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Title: PERFORMANCE OF CULTIVARS, HYBRIDS AND COMPOSITES OF WINTER WHEAT *(Triticum aestivum* L. em Thell) GROWN AT THREE LOCATIONS.

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Abstract approved: ______________________________

Warren E. Kronstad

The objective of this study was to compare three genetically different groups of winter wheat for their grain yield. Experimental material consisted of parental lines grown in pure stands, hybrids, and 1:1 mixtures of the parental combinations. Three sites were employed to evaluate possible interactions between the different groups across locations. Phenotypic correlations among selected agronomic traits and grain yield within each group along with the expression of heterosis and heterobeltiosis in the hybrids were studied.

Results of this investigation support the general conclusion reached by other investigators that hybrids and composites are not consistently superior to the best conventional cultivars of wheat for grain yield. However, at the Moro site, with the greater environmental stresses, some hybrids and composites appeared to yield more than the parental lines grown in pure stands. At Pendleton, the best environment for yield expression, the hybrids and conventional cultivars did not

differ for grain yield. At this location, the best hybrids and one composite did significantly outyield the commercial cultivars Stephens, Malcolm and Hill, but not four advanced parental selections when grown in pure stands.

Low to moderate values of heterosis and heterobeltiosis for grain yield were found. The degree of expression being affected by the specific growing site. Plant height and the number of kernels per spike showed relatively higher values for heterosis and heterobeltiosis over locations when compared to the other traits.

Phenotypic correlations suggested that a breeding program to develop hybrid wheat should combine high number of kernels per spike with high kernel weight. The positive correlation between grain yield and plant height indicated that increases in grain yield could be obtained by increasing plant height if lodging did not present a problem.

PERFORMANCE OF CULTIVARS, HYBRIDS AND COMPOSITES OF WINTER WHEAT (*Triticum aestivum* L. em Thell) GROWN AT THREE LOCATIONS

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Typed by Ruben P. Verges

DEDICATED TO:

my wife,

Susana

my sons,

Enrique and Gerardo

and my parents,

Ruben and Maria Cristina

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INTRODUCTION

The major objective of most breeding programs is to develop cultivars which combine high yield, adequate quality, and stability of performance. Historically, to achieve these objectives wheat breeders have developed genetically near homogeneous lines. With the discovery of cytoplasmic male sterility and the identification of nuclear restoring genes, a major effort to develop hybrid wheat was undertaken. Due to the increased cost of producing F1 seed for commercial production and lack of an yield advantage over conventionally developed cultivars, interest in hybrid wheat decreased. Recent work with chemical male gametocides has renewed the interest in hybrid wheat. The question that remains to be answered is; will hybrid wheat have an economic advantage over conventionally developed cultivars?

A further approach to cultivar development is the use of genotype mixtures, or composites. There is evidence to support the idea that mixtures could have advantages over monocultures by providing greater stability of performance across diverse environments, and more stable resistance to disease.

The state of Oregon provides a great diversity of climatic conditions to evaluate the yield potential and stability of performance of wheats with different levels of genetic diversity. It was the objective of this study to compare hybrids, composites and conventional cultivars (near-homogeneous lines) for grain yield at three diverse locations in Oregon. A second objective was to determine the possible associations among selected agronomic traits and grain yield in each group of cultivars when grown at the different sites. Also an evaluation of the amount of heterosis and heterobeltiosis was noted for specific parental combinations.

LITERATURE REVIEW

This literature review will focus on the performance of hybrids and composite cultivars, and the associations among agronomic traits, with emphasis on wheat.

Wheat Hybrids

The discoveries of cytoplasmic male sterility and genes which restore fertility in wheat (*Triticum aestivum* L.) were the stimulus for developing hybrids on a commercial scale (Wilson and Ross, 1961; Schmidt et al., 1962).

Heterosis, as originally proposed by Shull and East in 1908, was defined as the superiority of the F1 over the average of its parents. Heterosis was first reported in wheat in 1919 by Freeman when he observed that F1 plants were generally taller than the tallest parent (cited by Virmani and Edwards, 1983). The literature on heterosis in wheat has been reviewed by Briggle (1963), Johnson and Schmidt (1968), Virmani and Edwards (1983), Wilson and Driscoll (1983) and Wilson (1984).

Evidence of Heterosis

A common problem noted in earlier reports on heterosis in wheat was the limited scope and application of many of the studies (Virmani and Edwards, 1983). These included: a) only a small number of crosses were evaluated; b) noncommercial and unproductive cultivars were frequently used; c) small populations were space planted either in the field or in greenhouses, and d) yield components were measured more often than heterosis for grain yield per se.

The levels of heterosis for yield in wheat reported prior to 1963 were reviewed by Briggle (1963). Among the 23 publications surveyed by Briggle, the magnitude of heterosis ranged from 0 to more than 100%.

Hybrids resulting from crosses between cultivars in the International Maize and Wheat Improvement wheat breeding program were evaluated in space-planted experiments at Ciudad Obregon, Sonora, in 1964 and 1965. In 1964, 23 of 25 hybrids significantly outyielded the highest-yielding check cultivar. While in 1965, 13 of 20 hybrids outyielded the check cultivar, with the highest yield being over 20% more productive (Rodriguez et al., 1967). These authors pointed out that economic levels of heterosis in hybrids must be based upon comparisons of hybrid performance with grain yield of the most productive commercial cultivars available.

A diallel cross involving eight cultivars and two experimental selections was used by Kronstad and Foot (1964) for estimating general and specific combining ability in winter wheat. They observed that the largest amount of genetic variability was associated with general combining ability for both grain yield and the components of yield. In addition, they emphasized that hybrid vigor must be considered as that which exceeded the highest yielding parent. Fonseca and Patterson (1968a) later coined the term heterobeltiosis for this condition.

Seven spring wheat crosses were tested to determine the presence of heterosis by Knott (1965). The parents represented a wide range of different genetic types. Four of the hybrids yielded more than the parental means with the greatest advantage being 22.5%. He concluded that high-yielding hybrids can be expected from crosses involving high-yielding parents.

Heterosis values for grain yield were studied by Brown et al. (1966) using seven winter wheat parents. Five of the 16 hybrids were significantly higher in grain yield than the best parent in the crosses. Twelve of the 16 hybrids were significantly higher than the mid-parents. The heterosis values of grain yield over the mid-parent ranged from 107 to 138%, and the value over the best parent varied from 96 to 131%.

Wilson (1968) reported hybrid yield increases of more than 30% from handmade crosses between North American and Mexican cultivars. A Hard Red Winter Wheat hybrid exceeded its commercial parent by nearly 19% over a four-year period.

Heterosis values for yield and yield components were studied by Singh and Singh (1971) in F1, F2 and F3 generations in ten wheat crosses. They noticed that eight hybrids exceeded their better parent for yield with values ranging from 1.8 to 42.3%. Heterosis in grain yield was reflected through heterosis in spike number and kernel weight.

Working with durum wheat, Triticum durum Desf., Widner and Lebsock (1973) found that the heterosis percentages for grain yield for one year, based on means of the higher parent, ranged from -19 to 84%. No hybrid was significantly higher than the check cultivar.

Heterosis in winter x spring wheat crosses was studied by Mani and Rao (1975). Heterosis values over the mid-parent ranged from -19 to

193% for grain yield. Twenty-four hybrids out of 55 exhibited significant heterosis, but when compared to the better parent none of the hybrids gave significant heterobeltiosis.

A diallel cross of six winter and two spring wheats was used by Mihaljev (1976) to study the expression of heterosis. Twelve hybrids exceeded the mid-parent, ranging from 3 to 25%. Five of the 28 hybrids exceeded the best parent for grain yield. The range was from 3 to 21%.

Fourteen hybrids originated from crosses between five cultivars of wheat were studied by Shebeski (1966). Grain yield of the hybrids ranged from 28% below to 26% above the better parent.

Eight adapted high-yielding spring wheats were crossed in a diallel manner by Cregan and Busch (1978). The hybrids exhibited heterosis values over the mid-parents from 5 to 58% and over the better parent from -17 to 41%. In this study, the potentials for grain yield developed via conventional breeding and via hybrids were similar.

Working with Soft Red Winter Wheat, Bitzer et al. (1982) used a diallel for crossing groups involving four low and four high-yielding parents. Heterosis values for yield above the mid-parent were about 30% for low x low crosses, 25% for low x high crosses, and 19% for high x high crosses. Hybrid vigor in low x high crosses did not differ significantly from other crossing groups. The authors pointed out that because of the preponderance of general combining ability effects in wheat, successful hybrids will most often come from high x high yielding crosses.

Environment and Expression of Heterosis

Livers and Heyne (1968) reported on a four-year study to determine the amount of hybrid vigor by intercrossing nine cultivars of well-adapted winter wheats at Hayes, Kansas. The 36 hybrids exceeded the yield of all conventional cultivars by 20, 37, 37 and 35% in the years 1964-1967, respectively, with an average hybrid superiority of 32%. The best hybrid was consistently better than the best conventional cultivar for the area.

Forty eight spring wheat hybrids were studied by Nettevich (1968) in a three-year period. He found that the yields of the hybrids ranged from 75 to 147% of their higher parent. Crosses between high-yielding cultivars which differed in origin and agronomic traits gave the highest-yielding hybrids. Agronomic traits and climatic conditions over years were found to affect the levels of heterosis observed.

The expression of heterosis in wheats of Canadian, Mexican and American origin was investigated by Walton (1971). He noted that the increases in yield over the high-yielding parent were different between years. The first year he obtained a range from 17 to 20%, while the second year the range was from 17 below to 4% above the higher parent. He concluded that the decline in the hybrid performance in relation to the parents indicated a hybrid x year interaction.

Working with durum wheat, Amaya et al. (1972) found that the hybrids from four crosses exceeded their high-yielding parent by an average of about 25% in grain yield, ranging from -12 to 60%. The expression of heterosis, however, varied widely over environments.

Allan (1973) found high-parent heterosis ranging from 23 to 113% among Soft White Winter Wheat hybrids grown in the state of Washington. The results were site-specific. When averaged over four locations, no hybrid outyielded the higher parent.

During two periods, 1970-71 and 1973-74, Hayward (1975) studied the performance of Hard Red Winter Wheat hybrids in Kansas. Thirty-nine hybrids and six high-yielding cultivars were tested in the first year. He found only one hybrid that equalled the yield of the highest yielding check. However, the hybrids were significantly higher in the second year when compared to the check. The mean yield of four hybrids over three locations was 19% greater than the mean of eight check cultivars, and the best hybrid yielded 13.7% more than the top cultivar.

According to Virmani and Edwards (1983), most of the Hard Red Winter Wheat hybrids evaluated have shown more specific adaptability to different regions and winter-hardiness zones than common cultivars.

Johnson (1977, 1978) reported on tests conducted at 11 sites in five states (Texas, Oklahoma, Kansas, Colorado and Nebraska) during two years. Of the 15 hybrids tested in 1976, the leading hybrid produced 70 kg/ha less than the check cultivar 'Centurk'. In 1977, 16 hybrids averaged 70 kg/ha less than Centurk, although the best hybrid exceeded Centurk by 130 kg/ha. Johnson concluded that the hybrids were not sufficiently superior to justify their use over the best available conventional cultivars.

