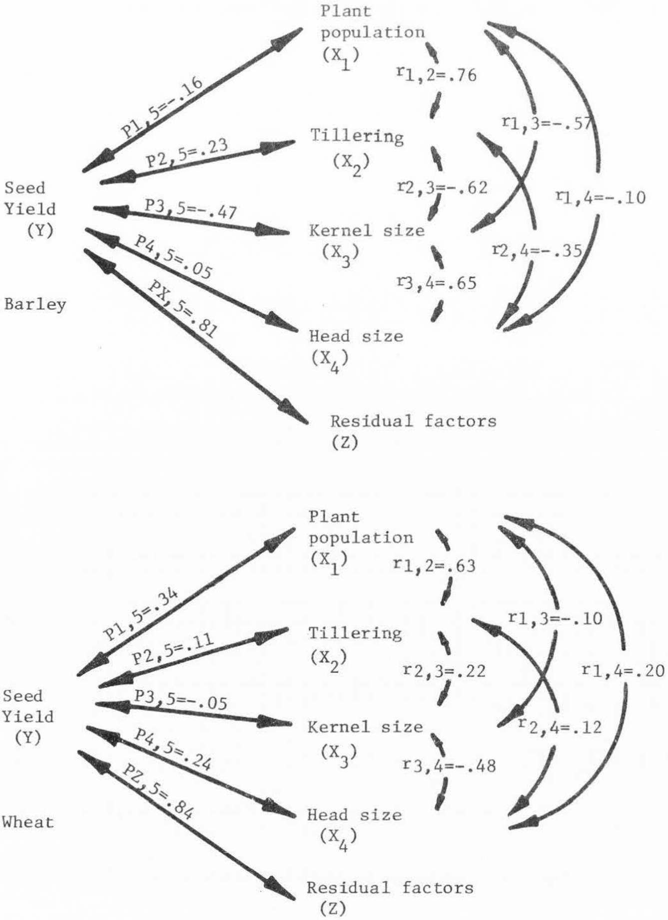
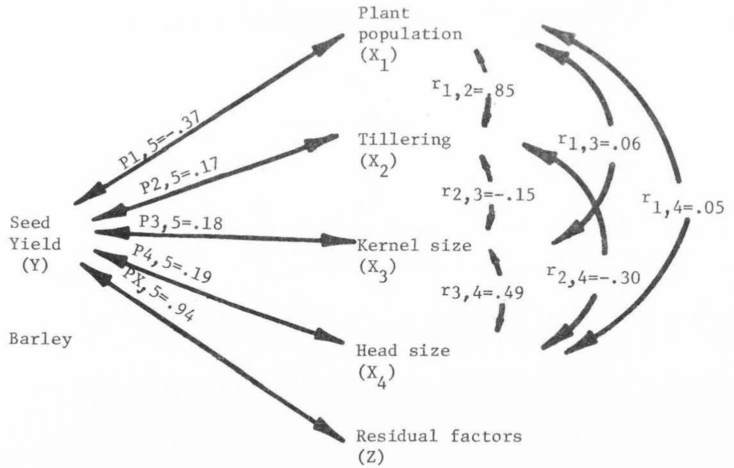


Figure 13. Path coefficient diagrams of the influence of four components upon seed yield of barley and wheat when grown in mixture of 50 percent barley and 50 percent wheat.



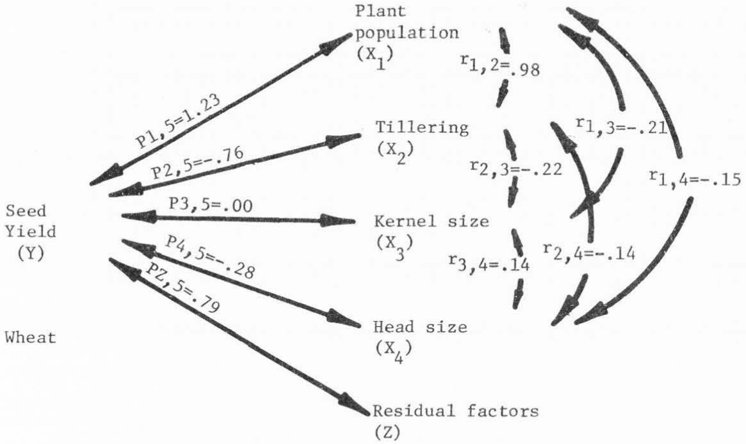


Figure 14. Path coefficient diagrams of the influence of four components upon seed yield of barley and wheat when grown in mixtures of 10 percent barley and 90 percent wheat.

coefficients which changed from -.927 to -.559 and to .222 for 100, 50, and 10 percent barley in the mixture.

