EVALUATION OF HYBRIDS VS. PURE-LINE CULTIVARS OF WINTER WHEAT

By

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CULTIVARS OF WINTER WHEAT

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INTRODUCTION

Chapters III, IV, and V of this thesis are separate and complete manuscripts to be submitted to Crop Science for publication. The format of each manuscript conforms to the style of Crop Science.

CHAPTER II

LITERATURE REVIEW

The successful utilization of hybrid wheat depends on the extent of hybrid vigor (heterosis) for economic traits that exists within the species. In 1919, Freeman (7) reported heterosis in wheat when he found that F_1 plants were generally taller than the tall parent. In 1931, Rosenquist (21) found that F_1 plants showed heterotic effects for certain characters at a low density, while these effects did not show up when sister F_1 plants were grown at a high population density. He pointed out that a hybrid may show heterosis when growing under conditions which allow ample space for development but may not be fully as vigorous when grown under normal population density. In 1938, Pal and Nek Alam (18) concluded that the expression of heterosis in wheat depends on environment. Besides sowing time and sowing depth, they also varied plant density in their experiment. Subsequent reports from other workers have indicated that heterosis exists for other agronomic characters such as yield, kernel weight, kernels/spike, tiller number, maturity, plant height, and general plant vigor (3, 12, 14, 22, 25).

A comprehensive review of heterosis in wheat was made in 1963 by Briggle (3) in which significant positive mid- and high-parent heterosis for yield, ranging from 0 to 100%, was reported. He emphasized, however, that caution should be exercised when evaluating these reports of heterosis due to a common problem of limited scope and application of many of the studies. In his review, most of the studies on heterosis involved small-sized plots that were space planted either in the field or greenhouse (3). Since this review, a number of publications describing heterosis for yield, its components and other characters have been issued.

Johnson et al. (12) studied F_1 and F_2 populations of a cross involving two hard red winter wheat varieties which differed greatly in regard to several agronomic traits including plant height, grain yield, spike length, maturity, and kernel weight. High-parent heterosis for grain yield, kernel weight, and number of spikes was reported.

Several studies have demonstrated heterosis for grain yield in intervarietal crosses, both under spaced and solid seeding (6, 8, 18). Of interest, however, is the choice of parents for the production of hybrids which demonstrate significant heterosis for important characters. McNeal et al. (17) evaluated F_1 and F_2 generations of three spring wheat crosses for several agronomic characters. The seeding rate was about one-half of the normal planting rate for wheat. For most traits, the F_1 and F_2 generations appeared to be intermediate between the parents, and no significant high parent heterosis was observed for any trait. They pointed out that the parental lines used in this study represented a rather narrow gene base, and emphasized the necessity of utilizing parents of wide genetic diversity in the development of wheat hybrids.

The performance of hybrids in spaced plantings, in hills, and in thinly planted nursery yield plots, was investigated by Fonseca and Patterson (6), who studied several agronomic characters in F_1 and F_2 wheat populations and evaluated hill plots as a technique of determining heterosis. They found no seeding rate-genotype interaction. They also reported that the advantages of hybrids may tend to be over estimated in hill plots.

Under near normal field testing procedures, Livers and Heyne (15) noted that 18 hybrids averaged 20% more than the mean value of seven parents for yield. They concluded that certain hard red winter wheat hybrids grown under near solid seeding could express significant heterosis for yield.

In 1968, Johnson and Schmidt (13) reviewed the progress of hybrid wheat production. They reported on improved breeding techniques as well as agronomic considerations important to the success of hybrid wheat. They also pointed out the economic ramifications of hybrid seed production.

Hayward (10) reported on a heterosis study involving 40 wheat hybrids possessing fairly wide genetic diversity. These hybrids and their respective inbreds were evaluated for maturity, height, lodging, test weight, and yield. Yield levels of hybrids varied from -13 to 46 and -16 to 35% of the mid-parent and high-parent, respectively. He pointed out that heterosis values are meaningful in predicting the success of hybrid wheat providing the yield of the parents (inbreds) is comparable to the yields of the best pure line cultivars available.

Zeven (27) reported on the effect of plant density on expression of heterosis for yield and its components in wheat. He found that density had no effect on expression of heterosis in his experiment. Although the density effect on expression of heterosis is only investigated on a limited scale most experiments show that with increasing density the expression of heterosis decreases or remains constant (2, 12, 20).

The discovery of a useful male sterile and restorer system reportedly would lead to substantial hybrid wheat development research by several private seed companies. Today much of the hybrid wheat research continues to be based on the *T. timopheevi* system discovered by Wilson and Ross (26). The *T. timopheevi* system involves the use of a cytoplasmic male sterile (CMS = A line) and fertility restoring (R line). Its widespread use has been largely the result of its apparent neutral effect on agronomic and quality characters. Most other cytoplasms have some deleterious effects on various traits (24). Subsequent research that solved many of the problems associated with the development of sterile and fertility-restorer lines was reported by Lucken (16).

In contrast to this biological method of hybrid production a few chemical companies are currently evaluating chemical pollen suppressant (CPS) compounds in wheat. Chemical hybridizing systems (CHA) have been developed which offer considerable flexibility in producing wheat hybrids. Baker (1) reported on a chemical gameticide method of pollen suppressant to be utilized in hybrid seed production. His company has commenced limited CPS production on several soft red winter and hard red winter hybrids.

In 1983, a review of the status and future prospects of hybrid wheat was published by Virmani and Edwards (25). The authors make several important observations in this review. They note that few studies in wheat have reported economically significant yield advantages of F_1 hybrids over the best conventional varieties. However, much of the research on hybrid wheat has been directed at perfecting the systems of hybrid production rather than on evaluating hybrid combinations. Only since the early 1970's has research been directed toward the improvement of economically important agronomic characters.

In compliance with State Seed Law 8-120 (24), Oklahoma State University has conducted performance trials of wheat hybrids annually.

These trials include both CMS-R and CHA hybrids. A review of the data from these tests indicates that relative to pure-line cultivars the performance of wheat hybrids has improved considerably since 1981. When comparing the yield of the best hybrid versus the best pure-line in these trials, the hybrids have ranged from 81% of the best pure-line in 1974 to 117% in 1983. Therefore, it seems that the emphasis on improving economically important characters has produced favorable results.

Concerning the future prospects for breeding hybrid wheat, Virmani and Edwards (25) point out that the identification of genotypes potentially useful as female inbreds, their rapid incorporation into a male-sterile conversion program, and the maintenance of pure seed will provide a management challenge to hybrid breeders. It is against this background that one must assess the advantages of hybrids over conventionally bred cultivars. A strong pure-line breeding program is fundamental for the production of female inbreds; to this extent hybrids and pure-lines are both complementary and competitive. Environmental adaptation combined with such factors as winter survival and maturity will all contribute to relative hybrid advantage (4, 9, 11, 19, 23). These factors should be considered in conjunction with yield data. More extensive hybrid evaluation is being conducted by a number of wheat programs, and the anticipated results are promising (25).