Edwards et al. (1980) reported on 1978 and 1979 tests with a series of spring wheat hybrids. Although the levels of heterobeltiosis ranged up to 35%, the top yielding hybrids exhibited grain yields of only 10 to 14% above the leading check cultivar 'Era'.

Two different environments, Zagreb, Yugoslavia and Hutchinson, Kansas, were used by Jost and Hayward (1980) to determine if a homozygous line that was superior to the F1 hybrid could be obtained from the same cross combination. At Zagreb (optimal environment), the grain yield of the F1 hybrid was significantly better than that of the best F7 lines. At Hutchinson (stress environment) the two leading F7 lines outyielded the F1 hybrid, however the differences were not significant.

Plant Density and Expression of Heterosis

A three-year study of hybrid performance under irrigation at five different rates of seeding was conducted by Briggle et al. (1967a, 1967b). Both spring and winter wheat hybrids were higher yielding on the average than their more productive parent at all seeding rates.

Wilson (1968) reported that restored hybrids having *Triticum timopheevi* cytoplasm and pollen restoring genes, when tested at normal seeding rates did not yield as much as the best conventional cultivars. Similarly, the performance of restored Hard Red Winter Wheat hybrids seeded at normal rates in Nebraska were intermediate to the parental cultivars in productivity (Johnson and Schmidt, 1968). Rodriguez et al. (1967) suggested that higher hybrid yields relative to the parents might have been obtained with hybrids obtained from Mexican cultivars if heavier seeding rates had been used.

In a review on hybrid wheat, Johnson and Schmidt (1968) pointed out that it is easy to demonstrate heterosis for yield in hybrids from handmade crosses where spaced seedings were used for yield determinations. They stated that such experiments would only have predictive value for commercial hybrid wheat production if the yield superiority of space-planted hybrids would persist under normal commercial seeding rates, or if it could be demonstrated that high yield levels could be achieved from low as well as high seeding rates with the hybrids.

The plant density effect on the expression of heterosis for yield and its components in wheat was investigated by Zeven (1972). He found no effect, but did point out that the conclusion was based on one experiment conducted at one location over one year, and with six density combinations.

In 1982, yield trials employing normal seeding rates were conducted at Oklahoma State University, involving 14 hybrids and 16 pure-line cultivars grown at seven locations (Pass and Smith, 1983). The mean hybrid performance was 15% above the mean pure-line cultivar performance, with the best hybrid being 10% better in mean performance compared to the best pure-line cultivar.

In summary, according to Wilson and Driscoll (1983), the anticipated yield increase from hybrid wheat has not yet eventuated and only in a few instances have hybrids been markedly superior to the best conventional cultivars. Similarly, Virmani and Edwards (1983) pointed out that few studies have reported economically significant yield advantages of hybrids over the best conventional cultivars. Whereas, in his review on hybrid wheat, Wilson (1984) stated that hybrids from various types of wheat have shown positive results in performance, but no one is yet sure that hybrid wheats will succeed as commercial cultivars.

Composite Cultivars

Composite cultivars are formed by blending seed of genetically different cultivars which may or may not be phenotypically similar.

One of the earliest records of the value of crop heterogeneity is from the work of Tozzetti (cited by Wolfe, 1985). He observed, in the eighteen century, a reduction of rust infection in mixtures of wheat and oats. In 1892, results with composites of wheat in Europe were collected by von Rumker (cited by Simmonds, 1962). The experiments, in 1881, by Genay, and of Heine in 1889-1890, showed that mixtures were superior in grain yield to the component cultivar means in the mixtures and to nearly all the individual components (Simmonds, 1962).

Competitive ability of winter wheat, when grown under Nebraska conditions, was investigated by Montgomery (1912). He concluded that in nearly every case a mixture of two cultivars gave a greater number of plants and grain yield than when either cultivar was sown alone.

Performance of four wheat cultivars and the six possible 1:1 mixtures grown at seven sites over three years was reported by Nuding (1936). The mean yield of composites was significantly better than the mean yield of the components. However, no composite significantly exceeded the grain yield of the better component. Similarly, Heuser (cited by Frankel, 1939) concluded, from blending trials of five wheat cultivars conducted over three years, that the pure cultivars yielded at least as well as the blends, and that there was even a tendency for lower yields in the latter.

In investigations of composites of New Zealand wheats, Frankel (1939) combined the cultivar 'Tuscan' with eleven other lines, which had similar grain yield performances. Gross yield agreed with mean expectations, with two composites giving nonsignificant increases over the pure stands. None of the composites resulted in a yield decrease when compared to the pure stands. Tuscan was found to be an aggressive competitor and depressed the yields of other lines in various combinations. However, the overall yield levels were compensated by the performance of Tuscan.

The effect of natural selection on varietal composites of winter wheat was examined by Laude and Swanson (1942). They reported cumulative changes in mixtures of the cultivars 'Kanred', 'Harvest Queen' and 'Currell', when grown at two locations over a nine-year period. Kanred, the best adapted cultivar, dominated all mixtures after nine years. This was attributed to survival of more Kanred plants in competition and more seeds per plant produced by Kanred. The survival of wheat and barley cultivars in composites was tested by Suneson and Wiebe (1942). They concluded that the relative yield of a cultivar is not necessarily a criterion of its ability to survive in competition. When grown in composite in the same locality, 'Ramona', a high-yielding and rather widely adapted wheat cultivar, was a poor competitor in mixtures with cultivars having lower individual yields than Ramona.

Shaalan et al (1966) reported that the year to year variation in the yield of Hard Red Winter Wheat could be reduced by employing annually reconstituted mixtures of cultivars. The effect of intra-populational genetic diversity on the stability of performance of equal mixed composites, as measured by their variance in yield over a range of environments, was investigated by Marshall and Brown (1973). They pointed out that composite yields will vary less than the yield of the most stable component only when the components respond quite differently to environmental changes.

Studying the effect of planting rate and genotypic frequency on yield and seed size, Chapman et al. (1969) found a significant positive interaction for yield between the mixtures of two cultivars when they were grown at high but not at low population densities. Seed size was significantly larger at the lower population densities. Using four spring wheat cultivars, Sage (1971) investigated the effect of seeding rates on yield of pure and mixed stands. When using low seeding rates, the mixtures significantly outyielded their components grown in pure stands. However, at normal seeding rates, mixtures did not show any advantage over the pure stands of the components.

Indelen (1975) studied the performance of five genetically and morphologically different winter wheat cultivars grown in composites and pure stands at three locations in Oregon. He found that composite populations were superior under high or medium stress conditions, and cultivars *per se* were superior under ideal growing conditions. He concluded that the performance of a cultivar under pure stand conditions in a given environment was not a direct measure of its yielding ability in a composite. Also, it would be necessary to test various composite combinations in different locations for several years before recommending a specific composite for commercial production.

Baker (1977), using a 1:1 mixture, examined the effect of seeding rates on pure and mixed stands of two spring wheat cultivars sown at five seeding rates in each of two years. A lack of agreement between cultivar performance in pure and mixed stands was observed. At the higher seeding rate, the mixture yielded more the first year but was lower the second year when compared to the components grown individually. He stated that the yield of composite cultivars could not always be predicted from the yields of the components in pure stands.

From 1975 through 1978, Valencia-Villarreal (1979) studied the performance of four different spring wheats blended in all possible combinations, in the Yaqui Valley, Sonora, Mexico. He found that the composites were as good or better than the pure stands under adverse environmental conditions. Furthermore the success of a cultivar in the pure stand could be a direct measure of its yielding ability in a composite.

The variability of height in wheat genotypes was used by Prasad and Reddy (1973) to create a systematic mixed stand to give a prismatic canopy surface. They found that such mixtures gave higher grain yield than the pure stands. Later, Reddy and Prasad (1977) reported more light transmission in a pyramidal canopy stand. Pyramidal and columnar canopy stands were also created by Sharma and Prasad (1978), using three spring wheat cultivars varying in plant height. The yield of mixed stands was significantly greater than the mean yield of the pure stands; whereas, mixed stands and the highest yielding cultivar in pure stand yielded almost the same. When grown in the mixed stand, the tall genotype (117 cm) yielded more than in a pure stand, but the dwarf genotype (64 cm) yielded less. According to Prasad and Sharma (1980), height variability in spring wheat cultivars permits a better utilization of solar radiation. They also studied the effect of the canopy created by pure and mixed cultures of tall and dwarf wheats using different row spacings and rates of nitrogen application. The mixed stands gave significantly higher straw and grain yield than the pure stand of the highest-yielding cultivar at a high rate of nitrogen (120 kg/ha). During two years, Rajeswara and Prasad (1984) studied intergenotypic competition in mixed stands of three spring wheat cultivars. In mixed stands, the dwarfed genotype supported the taller plants and prevented lodging. As a result, the taller cultivar yielded more in mixed stands. They pointed out that mixed stands were more stable for grain yield than pure stands.

Crew, a club winter wheat composite, was released by Washington Experimental Station in 1982 (Allan et al., 1983). It is a composite of ten closely related lines with at least nine different race-specific genes for resistance to strip rust (*Puccinia striiformis* f.sp. *tritici*). Also, there is some diversity for reactions to leaf rust (*Puccinia recondita* f.sp. *tritici*) and powdery mildew (*Erysiphe graminis* f.sp. *tritici*). In comparison of fungicide-treated versus untreated plots, the maximum yield loss for Crew was 7% as compared to its components which varied from 9 to 27%. In extensive yield trials, the composite exceeded or equalled the yield of all but one commercially grown club wheat cultivars.

The disease progression of _Septoria nodorum_ in pure and mixed stands of two spring wheat cultivars was investigated by Karjalainen (1986), from 1983 to 1986. He found that the apparent infection rates in the mixture were similar to that of the more resistant pure stand. Disease levels in mixed stands were lower than the arithmetic mean of the pure stands in all three years. Under low or moderated disease stress, mixtures buffered yield reduction effectively. However, when disease levels were high, mixtures appeared to be less effective for reducing yield losses.

Association Among Agronomic Traits

Frequently, plant breeders use the association among agronomic traits as a tool to select for yield. Grain yield in wheat is a function of the number of spikes per unit of area, the number of kernels per spike, and kernel weight. A strong tendency toward mutual compensation among these components is usually observed. However, the levels of association and compensation among yield components are generally altered by the environmental conditions in which the genotypes are cultivated.

The grain yield in oats was represented by Grafius (1956) as the volume of a rectangular parallelepiped with three edges corresponding to three yield components. He noted that an increase in one edge did not necessarily result in a corresponding increase in volume, as the responses of the yield components were not biologically independent.

Working with navy bean (Phaseolus vulgaris L.), Adams (1967) found that the yield components were genetically independent traits, but were frequently negatively associated. The negative correlation among yield components in barley was attributed by Rasmusson and Cannel (1970) to a linkage of genes controlling these components. Based on the data published by Rasmusson and Cannel (1970), Adams and Grafius (1971) proposed an alternative explanation, which was based on an oscillatory response of the yield components due to the sequential nature of the development of components and a limitation of environmental resources. The authors concluded that the data of Rasmusson and Cannel conformed to the oscillatory hypothesis.

