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Title: COMPETITIVE EFFECT FOR GRAIN YIELD OF FOUR CULTIVARS IN PURE AND MIXED POPULATIONS IN WHEAT (*Triticum aestivum* Vill., Host)

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Warren E. Kronstad

Concerns regarding maintaining wheat yield per hectare and extending the commercial life expectancy of cultivars grown in the Yaqui Valley of Mexico prompted this investigation. Four genetically diverse spring wheat cultivars were grown in pure stands and in all possible combinations at the Northwest Agricultural Research Center at Ciudad Obregon from 1975 through 1978. The composite populations included: 1) a base population with equal amounts of seed of each cultivar representing the various combinations which was reconstituted and grown each year, 2) a first derived population which was a random sample obtained at harvest from the previously grown base population and grown in 1976-77 and 1977-78 and 3) a second derived population composed of a random sample of seed obtained from the first derived population and grown in 1977-78.

The base, first and second derived populations were also grown simultaneously during the third year of the study so that a direct measure of the competitive ability of the cultivars within the composite could be obtained. Data collected from both the pure stands and composite treatments included: 1) grain yield, 2) number of spikes per unit area, 3) number of spikelets per spike, 4) number of kernels per spike, 5) 100 kernel weight and 6) plant height. Date of flowering was

obtained for the 1977-78 growing season only.

General and specific competitive ability of each cultivar in the composite combinations were determined for the treatments within and across years. Also, simple phenotypic correlations and path-coefficient analyses were employed to determine the relative importance of the components of yield to the competitiveness of a cultivar when grown in a composite.

It was observed in this study that those cultivars with the highest grain yield when grown in pure stands were the most competitive in the composites. There were some cultivar x year interactions for the pure stands; however, the same cultivars either ranked first or second for all three years. One cultivar was consistently the lowest each year. In 1976-77, six of the composite treatments exceeded the highest yielding pure stand treatment. This year coincided with the most adverse growing conditions including a leaf rust infection. Jupateco, a cultivar selected for its leaf rust resistance when the study was initiated, was overcome by the pathogen during the second year of this study and a valid comparison as to the selective pressure of this disease was lost as a consequence.

Spikes per unit area and kernel number were the most important components of yield both in contributing to high yield and stability of yield. They were also the most important components of yield in contributing to the selective advantage of certain cultivars in the composites. When generating composites, it is important to select varieties which complement one another in terms of their components of yield.

Results from this study strongly suggest that to achieve yield stability through the use of composites, a mixture of cultivars should be made each year as the genetic shift among cultivars within the composites is so rapid that the desired genetic diversity would be lost after the first harvest.

Competitive Effect for Grain Yield of Four Cultivars in Pure and Mixed Populations in Wheat (*Triticum aestivum* Vill., Host)

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Jose Antonio Valencia-Villarreal

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Professor of Agronomy, in charge of major

Redacted for Privacy

Head of Crop Science Department

Redacted for Privacy

Dean of Graduate School

Date thesis is presented December 10, 1979

Typed by Kathie Klahn for Jose Antonio Valencia-Villarreal

DEDICATED TO

My parents, Manuel and Rita

My wife, Lulu

My children, Manuel and Sandy I.

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INTRODUCTION

Historically, the production of wheat in Mexico has been confined to the Northwest part of the country in the states of Sonora, Sinaloa and Baja California. This region produces 75 to 80% of the wheat produced in Mexico. The same type of cultural practices and the growing of a single common cultivar characterized wheat production in these areas. Due to adverse environmental conditions, including disease epidemics, the life expectancy of a new cultivar is less than three years. As a result, plant breeders in the region must maintain a very active breeding program to ensure that new varieties are available at frequent intervals if high yields and stability of yield is to be achieved. Concerns have been expressed that yield levels have reached a plateau and alternate methods of wheat production need to be investigated. It would also be desireable if greater genetic diversity could be developed within the cultivars thus extending their life expectancy.

Two approaches which have been suggested are the use of multilines or the blending of different cultivars to form composites. The development of multilines has the disadvantage of requiring a costly breeding program to develop near isogenic lines and the genetic diversity is usually restricted to just source of disease resistance. With composites, existing adapted cultivars can be blended without involving an elaborate breeding program. Unlike the multiline approach, the composites are not phenotypically similar. However, if higher yields and greater stability of yield could be forthcoming, the growers would overlook the lack of uniformity.

The objectives of this study were to evaluate the use of composites in the Yaqui Valley in terms of: 1) their yield potential, 2) genetic shifts within the composites over years, 3) specific and general competitiveness of individual cultivars making up the composites and 4) yield components and their relative contribution to the selective advantage of certain cultivars within the composites.

LITERATURE REVIEW

Concerns regarding lack of yield stability due to various environmental stresses including changes in disease complexes have led plant breeders to seek other alternatives to prolong the life expectancy of cultivars. This is especially true for breeders of self-pollinating species where the resulting cultivars represent near pure lines. Such cultivars frequently lack sufficient genetic diversity to adjust to changes in the environment. One approach has been to evaluate the use of composite varieties.

Properties of Composite Varieties

In the literature, a mixture of varieties is often called a composite. Varieties so defined are blends of seed from genotypically different lines which may or may not be phenotypically similar in their characteristics (Scott and Bainbridge, 1978). Borlaug (1959) suggested the formation of composite lines by blending near isogenic lines. Such isogenic lines are obtained by a series of backcrosses to recover a common phenotype across lines which are heterogeneous for disease resistant genes. This mixture of isogenic lines is frequently called a multiline.

Composites or mixtures of varieties have the advantages of: 1) greater stability in yield over different environments, 2) greater yield through more efficient use of environmental factors and 3) lower incidence of diseases (Clay and Allard, 1969).

Some of the characteristics of composite varieties include: 1) The proportion of the lines in the composite is known and it is possible to reconstitute or modify the relative proportion of the component lines in the composite variety. 2) It is less expensive than breeding new varieties. 3) Seed certification is difficult with a composite variety due to the heterogeneity of plant type. 4) A composite variety has individual and populational buffering due to different genotypes. 5) A composite variety has specific and general adaptation (Indelen, 1975; Allard and Bradshaw, 1964; Marshal and Brown, 1962; Simmonds, 1962).

Performance and yield stability in composite populations

The use of varietal mixtures of species is as old as farming itself. When in the nineteenth century pure line varieties replaced mixed crops or land varieties, rational blending of individual lines became possible (Frankel, 1950).

Due to extensive work reported in the literature concerning composite varieties, this review will be confined to the self-pollinating small grains: barley, oats and wheat. The investigations cited will be presented with respect to historical development of the concept of the use of composites.

BARLEY

A classical work on the effects of natural selection on the fate of varietal components of a mixture was the study with barley by Harlan and Martini (1938). They determined the nature of natural selection in a composite consisting of 11 easily recognized varieties of barley. The composites were tested at ten different locations for a period of four to twelve years. Some varieties making up the composite were known to be well-adapted to specific locations while others were known to be poorly adapted. Initially, seed of the eleven varieties was mixed in equal amounts. A total of 500 plants from each year's planting were sampled to determine the relative proportion of each line still remaining in the composite. They found that at all locations there was a rapid elimination of the less-adapted types. At most locations the variety that would eventually dominate the composite was quickly evident. The leading variety varied with the location. A variety dominant at one location in some cases was eliminated at another location. The proportion of some varieties in the composite increased during the first few years and then decreased. The results of this study would suggest that the success of a variety in a composite could then be used as a measure of yielding ability and adaptation under commercial conditions when grown in pure stand.

However, other investigators have noted that the relative yield of a variety is not necessarily a criterion of its ability to survive in competition with other varieties when grown in mixtures at the same location. Suneson and Wiebe (1942) studied the survival of four commercial barley varieties in mixtures for nine years. Equal numbers of seed of all varieties were mixed together for the initial seeding. The mixture and pure stands were grown annually at seeding rates varying from 61.7 to 89.7 kg/ha. The seed for planting the mixtures was always taken from the previous year's mixed composite plots. The proportion of the varieties making up the resulting population was determined in spaced plantings of seed harvested from the previous season. After eight years, the percentages of the varieties in the mixture were 63.2% (Atlas), 17.3% (Club Mariout), 8.3% (Hero), and 11.3% (Vaughn). The mean yield of the pure stands for the same period was 4.9, 4.7, 4.7 and 5.3 tons/ha, respectively, for each cultivar. The high-yielding and rather widely adpated variety, Vaughn, was a poor competitor in the mixtures. In this study, the yielding ability of a cultivar when grown in a pure stand was not a valid means of predicting its performance in a composite. Suneson (1949) later extended the experiment for a total of 16 years. Two of the component varieties were nearly lost after ten years. The variety which ultimately dominated in the mixture had the poorest leaf disease record and its yield was below the mean of the component varieties used in this study.

The complementarity of barley genotypes in mixtures was studied by Gustafsson (1953). Three closely related barley varieties, Golden, Maja and Bones were tested in mixtures and in pure stands for two years. An equal amount of seed from each variety was used to establish the composite. The mixtures were superior but not significantly different for spike number, kernel number, kernel weight and total kernel weight. The mixture of Maja and Golden was 1.7 percent higher yielding than Maja, the superior component. Similarly, the mixture of Maja and Bonus surpassed the top component, Bonus for grain yield by 2.4 percent. The third mixture, Golden and Bonus, was intermediate in respect to its components for grain yield. He concluded that the two varieties which had similar yields were better in mixtures than varieties which differed greatly in yield potential. His conclusions supported the concept that a superior cereal composite should include several genotypes selected so as to complement one another in the mixture.

The yield of four equally blended cultivars of barley was studied in Denmark by Sandfaer (1954). Six different combinations for the four cultivars were tested. Five combinations exceeded the mean yield of the pure components by four percent. Only one of the combinations yielded more than the highest yielding component when grown in a pure stand.

In 1956, Suneson presented his evolutionary plant breeding method in barley which involved the hybridization and bulking of the resulting

F_1 progenies. Natural selection is the main factor of this method. Four composite crosses (II, V, XII and XIV) were studied extensively. Composite cross II involved 28 diverse varieties completely intercrossed, giving 378 separate F_1 combinations which were blended. Composite cross V resulted from combining 31 varieties in a succession of expanded crosses to give a complete recombination. Composite cross XII combined 26 varieties by a succession of pairings and crossing the F_1 plants with the F_1 of Atlas X Voughn. The last composite included in the study was cross XIV which combined nine varieties. This composite contained a male sterile gene which allowed for further gene recombinations through natural crossing. Each group of the composite populations was compared with Atlas 46. A parent in each of the four composite crosses was also Atlas 46. Composite crosses II, V, VII and XIV were grown for 29, 15, 14 and 12 generations, respectively. No selection other than natural selection was applied to the population in any of the generations. After fifteen generations, yield of the composites exceeded the yield of Atlas 46. During this period, Atlas 46 had been more variable in yield than the composite cross II. The yield of the other three composite bulk populations was inferior to Atlas 46 in early generations. In later generations, a marked yield improvement of the composites over their early generation performance was noted. The yield of composites in later generations was apprximately equal to that of Atlas 46. This increase in yield was the result of natural selection.

Using two of the same composite crosses, II and V, and the 28 parents, Bal et al (1959) determined the genetic shift of 19 characters as compared to the manner in which the same characters were expressed by their parents. The contribution of the 28 parents to the massselected F_{30} generation was estimated. All parents contributed, but disproportionately depending on the characters involved. Even though the two-row and smooth awn types were substantially reduced, the populations remained extremely diverse. In these populations the effects of natural selection resulted in a pronounced genetic shift for some of the characters.

Yield and stability of yield were studied in two sets of barley populations by Rassmusson (1968). Each set consisted of three distinct levels of genetic diversity: homogenous varieties, simple mechanical mixture, and complex mixtures (bulk hybrids). Both sets were grown at two locations for five years. As a group, the simple mixture was slightly higher yielding than varieties or complex mixtures. In general, he found that the mean of component lines and the mean of parental varieties provided a good estimate of the yields of the simple and complex mixtures, respectively. Varieties and simple mixtures were similar in stability and both were less stable than complex mixtures.

The components for yield and yield stability of 23 mixtures were studied in barley (Clay and Allard, 1969). These mixtures were grown at five locations over two years. The mixtures had a small advantage in yield over the average of the varieties when grown in pure stands, but were inferior to their component varieties for stability of yield when specific mixtures were considered. They concluded from this study that simple varietal mixtures have limited commercial possibilities.

OATS

Early in 1912, Montgomery studied the competitive ability of two oat cultivars over two years. The two cultivars were planted at different sowing rates in pure stand and as a composite. The mean yield of

Garton 70 was higher than the Swedish oat in pure stand for the two years, but the Swedish oat performed much better than Garton 70 in a composite. He concluded that the best yielding pure stand will not always be the one that survives under competition. He also stated that, for some reason, in almost every case when two cultivars are in competition, they produce a greater number of plants per unit area and a greater yield than when either cultivar was sown alone.

Changes in the proportions of the components in oat and barley mixtures were studied by Klages (1936). The mixtures were made up of two commercial varieties: Reward oats and Odessea barley. These mixtures were planted in triplicate rows at the seeding rate of 11 grams of seed per row. In the mixture, barley yielded more than the oat cultivar. The author suggested that this might be due to the differences in growth habits of these two cultivars.

Jensen (1952) studied the general and specific yield superiority of oat composites. In his paper, general yield superiority was defined as the mean yield of composites over the mean yield performance of component lines; whereas, specific composite superiority implied higher yields than the mean yield of the individual component lines and other commerical cultivars. To determine general yield superiority of composites, 124 composite combinations were utilized. For the determination of specific yield superiority, 12 oat cultivars and one composite were used. The composite consisted of five lines having dissimilar characteristics. Both experiments were continued for eight years. General yield superiority of the composite was 3.2 percent. Specific yield superiority of the composite was 7.3 percent. The composite yielded more than the mean yield of its component lines grown in pure stand and seven commercial oat cultivars. The conclusion was that higher yields could be obtained from mixtures grown in nonstress environments if the composites were properly chosen.

The relative productivity of homogeneous and heterogeneous oat cultivars was studied in optimum and suboptimum environments (Frey and Maldonado, 1967). They tested the yield of six oat cultivars and 57 possible mixtures among the lines when sown at two dates for three years. They found that the relative mean yield of all mixtures was 100 percent for the first sowing date and 104 percent for the second. The advantage of heterogeneous oat populations increased as the environment became more stressed. They indicated that the mixtures of cultivars gave a more stable production when tested across sowing dates than did cultivars alone. No association was found between the number of cultivars in a mixture and the grain yields of the mixtures. Also, several mixtures yielded more than the best cultivars grown in pure stands when averaged across both planting dates and years.

The performance and the yielding ability of two oat cultivars in mixtures were studied by Qualset and Granger (1970). Blount and Forkedeer were studied in pure stand and mixtures with 25, 50 and 75 percent of each cultivar in ten environments at four locations for three years. The mixtures were more stable than either Blount or Forkedeer alone. They found that mixtures became more stable as the frequency of Blount increased in the population.

Shorter and Frey (1979) reported the yield of mixtures and monocultures of oat genotypes. They compared grain yields of three sets of mixtures of eight cultivars and 20 random F_9 derived lines from bulk populations at two locations for two years. The first set represented

378 possible equal mixtures among the eight oat cultivars and 20 F_9 lines. Ten F_9 lines and 105 possible 25:75 percent mixtures among the lines and four oat cultivars were included in the second set. The third set included 105 possible 75:25 percent mixtures among four oat cultivars and ten F_9 lines. Only 15 of the equal mixtures were superior for grain yield to their higher yielding component. Seven mixtures were higher yielding for the 25:75 and 75:25 percent mixtures. Cultivar mixtures exceeded their component means by seven percent for yield; whereas random line mixtures were superior to their component means by 13 percent. Highest yielding mixtures were not superior to the highest yielding individual component. From this study, they concluded that the use of mixtures of oat cultivars or lines to obtain a yield advantage over pure cultivars would not be justified.

WHEAT

One of the first investigations of composites in wheat was reported by Montgomery in 1912. He examined winter wheat in pure and mixed stands for five years. An equal number of seeds was planted from Big Frame and Turkey Red varieties in pure stand and in a composite. Big Frame was higher yielding when sown alone than when grown in competition with Turkey Red. When sown alone, Turkey Red yielded more than Big Frame by 18 percent, but in the mixtures Turkey Red yielded approximately twice as much as Big Frame.

Nuding (1936) reported on the performance of six composite combinations of four wheat cultivars. The varieties included exhibited large morphological differences. Each combination had an equal among of seed of two of the wheat cultivars. The experiments were conducted for three years in seven locations which had widely different environmental conditions. The results showed a tendency for composites to exceed the mean yields of their component varieties particularly in the composites of those varieties which were better adapted to the environmental conditions at all locations. It was claimed that mixing suitable varieties reduced the risk of crop failure especially under unfavorable circumstances. The grain produced in the composites was used for sowing the same composite in the succeeding season; consequently, changes in the make-up of the composite could be followed from year to year. These changes were very marked when one of the component varieties had more adaptability than the other cultivars.

Analytical study of the components of varietal composites was made by Frankel (1939). For this study plants of pure varieties and of the same varieties grown in composites of varying proportions were submitted to an analysis of their yield characters. The components evaluated were: yield per plant, number of heads per plant, yield per spike, number of grains per spike and weight of 1000 grains. Two F_7 derived lines from the cross, Tuscan X White Fife, eight F_6 derived lines from the cross, (Tuscan X Marquis) X Tuscan, one F_6 derived line from the cross, (Tuscan X Reward) X Tuscan and the cultivar Tuscan were used for this study. Of the eleven lines which were composited with Tuscan, nine composites yielded the same as the expectation calculated from the components, and two composites yielded more than the expectation. However, the increases were not statistically significant.

Laude and Swanson (1942) examined the effect of natural selection on varietal composites of winter wheat. Two different mixtures were developed which included Kanred and Harvest Queen, and Kanred and Currel. Equal proportions of seed were used for each variety in the composites.

These were tested at two locations for seven and nine years, respectively. The rate of change was so rapid in each case as to shift the varietal ratios from equal proportions of the two paired varieties to nearly pure stands of Kanred in less than nine years.

A comparison of grain yield of four varieties of hard red winter wheat when grown in pure stands and in mixtures was studied by Schlehuber (1961). These experiments were conducted at two locations between 1952 and 1958. Composites were made from an equal number of seeds of each variety. A significant varietal shift in the composite was observed at the end of the study at each location. Some varieties were superior in pure stands, but they did not dominate their respective composites.

Suneson and Ramage (1962) investigated the competition between near isogenic lines of wheat. Awned and awnless Onas wheat developed from backcrosses were mixed in a two to one ratio and grown for seven years. No significant population shift resulted, even though the initial mixture was dominated by the isogenic line with the longer seed.

The intergenotypic competition and population structure in wheat was reported by Allard and Adams (1969). They found that plants of the wheat variety, Ramona, planted in hills produced about six percent higher yield when surrounded by plants of the variety Baart 46 than when surrounded by their own genotypes. The yield of Baart 46 was similarly enhanced when surrounded by Ramona. Chapman, Allard and Adams (1969) examined the effect of planting rate and genotypic frequency on yield and seed size in mixtures of the same varieties. They found a significant positive interaction for yield between the mixtures of the two varieties when they were grown at high but not low population densities. Their results suggested that intergenotypic interactions measured in hill planting provide a basis for predicting the yield of mixed populations.

Khalifa and Qualset (1974) examined the intergenotypic competition between tall and dwarf wheats in mechanical mixtures. An equal amount of seed of each variety was mixed and seeded without reconstruction for three years. The frequency of the short variety over time decreased with a decrease in the population yield level. Population yields were predictable on the basis of pure stand performance, but the contribution of the short variety to the total yield was significantly below expectation. Complementarity was indicated because the tall variety showed a corresponding increase in yield over expectations from pure-stand performance. The poor competitive ability of the short variety was expressed as a large decrease in number of kernels per spike and possibly decreased spike number, while kernel weight was not affected.

Performance of five winter wheat cultivars was studied in pure stand and in composite by Indelen (1975). Hyslop, Yamhill, Paha, Luke and Sprague were blended in all possible combinations. They were sown at three locations differing in rainfall, length of growing season and soil type. Based on one year's data, a pure stand was significantly better than all composite treatments at the highest yielding site. However, composites showed significantly better performance when they were grown under stress conditions. He concluded that the composites also reduced the amount of leaf rust thus providing a partial disease escape mechanism.