CHAPTER III

HETEROSIS DETERMINATION FOR SEVEN CHARACTERS IN THREE WINTER WHEAT HYBRIDS

Introduction

Plant breeders have long been concerned with the development of superior, high yielding cultivars. The successful development of hybrid corn in the early 1900's prompted breeders to examine the possibility of hybrid production of an array of other cross- and self-pollinating species. Wheat (*Triticum aestivum* L.) is a self-pollinating cereal and is a major food crop of the world. Since wheat is a highly inbred species, improvements have traditionally been through conventional selection of pure-line cultivars from segregating populations following hand made crosses. Only recently have effective pollination control systems been dicsovered for developing productive wheat hybrids on a commercial scale. Today, hybrid wheats are produced by two systems of pollination control; one is a cytoplasmic male sterility and nuclear fertility restoration system, while the second system involves the use of a chemical gameticide as a pollen suppressant. Since there should be no problems concerning sterility-fertility restoration associated with the chemical hybridizing system, a test for heterosis for yield and yield components in chemically produced hybrids is of particular interest.

Heterosis for yield is a major requisite for the successful utilization of hybrid wheat. The complex nature of yield combined with the degree of environmental influence on yield makes direct evaluation of heterosis for yield difficult. Indirect evaluation of heterosis for yield based on heterosis for yield components and/or other agronomic characters is a possible solution to this problem. A careful examination of the yield components (i.e., tiller number, kernel weight, and kernels/spike) as well as other agronomic characters such as harvest index, height, maturity, and seeding rate should provide some insight into the important contributing factors of heterosis for yield.

The objectives of this study were: 1) to determine the level of heterosis for yield in three chemically produced wheat hybrids, and 2) to examine the performance of those three hybrids for seven important agronomic characters as a possible explanation of heterosis if it is found to exist.

Materials and Methods

Three hard red winter wheat hybrids and their parents along with one pure-line cultivar were grown in a randomized complete block experiment at two locations in Oklahoma during the 1983-1984 growing season. Seed of the three hybrids were obtained from a private company (Rohm and Haas). The hybrids were 'HW 1010', 'HW 1030', and 'HW 1031'. They had been produced by the use of a chemical hybridizing agent. The parent lines, identified only by code numbers, were also obtained from the same company. The pure-line cultivar 'Chisholm' has been the highest yielding line in Oklahoma for the past several years and was included as a check.

The experiment was grown as a randomized complete block experiment with four replications each at Stillwater and Lahoma. Two seeding rates (based on seed number), equivalent to the standard rate of 60 lbs/acre (67.0 kg/ha) and one-half the standard rate of 30 lbs/acre (33.5 kg/ha) were sown in 1.2 m by 3.1 m plots. Each plot contained four rows spaced 30 cm apart. Plots were seeded with a cone planter. Nitrogen was broadcast at 60 kg/ha in a split application both preplant in the fall and then in the early spring at Stillwater, while 110 kg/ha of nitrogen was broadcast at Lahoma preplant in the fall. Soil type was a Norge loam at Stillwater and a Grant silt loam at Lahoma. Heading date and plant height were evaluated on a whole plot basis. Grain yield, harvest index, tiller number, kernels/spike, and 1000 kernel weight were determined on a sample consisting of two 30 cm^2 sections of row taken from each of the two outside rows of each plot. Both sample and plot grain yields were recorded. However, the yield from the sample was used in the analysis due to variable plant stands in the two center rows as a result of crusting which affected emergence. The sample was harvested using a hand sickle and measuring stick. The sample consisted of two 30 cm^2 sections of row (one section from each of the two outside rows). Yield component measurements were taken from this sample which was later threshed with a small Vogel thresher.

Characters Evaluated

Grain Yield

Grain yield for the sample was recorded as the weight of threshed grain including the weight from the five spikes selected for yield component determination from the sample and was expressed as kilograms per hectare.

Heading Date

Heading date was recorded as a visual estimation of the plot on the date when 50% of the plants in a plot were fully headed. This trait was expressed as the number of days after March 31.

Plant Height

Plant height was measured as the distance, in centimeters, from the soil surface to the tip of the tallest spike, excluding awns. This trait was recorded as an average of the upper-story spikes for each plot.

Harvest Index

Harvest index was determined as the ratio of grain yield to biological yield. Biological yield was taken as the weight of total plant material harvested approximately 3 cm above the soil line for the sample. Harvest index was expressed as a decimal.

Tiller Number

Tiller number was recorded as the number of fertile (seed bearing) spikes per sample at the time of threshing and expressed as the number of tillers per sample.

Kernels/Spike

The number of kernels per spike was determined by selecting five representative spikes from each sample. These were threshed individually and the kernels were counted. This trait was expressed as the mean number of kernels per spike.

1000 Kernel Weight

One thousand kernel weight was determined by dividing the weight (in grams) of grain obtained from the five selected spikes by the number of kernels from those five spikes. This trait was expressed as grams per one-thousand kernels.

Results and Discussion

Parent and hybrid means for the seven traits are presented in Table 1. Average yields were higher at Stillwater than at Lahoma. Analyses of variance conducted for all seven characters of all 10 genotypes are presented in Table 2. Significant differences among genotypes were found for all seven traits at each location except for tiller number at Stillwater. Seeding rate differences were found for tiller number, kernels/spike, maturity, and plant height at Stillwater and for harvest index, tiller number, kernels/spike, and maturity at Lahoma. No differences among seeding rates were found for yield or kernel weight at either location. No significant differences were found at either location for genotype by seeding rate interactions.

Heterosis in relation to mid-parent performance values was examined at two seeding rates for all characters analyzed. Means of all three hybrids for the seven characters measured were expressed as the percentage of their respective mid-parent means. These values are presented for both locations in Table 3.

Hybrid vs. Mid-Parent Contrasts

At Stillwater two of the three hybrids exhibited significant mid-parent heterosis for yield (Table 3). HW 1031 exhibited highly significant mid-parent heterosis at the standard seeding rate, but no significance was demonstrated at one-half the standard seeding rate. Conversely, the yield of HW 1030 was significantly better than its mid-parent value at half the standard seeding rate, but no significant difference was observed at the standard seeding rate. None of the hybrids yielded significantly lower than their respective mid-parent at either seeding rate. At Lahoma all three hybrids exhibited significant mid-parent heterosis for yield at one or both seeding rates.

Of the yield components, kernel weight was observed to have the most striking heterotic effect. At Stillwater two of the hybrids, HW 1010 and HW 1031, exhibited highly significant mid-parent heterosis for this character at both seeding rates. At Lahoma HW 1010 and HW 1030 exhibited significant mid-parent heterosis for kernel weight.

Tiller number and kernels/spike appeared to be of less importance than other factors contributing to heterosis for grain yield. At Stillwater none of the hybrids exceeded its mid-parent value for either trait, while HW 1031 was significantly lower than its mid-parent for tiller number. At Lahoma one hybrid, HW 1031, exhibited significant mid-parent heterosis for kernels/spike. No difference was observed for the other two hybrids from their mid-parents for this trait. At Lahoma none of the hybrids were different in tiller number from their mid-parent.

At Stillwater two hybrids, HW 1010 and HW 1031, exhibited significant mid-parent heterosis for harvest index. At Lahoma all three hybrids exhibited some mid-parent heterosis for harvest index.

At Stillwater heading dates were as early or earlier than the mid-parent value for all three hybrids. At Lahoma all three hybrids were earlier in maturity than their mid-parents.

As for plant height, no difference was observed at Stillwater between any of the hybrids and their mid-parents. At Lahoma HW 1031 was taller than its mid-parent.

Hybrid vs. Chisholm Contrasts

At Stillwater only HW 1031 at the standard seeding rate yielded significantly more than Chisholm, the pure-line check cultivar (Table 4). At Lahoma no differences were detected in yield between any hybrid and the pure-line check cultivar.