Positive associations of wheat grain yield with number of spikes and grain weight have been reported by many authors (Anand et al. 1972; Das, 1972; Bhatt, 1973; Ledent, 1982; Borojevic and Williams, 1982; Aguilar and Hunt, 1984; Salmeron-Zamora, 1985). In wheat, a positive relationship between grain yield and kernels per spike was reported by Fonseca and Patterson (1968b), Singh et al. (1970), Sidwell et al. (1976), Abi-Antoun (1977), Valencia-Villarreal (1979), Yunus and Paroda (1982), Ledent (1982) and Gebeyehou et al. (1982). While few workers have reported negative associations among yield and yield components in wheat, the existence of a negative association between yield and kernels per spike was observed by Anand et al. (1972), Nass (1973) and Yunus and Paroda (1982). Whereas, Gebeyehou et al. (1982) found a negative association between yield and spikes per unit of area; which could be due to the negative effects of spikes per unit of area on kernel per spike and kernel weight.

Negative correlations among the yield components of wheat have been noted by several authors (Kronstad, 1963; Fonseca and Patterson, 1968b; Anand et al., 1972; Sidwell et al., 1976; Firat, 1978; Yunus and Paroda, 1982).

In wheat, positive correlations between plant height and grain yield have been reported by Kronstad (1963), Khan et al. (1972), Virk et al. (1977), Yunus and Paroda (1982) and Salmeron-Zamora (1985). With respect to the relationship between heading date and grain yield, a negative correlation was found by Singh et al. (1970), and Bhatt (1973). However, Yunus and Paroda (1982) reported a positive association between those traits. These authors also found positive correlations between kernels per spike and heading date, between plant height and kernels per spike, and between kernel weight and heading date. A negative association between heading date and kernel weight was reported by Bhatt (1973) and Yunus and Paroda (1982).

Summary Statement

In reviewing the literature, the question of the superiority of hybrids, composites and pure stands for grain yield presents a complexity of results. It would appear the nature of the experimental material employed, location and year interactions all have played a role in confusing this issue.

MATERIALS AND METHODS

The experimental material for this research was made up of three different groups of winter wheat. These consisted of parental lines, hybrids, and 1:1 composites of the hybrid parental combinations. Pedigrees and selected agronomic data for the homogeneous lines are presented in Appendix Table 1. Entry number, entry group and identification are included in Table 1.

Three locations were employed during the crop season 1985-86. Included were the Hyslop Farm near Corvallis, Oregon, the Sherman Experimental Station at Moro, Oregon, and the Rugg site near Pendleton, Oregon. They are identified as Hyslop, Moro, and Pendleton, respectively. These experimental locations were chosen to represent a wide range of environmental conditions. Climatic conditions during the experimental period are shown in Appendix Table 2.

A chemical gametocide was used to induce male sterility for producing the hybrids employed in this study. Some plants were bagged in the treated plots to determine if self-pollination occurred.

Hyslop

Nineteen entries (Table 2) were planted on October 14, 1985. A randomized complete block design with three replications was used. The plot size was six rows spaced 20 cm apart and 5.4 m in length, with a sowing density of 100 kg/ha. The soil type at Corvallis is a fine silty, mixed mesic Aquultic Argixeroll. Prior to seeding, 55 kg/ha of nitrogen and 7 kg/ha of sulfur were applied. In the spring, 160 kg/ha of nitrogen and 25 kg/ha of sulfur were added. Weeds were controlled by

Table 1. Entry number, entry type, cross number, and name of the winter wheats included in the study.

Entry Number	Entry Type	Cross Number	Entry Name
1	Pure Line	-	Stephens
2	Pure Line	-	Malcolm
3	Pure Line	-	Hill
4	Pure Line	-	OR CW8314
5	Pure Line	-	OR CW8522
6	Pure Line	-	OR CW8626
7	Pure Line	-	OWW77385
8	Pure Line	-	OR CW8421
9	Pure Line	-	Nugaines
13	Hybrid	1	Malcolm / OR CW8314
14	Composite	-	Malcolm + OR CW8314
23	Hybrid	2	Malcolm / OR CW8626
24	Composite	-	Malcolm + OR CW8626
33	Hybrid	3	Malcolm / OWW77385
34	Composite	-	Malcolm + OWW77385
43	Hybrid	4	Hill / OR CW8314
44	Composite	-	Hill + OR CW8314
53	Hybrid	5	Hill / Malcolm
54	Composite	-	Hill + Malcolm
63	Hybrid	6	Hill / OWW77385
64	Composite	-	Hill + OWW77385
73	Hybrid	7	Stephens / OR CW8314
74	Composite	-	Stephens + OR CW8314
83	Hybrid	8	Stephens / OR CW8522
84	Composite	-	Stephens + OR CW8522
93	Hybrid	9	Hill / Nugaines
94	Composite	-	Hill + Nugaines
103	Hybrid	10	Hill / OR CW8421
104	Composite	-	Hill + OR CW8412

Table 2. Entry numbers of the wheat groups used at the different locations of the study.

Corvallis	Moro	Pendleton
1	1	1
2	2	2
3	3	3
4	4	4
5	5	5
-	6	6
-	7	7
8	-	-
9	-	-
--	13	13
--	14	14
--	23	23
--	24	24
--	33	33
--	34	34
43	43	43
44	44	44
53	53	53
54	54	54
--	63	63
--	64	64
73	73	73
74	74	74
83	83	83
84	84	84
93	--	--
94	--	--
103	---	---
104	---	---

applying Alachlor (1.68 kg AI/ha) and Chlorsulfuron (23.35 g AI/ha). The experiment data were collected from the plots on August 1, 1986, by harvesting 6.5 square meters from each plot.

Moro

Twenty-three entries (Table 2) were planted on September 25, 1985. A randomized complete block design with four replications was used. The plot size was represented by four rows spaced 35 cm apart and 4.65 m in length. The sowing density was 67 kg/ha. The soil type at Sherman Station is a coarse silty mixed mesic and typic Haploxeroll. Plots were fertilized with 56 kg/ha of nitrogen in June prior to planting. Weeds were controlled by preplanting application of Diclofop-methyl (1.0 kg IA/ha) plus Bromoxynil (0.5 kg IA/ha). An area of 6.5 square meters was harvested from each plot on July 24, 1986.

Pendleton

Arranged in a randomized complete block design with four replications, 23 entries (Table 2) were planted on October 4, 1985. Each plot consisted of six rows spaced 20 cm apart and 5.4 m in length. The sowing density was 100 kg/ha. The soil at Pendleton is a coarse silty mixed mesic and typic Haploxeroll, and was fertilized with 85 kg/ha of nitrogen and 17 kg/ha of sulfur. Bromoxynil (0.35 kg AI/ha) and Dicamba (0.08 kg AI/ha) were applied for controlling weeds. An area of 6.5 square meters was harvested from each plot on July 28, 1986.

Data Collected

The following data were collected on a plot basis in the three sites:

1. Plant height (cm) was obtained at maturity by taking two measurements from the ground level to the tip of the spikes, excluding awns if present. Plant height for a composite was calculated by taking the average plant height of the two individual components.

2. Number of spikes were counted from one meter of a center row of each plot to avoid border effect.

3. Number of kernels per spike were determined by averaging the kernel number from ten spikes taken at random from each plot.

4. Kernel weight was recorded in grams by weighing 300 kernels from the ten spikes noted under three above.

5. Grain yield per plot in grams was recorded as the grain weight obtained from the harvested area (6.5 square meter).

6. Heading date was recorded when 50% of the plot was headed. This was only computed for the Hyslop site. Heading date for a composite was computed by averaging the heading dates of both components.

7. Lodging was recorded as the percentage of the plot with lodged plants. Lodging was a serious problem only at the Hyslop site.

Statistical Analysis

An analysis of variance was conducted on the above traits for each site. For grain yield the data were analyzed separately, then data were combined and analyzed over locations to determine if there was an interaction between cultivars across sites (Gomez and Gomez, 1984).

The least significant difference test (LSD) was used to determine significant differences between cultivar means (Petersen, 1985). The group effects in the analysis of variance were divided into component effects to detect differences among and within groups. For grain yield, the following null hypotheses were tested using the LSD test:

a. The grain yield of the hybrids was equal to the grain yield of the conventional cultivars (pure lines).

b. The grain yield of the composites was equal to the grain yield of the components in pure stand (pure lines).

Heterosis was calculated for each trait as the percentage increase of the F1 above the mean of the parental lines. The formula used was that described by Matzinger et al. (1962):

$$\text{Heterosis} = [(F1-MP)/MP] \times 100$$

where MP is the mid-parent value and F1 is the mean of the first generation.

Hybrid performance superior to the highest parent was calculated as heterobeltiosis using the formula proposed by Fonseca and Patterson (1968a):

$$\text{Heterobeltiosis} = [(F1-HP)/HP] \times 100$$

where HP is the mean value of the highest parent and F1 is the mean of the first generation.

The relationships between agronomic traits were analyzed using phenotypic correlation coefficients. Such possible relationships were calculated for every possible combination of traits at each site, and over sites. Also, coefficients of determination were calculated to estimate the amount of variation in grain yield explained by the other agronomic traits for each entry group at the different sites, and for the combined sites.

RESULTS

The results are presented both separately for each location and combined across location to investigate the existence of genotype x location interaction for grain yield.

Since grain yield evaluation was the major criterion of this investigation, entry performance with regard to this trait will be considered in detail.

Hyslop

Analysis of Variance

Seven pure lines, six hybrids and six composites of winter wheat were the experimental materials used at this site. The analysis of variance was computed to detect possible differences among entries for seven traits. When differences were significant for the specific trait then differences among and within entry groups were further investigated.

Differences were noted among the 19 entries for plant height, heading date, kernels per spike, spikes per meter, kernel weight, and grain yield (Tables 3 and 4). Among the three groups (pure lines, hybrids and composites) differences were observed for all the traits, with the exception of kernel weight and grain yield, and for all the traits within the groups. The sources of variation were further partitioned within each of the three groups. Differences were noted among pure lines for all the traits. Among hybrids differences were found for heading date, kernels per spike, kernel weight and grain

Table 3. Observed mean square values for four agronomic traits from seven pure lines, six hybrids and six composites of wheat grown at Hyslop Agronomy Farm, Corvallis, Oregon, 1985-86.

Source of Variation	df	Plant Height	Heading Date	Kernels/ Spike	Lodging
Replications	2	18.86*	0.23	225.91**	9408.33**
Entries	18	55.99**	6.23**	160.08**	931.82
Among Groups	2	271.10**	1.92*	219.86**	-------
Within Groups	16	29.10**	6.77**	152.61**	-------
W/Pure Lines	6	69.04**	8.16**	230.56**	-------
W/Hybrids	5	5.56	3.96**	82.13*	-------
W/Composites	5	4.72	7.92**	129.56**	-------
Error	36	4.97	0.47	32.45	1308.80
Total	56				
Location Mean		118.00	148.00	43.00	52.00
CV (%)		1.89	0.46	13.16	68.85

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

Table 4. Observed mean square values for three agronomic traits from seven pure lines, six hybrids and six composites of wheat grown at Hyslop Agronomy Farm, Corvallis, Oregon, 1985-86.