Both the direct effects and correlation coefficients for head size (X_4), followed a very consistent trend of changing from negative to positive values as the proportion of barley in the seeded mixture decreased. Correlation coefficients went from -.866** to -.426* (Table 33) and to .206 in entries having 100, 50, and 10 percent barley, respectively. Direct effects of number of kernels per head upon grain yield went from -.186 to .054 and .189 at the 100, 50 and 10 percent barley mixtures.

Kernel size and head size showed highly significant negative correlations with grain yield in pure stands of barley. Plant population and tillering, on the other hand, showed significant (.05 level) positive correlations with grain yield (Table 33 and Figure 11). The sizes of all correlations and nearly all direct effects of components upon yield of barley were reduced as the proportion of barley in the mixture was decreased.

Coefficients of determination ranged from .951 when barley was grown in pure stands to .337 with 50 percent barley and down to .114 when the mixture contained only 10 percent barley. Thus, the proportion of yield variation accounted for by variation in the yield components consistently decreased with decreased proportion of barley in the mixture.

Wheat

Table 34 and Figures 12, 13 and 14 (Wheat) show phenotypic correlations between wheat yield and its components when grown at three

Table 34. Path coefficient analysis of the influence of four components upon wheat yield when grown in pure stand, in mixture of 50 percent barley and 50 percent wheat, and in mixture of 10 percent barley and 90 percent wheat, in the Greenville nursery.

Type of influence and association		Phenotypic values 100:0	50:50	10:90
Plant population vs. seed yield				
Direct effect	$P_{1,5}$	.220	.336	1.228
Indirect, via tillering	$r_{1,2}P_{2,5}$	-.211	.071	-0.750
Indirect, via kernel size	$r_{1,3}P_{3,5}$	.105	.006	0.000
Indirect, via head size	$r_{1,4}P_{4,5}$	.024	.049	0.042
Total correlation	$r_{1,5}$	.139	.463*	0.520*
Tillering vs. seed yield				
Direct effect	$P_{2,5}$	-.340	.113	-0.765
Indirect, via plant population	$r_{1,2}P_{1,5}$	.136	.212	1.203
Indirect, via kernel size	$r_{2,3}P_{3,5}$	.047	-.012	0.000
Indirect, via head size	$r_{2,4}P_{4,5}$	-.186	.030	0.037
Total correlation	$r_{2,5}$	-.342	.344	0.476*
Kernel size vs. seed yield				
Direct effect	$P_{3,5}$	-.160	-.054	-0.002
Indirect, via plant population	$r_{1,3}P_{1,5}$	-.144	-.036	-0.263
Indirect, via tillering	$r_{2,3}P_{2,5}$	.099	.025	0.167
Indirect, via head size	$r_{3,4}P_{4,5}$	-.096	-.114	-0.038
Total correlation	$r_{3,5}$	-.302	-.180	-0.135
Head size vs. seed yield				
Direct effect	$P_{4,5}$	.510	.240	-0.275
Indirect, via plant population	$r_{1,4}P_{1,5}$	.010	.068	-0.185
Indirect, via tillering	$r_{2,4}P_{2,5}$	.124	.014	0.103
Indirect, via kernel size	$r_{3,4}P_{3,5}$	.030	.026	-0.000
Total correlation	$r_{4,5}$	.675**	.349	-0.358
Coefficient of determination		.540	.288	.373

*Correlation coefficient must exceed .426 to be significant at the .05 level.

**Correlation coefficient must exceed .574 to be significant at the .01 level.

mixture levels. A breakdown of these correlations into their direct and indirect effects for the wheat component of the harvested crop are also shown.

The direct effect of plant population (X_1) followed a consistent pattern of increased influence upon seed yield (Y) as the amount of wheat decreased in the seeded mixture. This is exactly opposite from the pattern observed in the barley component. The correlation coefficients for wheat followed the same trend as the direct effects, going from a non-significant value of .139 in pure stands of wheat to significant values of .463* and .520* with 50 percent and 10 percent wheat mixtures, respectively (Table 34). Indirect effects were rather inconsistent in sign and magnitude.

The direct effect of tillering (X_2) upon seed yield of wheat was greatest when wheat made up only 10 percent of the mixture. A very high tillering indirect effect via plant populaiton was observed for the same level of mixture. Correlations between tillering and seed yield increased in size as the percentage of wheat in the mixture was decreased. This was the same pattern shown by the direct effect of this component in wheat; it was the exact opposite of the pattern found in barley.