From the literature, it would appear that under certain circumstances the greater genetic diversity achieved with composite varieties may have certain advantages over growing a single variety. Where biological stresses are present such as disease or moisture or large year to year changes in the climates, heterogeneous populations seem to have more yield stability than homogeneous populations; however, there still remain many conflicting reports regarding the advantages and disadvantages of the use of composites and especially what criteria should be used in developing the most productive composite combinations in terms of yield and yield stability.

MATERIALS AND METHODS

The experimental populations consisted of diverse genotypes representing four wheat cultivars: 'Jupateco 73' (J), 'Siete Cerros' (7C), 'Nuri 70' (N) and 'Lerma Rojo 64' (LR). These cultivars are adapted to the growing regions of the Yaqui Valley in Mexico. They differ in many agronomic traits, especially in the components of grain yield. Descriptions and pedigrees for the four cultivars are provided in Appendix Table 1. The respective reaction of the four cultivars to leaf rust (*Puccinia recondita* f. sp. *tritici*) for each year of the study is noted in Appendix Table 2.

The experiments were conducted over a three year period at the Northwest Agricultural Research Center (CIANO), located near Ciudad Obregon in the northwest part of Mexico. Northwest Agricultural Research Center is located at 27°N latitude at an elevation of 39 m above sea level.

Rainfall during the winter seasons of 1975-76, 1976-77 and 1977-78 was: 6.9, 84.9 and 7.3 cm, respectively. The soil type is a brown clay loam developed as a coastal plain outwash under desert conditions. A summary of climatic data for the three winter seasons is presented in Appendix Table 3.

Prior to seeding, 150 kg/ha of nitrogen and 80 kg/ha of phosphorus as P_2O_5 were applied each year. The plots were irrigated five times during the growing season to avoid any possible water stress. Treatments consisted of four genotypes and all possible mechanical combinations. The four genotypes can be readily identified phenotypically before and at maturity. A germination test of the four genotypes was conducted the first year and ranged between 95-100 percent.

Table 1. The four genotypes and eleven composite treatments utilized in the experiment.

Components of Treatments	
Jupateco	(J)
Siete Cerros	(7C)
Nuri	(N)
Lerma Rojo	(LR)
J-7C	
J-N	
J-LR	
7C-N	
7C-LR	
N-LR	
J-7C-N	
J-7C-LR	
J-N-LR	
7C-N-LR	
J-7C-N-LR	

Base, first and second derived populations were generated for this study. The three populations are described as follows:

BASE POPULATION: The base population consisted of all possible mechanical combinations of the four cultivars as noted in Table 1. This population was grown in the 1975-76, 1976-77 and 1977-78 winter cropping seasons at CIANO. Experiments were seeded on December 17, 10 and 15 in 1975, 1976 and 1977, respectively. In 1975-76, the experimental plot consisted of five rows spaced 30 cm apart. Each row was five meters in length. Only three rows spaced 30 cm apart were used in 1976-77 and 1977-78. Row length was also reduced to two meters. Grain yield and other agronomic data for 1975-76 and 1976-77 was obtained by harvesting one meter from the center row. In 1977-78 six samples of 50 cm were taken from two rows. Grain yield and data for other agronomic traits were transformed to a uniform size of .9 square meters for all experiments and for all years in order to be able to make the statistical comparisons among treatments.

FIRST DERIVED POPULATION: The first derived population consisted of the same number of treatments as the base population. Each treatment was generated from the harvested seed contributed by the cultivars in the mixture of the base population in 1975-76 and 1976-77. This population was sown during the 1976-77 and 1977-78 seasons at CIANO. The experimental unit and means of collecting data were the same as described for the base population.

SECOND DERIVED POPULATION: The second derived population consisted of the same number of treatments as the base and first derived populations. Each treatment for this population was generated from the harvested seed contributed by cultivars of the first derived population in 1976-77.

This population was seeded in 1977-78 at CIANO. The experimental unit and daya collected were the same as noted for the base and first derived populations.

The three populations (base, first and second derived populations) were grown in 1977-78 at CIANO. The following measurements were made for each treatment in 1975-76 for the base population and in 1976-77 for both the base and first derived populations:

1. Grain yield per meter squared for each variety grown in a pure stand or in the composite was recorded in grams. Total grain yield for a composite was computed by summing the grain yield of each component variety.

2. Number of spikes per meter squared was determined for both the pure stands as well as for each component within composite. The total number of spikes for a composite was obtained by summing the individual values for each component variety.

3. Number of spikelets per spike was determined for each variety grown in a pure stand as well as within the composite. This number was calculated by averaging the number of spikelets per spike for the total number of spikes in the harvested area. Number of spikelets per spike for the composites was obtained by taking the average number of spikelets per spike of each component variety.

4. Number of kernels per spike was determined for each variety when grown as a pure stand as well as within the composite. This number was obtained by taking the average kernel number from 20 spikes. Kernel number per spike for the composite was calculated by taking the average kernel number per spike of each component variety.

5. One hundred kernel weight (gm) was computed for each variety in the pure stand and within the composite. One hundred seeds were weighed to compute this value. The one hundred kernel weight for a composite was calculated by taking the average of the one hundred kernel weight of each component variety.

6. Plant height (cm) measurements were made for each variety in the pure stand as well as within the composite. Plant height for a composite was calculated by taking the average plant height of the individual component varieties.

7. Heading date was noted when 50% of the plants were headed for each variety in the pure stand as well as within the composite. Heading date for a composite was computed by taking the average heading date of each component variety.

8. Percentage of leaf infected and disease reaction types were read for leaf rust. Notes were taken on March 5 and 21 in 1976 and 1977, respectively.

The same data were collected in 1977-78 for each variety in the pure stand as well as within the composite; however, the measurements were taken from six samples of 50 cm from the two center rows with the following modifications:

1. Grain yield was recorded for each of the six samples and the sum for each variety of the composite was computed for total grain yield. Total grain yield for each composite was computed by summing the total yield of the six samples for each component variety.

2. Number of spikes were counted in each of the six samples for the varieties in pure stand and as a component of the composite. The sum of the six samples was computed for spike number of each variety.

Total number of spikes for each composite was obtained by summing the total number of spikes of the six samples from each component variety.

3. Number of spikelets per spike was computed in each of the six samples for each variety in the pure stand as well as within the composite. This number was computed by taking the average of the number of spikelets per spike for the total number of spikes harvested in each of the six samples. Total number of spikelets per spike of a composite was obtained by taking the average of number of spikelets per spike from six samples of each component variety.

4. Total kernel number was determined in each of the six samples for each variety in the pure stand and as a member of the composite. Ther kernel number per spike was computed for each variety. This number is the average of the kernel number for the total number of spikes harvested. Kernel number per spike of a composite was obtained by taking the average kernel number from six samples of each component variety.

5. One hundred kernel weight (gm) was computed for each variety both in the pure stand and as a member of the composite. This kernel weight was determined by the following proportion:

$$\text{100 kernel weight} = \frac{100 \text{ X } TW}{TKN}$$

Where TW is the total weight (gm) for each variety and TKN is the total kernel number harvested in each sample for each variety.

One hundred kernel weight of a composite was determined by taking the average 100 kernel weight for each component variety within the composite.

The experimental design for the base, first and second derived populations was a randomized block design with four blocks and fifteen treatments in 1975-76 and 1976-77.

A strip plot experimental design with four blocks was used for the base, first and second derived populations grown in 1977-78. Populations were the main plot. Each population was randomized within a block. The sub-plot contained the four varieties and the eleven composites. Each of the varieties and composites were randomized within each population.

A combined analysis of variance was used to determine the interaction of the base population across years. The same analysis of variance was used to determine the possible interaction of the three populations across years.

The F test was used to determine if significant differences existed among treatments. Duncan's multiple-range test was used to determine significant differences among composites and pure stands. The Least Significant Difference test was used to determine significant differences among component cultivars in a composite.

The competition of each cultivar within each composite plot was determined by analyzing each treatment separately for six agronomic traits. This analysis was made in the base, first and second derived populations across years and within the same year. This provided a measure of specific competitive ability of each cultivar. The total yield contribution of each component cultivar across the eleven composites provide a measure of the general competitive ability for each cultivar.

Two approaches were utilized to analyze the relationships between grain yield and the yield components. First, phenotypic correlation coefficients were calculated for every possible combination between grain yield per plot, number of spikes per unit area, number of spikelets per spike, number of kernels per spike and 100 kernel weight. The phenotypic correlation coefficients were calculated from 24 samples across replications in each composite cultivar. Phenotypic correlation coefficients between the dependent and each independent variable were then separated into direct and indirect effects by the path-coefficient analysis (Dewey and Lu, 1959) for the four cultivars when grown in pure stands and for the composite treatments.

EXPERIMENTAL RESULTS

Analysis of the base populations across years.

The observed mean squares from the combined analyses of variance for the base populations, treatments and their interaction for the six traits measured across years are provided in Table 2. Significant differences for all traits except grain yield and 100 kernel weight can be noted for the base populations, treatments and for the interaction between the base populations and treatments. The coefficients of variation range from 14.9% for grain yield to 6.7% for 100 kernel weight and plant height. The observed mean square values for the base populations grown in 1975-76, 1976-77 and 1977-78 from individual analysis of variance for the six traits studied are found in Appendix Table 4. The individual analysis for the base population for each year showed highly significant differences between treatments for the six traits, except for 100 kernel weight and in 1977-78 for plant height.

In Tables 3-8 mean values are presented for the base populations, three year averages and the results for individual years for each of the treatments involving the six traits.

For grain yield (Table 3), 7C had the highest three year average (529.3 g) however, it was not significantly different from the other treatments. When individual years are considered, J was the highest yielding in 1975-76 (660.2 g), 7C-LR in 1976-77 (457.9 g) and 7C in 1977-78 (558.9 g). For the three year period, the average of the four pure stands was 487.5 g in contrast to 468.7 g for the 11 composite treatments. In 1976-77, the average of the composites (401.4 g) was higher than the average of the pure stands with nine of the composite populations exceeding the average of the pure stands. The composite,

Table 2. Observed mean square values for the base populations, treatments and their interaction for six agronomic traits across years.

Source of Variation	df	Grain Yield	Number of Spikes	Number of spikelets per spike	Number of kernels per spike	100 Kernel Weight	Plant Height
Base Populations (BP)	2	324792.00**	21064.70**	23.84**	3435.11**	6.89**	1620.34**
Treatments (TMTS)	14	7691.51	6434.83**	6.07**	233.86**	0.11	135.13**
BP X TMTS[1]	28	8471.95**	1549.18**	1.70**	23.95**	0.74**	21.66**
Block (in years)	9	4252.45	699.34	0.7966	25.25	0.0755	7.4722
Block X TMTS (in years)[2]	126	2120.92	680.38	0.48	7.02	0.0567	6.09
C.V.		14.9	12.8	7.5	10.9	6.7	6.7

*Significant at 5% level of probablity
**Significant at 1% level of probablity
1/Error term for base populations (years) and treatments.
2/Error term for year x treatment interaction.

Table 3.

Mean values for grain yield in grams for the 15 treatments for the base population grown in 1975-76, 1976-77 and 1977-78; three year treatment average and the overall yearly means.

Treatments	Three Year Average	Base Population 1975-76	1976-77	1977-78
J	497.3	660.2 a[1/]	358.7 de	473.0 b-d
7C	529.3	594.3 a-c	434.8 ab	558.9 a
N	457.3	561.8 a-d	356.8 de	453.1 b-d
LR	466.1	582.5 a-c	371.3 b-e	444.3 cd
J-7C	465.2	536.0 b-e	364.4 c-e	495.1 a-d
J-N	466.8	591.8 a-c	346.7 e	462.0 b-d
J-LR	505.8	612.0 ab	412.5 a-d	492.9 a-d
7C-N	462.8	557.4 bd	401.6 a-e	429.3 d
7C-LR	509.8	552.1 bd	457.9 a	519.4 ab
N-LR	458.7	502.2 c-e	409.7 a-e	464.2 b-d
J-7C-N	455.5	477.7 de	390.3 b-e	498.6 a-c
J-7C-LR	465.7	502.7 c-e	391.9 b-e	502.5 a-c
J-N-LR	455.4	468.9 de	428.4 a-c	468.9 b-d
7C-N-LR	435.4	413.5 e	420.2 a-d	472.6 b-d
J-7C-N-LR	474.8	516.7 be	391.8 b-e	515.9 ab
AVERAGE				
Pure stands	487.5	599.7	380.4	482.3
Composites	468.7	521.0	401.4	483.7
Overall	473.7	542.0 a[2/]	395.8 c	483.4 b

[1/] Means within each column not followed by the same letter differ significantly at the 1% level of probability according to Duncan's multiple range test.

[2/] Means between each column not followed by the same letter differ significantly at the 1% level of probability according to Duncan's multiple range test.

7C-LR, was the highest yielding treatment (457.9 g). The overall treatment average for this year was significantly lower (395.8 g) when compared to the other two years. When the two, three and four cultivar combinations are examined, no consistent differences can be detected. In 1975-76 the two cultivar combinations appeared superior; however, in 1976-77 the three-way combinations were more promising with the four cultivar combinations being the highest yielding in 1977-78.

Mean values for number of spikes are noted in Table 4. The composite J-LR had the highest number of spikes for the three year period (353.9). This treatment was significantly different from all other treatments, except for J, LR, 7C-LR and J-N-LR. For the individual years, J-LR had the highest number of spikes for each of the three years. When considering the overall three-year average of the treatment means (301.0), it can be seen that the pure stands were slightly above (302.2) and the composite treatments below (300.6) this value. Three of the composite treatments had more spikes than the average of the pure stands with one (J-LR) being higher than the highest pure stand when the three year average is considered. There were no significant differences between the overall mean for the number of spikes of the base populations grown in 1975-76 (318.9) and 1976-77 (302.5); however, the overall mean in 1977-78 (281.6) was significantly different than the two previous years.

In Table 5 the mean values for number of spikelets per spike are presented. The composite J-N had the highest number of spikelets per spike over the three-year average being significantly different from LR, J-LR, 7C-LR and J-7C-N. When individual years are considered, the J-N composite was the highest for spikelets per spike in 1975-76 (20.3), 1976-77 (20.1) while N was higher in 1977-78 (20.3). For the three year period the average for the four pure stands (19.1) was greater than the 11

Table 4.

Mean values for number of spikes for the 15 treatments for the base population grown in 1975-76, 1976-77 and 1977-78; three year treatment average and the overall yearly means.

Treatments	Three Year Average	Base Population 1975-76	1976-77	1977-78
J	329.0 a-b[1/]	372.8 a	293.3 a-d	321.0 a-b
7C	281.8 b-d	294.8 bc	256.5 de	294.3 bd
N	272,2 d	299.3 bc	249.8 e	267.8 cd
LR	325.7 a-c	365.3 a	286.5 b-e	325.5 ab
J-7C	285.5 b-d	296.3 bc	254.3 e	306.0 bc
J-N	300.8 b-d	333.8 ab	258.0 de	310.8 bc
J-LR	353.9 a	375.8 a	326.3 a	359.8 a
7C-N	274.6 cd	309.8 b	255.8 de	258.5 d
7C-LR	310.7 a-d	336.8 b	315.0 c	280.5 b-d
N-LR	300.5 b-d	309.0 b	302.3 a-c	290.5 b-d
J-7C-N	290.5 b-d	312.0 b	259.5 de	300.3 b-d
J-7C-LR	298.3 b-d	301.5 bc	279.8 ce	313.8 b
J-N-LR	317.5 a-d	306.8 b	321.0 ab	324.7 ab
7C-N-LR	274.6 cd	255.8 c	283.5 b-e	284.5 b-d
J-7C-N-LR	299.6 b-d	315.5 b	282.8 b-e	300.5 b-d
AVERAGE				
Pure stands	302.2	333.1	271.5	302.2
Composites	300.6	313.9	285.3	302.7
Overall	301.0	318.9 a[2/]	281.6 b	302.5 a

[1/] Means within each column not followed by the same letter differ significantly at the 1% level of probability according to Duncan's multiple range test.

[2/] Means between each column not followed by the same letter differ significantly at the 1% level of probability according to Duncan's multiple range test.

Table 5.

Mean values for number of spikelets per spike for the 15 treatments for the base population grown in 1975-76, 1976-77 and 1977-78; three year treatment average and the overall yearly means.

Treatments	Three Year Average	Base Population 1975-76	1976-77	1977-78
J	19.6 a-c[1/]	19.7 a	19.8 bc	19.5 a-d
7C	19.3 a-d	19.4 ab	19.0 d	19.5 a-d
N	19.9 a-b	19.9 a	19.5 c	20.3 a
LR	17.7 d	16.9 de	17.8 f	18.5 cd
J-7C	18.6 a-d	17.6 cd	19.6 c	18.9 a-d
J-N	20.1 a	20.3 a	20.1 a	20.1 ab
J-LR	18.0 cd	17.4 cd	18.6 e	18.3 d
7C-N	19.2 a-d	18.5 bc	19.6 c	19.8 a-c
7C-LR	18.2 b-d	17.7 cd	18.5 e	18.4 d
N-LR	18.8 a-d	18.5 b c	19.0 d	19.0 a-d
J-7C-N	19.1 b-d	18.3 bc	20.0 ab	19.1 a-d
J-7C-LR	18.6 a-d	17.5 cd	19.7 c	18.7 cd
J-N-LR	18.4 a-d	16.8 de	19.7 c	18.9 a-d
7C-N-LR	18.4 a-d	17.5 de	19.2 c	18.7 a-d
J-7C-N-LR	18.3 a-d	16.1 e	19.8 bc	18.9 a-d
AVERAGE				
Pure stands	19.1	18.9	19.0	19.5
Composites	18.7	17.8	19.4	18.9
Overall	18.8	18.1 b[2/]	19.3 a	19.1 a

[1/] Means within each column not followed by the same letter differ significantly at the 1% level of probability according to Duncan's multiple range test.

[2/] Means between each column not followed by the same letter differ significantly at the 1% level of probability according to Duncan's multiple range test.

composite treatment means (18.7). The average of the composites (19.4) in 1976-77 for spikelet number was slightly higher than that of the pure stands (19.0). There were significant differences between the overall yearly means of the base populations. No significant differences between the overall means of the base population grown in 1976-77 (19.3) and 1977-78 (19.1) were observed; however, they were significantly higher than that of 1975-76 (18.1).

Mean values for number of kernels per spike are noted in Table 6. The pure stand 7C treatment had the highest three year average for number of kernels per spike which was significantly different from the other treatments. When individual years are considered, 7C was the highest in 1975-76 (57.3), 1976-77 (67.0) and 1977-78 (51.3). This cultivar produced a significantly greater number of kernels per spike when compared with all other treatments in the three years. When considering the overall mean for number of kernels per spike for the three years (47.0) it can be seen that pure stand means were slightly above (48.5) and composite treatment means below (46.5) this value. None of the composite treatments exceeded the pure stand of 7C; however, three (J-7C, J-N and 7C-N) were higher than the mean of the four pure stand entries. Significant differences were observed between the overall means of the base population grown in the three years, with the highest number of kernels per spike noted in 1976-77 (54.5).

Presented in Table 7 are the mean values for 100 kernel weight in grams. No significant differences were found between treatments for the three year average or for the base populations grown in different years. Jupateco and J-LR had the highest three year average values (4.1). The overall mean for the three year period was the same for both the

Table 6.

Mean values for number of kernels per spike for the 15 treatments for the base population grown in 1975-76, 1976-77 and 1977-78; three year treatment average and the overall yearly means.