Source of Variation	df	Spikes per Meter	Kernel Weight	Grain Yield
Replications	2	13.26	5.81*	374721.39
Entries	18	1313.94**	5.58**	599096.57**
Among Groups	2	1286.63**	2.70	173135.20
Within Groups	16	1317.35**	5.94**	652341.74**
W/Pure Lines	6	2618.56**	7.24**	904380.97**
W/Hybrids	5	166.80	7.48**	451641.39*
W/Composites	5	906.46**	2.84	550595.02*
Error	36	197.58	1.74	157915.48
Total	56			
Location Mean		96.00	9.57	3563.00
CV (%)		14.71	13.79	11.15

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

yield. Whereas, among composites the differences were observed for heading date, kernels per spike, spikes per meter, and grain yield.

The coefficient of variation (CV) values were low for plant height and heading date, 1.89 and 0.46%, respectively. For kernels per spike, spikes per meter, kernel weight and grain yield the CV values were relatively high, 13.16, 14.71, 13.79 and 11.15%, respectively. For lodging the CV value was very high (68.85%).

Mean values of the entries for the different traits are shown in Tables 5 and 6. Heading date ranged from 144 days for Entry 5 to 150 days for Entry 83. For plant height, Entry 43 was the tallest (125 cm), while Entry 9 (Nugaines) was the shortest (107 cm). The average for hybrids was 123 cm, whereas pure lines and composites averaged 116 cm. Entry 9 (Nugaines) showed the highest number of spikes per meter (156), but it had low values for kernels per spike and kernel weight, 30 and 7.09, respectively. Hybrids had the highest average value for kernels per spike (47), while the pure lines had the highest average for number of spikes per meter and kernel weight, 101 and 9.87, respectively. Entry 1 (Stephens) showed the highest kernel weight (11.99), but had a low value for kernels per spike (31).

A pure line (Entry 4) was the highest-yielding entry, while two hybrids (Entries 43 and 53) occupied the second and third place in the ranking. Stephens (Entry 1), a winter wheat cultivar, which has been the leading commercial cultivar for several years in Oregon, ranked 10; however, the yields of the first thirteen entries did not differ statistically. The yield mean of the pure lines was 3601 g/plot, compared to the hybrids and the composites which yielded 3631 and 3450

Table 5. Mean values for three agronomic traits and grain yeld ranking involving seven pure lines, six hybrids and six composites of wheat grown at Hyslop Agronomy Farm, Corvallis, Oregon, 1985-86.

Entry	Heading Date (days)	Plant Height (cm)	Grain Yield (g/plot)	Ranking for Grain Yield
1	146	115	3636	10
2	147	115	3954	5
3	149	122	3615	12
4	147	117	4166	1
5	144	117	3998	4
8	149	120	3293	15
9	148	107	2547	19
43	148	125	4063	2
44	148	118	3850	6
53	147	123	4051	3
54	148	117	3638	9
73	146	122	3761	7
74	146	115	3632	11
83	150	122	3453	13
84	145	115	3711	8
93	149	122	3325	14
94	149	117	2723	18
103	148	123	3134	17
104	149	117	3145	16
<u>AVERAGE</u>				
Pure Lines	147	116	3601	
Hybrids	148	123	3631	
Composites	148	116	3450	
Overall	148	118	3563	
LSD (5%)	1	4	659	
LSD (1%)	2	5	788	

Table 6. Mean values for three agronomic traits involving seven pure lines, six hybrids and six composites of wheat grown at Hyslop Agronomy Farm, Corvallis Oregon, 1985-86.

Entry	Spikes per Meter	Kernels per Spike	Kernel Weight (g)
1	103	31	11.99
2	88	38	10.94
3	81	54	9.40
4	78	43	10.47
5	123	44	10.37
8	76	48	9.03
9	156	30	7.09
43	91	49	10.69
44	86	44	9.82
53	92	46	10.51
54	102	39	8.73
73	86	46	10.94
74	111	36	9.78
83	91	40	6.66
84	122	39	10.22
93	78	48	9.67
94	102	39	7.63
103	75	56	9.52
104	73	54	8.64
<u>AVERAGE</u>			
Pure Lines	101	41	9.87
Hybrids	86	47	9.66
Composites	99	42	9.14
Overall	96	43	9.57
LSD (5%)	23	9	2.19
LSD (1%)	28	11	2.62

Table 7. Null hypothesis tests for grain yield of six pure lines, five hybrids and five composites of wheat grown at Hyslop Agronomy Farm, Corvallis, Oregon, 1985-86.

Null Hypothesis1/	Difference between group means (g/plot)	LSD (5%)
a	30	659
b	-151	659

1/ a: Grain yield of hybrids was equal to grain yield of pure lines (conventional cultivars).

b: Grain yield of composites was equal to grain yield of pure lines (components).

g/plot, respectively. The LSD test was used to test two null hypotheses (Table 7) related to the grain yield of the three entry groups. The LSD values indicated that for this location the grain yields of hybrids and composites were similar to the grain yields of pure lines.

Performance of Hybrids Compared to Their Parents

Estimates of heterosis and heterobeltiosis for six agronomic traits are summarized in Table 8. The highest estimate for heterosis for grain yield was 7.9%, involving cross 9. The highest heterobeltiosis value was 2.5%, observed in cross 5.

Values for heading date compared to the mid-parent ranged from -0.7 to 3.4% for crosses 5 and 8, respectively, with an average of 0.4%. When compared to the later parent, the values ranged from -1.3 to 2.7%, with and average of -0.1%.

For plant height, heterosis values ranged from 1.6 in cross 10 to 7.0% in cross 9, while heterobeltiosis estimates ranged from 0.0 to 4.3%.

Of all the yield components, kernels per spike had the greatest heterosis and heterobeltiosis average values, 9.3 and -5.6%, respectively. When compared to the mid-parent the values for kernels per spike ranged from 0.0 to 24.3%, for crosses 5 and 7, respectively, and when compared to the higher parent the values ranged from -14.9 to 7.0%, for the same crosses. Spikes per meter ranged from -33.9 (cross 9) to 13.8% (cross 4) with an average of -6.4% under the mid-parent, while heterobeltiosis for this trait ranged from -50.0 to 12.3% with an average of -13.8%.

Table 8. Heterosis (A) and heterobeltiosis (B) for six agronomic traits involving six F1 populations of wheat grown at Hyslop Agronomy Farm, Corvallis, Oregon, 1985-86.

Cross		Grain Yield	Heading Date	Plant Height	Spikes/ Meter	Kernels/ Spike	Kernel Weight
4	A	4.4	0.0	4.2	13.8	2.1	7.6
	B	-2.5	-0.7	2.4	12.3	-9.2	2.1
5	A	7.0	-0.7	4.2	9.5	0.0	4.5
	B	2.5	-1.3	0.8	4.5	-14.9	-2.0
7	A	-3.6	0.0	5.2	-4.4	24.3	-2.6
	B	-9.7	-0.7	4.3	-16.5	7.0	-8.8
8	A	-9.5	3.4	5.2	-19.5	5.3	-40.4
	B	-13.6	2.7	4.3	-26.0	-9.1	-44.4
9	A	7.9	0.7	7.0	-33.9	14.3	17.4
	B	-8.0	0.0	0.0	-50.0	-11.1	2.9
10	A	-9.3	-0.7	1.6	-3.8	9.8	3.2
	B	-13.3	-0.7	0.8	-7.4	3.7	1.3
AVERAGE							
	A	-0.5	0.4	4.6	-6.4	9.3	-1.7
	B	-7.4	-0.1	2.1	-13.8	-5.6	-8.2

Three crosses (4, 9 and 10) gave positive heterosis and heterobeltiosis values for kernel weight, with estimates ranging from 4.5 to 17.4% and from 1.3 to 2.9%, respectively.

Association Among Agronomic Traits

To measure possible relationships among agronomic traits, phenotypic correlation coefficients were computed. Seven agronomic traits were considered for each of the three groups of entries grown at Hyslop (Table 9).

Within pure lines, positive associations were observed for grain yield with plant height and kernel weight, and for plant height with kernels per spike. The correlation values of grain yield with spikes per meter and lodging, of spikes per meter with plant height and kernel weight, and of kernel weight with lodging were negative. The coefficient of determination value indicated that 77% of the variation in grain yield was explained by the six agronomic characters studied.

Among hybrids, grain yield showed a positive relationship with kernel weight; whereas, the associations between grain yield and lodging, and between heading date and kernel weight were negative. Seventy-nine percent of the variation in grain yield was explained by the six agronomic traits considered.

Within composites, grain yield was positively correlated with kernel weight and negatively correlated with heading date and lodging. Heading date showed negative associations with spikes per meter and kernel weight. Negative associations were also computed between spikes per meter and kernels per spike, and between kernel weight and lodging.

Table 9. Phenotypic correlations among seven agronomic traits for pure lines, hybrids and composites of wheat grown at Hyslop Agronomy Farm, Corvallis, Oregon, 1985-86.

Traits	Pure Lines1/	Hybrids2/	Composites2/
GRAIN YIELD VS			
Heading date	-0.403	-0.174	-0.513*
Plant height	0.488*	0.103	-0.113
Spikes per meter	-0.558**	0.396	0.057
Kernels per spike	0.182	-0.179	-0.011
Kernel weight	0.723**	0.498*	0.680**
Lodging	-0.565**	-0.672**	-0.532*
Coef. of determination	0.766	0.787	0.681
HEADING DATE VS			
Plant height	0.181	-0.083	0.342
Spikes per meter	-0.249	0.065	-0.634**
Kernels per spike	0.328	-0.091	0.395
Kernel weight	-0.426	-0.590**	-0.526*
Lodging	0.158	0.128	-0.064
PLANT HEIGHT VS			
Spikes per meter	-0.715**	0.357	-0.274
Kernels per spike	0.592**	-0.112	-0.068
Kernel weight	-0.206	0.213	-0.206
Lodging	0.142	0.109	0.142
SPIKES PER METER VS			
Kernels per spike	-0.411	-0.403	-0.696**
Kernel weight	-0.434*	-0.106	-0.013
Lodging	0.290	-0.192	0.287
KERNELS PER SPIKE VS			
Kernel weight	-0.127	0.338	-0.033
Lodging	0.034	0.207	-0.024
KERNEL WEIGHT			
Lodging	-0.467*	-0.135	-0.553*

* Significant at the 5% probability level.
** Significant at the 1% probability level.
1/, 2/ N = 21 and N = 18, respectively.

The coefficient of determination value indicated that the six agronomic traits explained 68% of the grain yield variation.

Moro

Analysis of Variance

Seven pure lines, eight hybrids and eight composites of winter wheat were the experimental materials used at this site. The analysis of variance was computed to detect possible differences among entries for five agronomic traits. When these were significant, differences among and within the three entry groups were investigated.

Differences were noted among the 23 entries for grain yield, plant height, kernels per spike and kernel weight (Tables 10 and 11). Among groups, differences were found for plant height. For within groups, differences were noted for plant height, kernels per spike, kernel weight, and for grain yield. Pure lines differed for all the traits considered. The hybrids were different for plant height, kernels per spike and kernel weight. Composites differed only for plant height and kernel weight.