At Stillwater no significance over the pure-line check kernel weight was observed for any of the three hybrids. Two hybrids, HW 1010 and HW 1030, exhibited significantly lower kernel weights than the check cultivar Chisholm. At Lahoma all three hybrids were significantly lower in kernel weight than the pure-line Chisholm. As in the Stillwater experiment, kernel weight was the yield component with the most striking heterotic effect and similarly failed to perform as well as the check for this character.

At Stillwater one hybrid, HW 1010, exhibited a significantly greater kernels/spike value than the pure-line check. Otherwise, there was no difference in the hybrids and the check for tiller number or kernels/spike. At Lahoma HW 1010 had a significantly higher value for kernels/spike than the check cultivar Chisholm while HW 1031 was significantly lower in performance for this trait than the pure-line check. At Lahoma all three hybrids exhibited significantly higher tiller numbers than the pure-line check.

At Stillwater no improvement in harvest index values was observed for any hybrid over the check cultivar Chisholm. Conversely, HW 1010 and HW 1030 were found to exhibit significantly lower harvest index values than Chisholm. At Lahoma all three hybrids were significantly lower in performance for this trait than the check cultivar.

At both locations all three hybrids were significantly later than the pure-line check.

At Stillwater two hybrids, HW 1030 and HW 1031, were significantly taller than the check, while no difference in height was observed between HW 1010 and Chisholm. At Lahoma all three hybrids were significantly taller than Chisholm.

At Stillwater seeding rate seemed to be of minor importance. Slight differences in performance values were observed for some traits. However, no profound contrast was determined to be due to the different seeding rates since in general the performance trends were consistent over both rates. At Lahoma seeding rates appeared to have little effect on hybrid performance. Both rates were observed to produce similar results.

A summary of the mean yields for all 10 genotypes is given in Table 5. In every case, the hybrids yielded more than either of their respective parents. In addition, one hybrid, HW 1031, was the highest yielding genotype at both locations and the only entry in either experiment to yield higher than the pure-line check cultivar Chisholm.

Table 1. Mean performance values of seven characters of three hybrids, their parents, and the check cultivar Chisholm at two seeding rates at two locations in 1983.

Cultivar	Grain Yield (kg/ha)		Harvest Index		Tiller Number		Kernels/ Spike		1000 Kernel Weight (gm)		Maturity (days)		Plant Height (cm)	
	Seeding Rate (kg/ha)													
	67.0	33.5	67.0	33.5	67.0	33.5	67.0	33.5	67.0	33.5	67.0	33.5	67.0	33.5
Stillwater														
Chisholm	4850	4835	.43	.43	107.3	97.3	36.3	39.1	32.5	31.8	37.8	38.3	72.5	71.3
HW 1010F[1]	4739	4052	.42	.41	105.0	88.5	42.3	46.7	25.3	25.6	41.0	41.5	71.0	67.3
HW 1010M[2]	3985	4331	.35	.36	96.0	95.0	42.9	47.5	22.4	23.5	46.5	47.8	78.0	80.0
HW 1010X[3]	4895	4514	.43	.38	94.0	84.3	44.9	50.6	29.6	28.9	41.3	41.8	74.5	69.3
HW 1030F	4636	3881	.39	.38	117.8	93.3	37.7	38.7	25.6	25.0	45.0	46.0	73.3	74.0
HW 1030M	4528	3904	.40	.39	104.8	82.3	33.8	40.1	30.3	28.7	47.5	49.0	81.0	76.5
HW 1030X	4450	4759	.40	.40	103.5	98.5	38.2	41.5	29.4	28.1	45.0	45.5	80.0	79.3
HW 1031F	4040	4577	.38	.39	103.8	105.5	36.5	40.5	24.0	25.8	45.3	46.0	77.5	75.5
HW 1031M	4745	4767	.37	.36	107.3	93.3	35.5	39.6	29.7	28.9	46.3	47.0	96.0	91.5
HW 1031X	5797	5214	.42	.42	105.5	82.5	39.6	42.7	31.5	32.7	45.3	46.3	91.0	79.8
MEAN	4666	4483	.40	.40	104.5	91.9	38.7	42.7	28.0	27.9	44.1	44.9	76.4	79.5
Lahoma														
Chisholm	3707	3483	.43	.47	86.3	62.3	30.1	35.2	36.3	35.3	42.5	43.0	72.5	68.3
HW 1010F	3682	3333	.42	.44	100.0	80.3	37.5	42.1	26.7	26.4	44.0	44.5	70.8	69.8
HW 1010M	2599	2988	.34	.34	76.8	81.5	39.4	42.0	22.2	22.2	49.3	50.3	80.8	78.3
HW 1010X	3248	3909	.42	.44	80.5	83.0	36.9	40.8	30.8	30.0	43.8	44.3	74.5	73.0
HW 1030F	3141	3073	.37	.38	107.5	86.5	29.7	32.6	26.9	26.7	47.8	49.3	78.5	77.0
HW 1030M	2813	2661	.36	.35	94.5	85.8	27.2	29.2	29.0	26.1	48.5	50.3	85.8	84.3
HW 1030X	3482	3186	.37	.38	110.5	91.3	30.0	32.2	27.8	30.4	47.0	47.5	82.8	83.3
HW 1031F	3417	3272	.36	.38	127.0	99.5	27.5	30.4	25.3	26.8	47.5	48.3	78.5	78.5
HW 1031M	2900	2914	.31	.32	107.8	89.3	25.3	28.8	26.3	27.8	48.8	49.0	95.0	97.8
HW 1031X	3721	3678	.36	.36	110.8	103.5	29.4	31.8	28.0	28.0	47.4	47.8	90.8	93.3
MEAN	3271	3250	.38	.39	100.2	86.3	31.3	34.5	27.9	27.9	46.6	47.4	81.0	80.3

[1,2,3] F,M,X = Female parent, male parent, and hybrid, respectively.

Table 2. Analyses of variance for seven characters of ten genotypes at each of two locations in 1983.

Source of Variation	df	Grain Yield	Harvest Index	Tiller Number	Kernels/ Spike	Kernel Weight	Maturity	Plant Height
Stillwater								
Replication	3	**	*	**	ns	ns	**	**
Seeding Rate (SR)	1	ns	ns	**	**	ns	**	**
Genotype	9	**	**	ns	**	**	**	**
Group[1]	3	**	**	ns	**	**	**	**
Generation[2]	3	**	**	ns	**	**	**	ns
Type[3]	3	ns	**	ns	ns	**	**	**
Genotype X SR	9	ns	ns	ns	ns	ns	ns	ns
Group X SR	3	ns	ns	ns	ns	ns	ns	ns
Generation X SR	3	ns	ns	ns	ns	ns	ns	ns
Type X SR	3	ns	ns	ns	ns	ns	ns	ns
Error (Mean Squares)	57	311,002	4.0	190.0	9.6	0.03	0.37	18.3
C.V. (%)		12.2	5.0	14.0	7.6	5.7	1.4	5.5
Lahoma								
Relication	3	ns	**	ns	ns	**	**	ns
Seeding Rate (SR)	1	ns	**	**	**	ns	**	ns
Genotype	9	**	**	**	**	**	**	**
Group	3	**	**	**	**	**	**	**
Generation	3	**	**	ns	*	**	**	*
Type	3	**	**	**	*	**	**	**
Genotype X SR	9	ns	ns	ns	ns	ns	ns	ns
Group X SR	3	ns	*	ns	ns	ns	ns	ns
Generation X SR	3	ns	ns	ns	ns	ns	ns	ns
Type X SR	3	ns	ns	ns	ns	ns	ns	ns
Error (Mean Squares)	57	113,251	2.1	134.3	5.2	0.04	0.45	10.7
C.V. (%)		10.3	3.8	13.4	6.9	7.0	1.4	4.1

*,** Significant at the .05 and .01 levels of probability, respectively.