Treatments	Three Year Average	Base Population 1975-76	1976-77	1977-78
J	46.1 b-e[1/]	53.1 ab	49.8 f-h	35.5 d-f
7C	58.5 a	57.3 a	67.0 a	51.3 a
N	48.0 bc	49.6 b-d	54.3 de	40.3 c
LR	41.4 de	43.4 e-g	46.7 gh	34.0 f
J-7C	49.2 bc	49.0 b-d	59.0 bc	39.8 c
J-N	48.7 bc	50.4 b-d	54.6 ce	41.2 c
J-LR	39.9 e	41.1 g	46.5 h	32.1 f
7C-N	51.4 b	51.4 bc	60.3 b	42.6 b
7C-LR	48.5 bc	48.6 b-e	54.6 c-e	42.4 bc
N-LR	45.3 bc	46.4 b-e	51.1 c-e	38.6 bc
J-7C-N	47.8 b-d	46.8 c-f	58.2 b-d	38.5 c-e
J-7C-LR	46.4 b-d	45.8 c-f	54.3 de	39.4 cd
J-N-LR	42.9 c-e	43.2 e-g	50.7 e-g	34.8 ef
7C-N-LR	46.6 b-d	42.8 f-g	56.2 b-d	40.9 c
J-7C-N-LR	44.5 c-e	41.2 g	53.8 d-f	38.7 c-e
<u>AVERAGE</u>				
Pure stands	48.5	50.9	54.5	40.3
Composites	46.5	46.1	54.5	39.0
Overall	47.0	47.3 b[2/]	54.5 a	39.3 c

[1/]Means within each column not followed by the same letter differ significantly at the 1% level of probability according to Duncan's multiple range test.

[2/]Means between each column not followed by the same letter differ significantly at the 1% level of probability according to Duncan's multiple range test.

Table 7.

Mean values for 100 kernel weight in grams for the 15 treatments for the base population grown in 1975-76, 1976-77 and 1977-78; three year treatment average and the overall yearly means.

Treatments	Three Year Average	Base Population 1975-76	1976-77	1977-78
J	4.1	4.4	3.7	4.1
7C	3.7	3.9	3.5	3.9
N	3.9	4.2	3.4	4.1
LR	3.9	4.2	3.7	4.1
J-7C	3.8	3.8	3.6	4.1
J-N	3.8	4.0	3.5	3.9
J-LR	4.1	4.2	3.7	4.3
7C-N	3.8	3.9	3.5	4.0
7C-LR	3.9	3.9	3.6	4.4
N-LR	4.0	4.3	3.7	4.1
J-7C-N	3.9	4.1	3.4	4.2
J-7C-LR	3.9	4.3	3.5	4.1
J-N-LR	4.0	4.2	3.5	4.3
7C-N-LR	3.9	4.1	3.5	4.0
J-7C-N-LR	4.0	4.1	3.6	4.5
AVERAGE				
Pure stands	3.9	4.2	3.6	4.1
Composites	3.9	4.0	3.6	4.1
Overall	3.9	4.1 a[1/]	3.6 b	4.1 a

[1/]Means within each column not followed by the same letter differ significantly at the 1% level of probability according to Duncan's multiple range test.

pure stands and composite treatments (3.9). There were, however, significant differences between the overall means of the base populations. There were no significant differences between the overall yearly means of the base population grown in 1975-76 (4.1) and 1977-78 (4.1) but they were significantly higher than the base population grown in 1976-77 (3.6).

The mean values for plant height in centimeters are noted in Table 8. The pure stand, LR, was the tallest as noted from the three year average for plant height. It was not significantly different from J-LR and 7C-LR. When individual years are considered, LR was the tallest in 1975-76 (108.0), 1976-77 (100.0) and in 1977-78 (102.5). This entry was significantly different from the other treatments in each of the three years, except for J (98.5) in 1977-78. When the average plant height is noted for the three year average, the pure stand value (95.9) was higher than the average of the composite (94.4). Three of the composite entries (J-LR, 7C-LR and N-LR) exceeded the average of the pure stands, but did not surpass the tallest pure stand (LR). Significant differences were observed between the overall yearly means of the base populations with the highest value for plant height noted in 1975-76 (99.6).

Analysis of the three populations across years.

The observed mean squares from the combined analyses of variance for populations (base, first and second derived populations) grown across years, treatments and population x treatment interactions for the six traits are provided in Table 9. Significant differences can be noted for populations, treatments and the population x treatment interactions for the six traits with the exception of grain yield and

Table 8.

Mean values for plant height in centimeters for the 15 treatments for the base population grown in 1975-76, 1976-77 and 1977-78; three year treatment average and the overall yearly means.

Treatments	Three Year Average		Base Population 1975-76		1976-77		1977-78	
J	96.2	bc [1]	100.0	b-d	90.0	cd	98.5	ab
7C	91.8	c	98.8	cd	86.3	e-g	90.5	f
N	92.0	c	100.0	b-d	81.3	h	95.0	b-e
LR	103.7	a	108.0	a	100.0	a	102.5	a
J-7C	92.8	bc	98.7	cd	88.0	d-f	91.8	ef
J-N	93.5	bc	99.0	cd	86.3	e-g	95.5	b-e
J-LR	99.0	ab	104.5	ab	94.5	b	98.3	bc
7C-N	92.0	c	99.5	b-d	84.8	g	92.0	ef
7C-LR	97.8	a-c	103.0	bc	94.8	b	95.8	b-d
N-LR	96.8	bc	102.3	bc	90.0	cd	98.3	bc
J-7C-N	91.8	c	95.7	d	85.5	fg	94.3	c-f
J-7C-LR	93.8	bc	96.0	d	91.0	c	94.5	b-e
J-N-LR	94.4	bc	96.0	d	89.5	cd	97.8	b-d
7C-N-LR	93.5	bc	96.7	d	88.8	ce	95.0	b-e
J-7C-N-LR	92.9	bc	95.5	d	89.3	cd	94.0	d-f
AVERAGE								
Pure stands	95.9		101.7		89.4		96.6	
Composites	94.4		98.9		89.3		95.2	
Overall	94.8		99.6	a [2]	89.3	c	95.6	b

[1] Means within each column not followed by the same letter differ significantly at the 1% level of probability according to Duncan's multiple range test.

[2] Means between each column not followed by the same letter differ significantly at the 1% level of probability according to Duncan's multiple range test.

Table 9. Observed mean square values from the combined analysis of variance for the base, first and second derived populations growing in 1975-76, 1976-77 and 1977-78, respectively, treatments and their interactions for six agronomic traits.

Source of Variation	df	Grain Yield	Number of Spikes	Number of Spikelets per Spike	Number of Kernels per Spike	100 Kernel Weight	Plant Height
Populations (POP)	2	432650.00**	30829.60**	25.45**	3939.66**	9.74**	1560.69**
Treatments (TMTS)	14	4958.86	7298.05**	8.03**	190.46**	0.18	125.12**
POP X TMTS[1/]	28	8872.72**	1527.37**	1.54**	22.70**	0.18**	22.76**
Block (in years)	9	6025.83	1433.50	3.32	34.4	0.39	28.25
Block X TMTS (in years)[2/]	126	2325.37	766.56	0.60	12.18	0.08	5.55
C.V.		19.7	14.1	7.0	18.9	11.6	6.3

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

[1/] Error term for populations (years) and treatments.
[2/] Error term for population x treatment interaction.

100 kernel weight within the treatment. The coefficients of variation range from 19.7 for grain yield to 6.3% for plant height.

The observed mean square values from the individual analysis of variance for the base, first and second derived populations grown in 1975-76, 1976-77 and 1977-78 for the six traits are shown in Appendix Table 4. The individual analysis of variance for the base, first and second derived populations showed a highly significant difference between treatments for the six traits, except for grain yield and plant height in the first derived population and for 100 kernel weight in all populations.

Mean values for treatments for each population (base, first and second derived) grown across years, three year treatment average and the overall yearly means for the six traits measured are found in Tables 10-15.

For grain yield (Table 10), J had the highest three year average across populations (498.5 g); however, it is not significantly different from the other treatments. When individual years are considered, J was the highest in the base population (660.2 g), N-LR in the first derived population (408.8 g) and 7C-N (540.0 g) in the second derived population. Significant differences were observed between J and nine of the treatments in the base population. The treatments were not significantly different in the first derived population. Siete Cerros-Nuri (7C-N) was significantly different when compared to N, LR, J-N, J-LR and N-LR in the second derived population. For the three year population average, the mean of the four pure stands was 476.3 g in contrast to 467.2 g for the 11 composite treatments. Three of the composite treatments (J-7C, J-LR, 7C-N) yielded more than the average

Table 10.

Mean values for grain yield in grams for the 15 treatments for the base, first and second derived populations grown in 1975-76, 1976-77 and 1977-78, respectively; three year treatment average and the overall yearly means for the three populations.

Treatments	Three Year Average	Populations		
		Base[3/]	First[4/]	Second[5/]
J	498.5	660.2 a[1/]	350.9	484.5 a-c
7C	491.8	594.3 a-c	376.9	504.2 a-c
N	435.0	561.8 a-d	323.3	420.0 d
LR	480.0	582.5 a-c	384.9	472.8 b-d
J-7C	489.8	536.0 b-e	407.5	525.9 ab
J-N	462.3	591.8 a-c	334.9	460.2 cd
J-LR	491.9	612.0 ab	395.4	488.3 b-d
7C-N	488.4	557.4 b-d	367.8	540.0 a
7C-LR	475.6	552.1 b-d	386.9	487.8 a-c
N-LR	454.7	502.2 c-e	408.8	453.1 cd
J-7C-N	455.4	477.7 de	376.9	511.6 a-e
J-7C-LR	464.3	502.7 c-e	391.5	498.1 a-c
J-N-LR	444.8	468.9 de	373.1	492.5 a-c
7C-N-LR	442.4	413.5 e	399.5	514.3 a-c
J-7C-N-LR	469.5	516.7 b-e	364.2	527.5 ab
<u>AVERAGE</u>				
Pure stands	476.3	599.7	359.0	470.4
Composites	467.2	521.0	382.4	499.9
Overall	469.6	541.9 a[2/]	376.2	492.1

1/ Means within each column not followed by the same letter differ significantly at the 1% level of probability according to Duncan's Multiple Range Test.

2/ Means between each column not followed by the same letter differ significantly at the 1% level of probability according to Duncan's multiple range test.

3/ Base population grown in 1975-76.

4/ First derived population grown in 1976-77.

5/ Second derived population grown in 1977-78.

of the four pure stands, but none exceeds the highest pure stand (J) when the three year average is considered. It should also be noted that there were significant differences between the overall yearly population means with the highest yield being noted for the base population (541.9 g) grown in 1975-76. In the first and second derived populations, the composite treatment average was higher than the pure stand treatment average.

Mean values for number of spikes are noted in Table 11. The composite J-LR had the highest three year average across populations and was significantly different from 7C-N, J-7C, J-7C-N, and 7C-N-LR. When individual populations are observed J-LR (375.8) is the highest in the base population, LR (312.0) in the first derived population and J (353.8) in the second derived population. The composite J-LR was not significantly different from 7C, N, 7C-N and 7C-LR in the first derived population. Jupateco (J) was not significantly different from LR, J-LR, N-LR and J-N-LR in the second derived population. For the three year average, the mean of the four pure stands was 301.1. This value was greater than the mean value of the 11 composite treatments (296.0) The composite treatment average (276.6) was higher than the pure stand treatment average (266.2) in the first derived population. There were significant differences between the overall yearly population means, with the highest number of spikes being noted for the base population (319.0) grown in 1975-76.

In Table 12, mean values for spikelets per spike for the 15 treatments in the base, first and second derived populations grown across years, three year treatment average and the overall yearly population means are presented. Nuri (N) had the highest three year average

Table 11.

Mean values for number of spikes for the 15 treatments for the base, first and second derived populations grown in 1975-76, 1976-77 and 1977-78, respectively; three year treatment average and the overall yearly means for the three populations.

Treatments	Three Year Average	Populations Base[3/]	First[4/]	Second[5/]
J	330.9 a [1/]	372.8 a	266.3 a-d	353.8 a
7C	266.8 b	294.8 bc	240.7 cd	265.0 e
N	269.2 b	299.3 bc	246.0 cd	262.3 e
LR	337.3 a	365.3 a	312.0 a	334.5 ab
J-7C	288.8 b	296.3 bc	275.3 a-c	295.0 ce
J-N	305.1 ab	333.8 b	282.0 a-c	299.5 be
J-LR	341.4 a	375.8 a	306.8 ab	341.8 a
7C-N	271.9 b	309.8 b	221.3 d	284.8 de
7C-LR	292.1 ab	336.8 b	254.3 b-d	285.3 de
N-LR	312.8 ab	309.0 b	309.0 a	320.3 a-d
J-7C-N	282.0 b	312.0 b	260.3 a-d	273.8 e
J-7C-LR	290.9 ab	301.5 bc	278.8 a-c	292.5 ce
J-N-LR	307.1 ab	306.8 b	291.0 a-c	324.0 a-c
7C-N-LR	271.1 b	255.8 c	273.0 a-c	284.3 de
J-7C-N-LR	293.5 ab	315.5 a-c	290.3 a-c	274.8 e
<u>AVERAGE</u>				
Pure stands	301.1	333.1	266.2	303.9
Composites	296.0	287.3	276.6	297.8
Overall	297.4	319.0 a[2/]	273.8 c	299.4 b

[1/]Means within each column not followed by the same letter differ significantly at the 1% level of probability according to Duncan's multiple range test.

[2/]Means between each column not followed by the same letter differ significantly at the 1% level of probability according to Duncan's multiple range test.

[3/]Base population grown in 1975-76.

[4/]First derived population grown in 1976-77

[5/]Second derived population grown in 1977-78.

Table 12.

Mean values for number of spikelets per spike for the 15 treatments for the base, first and second derived populations grown in 1975-76, 1976-77 and 1977-78, respectively; three year treatment average and the overall yearly means for the three populations.

Treatments	Three Year Average	Populations: Base [3/]	First [4/]	Second [5/]
J	19.7 ab [1/]	19.7 a	20.3 ab	19.0 b-e
7C	19.5 a-c	19.4 ab	19.5 ab	19.7 b
N	20.7 a	19.9 a	21.0 a	21.0 a
LR	17.6 d	16.9 de	18.3 b	17.8 g
J-7C	18.9 b-d	17.6 cd	20.1 ab	19.1 b-d
J-N	19.7 ab	20.3 a	19.3 ab	19.6 bc
J-LR	18.1 b-d	17.4 cd	18.9 b	18.1 eg
7C-N	19.1 a-d	18.5 bc	19.0 b	19.7 b
7C-LR	18.2 b-d	17.7 cd	18.5 b	18.4 d-g
N-LR	18.9 b-d	18.5 bc	19.6 ab	18.8 c-f
J-7C-N	19.0 a-d	18.3 bc	19.9 ab	18.9 b-e
J-7C-LR	18.1 b-d	17.5 cd	18.7 b	18.1 e-g
J-N-LR	18.5 b-d	16.8 de	19.6 ab	18.9 b-e
7C-N-LR	18.5 b-d	17.5 cd	19.3 ab	18.7 c-f
J-7C-N-LR	17.9 cd	16.1 e	19.3 ab	18.5 d-g
AVERAGE				
Pure stands	19.4	19.0	19.8	19.4
Composites	18.6	17.8	19.3	18.8
Overall	18.8	18.1 b [2/]	19.4 a	19.0 a

[1/] Means within each column not followed by the same letter differ significantly at the 1% level of probability according to Duncan's multiple range test.

[2/] Means between each column not followed by the same letter differ significantly at the 1% level of probability according to Duncan's multiple range test.

[3/] Base population grown in 1975-76.

[4/] First derived population grown in 1976-77.

[5/] Second derived population grown in 1977-78.

across populations; however, it was not significantly different from J, 7C, J-N, 7C-N and J-7C-N. When considering individual populations, J-N was superior for number of spikelets per spike in the base population, while N had the highest spikelet number in the first and second derived populations. When comparing the three populations for the three year period, the average of the four pure stands was 19.4. This is in comparison to the 11 composite treatments where the mean value is 18.6. It should be noted that there were significant differences between the overall yearly population means. There were no significant differences between the overall yearly means of the first and second derived populations grown in 1976-77 (19.4) and 1977-78 (19.0), respectively. However, both first and second derived population means were significantly higher than that of the base population grown in 1975-76 (18.1).

Three year treatment averages and the overall yearly population means are shown in Table 13 for mean values for number of kernels per spike. The pure stand, 7C, had the highest kernel number per spike in all three populations; however, it was not significantly different from N and 7C-N. When individual populations are considered, 7C was the highest in the three populations. Siete Cerros (7C) was not significantly different from J in the base population, N, J-7C, 7C-N, 7C-LR and J-7C-LR in the first derived population; however, 7C was significantly different from all treatments in the second derived population. When considering the three year average of each treatment across populations the average of the four pure stands (48.1) was higher than the mean of the 11 composite treatments (45.4). It can also be observed that there were significant differences among populations with the highest kernel number per spike being noted for the second derived population grown in 1976-77.

Table 13.

Mean values for number of kernels per spike for the 15 treatments for the base, first and second derived populations grown in 1975-76, 1976-77 and 1977-78, respectively; three year treatment average and the overall yearly means for the three populations.

Treatments	Three Year Average	Populations Base [3/]	First [4/]	Second [5/]
J	46.4 be [1/]	53.1 ab	53.5 bc	32.8 cd
7C	55.6 a	57.3 a	61.5 a	48.0 a
N	49.8 ab	49.6 b-d	60.8 a	39.0 b
LR	40.4 e	43.4 e-g	44.8 d	33.0 cd
J-7C	48.6 b-d	49.0 b-d	57.3 ab	39.4 b
J-N	48.5 b-d	50.4 b-d	52.6 bc	36.6 bc
J-LR	40.5 e	41.0 g	49.3 cd	31.1 d
7C-N	49.6 a-c	51.4 bc	56.9 ab	40.4 b
7C-LR	46.9 b-d	48.6 b-e	54.6 a-c	37.6 bc
N-LR	44.2 b-e	46.4 c-f	50.1 bd	36.0 b-d
J-7C-N	47.1 b-d	46.8 c-f	54.9 a-c	39.6 b
J-7C-LR	43.3 c-e	45.8 d-g	50.6 b-d	33.6 c-d
J-N-LR	42.8 de	43.2 è-g	49.3 cd	35.8 b-d
7C-N-LR	44.7 b-e	42.8 f-g	53.3 bc	37.9 bc
J-7C-N-LR	42.9 de	41.2 g	49.7 cd	37.9 bc
<u>AVERAGE</u>				
Pure stands	48.1	50.8	55.1	38.2
Composites	45.4	46.0	52.6	36.9
Overall	45.9	47.3 b [2/]	53.3 a	37.3 c

[1/] Means within each column not followed by the same letter differ significantly at the 1% level of probability according to Duncan's multiple range test.

[2/] Means between each column not followed by the same letter differ significantly at the 1% level of probability according to Duncan's multiple range test.

[3/] Base population grown in 1975-76.

[4/] First derived population grown in 1976-77.

[5/] Second derived population grown in 1977-78.

Mean values of 100 kernel weight for each of the 15 treatments in the base, first and second derived populations, three year average for each treatment across years and the overall yearly population means are presented in Table 14. For 100 kernel weight, the treatments J-7C-LR and J-N-LR had the highest three-population average which was not significantly different from the other treatment means. When individual populations are considered, J (4.4) was the highest in the base population, J-LR (4.0) in the first derived population and J-7C-LR (5.0) in the second derived population. No significant differences were found for the treatments within the base and first derived populations. The composite, J-7C-LR, was significantly different from J, 7C, N, LR, J-N, J-LR and N-LR in the second derived population. For the three year average of each treatment across populations, the mean of the four pure stands was 4.0 grams in contrast to 4.1 grams for the mean of the 11 composite treatments. It should also be noted that there were significant differences between the overall yearly population means, with the highest 100 kernel weight in grams noted for the second derived population grown in 1977-78. The average for the composite treatments (4.6) was higher than the pure stand average (4.1) in the same population.

In Table 15, mean values for plant height are presented for each of the 15 treatments in the base, first and second derived populations including a three year treatment average and the overall yearly population means. Lerma Rojo (LR) as a pure stand had the highest three year average across populations for plant height. When individual populations are considered, LR was the highest in the base (108.8), first (100.0) and second (99.3) derived populations for plant height. Lerma Rojo (LR) was not significantly different from J-LR in the base population. It was significantly different from all of the treatments in the first

Table 14.

Mean values for 100 kernel weight in grams for the 15 treatments for the base, first and second derived populations grown in 1975-76, 1976-77 and 1977-78, respectively; three year treatment average and the overall yearly means for the three populations.