The coefficients of variation (CV) were low for grain yield and plant height: 8.14 and 2.68%. respectively. For spikes per meter, kernels per spike and kernel weight, the CV values were relatively high: 16.46, 13.76 and 12.44%, respectively.

Mean values for the entries for the different traits are provided in Tables 12 and 13. Spikes per meter ranged from 129 for Entry 3 (Hill) to 192 for entries 7 and 34. For plant height, entries 1 and 2

Table 10. Observed mean square values for two agronomic traits from seven pure lines, eight hybrids and eight composites of wheat grown at Moro, Oregon, 1985-86.

Source of Variation	df	Grain Yield	Spikes per Meter
Replications	3	758272.48**	300.88
Entries	22	109801.24*	963.93
Among Groups	2	48434.43	------
Within Groups	20	115937.92*	------
W/Pure Lines	6	201346.06**	------
W/Hybrids	7	76897.50	------
W/Composites	7	81771.36	------
Error	66	56917.33	711.08
Total	91		
Location Mean		2929.00	162.00
CV (%)		8.14	16.46

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

Table 11. Observed mean square values for three agronomic traits from seven pure lines, eight hybrids and eight composites of wheat grown at Moro, Oregon, 1985-86.

Source of Variation	df	Plant Height	Kernels per Spike	Kernel Weight
Replications	3	42.03**	24.53	3.15
Entries	22	40.51**	82.61**	4.79**
Among Groups	2	195.09**	89.47	0.42
Within Groups	20	25.06**	81.93*	5.23**
W/Pure Lines	6	41.07**	82.70**	7.96**
W/Hybrids	7	15.96*	112.12**	3.39*
W/Composites	7	20.42**	51.07	4.72**
Error	66	5.66	33.00	1.32
Total	91			
Location Mean		89.00	42.00	9.24
CV (%)		2.68	13.76	12.44

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

Table 12. Mean values for two agronomic traits and grain yield ranking of seven pure lines, eight hybrids and eight composites of wheat grown at Moro, Oregon, 1985-86.

Entry	Spikes per Meter	Grain Yield (g/plot)	Ranking for Grain Yield
1	177	2887	15
2	158	2702	20
3	129	2958	8
4	156	2702	21
5	142	3185	3
6	164	3193	2
7	192	2669	23
13	174	2950	10
14	160	2826	18
23	165	3218	1
24	154	3119	5
33	171	2902	13
34	192	2889	14
43	160	2853	16
44	164	2809	19
53	160	2952	9
54	181	2911	12
63	166	2826	17
64	168	2689	22
73	139	3150	4
74	160	2968	7
83	140	2937	11
84	159	3081	6
<u>AVERAGE</u>			
Pure Lines	159	2900	
Hybrids	159	2973	
Composites	167	2912	
Overall	162	2929	
LSD (5%)	38	337	
LSD (1%)	50	449	

Table 13. Mean values for three agronomic traits of seven pure lines, eight hybrids and eight composites of wheat grown at Moro, Oregon, 1985-86.

Entry	Plant Height (cm)	Kernels per Spike	Kernel Weight (g)
1	84	36	10.97
2	84	43	9.39
3	86	48	7.85
4	86	36	8.06
5	90	40	11.21
6	88	46	9.72
7	92	42	8.01
13	89	43	9.62
14	86	41	9.60
23	94	46	9.28
24	86	41	9.72
33	94	39	9.07
34	92	37	8.84
43	91	42	8.30
44	85	41	8.32
53	92	48	8.63
54	88	42	8.48
63	94	40	8.23
64	89	46	7.96
73	90	36	11.06
74	88	38	10.30
83	90	53	8.67
84	88	34	11.14
AVERAGE			
Pure Lines	87	42	9.31
Hybrids	92	43	9.11
Composites	88	40	9.30
Overall	89	42	9.24
LSD (5%)	4	8	1.62
LSD (1%)	5	11	2.16

(Stephens and Malcolm, respectively) were the shortest (84 cm), while the hybrid entries 23, 33 and 63 were the tallest (94 cm). Respect to yield components, for spikes per meter the values ranged from 129 (Entry 3) to 192 (entries 7 and 34). For kernels per spike, the values ranged from 34 (Entry 84) to 53 (Entry 83), while for kernel weight, the highest value was 11.21 g (Entry 5) and the lowest was 7.85 g (Entry 3). Hybrids showed the highest average for kernels per spike but the lowest for kernel weight.

Grain yield values ranged from 2669 to 3218 g/plot, with an average of 2929. Hybrid Entry 23 was the highest yielding entry, and a pure line, Entry 7, was the lowest one. Even though Stephens (Entry 1) ranked 15, it was not significantly different from the first 20 entries. The average yield of hybrids was 2973 g/plot, while pure lines and composites averaged 2900 and 2912 g/plot, respectively.

Two null hypotheses related to the grain yield of the three groups of entries were tested by the LSD test (Table 14). The LSD values showed that the grain yields of pure lines, hybrids and composites were not different.

Performance of Hybrids Compared to Their Parents

Heterosis and heterobeltiosis values for the traits recorded at this location are summarized in Table 15. Heterosis estimates for grain yield ranged from -3.3 to 12.7%, with an average of 5.4%. Heterobeltiosis varied from -7.8 to 9.2%, with an average of 1.3%. Crosses 1, 3 and 7 gave the highest heterosis and heterobeltiosis.

Table 14. Null hypothesis tests for grain yield of seven pure lines, eight hybrids and eight composites of wheat grown at Moro, Oregon, 1985-86.

Null Hypothesis1/	Difference between group means (g/plot)	LSD (5%)
a	73	337
b	12	337

1/ a: Grain yield of hybrids was equal to grain yield of pure lines (conventional cultivars).

b: Grain yield of composites was equal to grain yield of pure lines (components).

Table 15. Heterosis (A) and heterobeltiosis (B) for five agronomic traits involving eight F1 populations of wheat grown at Moro, Oregon, 1985-86.

Cross		Grain Yield	Plant Height	Spikes/ Meter	Kernels/ Spike	Kernel Weight
1	A	9.2	4.7	10.8	7.5	10.3
	B	9.2	3.5	10.1	0.0	2.4
2	A	9.2	9.3	2.5	4.5	-2.9
	B	0.8	6.8	0.6	0.0	-4.5
3	A	8.1	6.8	-2.3	-7.1	4.4
	B	7.4	2.2	-10.9	-9.3	-3.3
4	A	0.8	5.8	12.7	0.0	4.4
	B	-3.5	5.8	2.6	-12.5	3.0
5	A	4.3	8.2	11.1	4.3	0.0
	B	-0.2	7.0	1.3	0.0	-8.2
6	A	2.3	5.6	3.8	-11.1	4.0
	B	-4.5	2.2	-13.5	-16.7	2.9
7	A	12.7	5.9	-16.3	0.0	16.2
	B	9.1	4.6	-21.5	0.0	0.8
8	A	-3.3	3.4	-12.5	39.5	-21.9
	B	-7.8	0.0	-20.9	32.5	-22.7
AVERAGE						
	A	5.4	6.2	1.2	4.7	1.8
	B	1.3	4.0	-6.5	-0.8	-3.7

For plant height, estimates ranged from 3.4 to 9.3% for heterosis, and from 0.0 to 7.0% for heterobeltiosis, with averages of 6.2 and 4.0%, respectively.

For the yield components, kernels per spike presented the highest average for heterosis (4.7%), with estimates ranging from -11.1 (cross 6) to 39.5% (cross 8), while the estimates for heterobeltiosis averaged -0.8%, with a range from -16.7 (cross 6) to 32.5% (cross 8). Estimates for spikes per meter compared to the mid-parent ranged from -16.3 (cross 7) to 12.7% (cross 4). When compared to the higher-parent, the estimates ranged from -21.5 (cross 7) to 10.1% (cross 1). For kernel weight, heterosis ranged from -21.9 (cross 8) to 16.2% (cross 7), and for heterobeltiosis the range was from -22.7 (cross 8) to 3.0% (cross 4). Cross 1 showed positive values of heterosis and heterobeltiosis for all the traits studied.

Association Among Agronomic Traits

Phenotypic correlation coefficients were computed to measure possible relationships among agronomic traits. Five agronomic traits were studied for each of the three groups of entries grown at Moro (Table 16).

When pure lines were considered, grain yield was positively correlated with kernel weight. Correlations of grain yield with the other traits were not significantly different from zero. Only 32% of the variation in grain yield was explained by the traits studied. A small negative association between spikes per meter and kernels per spike was observed.

Table 16. Phenotypic correlations among five agronomic traits for pure lines, hybrids and composites of wheat grown at Moro, Oregon, 1985-86.

Traits	Pure Lines1/	Hybrids2/	Composites2/
GRAIN YIELD VS			
Plant height	0.164	0.182	0.274
Spikes per meter	-0.174	-0.012	-0.032
Kernels per spike	0.280	0.158	0.056
Kernel weight	0.482*	0.583**	0.654**
Coef. of determination	0.321	0.515	0.537
PLANT HEIGHT VS			
Spikes per meter	0.240	0.305	0.259
Kernels per spike	0.128	-0.028	0.004
Kernel weight	-0.066	-0.076	0.077
SPIKES PER METER VS			
Kernels per spike	-0.391*	-0.087	-0.108
Kernel weight	-0.125	-0.169	-0.298
KERNELS PER SPIKE VS			
Kernel weight	0.098	-0.279	-0.208

* Significant at the 5% probability level.
** Significant at the 1% probability level.
1/ N = 28
2/ N = 32

Within hybrids grain yield was positively associated with kernel weight. The other traits did not show any significant relationship. For this entry group, 52% of the variation in grain production was explained by the coefficient of determination.

Among the composites, again, grain yield was only significantly correlated with kernel weight. No other correlation was found to be significant. The four agronomic traits studied accounted for 54% of the variation in grain yield.

Pendleton

Analysis of Variance

The experimental material for this site was made up of three groups including seven pure lines, eight hybrids and eight composites of winter wheat. The analysis of variance was computed to investigate possible differences among entries and among and within the three groups for five agronomic traits.

Differences were found among the 23 entries for grain yield, spikes per meter, plant height, kernels per spike and kernel weight (Table 17 and 18). Among groups, the differences were observed for grain yield and plant height. Within groups the differences were found for all traits. Pure lines differed for all the traits but spikes per meter. The same was true for the composites; whereas, hybrids did not differ for grain yield and kernel weight.

The coefficients of variation (CV) were low for grain yield and plant height: 6.75 and 3.57%, respectively. For spikes per meter,

Table 17. Observed mean square values for two agronomic traits from seven pure lines, eight hybrids and eight composites of wheat grown at Pendleton, Oregon, 1985-86.

Source of Variation	df	Grain Yield (g/plot)	Spikes per Meter
Replications	3	1113238.07**	446.80
Entries	22	271277.64**	439.15*
Among Groups	2	306164.52*	598.09
Within Groups	20	267788.95**	423.26*
W/Pure Lines	6	439248.56**	390.87
W/Hybrids	7	117321.21	611.07*
W/Composites	7	271291.32**	263.21
Error	66	79590.99	244.74
Total	91		
Location Mean		4182.00	98.00
CV (%)		6.75	15.89

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

Table 18. Observed mean square values for three agronomic traits from seven pure lines, eight hybrids and eight composites of wheat grown at Pendleton, Oregon, 1985-86.