[1] Group = comparison of three hybrids and Chisholm; [2] Generation = comparison of parents, hybrids, and Chisholm; [3] Type = comparison of female parents, male parents, hybrids, and Chisholm.

Table 3. Mean performance of seven characters of three hybrids expressed as percent of mid-parent performance at each of two seeding rates at two locations in 1983.

Hybrid	Grain Yield	Harvest Index	Tiller Number	Kernels/ Spike	Kernel Weight	Maturity	Plant Height
Stillwater			67.0 kg/ha Seeding Rate				
HW 1010	112	110**	94	105	124**	94**	100
HW 1030	97	101	93	107	105	97**	104
HW 1031	123**	111**	100	110	118**	99	105
			33.5 kg/ha Seeding Rate				
HW 1010	108	99	92	107	118**	94**	94
HW 1030	122*	103	112	105	105	96*	105
HW 1031	112	110**	92*	107	120**	100	96
Lahoma			67.0 kg/ha Seeding Rate				
HW 1010	103	110**	91	96	126**	94**	98
HW 1030	117*	102	109	106	100	98**	101
HW 1031	118**	106*	94	111*	109	98*	105
			33.5 kg/ha Seeding Rate				
HW 1010	124**	111**	103	97	124**	93**	99
HW 1030	111	106*	106	104	115**	95**	103
HW 1031	119**	103	110	107	103	98*	106*

*,** Significant at the .05 and .01 levels of probability, respectively.

Table 4. Mean performance of seven characters of three hybrids expressed as percent of the check cultivar Chisholm at each of two seeding rates at two locations in 1983.

Hybrid	Grain Yield	Harvest Index	Tiller Number	Kernels/ Spike	Kernel Weight	Maturity	Plant Height
Stillwater	67.0 kg/ha Seeding Rate						
HW 1010	101	99	88	124**	91*	109**	103
HW 1030	92	93*	96	105	90**	119**	110*
HW 1031	120*	97	98	109	97	120**	126**
	33.5 kg/ha Seeding Rate						
HW 1010	93	88**	87	129**	91*	109**	97
HW 1030	98	92*	101	106	88**	119**	111*
HW 1031	108	97	84	109	103	121**	112**
Lahoma	67.0 kg/ha Seeding Rate						
HW 1010	88	97	93	123**	85**	103*	103
HW 1030	94	86**	128**	100	77**	111**	114**
HW 1031	100	83**	128**	98	77**	111**	125**
	33.5 kg/ha Seeding Rate						
HW 1010	112	93**	113*	116**	85**	103*	107*
HW 1030	91	81**	147**	91	86**	110**	122**
HW 1031	106	77**	166**	90*	79**	111**	137**

*,** Significant at the .05 and .01 levels of probability, respectively.

Table 5. Mean yield of ten genotypes averaged across seeding rates for each of two locations in 1983.

	Stillwater kg/ha	Percent of Chisholm	Lahoma kg/ha	Percent of Chisholm	Location Average kg/ha	Percent of Chisholm
HW 1010F[1]	4395	90.8	3508	97.6	3952	93.7
HW 1010M[2]	4158	85.9	2793	77.7	3476	82.4
HW 1010X[3]	4705	97.2	3579	99.6	4142	98.2
HW 1030F	4258	87.9	3107	86.4	3683	87.3
HW 1030M	4216	87.1	2737	76.1	3477	82.4
HW 1030X	4604	95.1	3334	92.7	3969	94.1
HW 1031F	4308	89.0	3344	93.0	3826	91.5
HW 1031M	4756	98.2	2907	80.9	3832	90.8
HW 1031X	5505	113.7	3699	102.9	4602	109.1
Chisholm	4842	--	3595	--	4219	--

[1,2,3] F, M, X = female parent, male parent, and hybrid, respectively.

CHAPTER IV

YIELD AND YIELD COMPONENT PERFORMANCE OF HYBRIDS VS. PURE-LINE CULTIVARS OF WHEAT

Introduction

Plant breeders are continually in search of ways to improve the yield potential of crops plants. The development and utilization of hybrids offers a possibility of improving the yield potential of wheat (*Triticum aestivum* L.). The *Triticum timopheevi* based cytoplasmic male sterile and fertility restorer system in wheats was discovered in 1961 (26). This discovery led to substantial hybrid wheat development research by several private seed companies. Subsequent research has solved many of the problems associated with the development of a useful sterility-fertility restoration system. More recently, chemical hybridizing systems have been developed which offer considerable flexibility in producing wheat hybrids. In this system, a chemical gameticide is used as a pollen suppressant. At the present time, three private companies have programs aimed at developing hybrid wheats and sales of wheat hybrids are expected to increase substantially in the near future. Of these three companies, two are using the *Timopheevi* CMS-R system of producing hybrids and one is using a chemical gameticide.

If wheat hybrids are to become economically significant, more must be known about their ability to perform over a range of environments. On the assumption that yield component analysis can tell much about the ability to perform, a study to evaluate wheat hybrids and to compare them to standard cultivars is of interest. Also an estimate of the stability of yield components of these hybrids is of interest. Eberhart and Russell (5) define a stable cultivar as one with a unit regression coefficient (b = 1.0) and small deviations from regression ($s^2d = 0$).

One other item of interest would be to compare groups of hybrids from different companies to see how different systems affect the performance of wheat hybrids. The objective of this study was to evaluate the performance of hybrids vs. pure-line cultivars of wheat for yield and the yield components.

Materials and Methods

This experiment was conducted during the 1983-1984 growing season. Twelve genotypes were chosen from six Oklahoma locations. The materials used in this experiment consisted of nine hard red winter wheat hybrids and three pure-line cultivars. The nine hybrids and their respective companies of development were 'Bounty 100', 'Bounty 203', and 'Bounty 310', Cargill; 'Quantum XH 150A', 'Quantum XH 157B', and 'Quantum XH 165', Hybri Tech; and 'Hybrex HW 1010', 'Hybrex HW 1030', and 'Hybrex HW 1031', Rohm and Haas. The three pure-line cultivars were 'Tam 105', Texas; 'Vona', Colorado; and 'Chisholm', Oklahoma. The Cargill and Hybri Tech hybrids were produced by the cytoplasmic male sterile-nuclear restoration system and the Rohm and Haas hybrids were produced by a chemical gameticide system of pollination control.

The trials were grown as randomzied complete-block experiments with four replications at Stillwater, Lahoma, Altus, Goodwell (irrigated), Goodwell (dryland), and Woodward, hereafter referred to as locations 11, 12, 13, 14, 15, and 16, respectively. Approximately 480 seeds per plot (equivalent to 67 kg/ha), the standard seeding rate, were planted at all locations except Goodwell (dryland) where approximately 360 seeds per plot (equivalent to 50 kg/ha) were sown in plots 1.2 m by 3.1 m. Plots consisted of five rows spaced 24 cm apart. Sample grain yield, harvest index, tiller number, kernels/spike, and 1000 kernel weight were determined on a sample consisting of two 30 cm^2 sections taken from two bordered rows for each plot. In addition, plot grain yield was obtained. Fertilizer application and management of the trials was consistent with good wheat production practices at each location.