Treatments	Three Year Average	Populations: Base[3/]	First [4/]	Second [5/]
J	4.1	4.4	3.8	4.2 e-g[1/]
7C	3.9	3.9	3.7	3.9 g
N	3.9	4.2	3.4	4.1 e-g
LR	4.1	4.2	3.8	4.3 d-g
J-7C	4.0	3.8	3.8	4.5 a-d
J-N	4.0	4.1	3.6	4.4 b-f
J-LR	4.2	4.2	4.0	4.4 b-f
7C-N	4.0	3.9	3.5	4.6 a-d
7C-LR	4.1	3.9	3.8	4.5 a-e
N-LR	4.1	4.3	3.6	4.4 b-f
J-7C-N	4.2	4.1	3.7	4.9 ab
J-7C-LR	4.3	4.3	3.6	5.0 a
J-N-LR	4.3	4.2	3.7	4.9 ab
7C-N-LR	4.1	4.1	3.7	4.7 a-c
J-7C-N-LR	4.1	4.1	3.7	4.6 a-d
AVERAGE				
Pure stands	4.0	4.2	3.7	4.1
Composites	4.1	4.1	3.7	4.6
Overall	4.1	4.1 b[2/]	3.7 c	4.5 a

[1/]Means within each column not followed by the same letter differ significantly at the 1% level of probability according to Duncan's multiple range test.

[2/]Means between each column not followed by the same letter differ significantly at the 1% level of probability according to Duncan's multiple range test.

[3/]Base population grown in 1975-76.

[4/]First derived population grown in 1976-77.

[5/]Second derived population grown in 1977-78.

Table 15.

Mean values for plant height in centimeters for the 15 treatments for the base, first and second derived populations grown in 1975-76, 1976-77 and 1977-78, respectively; three year treatment average and the overall yearly means for the three populations.

Treatments	Three Year Average	Populations Base[3/]	First[4/]	Second[5/]
J	96.0 b-d[1/]	100.0 b-d	90.0 c-e	98.0 ab
7C	91.0 d	98.8 cd	83.8 e	90.5 h
N	93.3 b-d	100.0 b-d	83.8 e	96.3 a-d
LR	102.7 a	108.8 a	100.0 a	99.3 a
J-7C	93.3 b-d	98.8 cd	89.0 c-d	92.0 f-h
J-N	93.8 b-d	99.0 cd	86.5 d-e	96.0 a-e
J-LR	99.4 ab	104.5 ab	95.0 b	98.8 a
7C-N	92.1 fg	99.5 b-d	83.3 e	93.5 e-h
7C-LR	96.9 a-d	103.0 bc	92.8 bc	95.0 b-f
N-LR	97.6 a-c	102.3 bc	92.8 bc	97.8 a-c
J-7C-N	90.9 d	95.8 d	85.5 d-e	91.5 gh
J-7C-LR	94.3 b-d	96.0 d	92.0 cd	94.8 b-g
J-N-LR	94.3 b-d	96.0 d	89.5 de	97.5 a-d
7C-N-LR	93.7 b-d	96.8 d	90.3 c-e	94.0 d-h
J-7C-N-LR	92.6 cd	95.5 d	88.0 c-e	94.3 c-g
AVERAGE				
Pure stands	95.8	101.9	89.4	96.0
Composites	94.4	98.8	89.5	95.0
Overall	94.8	99.6 a[2/]	89.5 c	95.3 b

[1/]Means within each column not followed by the same letter differ significantly at the 1% level of probability according to Duncan's multiple range test.

[2/]Means between each column not followed by the same letter differ significantly at the 1% level of probability according to Duncan's multiple range test.

[3/]Base population grown in 1975-76.

[4/]First derived population grown in 1976-77.

[5/]Second derived population grown in 1977-78.

derived population and from 7C, J-7C, 7C-N, 7C-LR, J-7C-N, J-7C-LR, 7C-N-LR and J-7C-N-LR in the second derived population. When the three year average across populations is considered, the mean of the four pure stands (95.8) was slightly higher than the mean of the 11 composite treatments (94.4). It can also be observed that there were significant differences between the overall yearly population means, with the highest value for plant height in centimeters produced in the base population grown in 1975-76.

Specific competitive ability

Competition between component cultivars within a composite treatment was regarded as a measure of their specific competitive ability. The specific competitive ability of each cultivar in the 11 composite treatments is noted in Table 16. For grain yield, 7C followed by LR had the highest specific competitive ability within the treatments involving two cultivar composites for the three populations. It should be noted that when J, N and LR were present individually in a composite treatment that included 7C they decreased in frequency in all three populations. Considering the treatments with a three cultivar composite, 7C was again the highest yielding component in the three populations with the exception of 7C-N-LR in the base population and J-7C-LR in the first derived population. When the composite J-7C-N-LR is analyzed, LR had the highest specific competitive ability in both the base and first derived population with 7C being higher in the second derived population. Nuri (N) was the poorest competitor in all the composite treatments for the three populations.

Specific competitive ability of each cultivar for spike number per plot is also noted in Table 16 for the three populations. The component

Table 16. Summary of analysis of variance for within composite treatments for six traits in the base, first and second derived populations grown in 1975-76, 1976-77 and 1977-78.

Treatment.	Grain Yield			Spike Number			Spikelets/spike		
	Base (1)	First (2)	Second (3)	Base (1)	First (2)	Second (3)	Base (1)	First (2)	Second (3)
5 J	226.5	147.4 b[+]	147.5 b	157.5	123.8	109.5 b	17.8	20.7	18.5 b
7C	309.4	260.1 a	378.5 a	138.8	151.5	185.5 a	17.2	19.5	19.7 a
A.V		**	**			*			*
6 J	308.0	217.5 a	267.9	161.3	181.5 a	187.3 a	20.6 a	18.7	19.0 b
N	283.9	117.4 b	192.3	172.5	100.5 b	112.3 b	19.9 b	19.7	20.3 a
A.V		*			*	*	*		**
7 J	244.1 b	180.4	49.7 b	158.3 b	146.3	121.2 b	18.3	19.7 a	18.0
LR	367.9 a	216.0	318.6 a	217.5 a	160.5	220.5 a	16.5	18.0 b	18.2
A.V	**	NS	**	*	NS	**	NS	**	NS
8 7C	353.6 a	280.4 a	437.0 a	174.0 a	152.3 a	218.5 a	18.5	18.7	19.5
N	203.9 b	87.5 b	103.1 b	135.8 b	69.0 b	66.2 b	18.4	19.3	20.0
A.V	*	**	**	*	**	**			
9 7C	306.2	221.0	324.9 a	167.3	128.3	164.0 a	18.5 a	19.3 a	19.0 a
LR	266.1	165.9	162.9 b	169.5	126.0	121.3 b	17.3 b	17.8 b	17.7 b
A.V			**			*	**	**	**
10 N	195.6 b	94.5 b	112.6 b	125.3 b	82.5 b	68.5 b	19.9	21.2 a	20.0 a
LR	306.6 a	313.4 a	340.4 a	183.8 a	226.5 a	251.7 a	17.0	18.0 b	17.5 b
A.V	**	**	**	*	**	**		*	*
11 J	146.2 b	121.3 b	149.9 b	99.8 b	99.0 a	104.0 b	17.5	20.0	18.7
7C	215.4 a	181.8 a	275.4 a	122.3 a	101.3 a	130.5 a	18.1	19.8	19.7
N	116.2 c	73.8 b	86.3 c	90.0 b	60.0 b	39.3 c	19.3	20.0	18.5
A.V	**	*	**	*	*	**			
12 J	113.2 b	115.9	81.6 c	75.0	96.8	62.5 c	18.0 a	18.7	17.3
7C	215.4 a	136.4	265.0 a	103.5	73.3	124.0 a	18.0 a	19.5	19.0
LR	183.8ab	139.3	152.3 b	123.0	108.8	106.0 b	16.2 b	18.0	18.0
A.V	*		**			**	*		
13 J	164.5 b	107.0 b	174.9 b	108.8 a	105.0 b	119.5 b	17.9	20.0 a	19.2
N	110.1 c	94.4 b	65.9 c	73.5 b	45.0 c	35.7 c	16.7	20.3 a	19.0
LR	195.3 a	171.8 a	251.7 a	124.5	141.0 a	168.7 a	15.8	18.8 b	18.7
A.V	*	**	**	**	**	**		*	
14 7C	124.7ab	175.4 a	321.4 a	65.3 b	98.3 a	158.3 a	17.4 b	20.0	19.0
N	106.1 b	52.8 b	63.6 c	69.8 b	44.3 b	40.7 c	18.5 a	19.5	19.3
LR	182.9 a	171.3 a	129.3 b	120.8 a	130.5 a	85.3 b	16.5 b	18.5	18.0
A.V	*	*	**	**	**	**	*		
15 J	121.6	73.5 b	87.1 b	79.5	75.0 b	56.5 b	17.2 a	20.0 a	17.7 b
7C	134.0	120.6 a	280.6 a	84.8	72.8 b	133.2 a	15.2 b	19.7 a	20.0 a
N	101.3	45.8 c	68.6 b	66.0	43.5 b	41.3 b	17.4 a	19.7 a	18.5 b
LR	159.8	124.3 a	91.2 b	110.3	115.5 a	60.7 b	14.3 b	17.7 b	17.7 b
A.V		*	**		*	**	*	**	**

A.V.= Analysis of variance. * Significant at 5 % level. ** Significant at 1 % level. (1) Base population grown in 1975-76. (2) First derived population grown in 1976-77. Second derived population grown in 1977-78.

+ Least significant differences, means followed by different lower case letter differ significantly at the one percent level.

Table 16. - Continued

Treat-ment.	Kernels/Spike Base (1)	Kernels/Spike First (2)	Kernels/Spike Second (3)	Kernel weight Base (1)	Kernel weight First (2)	Kernel weight Second (3)	Plant Height Base (1)	Plant Height First (2)	Plant Height Second (3)
5 J	41.5 b	47.5 b	27.5 b	3.5	3.7	4.8 a	97.5	91.3	93.0
7C	56.5 a	67.0 a	51.2 a	4.1	3.8	4.1 b	100.0	86.3	90.7
A.V	*	**	**	*		*			
6 J	52.6	50.7	33.7 b	4.2 a	3.8	4.3	96.3	90.0 a	96.0
N	48.1	54.5	39.5 a	3.9 b	3.3	4.4	101.3	82.5 b	96.0
A.V			**	**				**	
7 J	41.3	50.5	34.5	4.2	3.7	4.7	97.5 b	90.0 b	93.7 b
LR	48.9	48.0	35.3	4.2	4.3	4.1	110.0 a	100.0 a	103.0 a
A.V							**	**	**
8 7C	59.5	66.3 a	47.5 a	3.8	3.5	4.3	100.0	83.8	93.0
N	43.3	47.5 b	33.3 b	3.9	3.4	4.8	98.8	82.5	93.7
A.V		**	**						
9 7C	51.9 a	63.8	46.0 a	3.8	3.6	4.3	96.3	86.3	90.5 b
LR	45.2 b	45.5	28.7 b	4.0	3.9	4.5	108.8	95.0	99.5 a
A.V	*	**	**				**		**
10 N	44.7	51.0	36.0	4.2	3.3 b	4.6	98.8	85.0 b	94.2 b
LR	48.1	49.3	36.0	4.3	3.7 a	4.2	105.0	100.0 a	100.5 a
A.V					**			**	*
11 J	42.1	47.8 b	30.2 c	4.4	3.8	4.7 b	93.8	90.0 a	91.0
7C	49.0	65.8 a	51.2 a	3.9	3.8	4.1 b	96.3	83.8 b	91.7
N	49.2	51.5 b	37.3 b	3.8	3.8	4.1 b	96.3	83.8 b	91.7
A.V		**	**			**		*	
12 J	43.5	44.3 b	23.0 c	4.5	3.5ab	5.7 a	92.5 b	90.0 b	92.5 b
7C	51.2	62.0 a	47.8 a	3.9	3.3 b	4.5 b	93.8 b	85.0 b	91.3 b
LR	42.7	45.5 b	30.0 b	4.6	3.8 a	4.8 b	101.3 a	100.0 a	100.7 a
A.V		**	**		*	**	**	*	**
13 J	42.5	47.0	40.0	4.4 a	3.9 a	4.3	93.8 b	96.0 b	94.7 b
N	45.5	51.8	37.2	3.7 b	3.4 c	5.0	92.5 b	81.0 c	96.7 b
LR	41.6	49.3	30.2	4.6 a	3.8 b	5.2	102.5 a	100.0 a	101.2 a
A.V				**	*		*	**	*
14 7C	48.3 a	66.5 a	50.0 a	3.9 b	3.7	4.1 c	91.3 c	86.3 b	90.0 b
N	39.6 b	48.5 b	31.3 b	4.1ab	3.3	5.1 a	96.3 b	83.7 b	92.5 b
LR	40.7 b	45.0 b	32.5 b	4.4 a	3.9	4.7 b	102.5 a	101.3 a	99.0 a
A.V	*	**	**	*		**	**	**	*
15 J	41.5 a	45.0 b	34.0 b	4.1	3.6 b	4.6 a	93.8 c	88.7 b	92.0 b
7C	41.8 a	62.5 a	52.0 a	4.1	3.6 b	4.0 b	91.3 c	82.5 c	88.7 b
N	44.8 a	46.2 b	33.0 b	3.9	3.4 b	5.0 a	96.3 b	81.3 c	93.5 b
LR	36.5 b	44.7 b	32.5 b	4.3	4.1 a	4.6 a	101.3 a	98.7 a	101.0 a
A.V	*	**	**		*	*	**	**	**

cultivar LR had the highest number of spikes per plot in the three populations which consisted of a mixture of two cultivars with the exception of the composite 7C-LR in the first and second derived populations. Where three and four cultivars were mixed, LR had the highest competitive ability with the exception in the second derived population of the composites J-7C-LR, 7C-N-LR and J-7C-N-LR. It can be noted that 7C became predominant in these latter composites. The component cultivar N was the poorest competitor in all the composite treatments for the three populations.

Table 16 includes the mean values and specific ability for spikelet number per spike for the three populations. There was no consistent advantage for the number of spikelets per spike found for any of the component cultivars for the composite treatments in the three populations, thus no attempt was made to interpret their specific competitive ability.

For kernel number per spike, the mean values and specific competitive ability for the component cultivars of the 11 composite treatments are presented in Table 16. Siete Cerros as a component cultivar had the highest number of kernels per spike for the composite treatments with both two and three cultivar mixtures in all three populations. When the composite treatment J-7C-N-LR is considered, 7C had the highest kernel number per spike in all populations except the base population.

Specific competitive ability for 100 kernel weight and plant height for the component cultivar within composite treatments can be observed in Table 16. Results for 100 kernel weight lacked any consistency making it difficult to interpret specific competitive ability for any of the component cultivars in the three populations. For plant height, the component cultivar LR had the highest value in all the composite treatments.

A graphic presentation of the percentage of the mean for each component cultivar within composite treatments is presented in Figures 1-3 for the base, first and second derived populations, respectively. This percentage was computed for grain yield, spike number per plot and kernel number per spike for each of the composite treatments in each population and is a measure of specific competitive ability of component cultivars within composite treatments.

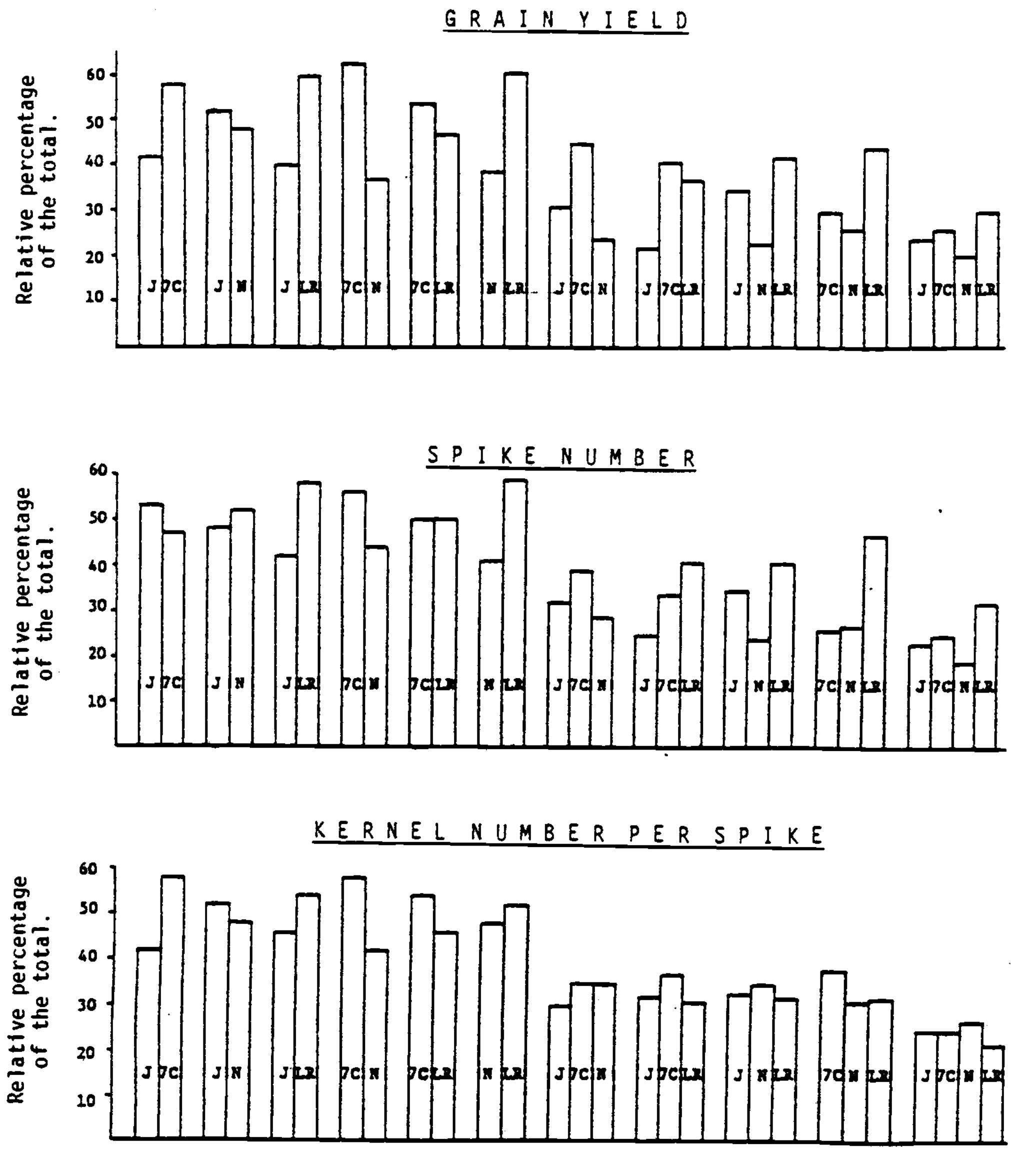
For grain yield (Figure 1), 7C had the highest percentage (63%) in contrast with N wich had the lowest (37%) for the composite treatments involving two cultivars in the base population. When three cultivar composite treatments are considered, 7C (45%) was again the highest while J was the lowest (22%). In the four cultivar composite treatment, LR was the highest (30%) and N was the lowest (20%).

In the two cultivar composite treatments, LR had the highest percentage for spike number per plot (59%) and N the lowest in the base population (41%) (Figure 1). For the three and four cultivar composite treatments, LR had the highest and N the lowest percentage of spikes per plot.

For kernel number per spike, 7C had the highest percentage (58%), J and N were the lowest (42%) for the composite treatments with two cultivars mixed in the base population (Figure 1). When considering those treatments with three cultivars, 7C had the highest (38%) and J the lowest percentage (30%). In the composite treatment with four cultivars, N had the highest (27%) and LR the lowest percentage (22%) for kernel number.

The relative percentage of the total contributed for each component cultivar within the composite treatments for grain yield, spike number per plot and kernel number per spike in the first derived population are

Figure 1. Relative percentage of the total contributed by each of the components of the composite for grain yield, spike number and kernel number per spike for the base population grown in 1975-76.



noted in Figure 2. For grain yield, LR had the highest (77%) and N the lowest percentage (23%) for the composite treatments with two cultivars. When those treatments with three cultivars are noted, 7C had the highest (48%) and N the lowest percentages (13%). In the composite treatment with four cultivars, LR had the highest (34%) and N the lowest percentages (13%) for grain yield.

For spike number per plot, LR had the highest (73%) and N the lowest percentage (27%) in the composite treatments with two cultivars (Figure 2). For those treatments with three cultivars, LR had the highest (48%) and N the lowest percentage (15%). In the four cultivar composite treatment, LR had the highest number of spikes (38%) and N the lowest percentage (14%).