Sources of Variation	df	Plant Height (cm)	Kernels per Spikes	Kernel Weight (g)
Replications	3	52.54*	76.76*	6.89**
Entries	22	82.56**	126.20**	3.08**
Among Groups	2	319.70**	13.25	0.56
Within Groups	20	58.84**	137.50**	3.33**
W/Pure Lines	6	95.24**	167.14**	3.56*
W/Hybrids	7	42.86*	171.32**	1.73
W/Composites	7	43.64*	78.27**	4.72**
Error	66	15.79	23.72	1.17
Total	91			
Location Mean		111.00	47.00	9.70
CV (%)		3.57	10.31	11.15

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

kernels per spike and kernel weight the CV values were relatively high; 15.89, 10.31 and 11.15%, respectively.

Means values of the entries for the different traits are shown in Tables 19 and 20. Spikes per meter ranged from 75 for Entry 23 to 116 for Entry 7. For plant height, Entry 2 (Malcolm) was the shortest (105 cm) and a hybrid, Entry 63, was the tallest (120 cm). Kernels per spike varied from 38 for Entry 1 (Stephens) to 61 for the hybrid Entry 83. Kernel weight varied from 8.41 g for the Entry 34 to 11.50 g with the pure line Entry 5.

Entry 5 was the highest yielding (4790 g/plot), and a composite, Entry 14, showed the lowest grain yield (3691 g/plot). Stephens ranked 18th and was significantly lower in yield than entries 5, 23 and 84. Hybrids averaged 4286 g/plot, while pure lines and composites averaged 4164 and 4093 g/plot, respectively.

Two null hypotheses regarding grain yield differences between groups were tested by the LSD test (Table 21). The values of LSD showed that the yields of hybrids and composites were similar to the yields of pure lines.

Performance of Hybrids Compared to Their Parents

Estimates of heterosis and heterobeltiosis for the five agronomic traits measured at this location are shown in Table 22. With the exception of crosses 1 and 8, positive values of heterosis and heterobeltiosis were observed for grain yield. Superiority of the hybrids with respect to the mid-parent and higher-parent yields was 5.9 and 1.9%, respectively. The hybrid from cross 5 showed the highest

Table 19. Mean values for two agronomic traits and grain yield ranking for seven pure lines, eight hybrids and eight composites of wheat grown at Pendleton, 1985-86.

Entry	Spikes per Meter	Grain Yield (g/plot)	Ranking for Grain Yield
1	94	3958	18
2	95	3876	20
3	87	3852	22
4	108	4115	16
5	93	4790	1
6	101	4368	6
7	116	4188	12
13	82	3929	19
14	103	3691	23
23	75	4504	3
24	97	4158	14
33	115	4299	7
34	114	3968	17
43	92	4420	4
44	101	4168	13
53	99	4284	8
54	99	3872	21
63	103	4236	10
64	98	4122	15
73	92	4376	5
74	115	4193	11
83	94	4243	9
84	92	4570	2
<u>AVERAGE</u>			
Pure Lines	99	4164	
Hybrids	94	4286	
Composites	102	4093	
Overall	98	4182	
LSD (5%)	22	399	
LSD (1%)	29	531	

Table 20. Mean values for three agronomic traits of seven pure lines, eight hybrids and eight composites of wheat grown at Pendleton, Oregon, 1985-86.

Entry	Plant Height (cm)	Kernels per Spike	Kernel Weight (g)
1	106	38	10.79
2	105	43	9.63
3	112	58	8.99
4	108	46	9.25
5	106	42	11.50
6	108	49	9.48
7	119	48	9.18
13	112	42	9.22
14	108	46	8.74
23	114	43	10.54
24	106	49	9.69
33	119	41	9.27
34	111	42	8.41
43	115	51	9.76
44	111	52	8.98
53	114	48	9.45
54	111	50	9.39
63	120	50	9.61
64	116	54	8.90
73	116	45	10.93
74	108	46	11.02
83	110	61	9.11
84	108	42	11.38
AVERAGE			
Pure lines	109	46	9.83
Hybrids	115	47	9.73
Composites	110	48	9.56
Overall	111	47	9.70
LSD (5%)	6	7	1.53
LSD (1%)	8	9	2.04

Table 21. Null hypothesis tests for grain yield of seven pure lines, eight hybrids and eight composites of wheat grown at Pendleton, Oregon, 1985-86.

Null Hypothesis1/	Difference between group means (g/plot)	LSD (5%)
a	122	399
b	-71	399

1/ a: Grain yield of hybrids was equal to grain yield of pure lines (conventional cultivars).

b: Grain yield of composites was equal to grain yield of pure lines (components).

Table 22. Heterosis (A) and heterobeltiosis (B) for five agronomic traits involving eight F1 populations of wheat grown at Pendleton, Oregon, 1985-86.

Cross		Grain Yield	Plant Height	Spikes/ Meter	Kernels/ Spike	Kernel Weight
1	A	-1.7	5.4	-19.6	-4.5	-2.3
	B	-4.5	3.7	-24.1	-8.7	-4.2
2	A	9.3	7.5	-23.5	-6.5	10.2
	B	3.1	5.6	-25.7	-12.2	9.4
3	A	6.6	6.2	8.5	-10.9	-1.4
	B	2.7	0.0	-0.9	-14.6	-3.7
4	A	10.9	4.5	6.1	-1.9	7.0
	B	7.4	2.7	-14.8	-12.1	5.5
5	A	10.9	5.6	8.8	-4.0	1.5
	B	10.5	1.8	4.2	-17.2	-1.9
6	A	5.4	3.4	1.0	-5.7	5.8
	B	1.1	0.8	-11.2	-13.8	4.7
7	A	8.4	8.4	-8.9	7.1	9.0
	B	6.3	7.4	-14.8	-2.2	1.2
8	A	-3.0	3.8	0.0	50.0	-18.1
	B	-11.4	3.8	0.0	42.8	-20.7
AVERAGE						
	A	5.9	5.6	-3.4	3.0	1.5
	B	1.9	3.2	-10.9	-4.8	-1.2

values for both heterosis and heterobeltiosis, 10.9 and 10.5%, respectively.

For plant height, heterosis estimates ranged from 3.4 to 8.4%. Heterobeltiosis estimates ranged from 0.0 to 7.4%. Cross 7 showed the highest values of heterosis and heterobeltiosis, 8.4 and 7.4%, respectively.

Among the yield components, kernels per spike presented the highest average for heterosis (3.0%), with estimates ranging from -10.9 to 50.0%. Heterosis averages for spikes per meter and kernel weight were -3.4 and 1.5%, respectively. For heterobeltiosis, the averages for yield components gave negative values.

Association Among Agronomic Traits

Phenotypic correlation coefficients were computed to measure possible associations among agronomic traits. Five agronomic characters were considered for each of the three groups of entries grown at Pendleton (Table 23).

Within pure lines, grain yield showed a positive relationship with kernel weight. No relationships were observed with plant height, spikes per meter, and kernels per spike. Only 24% of the variation in grain yield was explained by the four agronomic traits. Spikes per meter was found to be negatively correlated with kernel weight.

When hybrids were considered, grain yield was positively correlated with plant height and kernel weight. The coefficient of determination value was 0.40. Within hybrids, the rest of the correlation values were not statistically different from zero.

Table 23. Phenotypic correlations among five agronomic traits for pure lines, hybrids and composites of wheat grown at Pendleton, Oregon, 1985-86.

Traits	Pure Lines1/	Hybrids2/	Composites2/
GRAIN YIELD VS			
Plant height	0.096	0.422*	0.043
Spikes per meter	-0.217	0.162	-0.282
Kernels per spike	-0.012	-0.017	0.161
Kernel weight	0.411*	0.527**	0.535**
Coef. of determination	0.241	0.403	0.394
PLANT HEIGHT VS			
Spikes per meter	0.205	0.307	0.001
Kernels per spike	0.248	-0.168	0.469**
Kernel weight	-0.362	0.242	-0.355*
SPIKES PER METER VS			
Kernels per spike	-0.202	0.117	-0.087
Kernel weight	-0.443*	-0.196	-0.323
KERNELS PER SPIKE VS			
Kernel weight	-0.232	-0.017	-0.233

* Significant at the 5% probability level.
** Significant at the 1% probability level.
1/ N = 28
2/ N = 32

Among composites positive correlations were noted between grain yield and kernel weight, and between plant height and kernels per spike. A negative correlation between plant height and kernel weight was found. Thirty-nine percent of the variation in grain production was due to the agronomic traits studied.

Combined Analyses

Analysis of Variance

Two combined analysis of variance were computed to detect entry x location interactions for grain yield. One combined analysis involved Moro and Pendleton locations (Table 24). The second analysis was conducted using all three sites utilized in this investigation (Table 25).

The homogeneity of the error variances from the different experiments was investigated using the Bartlett'test. This test showed that the error variance corresponding to the Hyslop location was heterogeneous with respect to the error variances coming from Moro and Pendleton locations. According to Gomez and Gomez, 1985 (page 322): "For most purposes, if the highest error MS is not three-fold larger than the smallest error MS, the error variances can be considered homogeneous". Based on this consideration, the combined analysis involving the three locations was performed to obtain more information about the performance of the different entries over locations.

When Moro and Pendleton locations were combined, differences were noted for entries but not for the entry x location interaction. Similar results were obtained when combining the Hyslop, Moro and Pendleton

Table 24. Observed mean square values for grain yield from combined analysis of variance for Moro and Pendleton, 1985-86.

Sources of Variation	df	Mean Square
Locations	1	72150263.05
Entries	22	286814.19**
Entries x Locations	22	94264.19
Pooled Error	132	68254.16

** Significant at the 1% probability level.

Table 25. Observed mean square values for grain yield from combined analysis of variance for Hyslop, Moro and Pendleton, 1985-86.

Sources of Variation	df	Mean Squares
Locations	2	22073360.50
Entries	12	288663.17**
Entries x Locations	24	134016.67
Pooled Error	168	92707.25

** Significant at the 1% probability level.

Table 26. Means (g/plot) and rankings for grain yield involving the wheat entries used at Hyslop, Moro and Pendleton, 1985-86.