Characters Evaluated

Grain Yield

Grain yield for the total of two 30 cm^2 samples was recorded as the weight of threshed grain, including the weight from the five spikes selected for yield component determination, from the sample and was expressed as kilograms per hectare. Plot yields were harvested with a "Hege" combine, and the sample grain weight was included.

Harvest Index

Harvest index was determined as the ratio of grain yield to biological yield. Biological yield was taken as the weight of total plant material harvested approximately 3 cm above the soil line for the sample. Harvest index was expressed as a decimal.

Tiller Number

Tiller number was recorded as the number of fertile (seed bearing) spikes per sample at the time of threshing and expressed as the number of tillers per sample.

Kernels/Spike

The number of kernels per spike was determined by selecting five representative spikes from each sample. These were threshed individually and the kernels were counted. This trait was expressed as the mean number of kernels per spike.

1000 Kernel Weight

One-thousand kernel weight was determined by dividing the weight (in grams) of grain obtained from the five selected spikes by the number of kernels from those five spikes. This trait was expressed as grams per one-thousand kernels.

Results and Discussion

Analyses of variance conducted for all five traits along with contrasts of the hybrid and pure-line groups are presented in Table 1. Significant differences among genotypes were found for all five characters. The same was true for groups and lines. Genotype by location interactions were found for all characters except tiller number. Of the contrasts made, the group of Bounty hybrids exhibited differences from the group of pure-lines for all five traits; while the Quantum hybrids were different from the group of pure-lines for grain yield, tiller number, and kernels/spike; and the Hybrex hybrids were different from the group of pure-lines for harvest index and kernels/spike.

Eberhart and Russell (5) explain stability as consisting of two components. The first component ($\bar{b}$) is homogeneity of regression which measures the response of a genotype to varying environmental indexes. The second component ($\bar{s}^2d$), the deviation component or residual, is a measure of the unexplained deviation from the regression on the environmental index. They describe desirable genotypes as having $\bar{b}$ = 1.0, a high mean performance ($\bar{x}$), and $\bar{s}^2d = 0$.

Stability analyses of the genotype by environment interactions are presented in Table 2. The significant genotype by environment interactions are broken into components. Significant homogeneity of regression was found for grain yield, harvest index, and kernels/spike. Significant deviation from regression (residual) was found for grain yield, harvest index, kernels/spike, and kernel weight.

Table 3 presents mean performance, regression coefficients, and deviations from regression for the four characters exhibiting significant genotype by environment interactions. The tiller number interaction was not statistically significant and hence was not presented in the table. No genotype showed a regression coefficient for yield that was significantly different from 1.0. Regression values for yield ranged from .92 for XH 157B to 1.06 for Bounty 203, Bounty 310, HW 1010, and HW 1031. No difference from 1.0 was found for harvest index regression coefficients, but the values ranged from .42 for Bounty 310 to 1.29 for HW 1031. One genotype, HW 1031, had a regression coefficient for kernels/spike which was significantly different from 1.0. Regression values for this trait ranged from .44 for Chisholm to 1.70 for HW 1031. Both Bounty 203 and XH 150A showed values for kernel weight regression that were significantly different from 1.0. The regression coefficients for kernel weight ranged from .59 for Bounty 310 to 1.26 for Vona.

Table 4 presents contrasts for the three hybrid groups vs. the three pure-lines for five characters. The Bounty hybrids were the highest yielding group, performing significantly better than any pure-line. The Quantum hybrids yielded significantly higher than Chisholm or Vona but was not different from Tam 105, the highest yielding pure-line. The Hybrex hybrids were not significantly different from any pure-line for yield.

From Table 4, no hybrid group value for harvest index was as high as Chisholm. Only the Quantum hybrid group harvest index was as high as Vona and was slightly higher than Tam 105. Only the Hybrex hybrid group performed as well as or better than any of the pure-line cultivars for tiller number. The Bounty group was lower than all three pure-lines for tiller number and the Quantum group was lower than Tam 105 and Vona and no different from Chisholm for tiller number. All three groups of hybrids exceeded Chisholm and Tam 105 for kernels/spike. Only the Quantum group performed as well as Vona for this character, while both the Bounty and Hybrex groups were lower in kernels/spike than Vona. All three groups of hybrids exceeded Vona and either exceeded or did as well as Tam 105 in kernel weight. All three groups of hybrids were lower in kernel weight than the pure-line Chisholm.

In summary of Table 4, the Bounty hybrids performed highest of the three groups for plot yield and kernel weight, intermediate for kernels/spike, and lowest for tiller number and harvest index. The

Quantum hybrids were intermediate for yield and tiller number, highest in kernels/spike and harvest index, and lowest for kernel weight. The Hybrex hybrids were the lowest for yield and kernels/spike, highest in tiller number, and intermediate for kernel weight and harvest index.

Table 5 shows the mean performance and ranks of the 12 genotypes for the five characters evaluated. All three Quantum hybrids plus Bounty 100 and Bounty 203 had plot yields greater than the overall mean. Bounty 203 had the highest plot yield which was 4043 kg/ha. All three Hybrex hybrids plus Bounty 100, XH 165, and Chisholm exceeded the overall sample yield. Bounty 100 had the highest sample yield at 5371 kg/ha. Three hybrids, Bounty 100, HW 1010, and XH 165 plus Vona and Chisholm had harvest index values greater than the overall mean. XH 165 harvest index of .42 was the highest. All three Hybrex hybrids plus XH 150A, Tam 105, and Vona had tiller numbers greater than the overall mean. HW 1031 had the highest tiller number of 99.9 tillers/60 cm sample. Five hybrids, Bounty 203, Bounty 310, HW 1010, XH 157B, and XH 165 plus Vona had kernels/spike values greater than the overall mean. HW 1010 had the highest number of 37.2 kernels/spike. Three hybrids, Bounty 100, HW 1031, and XH 165 plus Chisholm exceeded the overall mean kernel weight. Bounty 100 had the highest kernel weight mean of 37.7 grams/1000 kernels.

The only apparent pattern with regard to yield components from Table 5 occurs when using the sample yield rankings. The top six genotypes for sample yield included the top six genotypes for kernel weight. In addition, the top three genotypes for sample yield had high values for harvest index. However, no real pattern was evident when using plot yield rankings and there was no good correspondence between sample yield and plot yield. This information points out the difficulty of trying to determine yield by sampling.

The simultaneous evaluation of yield and yield component means together with stability estimates for the 12 genotypes studied is complicated. A few generalizations can be made, however. For instance, increased yield appears to be associated with a trend toward instability or specific adaptation to favorable environments. Genotypes with extreme expression for any one yield component usually had regression coefficients that were markedly different from one, indicating lower than average stability for that character.

Table 1. Analyses of variance and contrasts for five characters of twelve genotypes evaluated at six locations in 1983.