The highest percentage for kernel number per spike was 58% for 7C and 41% for J, which was the lowest, in the two cultivar composite treatments (Figure 2). For those treatments with three cultivars, 7C had the highest (42%) and LR the lowest percentage (23%) of kernels. For the four cultivar composite, 7C had the highest number (31%) and J, N and LR the lowest percentages (23%).

The relative percentage of the total contributed for each component cultivar in the composite treatments for grain yield, spike number per plot and kernel number per spike in the second derived population are presented in Figure 3. For grain yield LR had the highest (87%) and J the lowest percentage (13%) for those treatments with two cultivars mixed. When three cultivar mixtures are noted, 7C had the highest grain yield (63%) and N the lowest percentage (22%). In the four cultivar composite treatment, 7C again had the highest grain yield (53%) and N the lowest percentage (13%).

Figure 2. Relative percentage of the total contributed by each of the components of the composite for grain yield, spike number and kernel number per spike for the first derived population grown in 1976-77.

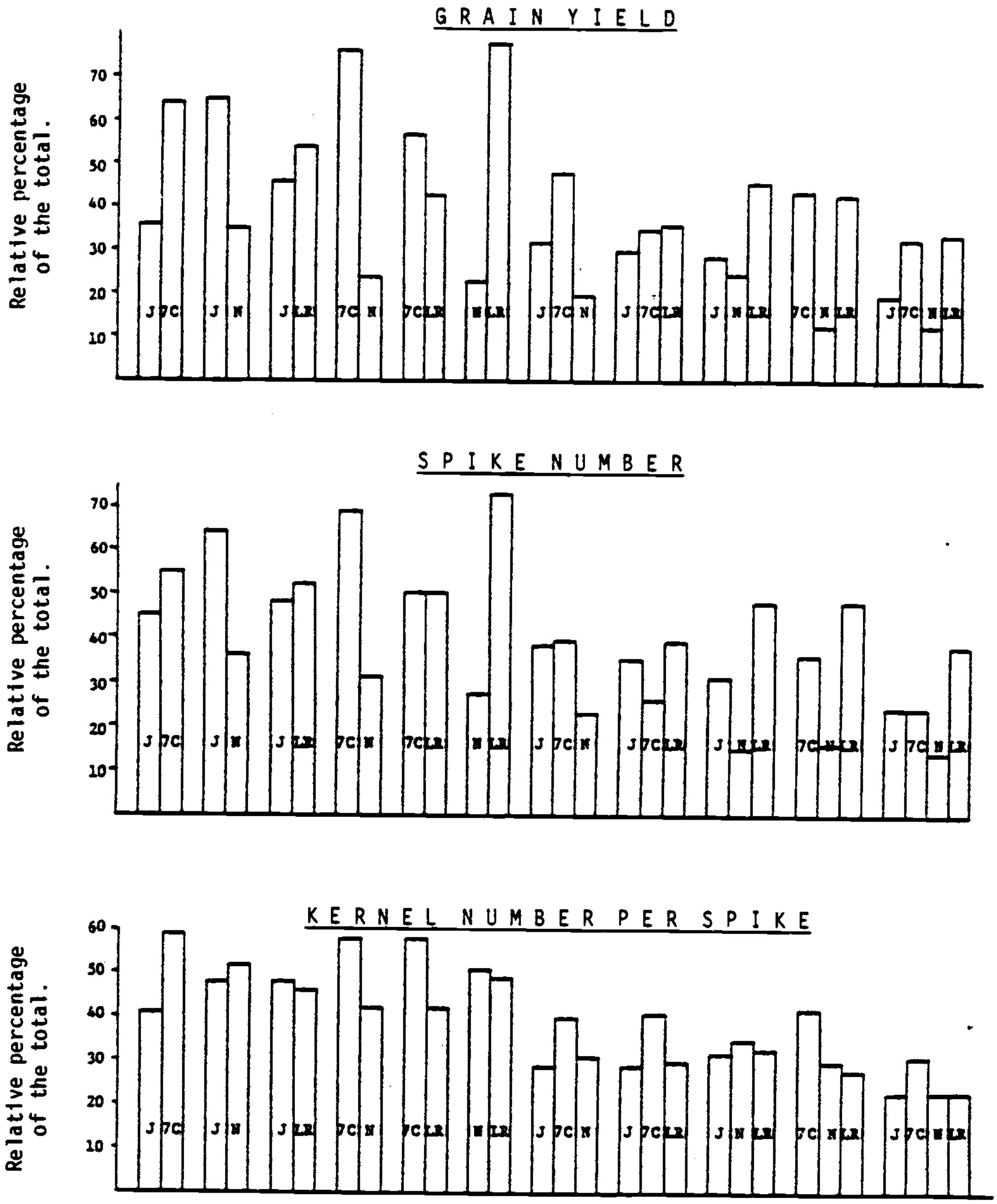
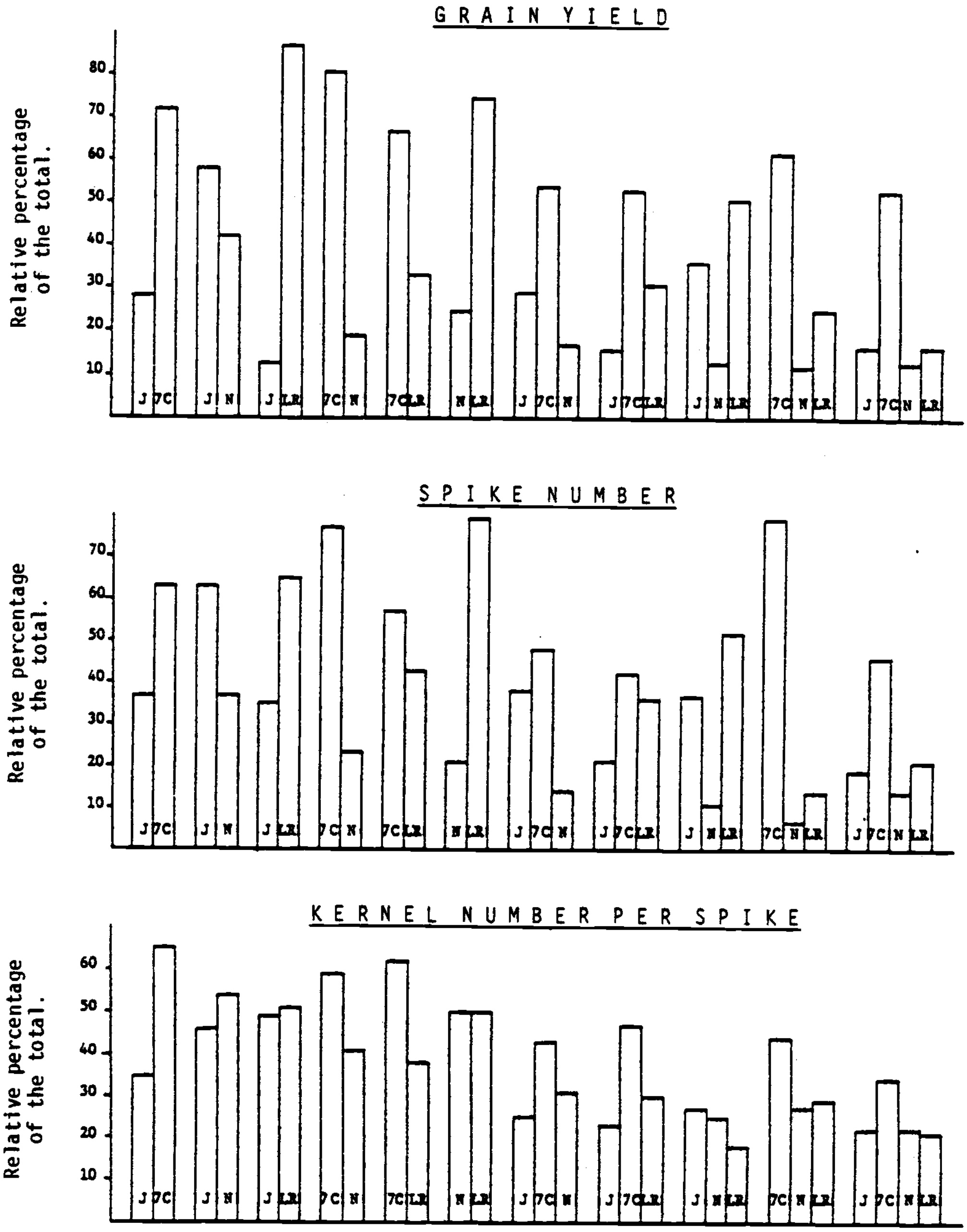


Figure 3. Relative percentage of the total contributed by each of the components of the composite for grain yield, spike number and kernel number per spike for the second derived population grown in 1977-78.



For spike number per plot, LR had the highest (79%) and N the lowest percentage (21%) for two cultivar composite treatments (Figure 3). With three cultivar composite treatments, 7C was the highest (79%) and N the lowest (7%). In the composite treatment with four cultivars, 7C had the highest (46%) and N the lowest percentages (14%) for this trait.

As it can be noted in Figure 3, the highest percentage for kernel number per spike was 65% for 7C with the lowest being 35% for J in the two cultivar composites. For three cultivar composites, 7C had the highest value (47%) and J the lowest (23%). In the composite treatment with four cultivars, 7C had the highest percentage for kernel number (34%) and J, N and LR the lowest (22%).

General competitive ability

General competitive ability was measured as the yielding ability of each component cultivar across composite treatments for each of the three populations. To determine general competitive ability across composite treatments, the contribution of each component cultivar was computed for each trait within each composite treatment in the three populations. For example, the total grain yield of a single composite treatment is considered to be 100 percent. Since there are 11 composite treatments, the total yield would be 1,100 percent. The total yield percentage contributed by a single component cultivar would be determined by summing the percentage values of each component cultivar across composite treatments and dividing by 11. The individual cultivars are presented in terms of their competitive ability for the six traits in each population (Table 17).

For grain yield and kernels per spike, 7C was equal or superior to the other cultivars in all three populations. The percentage of the

Table 17. General competitive ability for six traits involving pure stands and all possible composite combinations of four cultivars representing three different populations.

	1975-76				1976-77				1977-78			
	BASE POPULATION				FIRST DERIVED POPULATION				SECOND DERIVED POPULATION			
	J	7C	N	LR	J	7C	N	LR	J	7C	N	LR
1. Grain yield.	189.3	235.5	159.6	237.6	137.6	196.5	81.0	186.0	136.91	326.1	98.91	206.6
	22.0*	29.0	20.0	29.0	23.0	33.0	14.0	30.0	18.0	40.0	13.0	29.0
2. Spike number.	120.0	122.3	104.7	149.9	118.2	111.1	63.5	144.1	108.7	204.2	57.7	144.9
	23.0	25.0	21.0	30.0	26.0	27.0	15.0	32.0	23.0	37.0	12.0	28.0
3. Spikelet number/spike.	18.2	17.5	18.6	16.6	19.7	19.5	20.0	18.1	18.4	19.4	19.4	18.0
	26.0	26.0	25.0	24.0	25.0	25.0	26.0	24.0	29.0	21.0	25.0	24.0
4. Kernel number/spike.	43.6	51.2	45.0	43.4	47.6	64.8	50.2	46.8	31.9	49.4	35.4	32.2
	24.0	28.0	24.0	24.0	23.0	30.0	24.0	23.0	22.0	32.0	24.0	22.0
5. Kernel weight.	4.19	3.94	3.91	4.34	3.8	3.6	3.4	3.9	4.8	4.2	5.0	4.6
	25.0	25.0	24.0	26.0	25.0	25.0	24.0	26.0	26.0	23.0	31.0	20.0
6. Plant height.	95.0	95.6	97.4	104.5	90.0	85.0	83.0	99.0	93.3	90.9	94.1	100.7
	24.0	24.0	25.0	26.0	25.0	24.0	24.0	27.0	25.0	24.0	25.0	26.0

* Percentage.

population contributed by 7C increased each year from 29% in the base population in 1975-76 to 40% in the second derived population in 1977-78 for grain yield and from 28% to 32% for kernel number.

Nuri was the poorest in the base population (20%), first derived (14%) and second derived (13%) populations for grain yield in 1975-76, 1976-77 and 1977-78, respectively. Jupateco and Lerma Rojo declined in kernel number per spike from 24% in the base population to 22% in the second derived population. Lerma Rojo was superior for spike number per plot in the base (30%) and first (32%) derived populations; however, 7C was superior in the second derived population (37%). The contribution of J to the total percentage of the population for spikelet number per spike was higher (29%) in the second derived population and equal to 7C in the base (26%) and first derived (25%) populations. Nuri had the highest (26%) contribution in the first derived population.

For 100 kernel weight, LR had the highest (26%) contribution in the base and first derived populations and N in the second derived population (31%). Lerma Rojo had the highest contribution for plant height in the three populations.

Comparison of the three populations grown during the same year.

The observed mean squares for the seven traits measured in the 1977-78 growing season are provided in Table 18. Significant differences were found for the treatments involving the seven traits; however the population x treatment interaction was not significant and, except for 100 kernel weight, there were no significant differences between populations. The coefficients of variation ranged from 13.2% for kernel number per spike to 3.6% for heading date.

In Tables 19-25, mean values for treatments and populations are presented for each of the seven traits measured. When the average of

Table 18. Observed mean square values from the analysis of variance for each of the seven traits representing the base, first and second derived populations involving 15 pure stands and composite treatments in the same year.

Source of variation	df	Grain Yield	Spike Number	Spikelets per Spike	Kernels per Spike	100 Kernel Weight	Plant Height	Heading Date
POPULATION (POP)	2	2928.17	147.41	0.62	66.66	1.87*	2.02	0.50
TREATMENT (TMTS)	14	8898.82**	7559.26**	4.71**	214.53**	0.43**	98.29**	50.15**
POP X TMTS	28	1843.29	620.00	0.52	5.68	0.11	3.06	1.63
POP X BLOCK (B)1/	6	2815.52	1071.24	0.18	41.50	0.25	10.64	11.22
TMTS X BLOCK 2/	42	1918.18	600.00	0.44	9.20	0.07	4.47	1.59
POP X TMTS X B 3/	84	1546.43	494.71	0.39	5.99	0.09	5.03	1.01

*Significant at the 5% level.
**Significant at the 1% level.
1/Error term for population.
2/Error term for treatments.
3/Error term for population x treatment interaction.

the three populations is considered for grain yield (Table 19), 7C was the only treatment significantly different from N, LR, J-N and N-LR. No significant differences between populations or treatments within populations were found. The mean value for grain yield of the four pure stands (477.2 g) for the three populations was slightly below the mean of the 11 composite treatments (495.3 g) and also the overall mean (490.4 g).

For spike number per plot, mean values are noted in Table 20. The composite J-LR had the highest three population average and was significantly different from the other treatments with the exception of J, LR and J-N-LR. There were no significant differences between populations and among treatments within individual populations. The three population average of the four pure stands (303.0) was higher than the mean of the 11 composite treatments (300.3) and the overall mean (301.0).

Mean values of spikelet number per spike are presented in Table 21. Nuri in a pure stand had the highest number when the average of the three populations was observed. It was significantly different from the other treatments wtih the exception of J, J-N and 7C-N. There were no significant differences between populations and among treatments within each population. The three population average of the four pure stands (19.4) was above the mean of the 11 composite treatments (18.8) and the overall mean (19.0).

Kernel number per spike mean values are presented in Table 22. In a pure stand, 7C had the highest three-population average which was significantly different from all other treatments. No significant differences between populations among treatments within each population were observed. The three-population average of the four pure stands

Table 19.

Mean values for grain yield (gm) for 15 treatments involving pure stands and composites in the base, first and second derived populations grown in 1977-78.

Treatments	Average of Populations		Populations Base /2	First /3	Second /4
J	480.1	a-c	473.1	482.7	484.5
7C	531.2	a	558.9	530.6	504.2
N	432.1	c	453.2	423.2	420.0
LR	465.2	bc	444.3	478.5	472.8
J-7C	515.3	ab	495.2	525.0	525.9
J-N	462.9	b-c	462.0	466.5	460.2
J-LR	487.5	a-c	492.9	501.3	468.3
7C-N	496.4	ab	429.4	519.9	540.0
7C-LR	507.4	ab	519.4	514.9	487.8
N-LR	462.9	bc	464.3	471.5	453.1
J-7C-N	516.4	ab	498.6	539.1	511.6
J-7C-LR	499.2	ab	502.5	496.3	498.9
J-N-LR	476.9	a-c	468.9	469.4	492.5
7C-N-LR	500.9	ab	472.6	516.0	514.3
J-7C-N-LR	522.9	a	515.9	525.7	527.5
AVERAGE					
Pure stands	477.2		482.4	478.8	470.4
Composites	495.3		483.7	504.1	498.2
Overall	490.4		483.3	497.3	490.7

1/Mean within column not followed by the same letter differ significantly at 1% level of probability according to Duncan's multiple range test.

2/Base population.
3/First derived population.
4/Second derived population.

Table 20.

Mean values for number of spikes for 15 treatments involving pure stands and composites in the base, first and second derived populations grown in 1977-78.

Treatments	Average of Populations	Populations Base /2	First /3	Second /4
J	339.2 a	321.0	342.8	353.8
7C	277.5 d-f	294.3	273.3	265.0
N	262.8 f	267.8	258.3	262.3
LR	332.6 ab	325.5	337.8	334.5
J-7C	299.1 cd	306.0	296.3	295.0
J-N	302.8 bd	310.8	298.0	299.5
J-LR	348.3 a	359.8	343.5	341.8
7C-N	266.6 ef	258.5	256.5	284.8
7C-LR	293.7 c-e	280.5	315.3	285.3
N-LR	305.8 bd	290.5	306.8	320.3
J-7C-N	286.4 d-f	300.3	285.3	273.8
J-7C-LR	301.8 b-d	313.8	299.3	292.5
J-N-LR	319.5 a-c	324.8	309.8	324.0
7C-N-LR	286.0 d-f	284.5	289.5	284.3
J-7C-N-LR	293.0 c-e	300.5	304.0	274.8
AVERAGE				
Pure stands	303.0	302.2	303.1	303.9
Composites	300.3	302.7	300.4	297.8
Overall	301.0	302.6	301.1	299.4

1/Mean within column not followed by the same letter differ significantly at 1% level of probability according to Duncan's multiple range test.

2/Base population.
3/First derived population.
4/Second derived population.

Table 21.

Mean values for number of spikelets per spike for 15 treatments involving pure stands and composites in the base, first and second derived populations grown in 1977-78.

Treatments	Average of Populations	Populations		
		Base /2	First /3	Second /4
J	19.5 a-c	19.5	20.0	19.0
7C	19.2 b-d	19.5	18.2	19.7
N	20.4 a	20.2	20.0	21.0
LR	18.3 e	18.5	18.5	17.7
J-7C	19.0 b-e	18.8	19.0	19.1
J-N	19.7 ab	20.1	19.2	19.6
J-LR	18.1 e	18.2	18.0	18.1
7C-N	19.6 ab	19.7	19.3	19.7
7C-LR	18.4 de	18.3	18.3	18.3
N-LR	19.0 b-e	19.0	19.2	18.7
J-7C-N	18.9 b-e	19.0	18.9	18.9
J-7C-LR	18.4 de	18.7	18.3	18.0
J-N-LR	18.9 b-e	18.9	19.0	18.9
7C-N-LR	18.7 c-e	18.6	18.8	18.7
J-7C-N-LR	18.6 c-e	18.9	18.2	18.5
AVERAGE				
Pure stands	19.4	19.4	19.2	19.4
Composites	18.8	18.9	17.0	18.8
Overall	19.0	19.1	18.8	18.9

1/Mean within column not followed by the same letter differ significantly at 1% level of probability according to Duncan's multiple range test.

2/Base population.
3/First derived population.
4/Second derived population.

Table 22.

Mean values for number of kernels for 15 treatments involving pure stands and composites in the base, first and second derived populations grown in 1977-78.