Entry	Hyslop Mean	Hyslop Rank	Moro Mean	Moro Rank	Pendleton Mean	Pendleton Rank	Average	Rank
1	3636	10	2887	15	3958	18	3494	10
2	3954	5	2702	20	3876	20	3511	9
3	3615	12	2958	8	3852	22	3475	11
4	4166	1	2702	21	4116	16	3661	5
5	3998	4	3185	3	4790	1	3991	1
6	----	--	3193	2	4368	6	----	--
7	----	--	2669	23	4188	12	----	--
8	3293	15	----	--	----	--	----	--
9	2547	19	----	--	----	--	----	--
13	----	--	2950	10	3929	19	----	--
14	----	--	2826	18	3691	23	----	--
23	----	--	3218	1	4504	3	----	--
24	----	--	3119	5	4158	14	----	--
33	----	--	2902	13	4299	7	----	--
34	----	--	2889	14	3968	17	----	--
43	4063	2	2853	16	4420	4	3779	3
44	3850	6	2809	19	4168	13	3609	6
53	4051	3	2952	9	4284	8	3762	4
54	3638	9	2911	12	3872	21	3474	12
63	----	--	2826	17	4236	10	----	--
64	----	--	2689	22	4122	15	----	--
73	3761	7	3150	4	4376	5	3762	4
74	3632	11	2968	7	4193	11	3598	7
83	3453	13	2937	11	4243	9	3544	8
84	3711	8	3081	6	4570	2	3787	2
93	3325	14	----	--	----	--	----	--
94	2723	18	----	--	----	--	----	--
103	3134	17	----	--	----	--	----	--
104	3145	16	----	--	----	--	----	--
Average								
Pure Lines	3601		2900		4164		3626	
Hybrids	3631		2973		4286		3712	
Composites	3450		2912		4093		3617	
Overall	3563		2929		4182		3650	

sites. Entry means and rankings for grain yield from the three sites are shown in Table 26. When the three location results were averaged, Entry 5, an experimental pure line ranked first. The cultivars Malcolm (Entry 2), Stephens (Entry 1) and Hill (Entry 3) were 9, 10 and 11 in ranking, respectively. Entry 84, a composite, occupied the second position; whereas, two hybrids, Entries 43 and 53 occupied the third and fourth place, respectively. The hybrids averaged 3712 g/plot and the pure lines and composites averaged 3626 and 3617 g/plot, respectively. The hybrids yielded 2.4% more grain than the pure lines, and 2.6% more than the composites. The highest-yielding hybrid (Entry 43) yielded 8.2% more than Stephens, but 5.3% less than the highest yielding pure line (Entry 5). The highest-yielding composite (Entry 84) yielded 8.4% more than Stephens and 5.1% less than Entry 5. When the Moro and Pendleton locations were considered, Entry 5 was again the highest yielding pure line, and Entry 84 was the highest-yielding composite. In this case, Entry 23 was the highest-yielding hybrid, being first at Moro and third at Pendleton.

Association Among Agronomic Traits

Phenotypic correlations were used to measure possible association among agronomic traits for each group of entries across the three locations (Table 27).

Within pure lines, grain yield was positively correlated with plant height, kernels per spike and kernel weight, while its correlation with spikes per meter was negative. Fifty-nine percent of the variation in grain yield was accounted for by these agronomic

Table 27. Phenotypic correlations among five agronomic traits for pure lines, hybrids and composites of wheat grown at Hyslop, Moro and Pendleton, 1985-86.

Traits	Pure Lines1/	Hybrids2/	Composites2/
GRAIN YIELD VS			
Plant height	0.631**	0.674**	0.613**
Spikes per meter	-0.668**	-0.586**	-0.604**
Kernels per spike	0.256*	0.191	0.420**
Kernel weight	0.453**	0.444**	0.425**
Coef. of determination	0.593	0.552	0.642
PLANT HEIGHT VS			
Spikes per meter	-0.689**	-0.772**	-0.778**
Kernels per spike	0.186	0.209	0.343**
Kernel weight	0.137	0.224*	-0.030
SPIKES PER METER VS			
Kernels per spike	-0.324**	-0.243*	-0.429**
Kernel weight	-0.318**	-0.254*	-0.151
KERNELS PER SPIKE VS			
Kernel weight	-0.053	0.005	-0.093

* Significant at the 5% probability level.
** Significant at the 1% probability level.
1/ N = 77
2/ N = 82

traits. Plant height showed a negative relationship with spikes per meter. Also, negative correlations were found for spikes per meter with kernels per spike, and kernel weight.

When hybrids were considered, grain yield was found to be positively associated with plant height and kernel weight, and negatively correlated with spikes per meter. Yield components and plant height explained 55% of the variation in grain yield of the hybrids. Plant height showed a negative relationship with spikes per meter, and a positive correlation with kernel weight; whereas, spikes per meter gave negative correlations with kernels per spike and kernel weight.

Within composites, grain yield was positively associated with plant height, kernels per spike and kernel weight, and negatively associated with spikes per meter. These traits accounted for 64% of the variation in grain production of the composites. Plant height showed a negative association with spikes per meter and a positive relationship with kernels per spike. The correlation of spikes per meter with kernels per spike was negative.

DISCUSSION

Taking advantage of the broad spectrum of growing conditions observed in Oregon, the yielding abilities of three groups of wheat (conventional cultivars, hybrids and composites) were tested at three locations (Hyslop, Moro and Pendleton). Results from these three sites are discussed with emphasis on grain yield.

Wheat Hybrids

With the discovery of cytoplasmic male sterility and fertility restoring genes in wheat, the feasibility of developing commercial hybrid wheat became possible. As a result, the exploitation of heterosis for increasing the yield potential in wheat has received considerable attention in the last three decades. Critical prerequisites for the successful production of commercial hybrids are: a) that sufficient heterobeltiosis can be achieved through specific parental combinations, so the hybrids can be economically competitive; b) adequate level of outcrossing occurs to ensure maximum F1 seed production, and c) that the stability of yield of hybrids across locations and years be acceptable. Unfortunately, hybrids produced using the *Triticum timopheevi*-derived restorer lines have not met these criteria. Several factors have been cited as possible reasons. These include: a) a negative influence of the *T. timopheevi* cytoplasm; b) incomplete fertility restoration; c) relatively low yield of the restorer lines; d) a negative influence of the (alien) restorer genes; e) inadequate sampling of the gene pool and assessment of combining ability, and f) a low level of heterobeltiosis in wheat.

With the recent identification of chemicals which induce male sterility in wheat, there has been a renewed interest in hybrid wheat. Chemical induced male sterility offers the following advantages: a) development of cytoplasmic male sterile and restorer lines are not required; b) parental lines may be easily increased; c) parental combinations may be quickly changed, and d) many parental combinations may be easily tested to identify maximum heterobeltiosis. However, there are same disadvantages with such a procedure. These include: a) isolation to prevent randomly outcrossing would be needed; b) adjusting timing and chemical dosage may be difficult; c) male and female parents may not flower at the desired time; d) the environment may influence the amount of outcrossing, and e) chemicals may cause negative side effects both to plants and humans. Even if a system can be developed to produce hybrid wheat, the questions as to how much heterobeltiosis is present in wheat and whether hybrids may be produced commercially on an economic basis remain to be answered.

This discussion will focus on Moro and Pendleton locations where the same entries were grown, and lodging did not complicate the interpretation of the results as it did at the Hyslop site. Since the results were obtained from plots seeded at the standard density for each locality, they give an indication of the hybrid performance under similar population levels to which wheat is currently grown for commercial production.

The commercial utility of a hybrid will be determined by its superiority with respect to its better parent (heterobeltiosis) and with respect to the best conventional cultivar available. In this research, even though several hybrids outyielded their better parent, no hybrid yielded significantly more than the best conventional cultivar at either site. When hybrids and commercial cultivars were compared, there was a tendency for the best hybrids to yield more than the best commercial cultivars available for the Oregon conditions. At Hyslop and Moro, some hybrids yielded more than the commercial cultivars Stephens, Malcolm and Hill, even though the differences were not significant. Whereas at Pendleton, these cultivars yielded significantly less than the best hybrid (Entry 23). These comparisons would indicate that in improved environments, hybrids performed relatively better than the commercial cultivar available. For instance, at Moro the best hybrid (Entry 23) yielded 9% (400 kg/ha) more than the best commercial cultivar (Hill). Whereas at Pendleton, the best environment for yield expression, the highest yielding hybrid (Entry 23) was 14% (840 kg/ha) higher in yield than Stephens, the best commercial cultivar at this location. The best hybrids came from crosses between the cultivars Stephens, Malcolm and Hill with the experimental lines OR CW8626 and OR CW8314. This would indicate that the crosses involving cultivars with a good adaptability and advanced selections with high yielding potential originated the best hybrids in this study.

The levels of heterobeltiosis for grain yield varied widely depending on the cross and site. At Moro and Pendleton, the highest heterobeltiosis values were 9.2 and 10.5%, respectively. Whereas at Hyslop, the highest value was only 2.5%. In general, hybrids from parents which differed more in pedigree showed the higher values of heterobeltiosis. This finding is in agreement with those reported by several authors (Brown et al., 1966; Nettevich, 1968; Singh and Singh, 1971; Brajcich, 1980).

Despite the fact that Moro and Pendleton were environmentally diverse locations, mainly in relation to rainfall, the combined analysis showed that the entry x location interaction was not significant. This indicated that entries responded the same for grain yield across these locations. The cultivars used were the products of a shuttle breeding approach utilized by the Oregon State University cereal breeding program and as such had been selected at various stages in their development at the three sites used in this study. This might explain the lack of any genotype x environment interaction.

Plant height can be an important agronomic trait, especially under practices of crop management favoring lodging, such as irrigation and heavy fertilizer application. Relatively high values of heterosis and heterobeltiosis for plant height were observed at the three sites, with the higher values at Pendleton and Moro for three crosses (2, 3, and 5) involving the cultivar Malcolm and one cross (7) involving the cultivar Stephens. Of the yield components, kernels per spike presented the higher heterosis values at the three locations. When comparing the different hybrids, Entry 83, a hybrid from the cross between Stephens and the experimental line OR CW8522, showed the higher values of heterosis for kernels per spike at Moro and Pendleton. The expression of heterosis for yield components, mainly for spikes per meter and kernel weight, varied markedly over locations.

Composite Cultivars

The use of genetic diversity has been proposed as a tool to increase yield stability in cereal crops. The leaf rust epidemic of wheat in the Yaqui Valley of Mexico in 1976, is an example of the risks involved when a single genotype is grown over a large area. To control this vulnerability, the use of mixtures or composites of wheat cultivars has been suggested as an alternative approach by several investigators. Composites would have the following advantages: a) they may confer more stability against environmental changes than more genetically homogeneous cultivars, such as pure lines or hybrids; b) cultivars or experimental lines from current breeding programs may be mixed to obtain composites; c) if needed, mixtures can easily be reconstituted; d) they offer the opportunity to combine a greater number of desired traits than might otherwise be available in a single cultivar, and e) the use of mixture is an inexpensive and simple strategy of management which can be integrated with other strategies for improving grain production. The following would be some disadvantages of the composite approach: a) matching the components for maturity and yield may not be an easy task; b) quality requirements for end product use may be difficult to meet with mixtures; c) the phenotypic variability of the composites may be a barrier to their acceptance by the growers, and d) some countries have patent laws and certification requirements which would be difficult to meet with composite cultivars.

In this study, the relative performance of composite cultivars varied over locations. At Hyslop, no composite outyielded the higher yielding component grown in pure stand. For Pendleton, two composites were slightly superior to their better component. However, at Moro, where the greatest moisture stress was registered, three composites outyielded, even though not significantly, their higher yielding pure stand. It is interesting to note that one composite, Entry 84, although not outyielding its higher yielding component grown in pure stand, showed good performance at the three sites. This composite included the highest yielding entry, experimental line OR CW8522, and the commercial cultivar Stephens. The results would support the general conclusions that, with some exceptions, the yields of composites were near the average of their components, and that under more environmental stress, composites did better. It is important to point out that, with the exceptions of moisture at Moro and lodging at Hyslop, no other severe stresses were registered. At Hyslop and Moro sites, hybrids were slightly superior to composites for grain yield. However, under the best conditions for yield expression (Pendleton), composites, as a group, were evidently lower in yield when compared to the average of all hybrids.