Source	df	Grain Yield/Plot	Harvest Index	Tiller Number	Kernels/ Spike	Kernel Weight
Location	5	**	**	**	**	**
Replication	18	**	**	ns	**	**
Genotype	11	**	**	**	**	**
Group[1]	5	**	**	**	**	**
Line[2]	6	**	**	**	**	**
Genotype X Location	55	**	**	ns	**	**
Location X Group	25	**	**	ns	**	**
Location X Line	30	**	**	ns	**	**
Error (Mean Squares)	198	101,298	2.3	108.8	7.3	0.04
C.V. (%)		8.6	4.0	11.4	8.0	6.5
These Contrasts Were Made:						
B[3] vs. C[4]	1	**	**	**	**	**
B-C X Loc	5	**	**	*	ns	**
Q[5] vs. C	1	**	ns	**	**	ns
Q-C X Loc	5	**	**	ns	*	ns
H[6] vs. C	1	ns	**	ns	*	ns
H-C X Loc	5	ns	ns	ns	**	ns

[1]Group = comparison of six groups: three hybrid groups and three pure-lines; [2]Line = comparison of hybrids in each hybrid group: three hybrids in each group; [3]Bounty hybrid group; [4]Cultivars (pure-lines); [5]Quantum hybrid group; [6]Hybrex hybrid group.

*,**Significant at the .05 and .01 levels of probability, respectively.

Table 2. Stability analysis of genotype x environment interaction for five characters of twelve genotypes evaluated at six locations in 1983.

Source	df	Grain Yield/Plot	Harvest Index	Tiller Number	Kernels/ Spike	Kernel Weight
Genotype	11	**	**	**	**	**
Environment	5	**	**	**	**	**
Genotype X Environment	55	**	**	ns	**	**
Homogeneity of Regression	11	**	**	--	**	ns
Residual	44	**	**	--	**	**
Error (Mean Squares)	198	101,298	2.3	108.8	7.3	0.04

*,** Significant at the .05 and .01 levels of probability, respectively.

Table 3. Mean performance, regression coefficients and deviations from regression for four characters of twelve genotypes evaluated at six locations in 1983.

	Grain Yield/Plot (kg/ha)			Harvest Index			Kernels/Spike			1000 Kernel Weight (gm)		
	Mean ($\bar{x}$)	Regression Coeff. ($\bar{b}$)	s^2d (x .001)†	Mean ($\bar{x}$)	Regression Coeff. ($\bar{b}$)	s^2d	Mean ($\bar{x}$)	Regression Coeff. ($\bar{b}$)	s^2d	Mean ($\bar{x}$)	Regression Coeff. ($\bar{b}$)	s^2d
Bounty 100	3783	.94	18	.39	1.01	2.56**	31.5	.45	.14	37.7	1.09	.01
Bounty 203	4043	1.06	79**	.35	1.07	0	34.2	1.03	.01	27.9	.75*	0
Bounty 310	3678	1.06	0#	.35	.42	2.12**	35.2	1.26	0	26.8	.59	.05
Hybrex HW 1010	3621	1.06	71**	.40	.99	4.31**	37.2	1.39	.27	29.2	.81	.01
Hybrex HW 1030	3466	.97	9	.38	1.16	.37	31.8	1.01	2.62*	28.8	.98	.01
Hybrex HW 1031	3666	1.06	0	.37	1.29	.66	31.0	1.70*	0	29.5	1.04	.01
Quantum XH 150A	3770	.94	66**	.38	1.04	0	33.3	1.29	4.52**	27.5	1.17**	0
Quantum XH 157B	3800	.92	31	.38	.93	1.94**	36.3	.60	1.55	27.7	1.07	.01
Quantum XH 165	3738	1.04	62*	.42	1.08	.25	36.5	.97	0	31.0	1.13	.01
Chisholm	3580	1.01	48*	.41	1.05	3.13**	31.2	.44	0	32.5	1.07	.01
Tam 105	3617	.93	0	.38	.78	2.04**	29.7	1.14	0	28.0	1.05	0
Vona	3638	1.02	126**	.39	1.19	.17	36.3	.73	4.26*	25.3	1.26	.02

† s^2d = deviation = Residual MS - (Experimental Error MS/Number Reps.).

*,** Significant at the .05 and .01 levels of probability, respectively. (Each genotype has its own standard error.)

0 means the estimate was negative.

Table 4. Contrasts for three hybrid groups vs. three pure-line cultivars for five characters evaluated at six locations in 1983.

	Hybrid Group			Pure-Line		
Loc.	Bounty (3 hybrids)	Hybrex (3 hybrids)	Quantum (3 hybrids)	Chisholm	Tam 105	Vona
Grain Yield/Plot (kg/ha)						
11	4183[t,v]	3490[c]	4084[t,v]	3896	3569	3323
12	2400	2217	2679[v]	2439	2334	2247
13	1764	1623	1791	1901	1642	1803
14	6386[c,t]	6218[t]	6378[c,t]	5937	5762	6048
15	2213	1990	2032	1877	1991	1908
16	6064[c,t]	5968[t]	5654[t,v]	5651	6529	6152
Mean	3835[c,t,v]	3584	3770[c,v]	3617	3638	3580
Harvest Index						
11	.39[c,v]	.42[c]	.43[t]	.45	.41	.43
12	.35[c,t]	.38[c,v]	.39[c,t]	.42	.36	.41
13	.34[c]	.35[c]	.37[t]	.38	.33	.36
14	.38[c,t]	.41	.40	.42	.41	.39
15	.38[c,t]	.39[c,t]	.41[v]	.42	.40	.39
16	.34[c,t,v]	.36[v]	.34[c,t,v]	.36	.37	.38
Mean	.37[c,t,v]	.38[c,v]	.39[c,t]	.41	.38	.39
Tiller Number						
11	82.3	88.5	84.3	77.8	84.3	92.8
12	63.3[t]	71.5	67.3	73.8	75.5	68.5
13	71.2[t,v]	90.4	82.0[v]	80.0	85.5	95.5
14	110.2[t,v]	124.2	114.3[t]	121.0	129.8	124.8
15	70.7	77.6	72.3	67.0	75.8	79.5
16	110.9[c,t,v]	131.7	111.3[c,t,v]	124.3	124.8	135.5
Mean	84.8[c,t,v]	97.3[c]	88.6[t,v]	90.6	95.9	99.4
Kernels/Spike						
11	37.0[c,t,v]	36.7[c,t,v]	38.8[c,t]	30.3	31.1	40.2
12	33.2[t]	33.8[t]	36.2[c,t]	31.7	29.9	35.7
13	33.3[t]	34.5[c,t]	35.4[c,t]	30.7	38.7	34.8
14	34.8[t,v]	34.2[t,v]	38.2[c,t]	34.6	29.7	39.6
15	33.3	31.1[v]	35.2[t]	33.7	31.5	35.0
16	30.3[c]	29.7[c]	29.7[v]	26.7	27.5	32.8
Mean	33.6[c,t,v]	33.3[c,t,v]	35.6[c,t]	31.2	29.7	36.3
1000 Kernel Weight (gm)						
11	31.0[c,v]	30.0[c,v]	31.1[c,t,v]	35.2	28.9	26.9
12	30.7[c,t,v]	38.5[c,t,v]	29.1[c,t,v]	34.6	26.2	24.7
13	25.1[c,t,v]	21.6[v]	22.0[v]	22.7	20.9	18.2
14	32.1[c,v]	32.6[v]	30.2[c]	34.8	31.1	28.8
15	29.5[t,v]	26.3[c,v]	25.9[c,v]	29.1	25.8	22.3
16	36.3[c,v]	36.0[c,v]	34.1[c,v]	38.9	35.0	31.2
Mean	30.8[c,t,v]	29.2[c,t,v]	28.7[c,v]	32.5	28.0	25.3

Note: c,t,v indicates that the hybrid group mean value is significantly different from the cultivar(s) Chisholm, Tam 105, and/or Vona value(s) at the .05 level of probability, respectively.