Treatments	Average of Populations	Populations Base /2	First /3	Second /4
J	33.9 e-g	35.5	33.5	32.7
7C	49.8 a	51.2	50.2	48.0
N	40.0 bc	40.2	40.7	39.0
LR	33.7 fg	34.0	34.0	33.0
J-7C	39.7 bc	39.7	40.1	39.3
J-N	38.5 b-d	41.2	37.8	36.6
J-LR	32.0 g	32.1	32.8	31.1
7C-N	41.7 b	42.6	42.3	40.3
7C-LR	40.2 bc	42.3	40.7	37.6
N-LR	36.6 c-f	38.6	35.3	36.0
J-7C-N	39.3 bc	38.5	39.7	39.5
J-7C-LR	36.8 c-f	39.3	37.7	33.5
J-N-LR	35.3 d-g	34.8	35.4	35.8
7C-N-LR	39.5 bc	40.9	39.8	37.9
J-7C-N-LR	37.6 c-e	38.6	36.2	37.9
AVERAGE				
Pure stands	39.3	40.2	39.6	38.2
Composites	37.9	39.0	38.0	36.9
Overall	38.3	39.3	38.4	37.2

1/Mean within column not followed by the same letter differ significantly at 1% level of probability according to Duncan's multiple range test.

2/Base population.
3/First derived population.
4/Second derived population.

39.3) was above the mean of the 11 composite treatments (37.9) and the overall mean (38.3).

In Table 23, the mean values for 100 kernel weight are provided. The composite treatments J-7C-N, J-N-LR and J-7C-N-LR had the highest averages over populations which were significantly different from J, 7C, N, LR and J-N only. There were significant differences between populations with the highest 100 kernel weight being noted for the second derived population (4.4 g). No significant differences among treatments within populations were detected. The average over the three populations of the four pure stand (4.1 g) was below the mean of the 11 composite treatmens (4.4 g) and the overall mean (4.3 g).

Mean values for plant height are found in Table 24. Lerma Rojo had the highest three-population average and was significantly different from the remaining treatments with the exception of J-LR. There were no significant differences between populations and among treatments within populations. The three-population mean of the four pure stands (96.2 cm) was slightly greater than the mean of the 11 composite treatments (95.2 cm) and the overall mean (95.7 cm).

Table 25 provides the mean values for heading date for treatments and populations. Jupateco was the latest in the three-population average and was significantly different from the other treatments. No significant differences between populations and among treatments within populations were detected. The three-population mean of the four pure stands (67.7), 11 composite treatments (67.2) and overall treatments (67.3) was nearly the same even though a significant difference was noted from the analysis of variance.

Table 23.

Mean values for 100 kernel weight (gm) for 15 treatments involving pure stands and composites in the base, first and second derived populations grown in 1977-78.

Treatments	Average of Populations	Populations		
		Base /2	First /3	Second /4
J	4.2 bc	4.1	4.2	4.1
7C	3.9 c	3.8	3.8	3.9
N	4.2 bc	4.0	4.2	4.1
LR	4.2 bc	4.0	4.1	4.3
J-7C	4.3 ab	4.1	4.2	4.4
J-N	4.2 bc	3.9	4.2	4.3
J-LR	4.4 ab	4.3	4.4	4.4
7C-N	4.3 ab	4.0	4.3	4.5
7C-LR	4.4 ab	4.3	4.2	4.4
N-LR	4.3 ab	4.0	4.4	4.4
J-7C-N	4.6 a	4.2	4.6	4.9
J-7C-LR	4.5 ab	4.1	4.2	5.0
J-N-LR	4.6 a	4.3	4.4	4.8
7C-N-LR	4.4 ab	4.0	4.5	4.6
J-7C-N-LR	4.6 a	4.4	4.8	4.6
AVERAGE				
Pure stands	4.1	4.0	4.1	4.1
Composites	4.4	4.1	4.4	4.6
Overall	4.3	4.1	4.3	4.4

1/Mean within column not followed by the same letter differ significantly at 1% level of probability according to Duncan's multiple range test.

2/Base population.
3/First derived population.
4/Second derived population.

Table 24.

Mean values for plant height (cm) for 15 treatments involving pure stands and composites in the base, first and second derived populations grown in 1977-78.

Treatments	Average of Populations	Populations Base /2	First /3	Second /4
J	98.0 bc	98.5	97.5	98.0
7C	90.5 g	90.5	90.5	90.5
N	95.0 de	95.0	94.0	96.2
LR	101.2 a	102.0	102.0	99.2
J-7C	92.1 fg	91.7	92.7	92.0
J-N	95.6 c-e	95.5	95.5	96.0
J-LR	98.6 ab	98.2	99.0	98.7
7C-N	92.8 e-g	92.0	93.0	93.5
7C-LR	95.2 de	95.7	95.0	95.0
N-LR	98.5 b	98.2	99.7	97.7
J-7C-N	93.3 ef	94.2	94.2	91.5
J-7C-LR	94.7 e	94.5	95.0	94.7
J-N-LR	97.5 b-d	97.7	97.2	97.5
7C-N-LR	94.0 ef	95.0	93.0	94.0
J-7C-N-LR	94.5 ef	94.0	95.5	94.2
AVERAGE				
Pure stands	96.2	96.5	96.0	95.9
Composites	95.2	95.2	95.4	94.9
Overall	95.7	95.5	95.6	95.3

1/Mean within column not followed by the same letter differ significantly at 1% level of probability according to Duncan's multiple range test.

2/Base population.
3/First derived population.
4/Second derived population.

Table 25.

Mean values for heading date for 15 treatments involving pure stands and composites in the base, first and second derived populations grown in 1977-78.

Treatments	Average of Populations	Base /2	Populations First /3	Second /4
J	71.9 a1/	71.0	72.0	72.5
7C	69.6 b	70.2	69.2	69.5
N	64.5 f	65.0	63.5	65.2
LR	64.9 ef	65.7	65.0	64.0
J-7C	69.5 b	69.0	69.5	70.0
J-N	67.8 cd	67.5	68.0	68.0
J-LR	66.7 cd	67.0	67.0	66.2
7C-N	67.4 cd	67.5	66.7	68.0
7C-LR	67.6 cd	68.5	66.7	67.7
N-LR	64.2 f	64.7	64.2	63.7
J-7C-N	68.0 bc	64.7	68.0	68.5
J-7C-LR	68.2 bc	67.7	68.5	68.5
J-N-LR	66.1 de	66.2	65.7	66.5
7C-N-LR	66.3 de	66.5	66.2	66.2
J-7C-N-LR	67.5 cd	67.2	68.5	66.7
AVERAGE				
Pure stands	67.7	67.9	67.4	67.8
Composites	67.2	66.9	67.2	67.3
Overall	67.3	67.2	67.2	67.4

1/Mean within column not followed by the same letter differ significantly at 1% level of probability according to Duncan's multiple range test.

2/Base population.
3/First derived population.
4/Second derived population.

Specific competitive ability

The specific competitive ability of each cultivar in the 11 composite treatments is noted in Table 26 for the six traits in each population. For grain yield, 7C and LR had the highest yielding competitive ability for two and three cultivar composites in all three populations. When considering the four cultivar composite, 7C had the highest yielding competitive ability. Nuri was the poorest competitor in all composite treatments.

Specific competitive ability for spike number is observed in Table 26. The component cultivars, 7C and LR, and the highest competitive ability in all composite treatments with the exception of 7C in J-7C-LR and J-7C-N-LR in the base population and 7C-LR in the first derived population. Nuri was again the poorest competitor in all the composite treatments.

In Table 26, the mean values and specific competitive ability for spikelet number per spike in the three populations are presented. Nuri and Siete Cerros had the highest competitive ability in most of the composite treatments in the three populations. For kernel number per spike, the mean values and the specific competitive ability for the component cultivars of the 11 composite treatments are also presented in Table 26. Siete Cerros as a component cultivar had the highest competitive ability for all composite treatments. Jupateco was the poorest competitor in all composite treatments for this trait.

Specific competitive ability for 100 kernel weight, plant height and heading date for the component cultivars within composite treatments in each of the three populations are noted in Table 26. One hundred kernel weight was variable and therefore it was difficult to interpret the competitive ability of the individual cultivars. For plant height,

Table 26. Summary of analysis of variance for within composite treatment for six traits in the base, first and second derived populations involving pure stands and 11 composite treatments in 1977-78.

Treat-ment.		Grain Yield			Spike Number			Spikelets/Spike			Kernels/Spike		
		Base (1)	First (2)	Second (3)	Base (1)	First (2)	Second (3)	Base (1)	First (2)	Second (3)	Base (1)	First (2)	Second (3)
5	J	175.8 b+	141.5 b	147.5 b	150.2	107.0 b	109.5 b	18.5	18.0	18.5 b	26.7 b	29.5 b	27.5 b
	7C	319.4 a	383.6 a	378.5 a	155.7	189.3 a	185.5 a	19.3	19.5	19.7 a	52.7 a	50.8 a	51.2 a
	A.V	*	**	**		**	*			*	*	**	**
6	J	242.9	289.8 a	267.9	154.8	189.0 a	187.3 a	19.8	19.3	19.0 b	38.3	35.3	33.7 b
	N	219.2	176.7 b	192.3	135.0	108.0 b	112.3 b	20.5	19.3	20.3 a	44.3	40.5	39.5 a
	A.V		**			**	*			**			**
7	J	218.7	170.6 b	49.7 b	171.0	131.0 b	121.2 b	19.0 a	18.5	18.0	29.5	28.8 b	34.5
	LR	274.2	330.8 a	318.6 a	188.8	212.5 a	220.5 a	17.5 b	17.5	18.2	34.8	37.0 a	35.3
	A.V		**	**		*	**	*				*	
8	7C	309.0 a	422.7 a	437.0 a	153.7 a	208.8 a	218.5 a	20.3	19.5	19.5	50.5 a	51.0 a	47.5 a
	N	145.4 b	92.2 b	103.1 b	104.8 b	63.0 b	66.2 b	19.3	19.3	20.0	34.7 b	33.8 b	33.3 b
	A.V	**	**	**	*	**	**	NS	NS	NS	*	**	**
9	7C	321.1 a	270.6	324.9 a	141.8	129.3 b	164.0 a	19.3 a	19.5	19.0 a	51.3 a	50.5 a	46.0 a
	LR	198.3 b	244.4	162.9 b	138.8	186.0 a	121.3 b	17.5 b	17.3	17.7 b	33.5 b	31.0 b	28.7 b
	A.V	*		**		*	*	*		**	*	**	**
10	N	197.1 b	126.8 b	112.6 b	122.3 b	81.5 b	68.5 b	20.3 a	19.8	20.0 a	41.5 a	35.0	36.0
	LR	267.2 a	344.7 a	340.4 a	170.8 a	225.3 a	251.7 a	18.0 b	18.8	17.5 b	37.0 b	35.5	36.0
	A.V	*	**	**	*	**	**	*		*	*		
11	J	140.7 b	93.3 b	149.9 b	103.3 b	65.3 b	104.0 b	18.0 b	18.0 b	18.7	29.5 b	28.5 c	30.2 c
	7C	240.3 a	351.8 a	275.4 a	115.8 a	165.5 a	130.5 a	19.5 a	19.5 a	19.7	51.0 a	53.0 a	51.2 a
	N	117.6 b	94.1 b	86.3 c	81.3 c	54.5 b	39.3 c	19.8 a	19.5 a	18.5	35.3 b	37.8 b	37.3 b
	A.V	**	**	**	**	**	**	*	*		**	**	**
12	J	135.0 b	78.8 c	81.6 c	105.5	62.3 c	62.5 c	18.5 b	17.8	17.3	29.0 c	27.5 b	23.0 c
	7C	210.5 a	271.4 a	265.0 a	101.0	134.8 a	124.0 a	19.8 a	19.3	19.0	52.0 a	52.0 a	47.8 a
	LR	157.1 b	146.1 b	152.3 b	107.3	102.3 b	106.0 b	18.0 b	18.3	18.0	37.3 b	33.8 b	30.0 b
	A.V	*	**	**		**	**	*			**	**	**
13	J	163.1	130.2 b	174.9 b	112.3	83.8 b	119.5 b	18.8 b	18.8	19.2	34.5	31.5 c	40.0
	N	141.2	115.7 b	65.9 c	94.0	69.8 b	35.7 c	20.0 a	20.3	19.0	36.0	37.0 a	37.2
	LR	164.7	223.5 a	251.7 a	118.5	156.3 a	168.7 a	18.0 c	18.3	18.7	34.0	36.3 b	30.2
	A.V		**	**	NS	**	**	**	**			*	
14	7C	195.9	260.6 a	321.4 a	105.0 a	125.3 a	158.3 a	19.8 a	19.3	19.0	51.5 a	51.0 a	50.0 a
	N	126.2	75.5 c	63.6 c	70.5 b	43.3 b	40.7 c	19.8 a	18.8	19.3	37.5 b	34.8 b	31.3 b
	LR	150.6	180.0 b	129.3 b	100.0 a	121.0 a	85.3 b	17.8 b	18.5	18.0	34.0 b	33.8 b	32.5 b
	A.V		**	**	*	**	**	**	NS	NS	**	**	**
15	J	104.3 c	94.0 c	87.1 b	71.7ab	68.8 b	56.5 b	18.3	18.0	17.7 b	30.5 c	29.0 b	34.0 b
	7C	179.0 a	226.2 a	280.6 a	81.5 a	100.8 a	133.2 a	19.8	18.3	20.0 a	53.0 a	50.8 a	52.0 a
	N	102.9 c	56.4 d	68.6 b	63.0 b	34.3 c	41.3 b	19.5	19.3	18.5 b	36.0 b	32.3 b	33.0 b
	LR	129.8 b	149.0 b	91.2 b	84.2 a	100.3 a	60.7 b	18.3	17.8	17.7 b	35.0 b	32.8 b	32.5 b
	A.V	**	**	**	*	**	**			**	**	**	**

A.V = Analysis of variance *, Significant at 5% level **, Significant at 1% level.
(1) Base population (2) First derived population (3) Second derived population.
+ Least significant differences, means followed by different lower case letter differ significantly at the one percent level.

Table 26 .- Continued

Treat-ment.	Kernel weight			Plant Height			Heading date		
	Base (1)	First (2)	Second (3)	Base (1)	First (2)	Second (3)	Base (1)	First (2)	Second (3)
5 J	4.3	4.5 a	4.8 a	93.0	94.3	93.0	68.5	68.0 b	68.7
7C	3.9	4.0 b	4.1 b	90.0	90.5	90.7	69.3	70.8 a	70.7
A.V		*	*					*	
6 J	4.1	4.4	4.3	94.8	95.5	96.0	68.8	70.5	70.3 a
N	3.7	4.1	4.4	96.0	95.5	96.0	65.8	65.5	65.3 b
A.V									**
7 J	4.4	4.5	4.7	95.0 b	96.0 b	93.7 b	68.0	68.3	67.0 a
LR	4.2	4.3	4.1	100.8 a	101.5 a	103.0 a	65.5	65.5	64.8 b
A.V				**	*	**			**
8 7C	4.0	4.0 b	4.3	90.3 b	93.0	93.0	70.0 a	69.0 a	70.0 a
N	4.0	4.7 a	4.8	93.3 a	93.0	93.7	64.8 b	64.3 b	66.0 b
A.V		*		**			**	*	**
9 7C	4.5	4.2	4.3	90.0 b	89.0 b	90.5 b	71.0 a	69.3 a	70.0 a
LR	4.3	4.3	4.5	100.8 a	100.5 a	99.5 a	65.3 b	64.0 b	64.8 b
A.V				*	**	**	**	**	**
10 N	3.9	4.5	4.6	95.0 b	96.3 b	94.2 b	65.3	63.8	63.5
LR	412	4.3	4.2	101.8 a	102.8 a	100.5 a	64.7	64.3	63.3
A.V	NS			*	*	*			
11 J	4.7	5.1 a	4.7 b	96.3 a	94.8 a	91.0	68.0ab	69.0 a	69.5 b
7C	4.1	4.0 b	4.1 b	91.8 c	91.8 b	91.7	70.0 a	70.5 a	71.0 a
N	4.1	4.6 b	5.9 a	95.5 b	95.5 a	91.7	66.0 b	64.5 b	66.0 c
A.V		*	**	**	*		*	**	**
12 J	4.4	4.7 a	5.7 a	94.8 b	93.0 b	92.5 b	68.0 b	69.5 a	68.8 a
7C	4.0	3.9 b	4.5 b	90.0 c	90.8 b	91.3 b	69.8 a	70.5 a	70.5 a
LR	3.9	4.2 b	4.8 b	100.0 a	100.8 a	100.7 a	65.5 c	66.3 b	65.0 b
A.V		*	**	**	**	**	**	*	**
13 J	4.3	4.9 a	4.3	95.0 b	94.3 b	94.7 b	67.8 a	68.0	67.5 a
N	4.4	4.5ab	5.0	95.5 b	96.3 b	96.7 b	65.3 b	64.5	65.5 b
LR	4.3	3.9 b	5.2	102.5 a	102.0 a	101.2 a	65.5 b	65.0	66.3 b
A.V		*		**	**	*	*		*
14 7C	3.9	4.1 b	4.1 c	91.8 b	87.8 c	90.0 b	70.8 a	69.5 a	69.5 a
N	4.1	5.1 a	5.1 a	93.5 b	92.0 b	92.5 b	64.5 b	65.0 b	64.8 b
LR	4.5	4.4 b	4.7 b	100.0 a	99.8 a	99.0 a	64.8 b	64.5 b	64.3 b
A.V		**	**	**	**	*	**	**	**
15 J	4.9 a	4.7	4.6 a	91.8bc	95.5	92.0 b	69.3 b	68.5	67.5 b
7C	4.2 c	4.3	4.0 b	89.5 c	90.5 c	88.7 b	70.5 a	70.3	69.3 a
N	4.5 b	5.2	5.0 a	93.8 b	95.8 b	93.5 b	64.8 c	66.0	65.0 c
LR	4.4bc	4.6	4.6 a	100.5 a	99.3 a	101.0 a	65.5 c	68.3	64.5 c
A.V	**		*	**	**	**	**		**

LR had the highest value in all the composite treatments. For heading date (Table 26), J and 7C were the latest in all the composite treatments including the three populations.

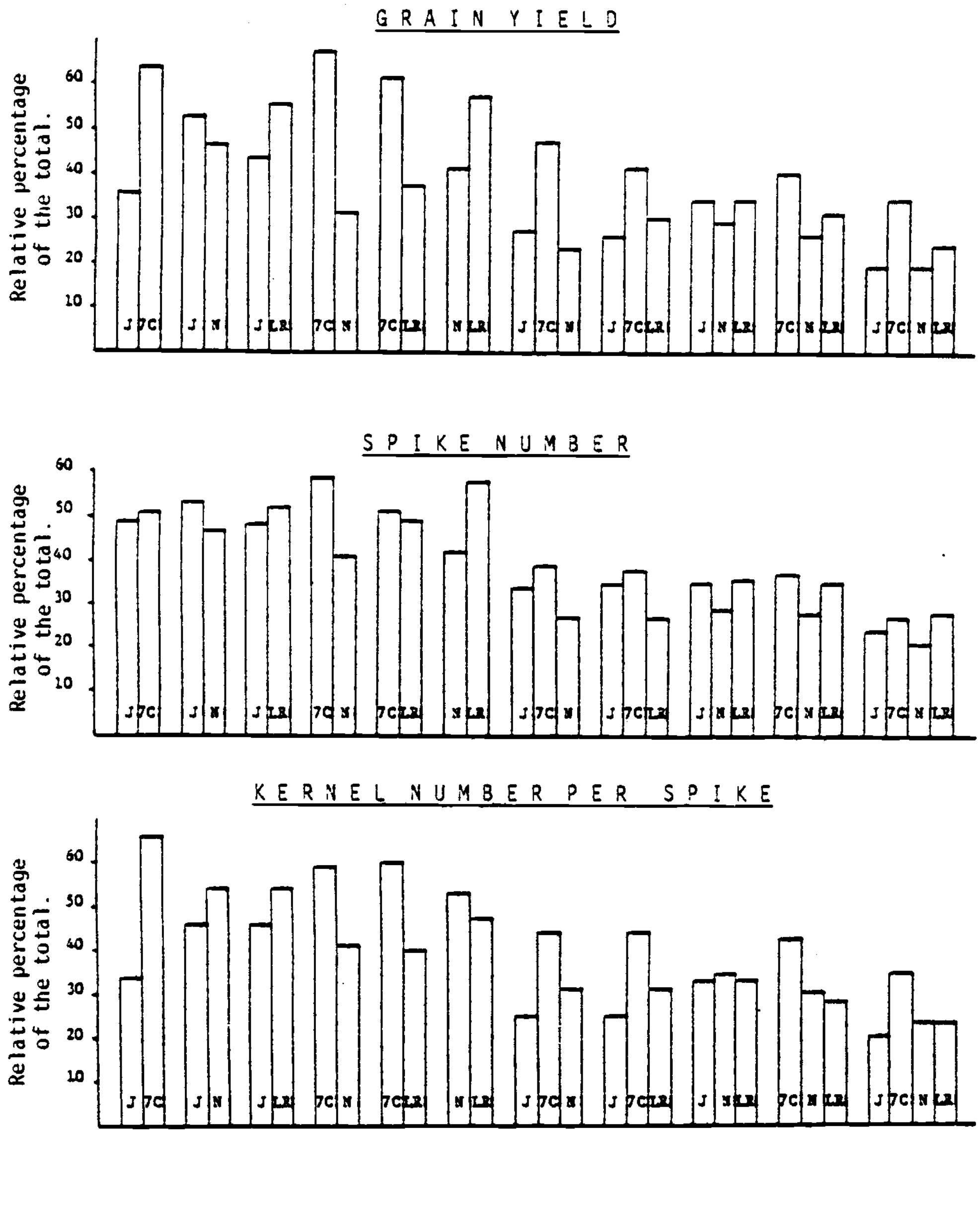
The percentage of the mean for each component cultivar within composite treatments is presented in Figures 4, 5 and 3 for the base, first and second derived populations, respectively. This percentage was computed for grain yield, spike number per plot and kernel number per spike for each of the composite treatments in each population. This percentage is a measure of specific competitive ability of component cultivars within composite treatments.