Direct effects of kernel size (X_3) upon seed yield changed negligibly from -.170 to -.054 to -.002 when the proportion of wheat in the sown mixture was decreased from 100 to 50 and to 10 percent, respectively. Correlations between this component and yield were low and non-significant for all three levels of wheat used.

Direct effect of head size (X_4) upon seed yield decreased steadily as the proportion of wheat in the sown mixture decreased.

Correlations between head size and seed yield showed essentially the same pattern as did the direct effects. The pure wheat entry was the only treatment in which a significant correlation occurred between head size and seed yield.

Coefficients of determination decreased with decreased proportions of wheat in the sown mixture. Coefficients of determination values dropped from .540 for pure wheat populations to .288 and .373 for mixtures containing 50 and 10 percent wheat, respectively.

In general, wheat and its yield components responded differently to changes in mixture compositions than did barley. This was evidenced by the different relative contribution to yield of the same yield components in the two crops at corresponding mixture levels.

DISCUSSION

Results of the present study and those reported by Clay and Allard (1969), Jensen (1965) and Klages (1936) suggest that mixtures tend to yield slightly more than the mean of their components (mid-component), and occasionally better than the best component. Results from irrigated nurseries in the present study showed roughly 80 percent of the mixtures to have higher grain yields than the respective mid-component value and approximately 30 percent were higher yielding than the best component. Many of the observed differences were not statistically significant. In fact, the mixture yield was significantly higher than that of the best component in only two cases (Greenville nursery) among all comparisons made. Results obtained from the dryland nurseries were much the same as those described for the irrigated nurseries.

Roy (1960) was cited by Clay and Allard (1969) as the only study in which a mixture had been found to yield significantly higher than that of its best component. The present study provides additional evidence of mixtures having significantly higher grain yields than that of the mid-component and/or best component. However, some of the results of the present study should be interpreted with caution, since the yield of Woodvale in the Greenville nursery was far below its normal level.

Results of the present study suggest that mixtures of wheat and barley have a negative influence upon test weight. All mixtures had lower test weight than that of their respective mid-component. This may have been due largely to the higher than expected yield of barley in most mixtures, and the inherent lower test weight of barley compared to wheat. Test weight of the mixtures was significantly lower than that of respective best component in all cases. This would be expected because of the much higher inherent test weight of the best parent, wheat, compared to that of barley.

Number of plants per .60 m (2-foot) section showed that Steveland barley and the two wheat varieties, Inia 66 and Siete Cerros, had fewer plants per .60 m section of row than was expected when grown in mixtures. Woodvale consistently had more than the expected number of plants per .60 m section of row. Differential seed germination may have been the cause of such differences.

Results of the tillering study showed that in all cases, tillering decreased in both wheat varieties, Inia 66 and Siete Cerros, when grown intermixed with either barley variety, compared to the same wheat variety grown in pure stand. Both barley varieties showed a consistent increase in tillering as the amount of wheat in the sown mixture increased. These results suggested that barley is a more competitive crop than wheat in this characteristic. Thus, mixing stimulated tillering in barley while it had the opposite effect on wheat.

Ninety-two percent of the mixtures in the irrigated nurseries had an increased proportion of barley in the harvested crop, compared with the make-up of the seeded mixture. Similar results were also found in the 1972 Blue Creek nursery using a different set of dryland wheat and barley varieties. These results are in agreement with those reported by Klages (1936). Woodvale showed the greatest excess in percentage harvested barley when it made up 25 percent of the seeded mixture. Obviously, percentage of wheat in the harvested mixtures was decreased exactly the same amount by which barley was increased in the mixture being considered.

The increased proportion of barley in the harvested crop was likely due to the superior tillering ability of the barley compared to that of the wheat. This differential tillering ability was likely due to differences in growth habit of the two crops. The barley varieties were able to develop a heavy vegetative growth in the early stage of crop development which persisted throughout the growing season and resulted in severe competition for the wheat varieties.

Both wheat varieties, Inia 66 and Siete Cerros, and the barley variety Woodvale showed a general trend of slight decrease in kernel weight per head and in kernel number per head as the considered variety decreased in percentage of the sown mixture. On the other hand, Steveland produced more kernels per head and increased kernel weight per head as the percentage of Steveland in the seeded mixture was decreased, or as the percentage of wheat was increased. These two characters are positively related since kernel number per head and weight of kernels per head are two different ways of measuring the same thing, namely head size.