Table 5. Mean performance values and ranks of twelve genotypes for five characters evaluated over six locations in 1983.

Genotype	Plot Grain Yield (kg/ha) Mean (Rank)	Sample Grain Yield (kg/ha) Mean (Rank)	Harvest Index Mean (Rank)	Tiller Number Mean (Rank)	Kernels/ Spike Mean (Rank)	1000 Kernel Weight (gm) Mean (Rank)
Bounty 100	3783 (3)	5371 (1)	.39 (4)	84.0 (10)	31.5 (8)	37.7 (1)
Bounty 203	4043 (1)	4822 (9)	.35 (7)	86.9 (9)	34.2 (5)	27.9 (8)
Bounty 310	3678 (6)	4547 (11)	.35 (7)	83.5 (11)	35.2 (4)	26.8 (11)
Hybrex HW 1010	3621 (9)	5290 (2)	.40 (3)	93.3 (6)	37.2 (1)	29.2 (5)
Hybrex HW 1030	3466 (12)	5002 (6)	.38 (5)	98.8 (3)	31.8 (7)	28.8 (6)
Hybrex HW 1031	3666 (7)	5079 (4)	.37 (6)	99.9 (1)	31.0 (10)	29.5 (4)
Quantum XH 150A	3770 (4)	4831 (8)	.38 (5)	94.0 (5)	33.3 (6)	27.5 (10)
Quantum XH 157B	3800 (2)	4890 (7)	.38 (5)	87.8 (8)	36.3 (3)	27.7 (9)
Quantum XH 165	3738 (5)	5078 (5)	.42 (1)	84.0 (10)	36.5 (2)	31.0 (3)
Chisholm	3617 (10)	5212 (3)	.41 (2)	90.6 (7)	31.2 (9)	32.5 (2)
Tam 105	3638 (8)	4535 (12)	.38 (5)	95.9 (4)	29.7 (11)	28.0 (7)
Vona	3580 (11)	4768 (10)	.39 (4)	99.4 (2)	36.3 (3)	25.3 (12)
Overall Mean	3700	4951	.38	91.5	33.7	29.3
C.V. (%)	8.6	12.5	4.0	11.4	8.0	6.5
LSD .05	441	858	.21	14.5	3.74	2.63

CHAPTER V

YIELD STABILITY FOR WINTER WHEAT HYBRIDS VS. PURE-LINE CULTIVARS

Introduction

Genotype by environment interactions are of major importance to the plant breeder in developing improved cultivars. When comparing a set of genotypes over a series of environments, the relative rankings usually differ. Therefore demonstrating the significant superiority of any cultivar is difficult. This interaction is usually present whether the genotypes are pure-lines, hybrids or any other material the breeder may be working with.

State-wide yield performance tests of hybrids and pure-line wheat (*Triticum aestivum* L.) cultivars have been conducted in Oklahoma since 1974 over a variety of environments. For the past three years, 1982, 1983, and 1984, the mean performance of the hybrids has been greater than the mean of the pure-lines (24). This observed hybrid superiority may be related to the ability of the most recently developed hybrid wheats to perform better than pure-line cultivars under a range of environmental conditions. This implied stability of hybrids was the focus of this study. The objective of this study was to determine the differences in stability of yield for hybrids vs. pure-line cultivars of wheat for the past three years.

Materials and Methods

Data sets for grain yield performance were obtained from the record books of the Oklahoma State University wheat breeding project. Thirty winter wheat genotypes were grown in a randomized complete-block experiment at each of six locations during the 1982, 1983, and 1984 growing seasons. Within each year the genotypes were the same at all locations; however, some genotypes were not present in all three years because some entry changes were made from year to year to include new improved genotypes. Each year, approximately half of the entries were hybrids. Over the three year period, a total of 55 different genotypes were evaluated.

The locations at which the tests were conducted represent a range of soil types and environmental conditions. The locations were Stillwater, Lahoma, Altus, Goodwell (irrigated), Goodwell (dryland), and Woodward.

The experiments employed a randomized complete block design with four replications. Standard seeding rates were used. Plot size was 1.2 m by 3.1 m. Plots consisted of either four or five rows spaced 31 or 24 cm apart. Grain yield was measured on a whole plot basis and expressed in kg/ha.

Results and Discussion

Analyses of variance conducted for yield by year are presented in Table 1. Significant differences were found for locations, genotypes, and genotype by location interactions for yield in all three years. The presence of these interactions warrants further investigation of specific genotype response to varied environments.

Means, regression coefficients, and deviations from regression along with the origin of each genotype are presented in Table 2. Average regression coefficients for specific group comparisons are presented in Table 3. From Table 2 and Table 3, several trends are noted. The regression coefficients for yield tend to be greater than 1.0 for the hybrids and less than 1.0 for the pure-lines. This trend is consistent for all three years. The hybrids appear to perform better than pure-line wheats under more favorable environmental conditions.

The response of genotypes to a range of environments provides information about how the production capabilities of a variety changes from favorable environments to stress environments. The model proposed by Eberhart and Russell (5) concerning stability provides a good method of characterizing production traits of a set of genotypes. If stability is interpreted as a regression line of less than 1.0 and instability as regression greater than 1.0, then according to the results of this study (see Table 3), a trend toward higher yield seems to be associated with instability.

Over the three years of testing, the Quantum group of hybrids had the highest average grain yield (4192 kg/ha) and also the highest regression coefficient (1.12), or the lowest stability. Next were the Bounty group of hybrids with average yield of 4164 kg/ha and regression coefficient of 1.07. The Hybrex group of hybrids had an average yield of 3949 kg/ha and a regression coefficient of 1.04. In contrast to the hybrid group, the semi-dwarf pure-line cultivar group had an average yield level of 3752 kg/ha and a regression coefficient of 0.99, while the standard height cultivars had the lowest average yield (3419 kg/ha) and the lowest regression coefficient (0.79), indicating high stability.

From Table 4, average heterosis of hybrids over pure-lines ranged from 9% to 15%. This is a marginal level of superiority if hybrids are to be economically feasible; a figure of 20% is generally considered by wheat researchers to be the minimal level of heterosis necessary.

Mean yields expressed in kg/ha and as a percent of the pure-line value are presented in Table 4. It should be noted that the hybrids performed better than the pure-lines in every case.

The interpretation of yield stability for the genotypes in this study is difficult. In general, average yield increases appear to be associated with a trend toward instability. Bounty 203, the highest yielding hybrid the last two years, had regression coefficients of .94 in 1983 and 1.10 in 1984, and Quantum XH 165, the highest yielding hybrid in 1982, had a regression coefficient of 1.32 that was significantly greater than 1.0. Optimum expressions of yield are yet to be established; however, it is clear that further investigation and research into the stability of yield should be of interest to plant breeders endeavoring to produce higher yielding cultivars.

Table 1. Analyses of variance for cultivar-hybrid performance tests consisting of thirty genotypes per year at the same six locations for each of three years.

		Grain Yield		
		Year		
Source	df	1982	1983	1984
Location	5	**	**	**
Replication	18	**	**	**
Type[1]	1	**	**	**
Genotype	28	**	**	**
Location x Type	5	**	**	**
Location x Genotype	140	**	**	**
Error (Mean Squares)	522	140,952	149,490	92,659
C.V.		9.4	9.4	8.6

[1]Type = comparison of hybrids and pure-line cultivars.

*,**Significant at the .05 and .01 levels of probability, respectively.

Table 2. Mean yield performance, regression coefficients, and deviations from regression for fifty-five genotypes evaluated for all or a part of a three year period, 1982-1984.