For grain yield (Figure 4), 7C had the highest percentage (68%) and N the lowest (32%) for two cultivar composite treatments in the base population. When considering those composite treatments with three cultivars involved, 7C had the highest (48%) and N the lowest percentage (24%). In the four cultivar composite treatment, 7C had the highest (35%) and N the lowest grain yield percentage (20%).

In two cultivar composite treatments, the component cultivar 7C had the highest percentage (59%) for spike number per plot and N the lowest (41%) in the base population (Figure 4). When considering three cultivar composite treatments, 7C had the highest (39%) and Nuri the lowest percentage (27%). In the composite J-7C-N-LR, Lerma Rojo had the highest (28%) and Nuri the lowest percentage (21%). For kernel number per spike, the highest percentages (66%, 44% and 34%) were found in Siete Cerros for all composite treatments in the base population (Figure 4).

The relative percentage of the total contributed for each component cultivar within the composite treatments for grain yield, spike number per plot and kernel number per spike in the first derived population are

Figure 4. Relative percentage of the total contributed by each of the components of the composite for grain yield, spike number and kernel number per spike for the base population grown in 1977-78.



noted in Figure 5. For grain yield, 7C had the highest percentage (82%) for those treatments which consisted of a mixture of two cultivars. Considering the three cultivar composites, 7C had the highest (65%) and N the lowest percentage (15%). In the four cultivar composite, 7C had the highest (43%) and N the lowest percentage (11%).

For spike number per plot, 7C had the highest (77%) and N the lowest percentage (23%) in the treatments with two cultivar composites (Figure 5). When considering those treatments with three cultivar composites, 7C had the highest (58%) and N the lowest percentage (15%). In the composite J-7C-N-LR, the component cultivars 7C and LR were the highest (33%) and N was the lowest (11%).

The highest percentage for kernel number per spike was 62% in 7C and the lowest (37%) in J for the treatments with a two cultivar composite (Figure 5). For those treatments with three cultivar composites, 7C had the highest (46%) and J the lowest (24%). Siete Cerros had the highest (35%) in the composite J-7C-N-LR and Jupateco the lowest percentage (20%).

The relative percentage of the total contributed for each component cultivar in the composite treatments for grain yield, spike number per plot and kernel number per spike in the second derived population was previously presented in Figure 3.

General competitive ability

General competitive ability was measured as the yielding ability of each component cultivar across composite treatments for each of the three populations. The contribution of each component cultivar was computed for each trait within each composite treatment in the three populations. For grain yield, spike number per plot, spikelet number per spike and kernel number per spike, Siete Cerros was superior to the

Figure 5. Relative percentage of the total contributed by each of the components of the composite for grain yield, spike number and kernel number per spike for the first derived population grown in 1977-78.

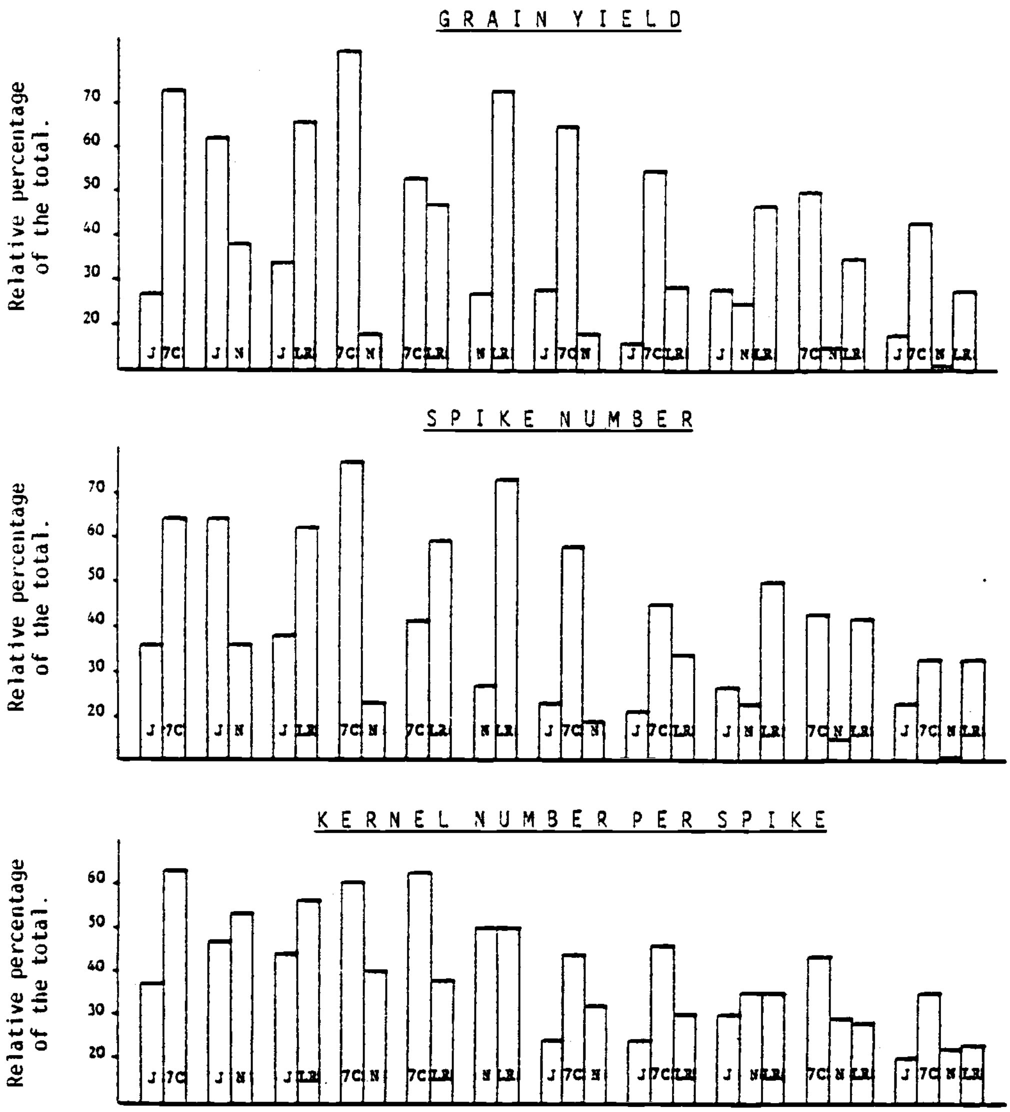


Table 27. General competitive ability for four cultivars in pure stands and composites combinations in the base, first and second derived populations involving seven agronomic traits grown in the same year.

TRAITS	BASE POPULATION				FIRST DERIVED POPULATION				SECOND DERIVED POPULATION			
	J	7C	N	LR	J	7C	N	LR	J	7C	N	LR
1. Grain yield	168.6	253.6	149.9	191.7	142.6	312.4	105.3	231.2	136.95	326.1	98.91	206.6
	22.0	33.0	20.0	25.0	18.0	38.0	14.0	30.0	18.0	40.0	13.0	29.0
2. Spike number	124.1	122.0	97,1	129.8	101.10	150.5	64.9	157.6	108.7	204.2	57.7	144.9
	25.0	28.0	21.0	26.0	21.0	33.0	14.0	32.0	23.0	37.0	12.0	28.0
3. Spikelet number/spike	18.7	19.6	19.9	17.9	18.4	19.3	19.4	18.0	18.4	19.4	19.4	18.0
	25.0	26.0	26.0	23.0	25.0	26.0	25.0	24.0	29.0	21.0	25.0	24.0
4. Kernel number/spike	31.1	51.7	37.9	35.1	30.0	51.3	35.9	34.3	31.9	49.4	35.4	32.2
	21.0	32.0	24.0	23.0	20.0	32.0	24.0	24.0	22.0	32.0	24.0	22.0
5. 100 kernel weight	4.42	4.00	4.10	4.30	4.7	4.1	4.7	4.3	4.8	4.2	5.0	4.6
	26.0	24.0	25.0	25.0	27.0	23.0	26.0	24.0	26.0	23.0	31.0	20.0
6. Plant height	94.5	90.5	94.6	100.9	94.8	90.5	94.9	100.9	93.3	90.9	94.1	100.7
	25.0	24.0	25.0	26.0	25.0	24.0	25.0	26.0	25.0	24.0	25.0	26.0
7. Heading date	68.3	70.2	65.2	65.3	68.8	70.0	64.8	64.4	68.5	70.1	65.0	64.7
	25.0	26.0	25.0	24.0	25.0	26.0	24.0	25.0	25.0	26.0	24.0	24.0

other cultivars for general competitive ability in the three populations (Table 27). Nuri was equal to 7C for spikelet number per spike in the base population. Jupateco was superior for 100 kernel weight in the base and first derived populations and Nuri in the second derived population. Lerma Rojo was the tallest cultivar and Siete Cerros was the latest in the three populations.

Association of Yield and Yield Components for Pure Stands and the Four Cultivar Composite.

The possible associations between the traits measured were determined for Jupateco, Siete Cerros, Nuri and Lerma Rojo in pure stands and in a four cultivar composite for the base and second derived populations grown in 1977-78.

In Table 28, the phenotypic correlations between grain yield and yield components are presented for cultivars grown in pure stands. The associations between grain yield and spike number per plot were positive and significant for the four pure stands. Phenotypic correlations ranged from 0.949 in 7C to 0.655 in LR. Number of spikelets per spike, kernel number per spike and 100 kernel weight showed no significant association with grain yield. Spike number per plot showed no significant association with spikelet number per spike, kernel number per spike and 100 kernel weight. Spikelet number per spike exhibited no significant association with kernel number per spike and 100 kernel weight. Kernel number per spike had no significant association with 100 kernel weight.

Phenotypic correlations between the traits measured for individual components of the composites J-7C, 7C-LR, J-7C-LR and J-7C-N-LR in the base and second derived populations are shown in Appendix Table 5-12.

Table 28. Phenotypic correlation coefficients between yield and yield components for Jupateco, Siete Cerros, Nuri and Lerma Rojo as a pure stand in 1978.

	Grain Yield per Plot	No. of Spikes per Unit Area	No. of Spikelets per Spike	No. of Kernels per Spike	100 Kernel weight
Grain Yield per Plot	1.00 +	0.7714 **	0.1459	0.4798	0.1935
	1.00	0.9490 **	-0.1098	0.5612	0.5553
	1.00	0.7000 **	0.1308	0.3523	0.1148
	1.00	0.6550 *	0.0766	0.5128	-0.0147
No. of Spikes per Unit Area		1.00	0.0514	-0.1181	-0.0656
		1.00	-0.0572	-0.2226	-0.4787
		1.00	-0.0960	0.1648	-0.4704
		1.00	0.0164	0.1404	-0.1788
No. Spikelets per Spike			1.00	0.1074	0.2405
			1.00	0.3123	0.1102
			1.00	-0.2512	0.0750
			1.00	-0.1768	-0.1219
No. of Kernels per Spike				1.00	-0.0135
				1.00	-0.6001
				1.00	0.0352
				1.00	-0.3244
100 Kernel Weight					1.00
					1.00
					1.00
					1.00

n=28

*, ** Significant at 5% and 1% levels of probability, respectively.
+ From the upper to the lower correlation coefficients, within each cell represent, Jupateco, Siete Cerros, Nuri and Lerma Rojo, respectively.

The association between traits in each component for the base and second derived populations showed little or no changes from those observed in the pure stands.

The path-coefficient analysis for each pure stand is presented in Table 29. Path-coefficient analyses illustrated that the relationship between grain yield and yield components were relatively constant for the cultivars. The direct effects between spike number per plot and grain yield were 0.8593, 0.9468, 0.8841 and 0.9238 for J, 7C, N and LR, respectively. These values can be interpreted to mean that for each standard deviation unit increase in spike number per unit area, there will be a corresponding increase of 0.8593, 0.9468, 0.8841 and 0.9238 in grain yield for J, 7C, N and LR, respectively. All direct effects from the path-coefficient analysis can be interpreted in the same manner. The direct effects of kernel number per spike on grain yield were 0.5876, 0.3530, 0.5183 and 0.7503 for J, 7C, N and LR, respectively. Spikelet number per spike showed the lowest direct effect on grain yield in each cultivar. The direct effect of kernel weight on grain yield was larger for N and LR than for J and 7C; however, they were also low compared to spike number per plot and kernel number per spike.

In Tables 30 and 31, the path-coefficient analysis for each component cultivar of the J-7C-N-LR composite in the base population and second derived population is presented. The results of the path-coefficent analysis for each cultivar in the composite showed no changes from the base to the second derived populations for the direct effect between grain yield and spike number per plot and spikelets per spike. However, a decrease in values of the direct effect between grain yield and kernel number per spike was observed for the four cultivars from the base to

Table 29.

Direct and indirect effects between grain yield and the components of yield for Jupateco, Siete Cerros, Nuri and Lerma Rojo composite in pure stands grown in 1977-78.

Pathways of association	Jupateco	Siete Cerros	Nuri	Lerma Rojo
Yield/plot vs No. of spikes per unit area				
Direct effect	0.8593	0.9468	0.8841	0.9238
Indirect effect via No. of spikelets per spike	-0.0013	-0.0002	-0.0053	0.0001
Indirect effect via No. of kernels per spike	-0.0694	0.1102	-0.1302	-0.1327
Indirect effect via kernel weight	-0.0173	-0.1095	0.0156	-0.1362
Total correlation	0.7713	0.9473	0.7642	0.6550
Yield/plot vs No. of spikelets per spike				
Direct effect	-0.0249	0.0029	0.0548	0.0072
Indirect effect via No. of spikes per unit area	0.0442	-0.0513	-0.0849	0.0152
Indirect effect via No. of kernels per spike	0.0631	-0.0786	0.0854	0.1053
Indirect effect via kernel weight	0.0634	0.0201	0.0333	-0.0512
Total correlation	0.1458	-0.1069	0.0886	0.0765
Yield/plot vs No. of kernels per spike				
Direct effect	0.5876	0.3530	0.5183	0.7503
Indirect effect via No. of spikes per unit area	-0.1015	0.2957	-0.2221	-0.1633
Indirect effect via No. of spikelets per spike	-0.0027	-0.0006	0.0090	0.0010
Indirect effect via kernel weight	-0.0036	-0.0874	-0.2087	-0.0751
Total correlation	0.4799	0.5607	0.0965	0.5129
Yield/plot vs kernel weight				
Direct effect	0.2637	0.1825	0.4436	0.4198
Indirect effect via No. of spikes per unit area	-0.0564	-0.5682	0.0311	-0.2997
Indirect effect via No. of spikelets per spike	-0.0060	-0.0003	0.0041	-0.0009
Indirect effect via No. of kernels per spike	-0.0079	-0.1690	-0.2438	-0.1342
Total correlation	0.1934	-0.5544	0.2350	-0.0150
Coefficient of determination R^2	99.21	99.33	83.47	98.42

Table 30.

Direct and indirect effects between grain yield and the components of yield for Jupateco, Siete Cerros, Nuri and Lerma Rojo composite in the base population grown in 1977-78.

Pathways of association	Jupateco	Siete Cerros	Nuri	Lerma Rojo
Yield/plot vs No. of spikes per unit area				
Direct effect	1.0996	1.055	0.9719	1.0048
Indirect effect via No. of spikelets per spike	-0.0002	0.0046	-0.0015	-0.0015
Indirect effect via No. of kernels per spike	-0.0816	-0.0591	0.0411	-0.1975
Indirect effect via kernel weight	-0.0913	-0.0784	-0.1421	-0.1201
Total correlation	0.9265	0.9221	0.8694	0.6858
Yield/plot vs No. of spikelets per spike				
Direct effect	0.0120	0.0114	-0.0225	-0.0784
Indirect effect via No. of spikes per unit area	-0.0164	0.4318	0.0644	-0.0195
Indirect effect via No. of kernels per spike	0.1209	0.0958	0.0472	0.0580
Indirect effect via kernel weight	0.0335	-0.0503	-0.0344	0.0633
Total correlation	0.1500	0.4886	0.0548	0.1802
Yield/plot vs No. of kernels per spike				
Direct effect	0.3376	0.3402	0.4343	0.6772
Indirect effect via No. of spikes per unit area	-0.2659	-0.1834	0.0919	-0.2930
Indirect effect via No. of spikelets per spike	0.0043	0.0032	-0.0024	0.0067
Indirect effect via kernel weight	-0.0412	-0.0330	-0.0344	-0.0065
Total correlation	0.0338	0.1270	0.4894	0.3844
Yield/plot vs kernel weight				
Direct effect	0.2102	0.2212	0.2882	0.3166
Indirect effect via No. of spikes per unit area	-0.4777	-0.3739	-0.4792	-0.3810
Indirect effect via No. of spikelets per spike	0.0019	-0.0026	0.0027	0.0157
Indirect effect via No. of kernels per spike	-0.0662	-0.0508	-0.0707	-0.0138
Total correlation	-0.3294	-0.2004	-0.2591	-0.0626
Coefficient of determination R^2	96.31	97.73	98.16	94.37

Table 31.

Direct and indirect effects between grain yield and the components of yield for Jupateco, Siete Cerros, Nuri and Lerma Rojo composite in the second derived population grown in 1977-78.

Pathways of association	Jupateco	Siete Cerros	Nuri	Lerma Rojo
Yield/plot vs No. of spikes per unit area				
Direct effect	0.9668	1.0397	0.8645	1.1083
Indirect effect via No. of spikelets per spike	-0.0138	-0.0015	0.0345	-0.0097
Indirect effect via No. of kernels per spike	-0.0156	-0.0193	-0.0044	-0.0603
Indirect effect via kernel weight	-0.3418	-0.0667	0.0128	-0.0697
Total correlation	0.5956	0.9522	0.9075	0.9686
Yield/plot vs No. of spikelets per spike				
Direct effect	0.1206	-0.0120	-0.1764	-0.0305
Indirect effect via No. of spikes per unit area	-0.1106	0.1261	0.1692	0.3534
Indirect effect via No. of kernels per spike	0.1374	-0.0212	-0.0080	0.0495
Indirect effect via kernel weight	-0.0671	-0.0567	-0.0524	-0.0424
Total correlation	0.0803	0.0362	-0.4060	0.3300
Yield/plot vs No. of kernels per spike				
Direct effect	0.2864	0.2898	0.0147	0.1916
Indirect effect via No. of spikes per unit area	-0.0525	-0.0692	-0.2556	-0.3487
Indirect effect via No. of spikelets per spike	0.0579	0.0009	0.0959	-0.0079
Indirect effect via kernel weight	-0.1590	-0.0829	0.0360	-0.0222
Total correlation	0.1327	0.1386	0.0237	-0.1872
Yield/plot vs kernel weight				
Direct effect	0.4770	0.2447	0.0897	0.1935
Indirect effect via No. of spikes per unit area	-0.6927	-0.2836	0.1235	-0.3993
Indirect effect via No. of spikelets per spike	-0.0170	0.0028	0.1031	0.0067
Indirect effect via No. of kernels per spike	-0.0955	-0.0982	0.0059	-0.0220
Total correlation	-0.0546	-0.1343	0.3222	-0.2212
Coefficient of determination R^2	59,75	99,69	88.54	98,48

the second derived population. The direct effects between grain yield and kernel number per spike were 0.3376, 0.3402, 0.4343 and 0.6772 in the base population in contrast to 0.2864, 0.2898, 0.0147 and 0.1916 in the second derived population for J, 7C, N and LR, respectively. The direct effect between grain yield and kernel weight was increased in J from 0.2102 in the first derived population to 0.4770 in the second derived population. For 7C there was no change at all. However, N and LR showed reduction in their direct effects between grain yield and kernel weight.