Association Among Agronomic Traits

Grain yield is a complex trait and direct selection is generally ineffective because of the quantitative nature of inheritance and the large environmental influence. Therefore, some plant breeders have been interested in using yield components with higher heritability estimates which may be positively correlated with yield. However, indirect selection for grain yield using the component approach has often failed to produce yield increases. Generally, this failure has been due to negative associations where an increase of one component results in the decrease of another.

Many associations involving the components of yield have been reported from studies conducted in greenhouses, or conducted in the field using space planted material. This has limited their scope of application to specific conditions which are different to those found in commercial production. To what extent yield components can effectively be used for improvement of grain yield is still an open question.

At Hyslop, correlation coefficients indicated a positive and strong association between grain yield and kernel weight for the three entry groups. This finding has been also reported by many other workers (Kronstad and Foote, 1964; Das, 1972; Maya de Leon, 1975; Abi-Antoun, 1977; Borojevic and Williams, 1982; Aguilar and Hunt, 1984). A negative correlation was observed between grain yield and spikes per meter for pure lines at Hyslop, and for the three groups from the combined site correlations. Which is in agreement with results reported by Gebeyehou et al. (1982). The negative relationship between grain yield and heading date agrees with results of Singh et al. (1970) and Bath (1973). The detrimental effect of lodging on grain yield was reflected by the high negative correlation found between these two traits in the three groups at Hyslop.

When the Moro and Pendleton sites are considered, grain yield was positively associated with kernel weight in all three groups. Several negative associations between the yield components were found at each location, but most correlations were not significantly different from zero.

Correlation values from the combined sites confirmed the strong and positive association between grain yield and kernel weight found for each site separately. Plant height showed a high and positive correlation with grain yield within each group. This is in agreement with results reported by Khan et al. (1972), Virk et al. (1977), Yunus and Paroda (1982) and Salmeron-Zamora (1985). The strong and negative correlation between plant height and spikes per meter observed in the three groups, has not been reported in the literature. The negative associations among all yield components, with the exception of kernels per spike and kernel weight, found in this study agrees with the findings of Kronstad and Foote, (1964), Fonseca and Patterson (1968b), Anand et al. (1972), Sidwell et al. (1976), Firat,(1978) and Yunus and Paroda (1982).

In summary, the results of the investigation support the general conclusion that hybrids and composites are not consistently superior to the best conventional cultivars of wheat. However, under more abiotic stresses, the composites appeared to perform better than conventional cultivars. While in the best environment of the study, hybrids produced slightly higher yields, on average, than pure stands; with one hybrid yielding significantly more than the commercial cultivars Stephens, Malcolm and Hill. Low to moderate values of heterosis and heterobeltiosis for grain yield were found with the degree of their expression being influenced by the specific growing site. According to the heterobeltiosis values, crosses between cultivars with a good adaptability and cultivars with a high-yielding capacity would originate the best hybrids. Correlation values indicated that a breeding program to develop hybrid wheats should try to combine high number of kernels per spike with high kernel weight. This also would be true for developing composites and conventional cultivars. The high positive correlation between grain yield and plant height would suggest that for the materials used in this study, increases in grain yield could be obtained by increasing plant height. However, limits to plant height could be imposed by lodging problems associated with increases in height. Except for the Hyslop site, no lodging was registered in this study.

It is important to point out that these results were obtained from only one year of experimentation. Therefore, more investigation would be necessary before drawing definitive conclusions about the value of hybrids and composites with respect to conventional cultivars of wheat for the Oregon conditions.

SUMMARY AND CONCLUSIONS

The objective of this investigation was to compare hybrids, composite cultivars and conventional cultivars (pure lines) of winter wheat for grain yield at three environmentally diverse sites in Oregon. A second objective was to determine the possible associations among selected agronomic traits and grain yield in each entry group when grown at the different locations. Also, the expression of heterosis and heterobeltiosis in the hybrids for the different traits was estimated. The experimental material consisted of parental lines, hybrids, and 1:1 mixtures of the parental combinations that gave origin to the hybrids.

The sites employed were the Hyslop Agronomy Farm near Corvallis, the Sherman Experimental Station at Moro, and the Rugg Farm near Pendleton. The experiments were conducted during the crop season 1985-86.

Data were collected on a plot basis for heading date, plant height, spikes per meter, kernels per spike, kernel weight, grain yield and lodging at the Hyslop site. At Moro and Pendleton sites, data were collected on a plot basis for plant height, spikes per meter, kernels per spike, kernel weight and grain yield. Analyses of variance were done on all traits studied. Mean values were compared using the least significant difference test (LSD). Entry effects in the analysis of variance were further divided to detect differences among and within entries, hybrids and composites. Each location was analyzed separately and then the data for the sites were combined and analyzed to detect possible cultivar by location interactions. Two null hypotheses involving grain yield comparisons between entry groups at each location were tested with the LSD test.

The following conclusions were reached based on the results of this investigation:

1. At the three sites, the best hybrids were not superior to the best pure stands of conventional cultivars. However, in the best environment for grain yield (Pendleton), the hybrids, as a group, showed a tendency to yield more than the parental lines grown in pure stands.
2. At all locations, the best hybrid outyielded the commercial cultivars Stephens, Malcolm and Hill. However, only at Pendleton were the differences significant.
3. At the three locations, the hybrids, as a group, yielded more than the composites, but no hybrid outyielded significantly the best composite at any location.
4. As a group, the composites yielded lower than the components grown in pure stands at Hyslop and Pendleton. However, at the more stressful environment (Moro), the composites showed a tendency to yield more than the components grown in pure stands.
5. At both Moro and Pendleton, some composites outyielded the commercial cultivars Stephens, Malcolm and Hill, but the differences were not significant, with the exception of one composite entry at Pendleton.
6. When grain yield data from different locations were combined, genotype by location interactions were not significant.

7. Grain yield and plant height showed the highest values of heterosis and heterobeltiosis. Within yield components, number of kernels per spike gave the highest heterosis and heterobeltiosis values.
8. A consistent and positive association between grain yield and kernel weight was found at the three locations for all entry groups. Other associations among grain yield and yield components and among yield components varied depending on location and entry group.
9. When the data from the three sites were combined, grain yield was positively correlated with plant height, kernels per spike and kernel weight, and negatively associated with spikes per meter. Also, there were negative associations between spikes per meter and kernels per spike and kernel weight. No association was observed between kernels per spike and kernel weight.

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APPENDIX

Appendix Table 1. Pedigree of commercial cultivars and experimental lines of winter wheat included in the study.

Entry	Identification	Pedigree
1	Stephens	Nord Desprez/Pullman Selection 101
2	Malcolm	Stephens//63-189-7/Bezostaya 1
3	Hill	Yamhill/Hyslop
4	OR CW8314	7C/Cno//Cal/3/Ymh
5	OR CW8522	Rmn F3-71/Torim
6	OR CW8626	Cer/Ymh/Hys
7	OWW77385	6720-11//Mda38/Wrm
8	OR CW8421	Tjb 841/1543//Ymh/63-122-66-2
9	Nugaines	Norin 10-Brevor//Orfed/Brevor sib/3/Burt

Appendix Table 2. Description of commercial cultivars of winter wheat included in the study.

STEPHENS

An awned, semidwarf, soft white winter wheat released by Oregon State University. Stephens is mid to late in maturity, moderate to high tillering, and moderate in head fertility. Its kernels are large in size. It is widely adapted to the Pacific Northwest.

MALCOLM

Malcolm was released in 1985 by Oregon State University. It is a semidwarf soft white winter wheat with stiff white straw. Its spikes are awned, oblong, mid-dense and nodding. Glumes are of medium size with a shallow crease. Malcolm is better in leaf rust resistance than available commercial cultivars and possesses higher resistance to powdery mildew as compare to Stephens.

HILL

A soft white winter wheat cultivar released by Oregon State University in 1981. This semi-dwarf, awned cultivar has high yield potential, good test weight, good winter hardiness, intermediate maturity, and strong straw. It has moderate resistance to stripe rust and leaf rust and moderate susceptibility to both powdery mildew and leaf blotch; however, yield reductions from these two diseases are not severe because of the greater height and later heading and maturity date of this cultivar. Hill is widely adapted to the winter wheat growing areas of the Pacific Northwest.

NUGAINES

This soft white winter wheat cultivar was released by Washington State University. Nugaines is awned, semi-dwarf, and low in protein content. It has moderate to high tillering capacity and moderate to low head fertility and seed weight.

Appendix Table 3. Summary of climatic data at Hyslop, Moro and Pendleton for the crop year 1985-86.

	Location								
	Hyslop			Moro			Pendleton		
	Temp.(C)		Prec.	Temp.(C)		Prec.	Temp.(C)		Prec.
Month	Max.	Min.	(mm)	Max.	Min.	(mm)	Max.	Min.	(cm)
September	22.0	7.6	19.8	19.0	5.2	28.2	20.8	4.3	39.1
October	17.6	4.7	98.8	14.7	2.3	29.0	16.8	1.5	34.0
November	7.1	-0.2	119.1	0.8	-7.3	30.2	1.8	-8.6	67.6
December	4.5	-3.6	94.5	-4.3	-10.7	28.4	-3.6	-10.7	32.3
January	9.7	2.1	165.9	3.7	3.0	46.7	6.0	-2.4	60.5
February	10.0	3.0	251.5	5.8	-1.4	60.7	7.7	-0.5	77.2
March	15.6	5.3	77.2	12.7	2.6	24.9	14.7	3.2	49.3
April	15.1	4.1	46.7	13.2	1.7	8.6	15.9	1.7	21.1
May	18.7	6.9	63.5	19.3	7.1	8.9	20.8	6.0	47.5
June	25.2	10.6	7.9	26.4	10.9	1.5	29.7	9.9	2.3
July	24.6	10.0	29.2	24.1	10.5	13.7	28.2	9.6	15.5
August	30.6	11.3	0.0	30.7	13.9	1.8	33.9	11.4	4.8
Total	----	----	974.1	----	----	282.6	----	----	451.2

Appendix Table 4. Means (kg/ha) for grain yield of the wheat entries used at the three locations involved in the study.

Entries	Hyslop	Moro	Pendleton
1	5594	4441	6089
2	6083	4157	5963
3	5562	4551	5926
4	6409	4157	6332
5	6151	4900	7369
6	----	4912	6720
7	----	4106	6443
8	5066	----	----
9	3918	----	----
13	----	4538	6045
14	----	4348	5678
23	----	4951	6929
24	----	4798	6397
33	----	4465	6614
34	----	4445	6105
43	6251	4389	6800
44	5923	4322	6412
53	6232	4542	6591
54	5597	4478	5957
63	----	4348	6517
64	----	4137	6342
73	5786	4846	6732
74	5588	4566	6451
83	5312	4518	6528
84	5709	4740	7031
93	5115	----	----
94	4189	----	----
103	4822	----	----
104	4838	----	----
<u>Average</u>			
Pure Lines	5540	4462	6406
Hybrids	5586	4574	6594
Composites	5308	4480	6297
Overall	5482	4506	6434