			1982			1983			1984		
Genotype	Type	Origin	Mean ($\bar{x}$) kg/ha	Reg. Coef. ($\bar{b}$)	s^2d † (x .001)	Mean ($\bar{x}$) kg/ha	Reg. Coef. ($\bar{b}$)	s^2d (x .001)	Mean (x) kg/ha	Reg. Coef. (b)	s^2d (x .001)
Osage	PL	OK	3608	.78	214**						
Russian Wheat	PL	R. Treadwell	3416	.96	0#						
Sandy	PL	CO	3222	.54	2						
Scout 66	PL	NB	3472	.68	192**						
573A	HYB	Dekalb	4251	1.16	17						
H 169	HYB	Dekalb	4193	1.16	77*						
X 3214	HYB	Cargill	4228	1.07	88**						
X 3418	HYB	Cargill	4240	.96	278**						
X 4117	HYB	Cargill	4234	1.17	135**						
Hybrex HW 1007	HYB	R & H	3971	1.07	0						
Hybrex HW 1009	HYB	R & H	3889	1.02	67*						
Hybrex HW 1014	HYB	R & H	4136	1.01	0						
Hybrex HW 1015	HYB	R & H	4157	1.06	0						
Centurk 78	PL	NB	3779	.85	128**	3862	.85	70*			
Hawk	PL	NAPB	3923	.90	42	4023	.97	66*			
Wings	PL	NAPB	4128	1.04	0	4135	96	29			
Probrand 835	PL	NK	3730	1.14	77*	3949	1.05	59*			
Triumph	PL	OK	3313	.95	0	3399	.78*	0			
579A	HYB	OK	4382	1.14*	0	4316	1.01	41			
H 166	HYB	Dekalb	4590	1.30	135**	4224	1.17	113**			
Hybrex HW 1001	HYB	R & H	4208	1.11	21	4020	.86	14			
Bounty 204	HYB	Cargill				4545	1.09	269**			
Bounty 302	HYB	Cargill				4175	.91	95**			
Hybrex HW 1021	HYB	R & H				4237	.94	0			
WXB 8017	HYB	Sd. Res. Inc.				3800	1.05	0			
Concho	PL	OK	3082	.69	135**	3429	.66	193**	2908	.75**	10
Newton	PL	KS	3991	.84	110**	3796	1.02	114**	3321	1.05	1
Payne	PL	OK	4072	1.03	103**	4016	.94	147**	3255	82	74**
Tam W-101	PL	TX	3875	.92	24	3627	1.16	93**	3279	89	30
Tam 105	PL	TX	4172	94	0	3870	97	43	3550	1.07	128**
Triumph 64	PL	OK	3601	.92	0	3641	.86	78*	3115	72**	31
Vona	PL	CO	4166	1.08	41	4043	.98	3	3488	1.05	58**
Hybrex HW 1010	HYB	R & H	4504	1.19	66*	4155	1.13	53*	3526	1.09	82**
Quantum XH 165	HYB	Hybri Tech	4697	1.32*	76*	4487	1.21	417*	3635	1.05	49*
Chisholm	PL	OK				4152	1.21	53*	3526	.95	0
Bounty 100	HYB	Cargill				4407	1.11	134**	3686	.96	8
Bounty 201	HYB	Cargill				4310	1.16	89**	3720	1.08	43*
Bounty 202	HYB	Cargill				4662	1.13	29	3883	1 21*	38*
Bounty 203	HYB	Cargill				4797	.94	196**	3945	1.10	81**
Bounty 301	HYB	Cargill				4610	80	60*	3840	1.20	230**
Bounty 310	HYB	Cargill				4215	1 24*	1	3580	1.09*	0
Quantum XH 150A	HYB	Hybri Tech				4147	.98	44	3672	95	62**
Hybrex HW 1030	HYB	R & H				4214	.95	20	3376	99	24
Garst E 3580	PL	Garst							3501	1 02	65**
Garst HR 64	PL	Garst							3355	.95	108**
Garst 428402	PL	Garst							3410	94	1
Jesse	PL	Hill Sd. Co.							3618	1.01	0
NK 77W 4505	PL	NK							3474	.93	35*
Wrangler	PL	NAPB							3518	.92	74**
ArKan	PL	KS							3599	1.07	153**
Bounty 205	HYB	Cargill							3871	1.08	78**
Quantum XH 157B	HYB	Hybri Tech							3708	94	36*
Hybrex HW 1019	HYB	R & H							3593	.99	48*
Hybrex HW 1031	HYB	R & H							3593	.99	48*
Hybrex HW 1031	HYB	R & H							3566	1.08	0
Hybrex HW 1035	HYB	R & H							3689	1.03	0
C.V. (%)			9.4			9.4			8.6		
LSD .05			520			536			422		

† s^2d = deviation = Residual MS - (Experimental Error MS/Number of Reps.).

*,** Significant at the .05 and .01 levels of probability, respectively. (Each genotype has its own standard error)

0 means the estimate was negative.

Table 3. Average regression coefficients and mean yields for comparisons of groups of hybrids and pure-lines at the same six locations for each of three years.

Group	1982			1983			1984			3 Year Average	
	No. Genotypes/ Group	Mean Grain Yield kg/ha	Avg. Reg. Coef.	No. Genotypes/ Group	Mean Grain Yield kg/ha	Avg. Reg. Coef.	No. Genotypes/ Group	Mean Grain Yield kg/ha	Avg. Reg. Coef.	Mean Grain Yield kg/ha	Avg. Reg. Coef.
<u>Hybrids vs. Pure-Lines</u>											
Hybrids	(14)	4263	1.12	(17)	4313	1.03	(15)	3686	1.06	4093	1.07
Pure-Lines	(16)	3722	.89	(13)	3841	.95	(15)	3394	.94	3645	.92
<u>Groups of Hybrids</u>											
Bounty Hybrids	(3)	4234	1.07	(8)	4465	1.05	(7)	3789	1.10	4164	1.07
Hybrex Hybrids	(6)	4144	1.08	(4)	4157	.95	(5)	3550	1.05	3949	1.04
Quantum and/or DeKalb Hybrids	(5)	4423	1.22	(4)	4294	1.09	(3)	3672	.98	4192	1.12
<u>Groups of Pure-Lines</u>											
Semi-Dwarf Cultivars	(8)	4007	.99	(9)	3957	1.03	(13)	3453	.97	3752	.99
Standard Height Cultivars	(8)	3438	.80	(4)	3583	.79	(2)	3012	.74	3419	.79

Table 4. Grain yield performance of hybrids expressed as a percent of pure-lines evaluated at the same six locations for each of three years.

Year / Type of Comparison	Number of Genotypes	Average Yield (kg/ha)	Percent of Pure-Line Value
1982			
Hybrid	(14)	4263	115
vs.			
Pure-Line	(16)	3722	100
Best Hyb. (XH 165)	(1)	4697	113
vs.			
Best P-L (Tam 105)	(1)	4172	100
1983			
Hybrid	(17)	4313	112
vs.			
Pure-Line	(13)	3841	100
Best Hyb. (Bounty 203)	(1)	4797	116
vs.			
Best P-L (Chisholm)	(1)	4152	100
1984			
Hybrid	(15)	3686	109
vs.			
Pure-Line	(15)	3394	100
Best Hyb. (Bounty 203)	(1)	3945	109
vs.			
Best P-L (Jesse)	(1)	3618	100

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