No significant differences in kernel size (weight) were observed between different mixtures involving the same varieties. However, a consistent pattern of slight increase in barley kernel size was noted as the percentage of barley decreased in the seeded mixture. Conversely, wheat showed a very consistent pattern of decreasing kernel weight as the percentage of wheat decreased in the seeded mixture. In a different set of dryland barley and wheat varieties studied in the 1972 Blue Creek nursery, kernel size (weight) was not affected by mixture level.

In all nurseries, variability in seed weight was dominated by varietal differences rather than levels of mixture within the same varieties.

A number of interesting relationships were observed in path coefficient analyses of the barley and wheat yield components. The direct effects (path coefficients) and the correlation coefficients between yield and its components in barley made similar changes as the proportion of barley in the seeded mixture changed. Likewise, direct effects and correlation coefficients in wheat showed similar patterns, but in most cases the pattern was in the opposite direction of that shown in the barley analyses.

Coefficients of determination in both wheat and barley decreased as the percentage of that crop in the seeded mixture was decreased. Thus, the proportion of yield variation accounted for by variation in the yield components analyzed consistently decreased as the percentage of the crop being analyzed decreased in the seeded mixture.

One of the outlined objectives of the study was to determine the effect of mixtures upon lodging resistance in barley. The particular growing conditions of the seasons in which these studies were conducted did not permit the accomplishment of this objective, since no lodging occurred in any of the nurseries.

SUMMARY AND CONCLUSIONS

Two Mexican wheat varieties, Inia 66 and Siete Cerros, and two barley varieties, Steveland and Woodvale, were grown in seven combinations with the following percentages of one barley and one wheat variety: 100:0, 90:10, 75:25, 50:50, 25:75, 10:90 and 0:100. These varieties were utilized in irrigated nurseries grown two years and in the 1971 dryland nursery. Better adapted dryland varieties (Red River 68 and Bannock wheat and Caribou and Gem barley) were used in the 1972 dryland nursery.

These studies were conducted to determine the effect of mixtures upon grain yield, yield components and other agronomic characteristics.

Grain yield of mixtures in the irrigated nurseries was higher than that of the mid-component value in 80 percent of the mixtures. A number of these differences were statistically significant. Thirty percent of the mixtures were higher yielding than the best component. Only two of these differences (in the 1972 Greenville nursery) were statistically significant. These two differences should be interpreted with caution, since the yield of Woodvale in this nursery was far below its normal level in comparison with other entries.

When these same varieties were tested under dryland conditions at Blue Creek in 1971, half of the mixtures had yields higher than that of their respective mid-component value. Only one of these differences was statistically significant. Twenty percent of the mixtures yielded higher than the best component, but no observed difference was statistically significant. Results obtained in the 1972 dryland nursery were much the same as those described for the other nurseries.

All of the mixtures had lower test weight than that of their respective mid-component and best component. Ninety percent of the observed differences between mixture and mid-component value showed statistical significance; all of the differences between mixture and best component were significant.

Steveland barley and the two wheat varieties, Inia 66 and Siete Cerros, in mixtures had fewer plants per .60 m (2-foot) section of row than was expected on the basis of seeded mixture. Woodvale had more plants per .60 m section than was expected.

Tillering of both wheat varieties decreased when grown in mixtures with barley, compared to the same variety grown in pure stand. Both barley varieties showed a consistent increase in tillering as the amount of wheat in the mixture increased.

Ninety-two percent of the mixtures in the irrigated nurseries had a greater proportion of barley in the harvested crop than was present in the seeded mixture. These differences were greatest around the 50:50 mixture level. Results obtained from the 1972 Blue Creek nursery were similar to those described for the irrigated nurseries.

Both wheat varieties, Inia 66 and Siete Cerros, and the barley variety, Woodvale, showed a generally slight decrease in kernel weight per head and in kernel number per head with progressive decreases in the mixture of the variety being considered. Steveland produced more kernels per head and increased weight of kernels per head when grown in mixtures than when grown in pure stand.

A consistent pattern of slight increase in barley kernel weight was observed as the amount of barley decreased in the seeded mixture. Conversely, wheat showed a very consistent pattern of decreasing kernel weight as the amount of wheat decreased in the seeded mixture. Although the patterns described above were generally true for both irrigated nurseries, no observed difference was statistically significant. Kernel size was not affected by mixture level in a different set of dryland barley and wheat varieties studied in the 1972 Blue Creek nursery.

Direct effects and correlation coefficients between yield and its components in barley made similar changes as the proportion of barley in the seeded mixture changed. Likewise, direct effects and correlation coefficients in wheat showed patterns similar to each other, but in most cases, the pattern was in the opposite direction of that shown in barley. Coefficients of determination in both wheat and barley decreased as the percentage of that crop in the seeded mixture was decreased.

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