For the base and second derived populations, the path-coefficient analysis was determined for the component cultivars of J-7C, 7C-LR and J-7C-LR composites. The results of path-coefficient analysis for the relationship between grain yield and yield components for each component within the composite are presented in Appendix Tables 13-18. These results can be interpreted in the same way as the ones obtained from the composite J-7C-N-LR above.

DISCUSSION

Lack of yield stability in crop species due to adverse environmental factors has long been a concern to plant breeders. Such limiting factors to maximum production as moisture stress, temperature extremes and disease epidemics are well-documented throughout history. Recently the southern corn leaf blight (Helminthosporium torcicum Pass.) in the United States and the leaf rust outbreak in Mexico have been reminders that such problems still remain as a threat to world food production. In both the southern corn leaf blight and leaf rust epidemics, a contributing situation was the extensive use of certain breeding approaches which resulted in narrowing of the genetic diversity within and between commerical cultivars. For southern corn leaf blight it was the total dependence by breeders on the Texas cytoplasm for inducing male sterility in the production of hybrid seed corn. The situation for leaf rust in Mexico is not as clear. There may have been a narrowing of the genetic diversity of the commercial wheat cultivars due to the emphasis placed on the 'Norin 10-Brevor 14' dwarfing source and resulting selection pressure for the semidwarf phenotype. However, the major factor contributing to the lack of yield stability in the Yaqui Valley appears to be the growing of a single cultivar over a large area in successive years. This situation has resulted in the life expectancy of a cultivar to be approximately two to three years in commerical production. Breeding programs in Mexico have been called upon to develop and release cultivars at an ever-increasing frequency. This is expensive both in terms of physical and financial resources and in exhausting the available genetic variation.

Disease and adverse environmental conditions have lead plant breeders to seek other alternatives in providing for greater genetic diversity within and between cultivars. Approaches to gain greater diversity in self-pollinating species have ranged from the releasing of naturally selected bulk populations to the use of multilines and blends of different cultivars to form composite varieties.

It was the major goal of this study to evaluate the use of various combinations of four high yielding cultivars grown as composites in the Yaqui Valley of Mexico in terms of grain yield and yield stability. The four cultivars differed in several morphological and agronomic traits thus they could easily be identified before and after harvest. These cultivars also differed in their reaction to leaf rust with the cultivar Jupateco being resistant when this study was initiated. Unfortunately, due to a change in physiological races or the increase of an existing race, the resistance in Jupateco was overcome by the pathogen in 1976-77. This prevented a valid comparison as to how leaf rust per se influenced the composition of the composites involving Jupateco over time. The 15 treatments which represented the pure stands and all possible combinations or composites were grown as three populations. In each of the three years, equal portions of seed involving the cultivars were reconstructed and identified as the base population. In addition, two derived populations were the result of one and two years of natural selection. The first derived population represented a sample of seed taken from the base population at harvest representing each treatment. A second derived population represented a sample of seed obtained at harvest from the first derived population. During the final year of this three year study, all three populations were available for comparison. This provided an opportunity to not only measure yield and yield stability of the respective treatments but to determine the role of natural selection and the competitiveness of the cultivars making up each of the composites. In addition, the influence of natural selection on the various components of yield were evaluated to determine which trait or traits might provide a greater competitive advantage if genetic shifts among the four cultivars occurred.

Observations regarding the performance of the four cultivars with respect to grain yield and the components of yield when grown in pure stands were as follows:

Jupateco was second to Siete Cerros in grain yield when a three year average is considered. However, Jupateco showed a marked reduction in grain yield in the second year due in part to a heavy leaf rust infection. In the three year average, Jupateco was lower in number of spikes per unit area than Lerma Rojo but higher than both Siete Cerros and Nuri. Jupateco was stable across years for the number of spikelets per spike and plant height but when the number of kernels per spike and 100 kernel weight are considered, a large reduction was noted when the environemental stress was the greatest during the second year.

Siete Cerros exhibited more stability for grain yield and the yield components across years than the other treatments. It also showed the highest kernel number per spike; however, for number of spikes, Siete Cerros was lower than either Jupateco or Lerma Rojo. Spikelets per spike and kernel weight were stable across years.

Nuri was the lowest yielding cultivar. It had a low number of spikes per unit area and was second to Siete Cerros with regard to kernel number per spike. The other yield components were stable across years for this cultivar.

Lerma Rojo had the lowest kernel number per spike but it was second to Jupateco in the number of spikes per unit area. It was also the tallest cultivar. The other yield components of Lerma Rojo were stable. Lerma Rojo and Nuri headed a week earlier than either Jupateco or Siete Cerros.

Base populations across years

In general, Siete Cerros as a pure stand had a higher and more stable grain yield than Jupateco, Nuri, Lerma Rojo and the 11 composite treatments across years. The grain yield of the base population was significantly reduced in 1976-77. This year was characterized by being warmer and wetter than the other two years of the study (Appendix Table 3). These conditions were favorable for a heavy leaf rust infection. Jupateco also showed a significant reduction in grain yield this year which may have resulted from the fact that the leaf rust pathogen overcame the Jupateco source of resistance.

None of the composite treatments yielded more than the best pure stand treatment except for 1976-77. During this year, the component 7C-LR out-yielded the best pure stand (Siete Cerros); however, the difference was not significant. It is interesting to note that during the same year the mean value of the 11 composite treatments was higher than the mean of the four pure stand treatments. The observed interaction between the years, pure stands and composite treatments for the base population across years further reflects the adverse growing conditions experienced in 1976-77. Results from these comparisons support the general conclusion of other investigators in that the greater genetic diversity of the composite is an advantage under stress conditions.

The associations between traits in the four pure stand treatments grown in 1977-78, showed that the number of spikes and number of kernels per spike were the most important traits associated with yield. Path-coefficient analysis further indicated a large direct effect of these two components on grain yield. The selective advantage observed with Siete Cerros and Lerma Rojo in the subsequent derived populations can be attributed to their higher number of kernels per spike and number of spikes, respectively. As a consequence, these two cultivars were contributing a higher portion of kernels to the sample obtained for generating the first and second derived populations. If selection is differential reproduction, than it would appear logical that the cultivar which contributed the most seed to subsequent generations would have a selective advantage.

The question as to the optimum level of genetic diversity to be achieved in composites was not evident from the results of this study. During the first year the composite treatments involving two cultivars were superior; however, three cultivar combinations were higher yielding in the second year. During the third year, the four combination composite was the highest yielding. Of greater importance than the amount of genetic diversity in determining the success of a composite appears to be the selection of the individual cultivars making up the composite treatments. Siete Cerros, which had the highest number of kernels per spike and Lerma Rojo which contributed a large number of spikes per unit area complemented each other in terms of the two components of yield which most effect grain yield. Therefore, in selecting cultivars for composites, it is necessary to evaluate the individual cultivars in terms of their components of yield so that each might complement or compensate for deficiencies associated with the other selected cultivars. This is particularly true for kernels per spike and spikes per unit area since it has been well established that there is a compensating effect among the components of yield when considered on an individual plant basis, the composite approach may avoid such an effect which limits yield. This would be especially true under environmentally stressed conditions where the compensating effects among the yield components are most obvious. Such complementarity might be equally true for other traits such as stages of growth and rooting patterns, thus making greater use of the available resources such as moisture, nutrients and light.

Base, first and second derived populations grown across years.

Significant differences were found between the base, first and second derived populations for grain yield when each was grown in different years. The favorable environmental conditions observed during the 1975-76 crop year are expressed with the base population yielding significantly more than the two derived populations grown in the two subsequent years. When the average of the composite treatments is considered for 1975-76, it was well below the average of the pure stand treatments. Also, none of the composite treatments yielded as much as Jupateco along suggesting that under less environmental stress the pure stands did better. This is in agreement with the results found for the first derived population grown in 1976-77 when the largest environmental stress was observed. Even though there were no significant differences for grain yield, six composite treatments out-yielded the highest pure stand treatment (LR). The 1977-78 growing season was more favaroable than 1976-77; however, the yields were still below the 1975-76 crop year. The average of the composite treatments was higher again than the average for the pure stand treatments with five of the individual composite treatments yielding more than the highest pure stand (Siete Cerros).

It must be remembered that considerable genetic shifts within the composite treatments of the first derived population had occurred during the 1976-77 year. Therefore, the relative composition of the cultivars within each composite treatment was different when grown as a second derived population in 1977-78. However like the results found with the base populations, when environmental stresses are present, the composite treatments on the average did better than when the respective cultivars were grown in pure stand. This, again, supports the general conclusion of the superiority of composites during stress periods drawn by other investigators with several different crops.

When the components of yield are considered, spikes per unit area and kernel weight were again the yield components most influenced by adverse environmental conditions as experienced in 1976-77. The composite treatments which were superior during the adverse periods were those in which the cultivars within the composite complemented one another for kernel number and spikes per unit area. Thus, either Siete Cerros (kernel number) or Lerma Rojo (spike number) were always involved in the higher yielding composites.

<u>Base, first and second derived populations grown during the same year</u>.

When the three populations were grown during the final year (1977-78) the effects of natural selection can be evaluated. The overall yield level achieved this year was higher than observed in 1976-77; however, it was significantly less than noted in 1975-76. This would suggest that certain environmental stresses prevented a full expression of the yield potential for all 15 treatmens within the three populations. Again, it was found that the average of the composite treatments was slightly higher than that of the pure stand treatments for the base population and substantially higher in the first and second derived populations. Despite the lack of significant differences between the three populations, such differences were found when the treatments were averaged across the three populations. It should be noted that the relative composition of the cultivars of a given composite treatment was different across the populations due to genetic shifts induced by natural selection within the composites. Siete Cerros, as a pure stand, was the highest yielding treatment across populations. It was, however, not significantly different from Jupateco as a pure stand or nine of the composite treatments. To determine the selective advantage for each of the cultivars with regard to the components of yield and grain yield the specific and general competitive ability for each cultivar was determined. This information also provided a measurement of the genetic shift among cultivars within the composite due to one and two years of natural selection.

Specific competitive ability

Competition between component cultivars within composite treatments was regarded as a measure of their specific competitive ability. For grain yield, Siete Cerros, followed by Lerma Rojo showed the highest specific competitive ability within the composite cultivars for the three populations grown across years or in the same year. As a result of the increase in the frequency of Siete Cerros within a composite from the base to the second derived population, grain yield also increased which reflects perhaps more the superior yielding ability of Siete Cerros rather than the greater genetic diversity of the composite treatment. This increase in grain yield by Siete Cerros was due to the increase in spike number per unit area as well as by its high kernel number per spike. Kernel number per spike was the most important trait responsible for the dominance of Siete Cerros within the composite when the base and the second derived populations are compared. Nuri had the poorest specific competitive ability for grain yield in the three populations. This could be due to the disadvantage of Nuri in the base population in terms of its lower spike number per unit area with respect to the other cultivars, even though Nuri was second to Siete Cerros for kernel number per spike.

Some differences in yield components were observed for each component cultivar within the composite treatment from the base to the second derived population across years. These differences in yield components are a result of the changes in frequency of the component cultivars within the composite treatment as a consequence of natural selection. However, large changes were observed in number of spikes per unit area and as a consequence some of the component cultivars increased or decreased in frequency and subsequently in their grain yield as they were exposed to natural selection.

When direct and indirect effects between yield and the components of yield were examined by the path-coefficient analysis for the individual cultivars of the composites J-7C, 7C-LR, J-7C-LR and J-7C-N-LR in the base and second derived populations grown during the same year, no changes were observed compared to earlier observation. The relationship of grain yield and yield components of the pure stands was the same as the individual component cultivars in the composites analyzed. Therefore, these results further suggest that the most important yield components for a pure stand are also the most important for the shift of an individual component cultivar in competition within a composite treatment. These were kernel number per spike (Siete Cerros) and number of spikes per unit area (Lerma Rojo) in both a pure stand and for an individual cultivar within a composite treatment.

General competitive ability

General competitive ability was measured as the yielding ability of each component cultivar across composite treatments for each of the three populations. Siete Cerros had the highest general competitive ability for grain yield in the three populations when grown across years as well as during the same year. This selective ability of Siete Cerros for grain yield was the result of the high number of kernels per spike in the three populations. This higher number of kernels from Siete Cerros contributed to the subsequent high number of spikes per unit area in the next derived populations and consequently the greater frequency of Siete Cerros in the subsequent first and second derived populations. The other yield components remained more or less constant across populations and did not give any advantage to Siete Cerros or any of the other cultivars.

Lerma Rojo was second to Siete Cerros in general competitive ability for grain yield over the three populations. For this cultivar, it appears that spike number per unit area was more important than kernel number per spike for grain yield when compared to Jupateco and Nuri across populations.

Nuri had the poorest general competitive ability as reflected by its low spike number per unit area across populations for the three growing seasons and within the same season.

In summary, the desirability of using composite cultivars to achieve stability of yield when growing conditions are favorable is questionable. However, in the Yaqui Valley of Mexico the recurring leaf rust epidemic dictates that a new system of wheat production be implemented. The farmers in the region have enjoyed a long succession of new cultivars and have adapted new cultivars quickly. Consequently, for a given year a large number of hectares are devoted to growing a single new cultivar. This has placed wheat production in a very vulnerable position. Results from this study suggest that the composite cultivars did not provide a superior level of yield stability in comparison to the pure stands. Either Jupateco or Siete Cerros in a pure stand were superior to any of the composites between and across years when the populations were averaged. When there was sufficient selection pressure by adverse environmental conditions as in 1976-77, six of the composites did outyield the highest pure stand cultivar in the first derived population. This would suggest that during years of environmental stress, as in 1976-77, the diversity of genes present in the composites was important and did influence the make-up of the subsequent derived populations. For example, the contribution by Jupateco to the composites was decreased between 1976-77 and 1977-78 for kernel number and spikes per unit area. This change coincides with the breakdown of the resistance of Jupateco to leaf rust as the pathogen overcame this source of resistance.

In developing new cultivars, the plant breeder should concentrate on kernel number or fertility and spikes per unit area. These appear to be the most important components in determining yield and yield stability. Even though Siete Cerros was susceptible to leaf rust, it was always a major contributor to the composites over the three year period since it was superior in both of these components of yield.

Of particular interest is that based on both the specific and general competitive ability, Siete Cerros could be identified as the superior cultivar not only in developing composite varieties, but to be grown in pure stands as well. Under the growing conditions observed in this study, natural selection was effective in isolating the highest yielding genotype. This finding would suggest that the bulk method of handling segregating populations would be effective following hybridization. By bulking F_2 through F_5 generations, many more populations could be evaluated in contrasts to the more commonly used pedigree method. In this investigation, after only two cycles of natural selection, the superior yielding genotype emerged. By using the bulk method of breeding, greater diversity combined with superior yield and stability of yield could be achieved.

SUMMARY AND CONCLUSIONS

Four genotypically and morphologically different spring wheat cultivars; Jupateco (J), Siete Cerros (7C), Nuri (N) and Lerma Rojo (LR), were blended in all possible combinations. The resulting 11 composites and four cultivars grown in pure stands were planted at the Northwest Agricultural Research Center (CIANO) in Mexico. Equal amounts of seed were used for each cultivar to form the 11 treatments for the base composite population. Each base composite population was also regenerated for the 1976-77 and 1977-78 growing seasons. Seed for the first derived population was obtained from sampling the base composite population following harvest. A second derived population was obtained in a similar manner from the first derived population grown in 1976-77.

To compare the performance of the four cultivars in pure stands with their respective composites, the base, first and second derived populations were seeded in 1977-78.

Grain yield, spike number per unit area, number of kernels per spike, 100 kernel weight and plant height were measured for each of the component cultivars within the composites. During the 1977-78 growing season, flowering date was also recorded. General and specific competitive ability of the component cultivars were determined across years as well as during the same year for the three populations.

The following results were obtained for the four cultivars and 11 composites used in this study:

1. Cultivars grown in pure stands ranked differently for grain yield each year; however, 7C ranked either first or second in each of the three years and had the highest three year average.

2. The most stable composites for grain yield in the base populations

for individual years were J-LR, 7C-LR and J-7C-N-LR in 1975-76, 1976-77 and 1977-78, respectively.

3. Pure stands and base composite populations grown for three years showed a highly significant interaction with years.

4. The composites in the base and first derived populations were as good or better than the pure stand when environmental conditions were more adverse in 1976-77.

5. The success of a cultivar in the pure stand could be used as a direct measure of its yielding ability in a composite for those cultivars used in this study.

6. The component cultivar which had the highest general competitive ability in the three composite populations was the one which also produced the most grain yield when grown in pure stand.

7. Siete Cerros, followed by LR, had the highest specific and general competitive ability for grain yield in the three populations grown across years as well as in the same year.

8. Number of spikes per unit area and kernel number per spike were the most important components of yield favoring the dominance of Lerma Rojo and Siete Cerros within composites, respectively. Nuri, which has the lower number of spikes, was the poorest competitor for grain yield in the three populations as a pure stand as well as within the composites.

9. Jupateco was a major component of the base composite population in 1975-76; however, due to environmental changes and to the leaf rust pathogen breakdown in the Jupateco source of resistance in 1976-77, those populations subsequently derived in 1977-78 were lacking in the Jupateco contribution.

10. Results from this study suggest that to achieve yield stability through composite cultivars, a mixture of cultivars should be made each

year as the genetic shift among cultivars within the composites was so rapid that the desired genetic diversity would be lost after a single growing season.

11. The level of genetic diversity within a composite appears less important than the complementarity of the respective cultivars making up the composite, especially for spikes per unit area and kernel number.

BIBLIOGRAPHY

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

Allard, R. W. and J. Adams. 1969. Population studies in predominantly self-pollinated species. XIII. Intergenotypic competition and population structure in barley and wheat. Amer. Nat., 103:621-645.

Bal, B. S., C. A. Suneson and R. T. Ramage. 1959. Genetic shift during 30 generations of natural selection in barley. Agron. J. 51:555-557.

Borlaug, N. E. 1959. First International Wheat Genetics Symposium, University of Manitoba, Winnipeg, Canada. p. 12.

Chapman, S. R., R. W. Allard, and J. Adams. 1969. Effect of planting rate and genotypic frequency on yield and seed size in mixtures of two wheat varieties. Crop Sci. 5:575-576.

Clay, R. E. and R. W. Allard. 1969. A comparison of the performance of homogeneous and heterogeneous barley populations. Crop Sci. 9: 407-412.

Frankel, O. H. 1939. Analytical yield investigations on New Zealand wheat. IV. Blending varieties of wheat. Jour. Agr. Sci. 29: 249-261.

Frankel, O. H. 1950. The development and maintenance of superior genetic stocks. Heredity 4:89-102.

Frey, K. J. and U. Maldonado. 1967. Relative productivity of homogeneous and heterogeneous oat cultivars in optimum and suboptimum environments. Crop. Sci. 5:532-535.

Gustafsson, A. 1953. The cooperation of genotypes in barley. Hereditas 39:1-18.

Harlan, H. V. and M. L. Martini. 1938. The effect of natural selection in a mixture of barley varieties. J. Agron. Res. 57:189-199.

Indelen, E. 1975. Performance of five winter wheat cultivars when grown in a composite and pure stand populations under different environmental stresses. M.S. Thesis. Oregon State University, Corvallis.

Jensen, N. F. 1965. Multiline superiority in cereals. Crop Sci. 5: 566-568.

Khalifa, M. A. and C. O. Qualset. 1974. Intergenotypic competition between tall and dwarf wheats. I. In mechanical mixtures. Crop Sci. 6:795-799.

Klages, K. H. W. 1936. Changes in the proportions of the components of seeds and harvested cereal mixtures in abnormal seasons. Jour. Amer. Soc. Agron. 28:935-940.

Laude, H. H. and A. F. Swanson. 1942. Natural selection in varietal Mixtures of winter wheat. J. Amer. Soc. Agron. 34:270-274.

Marshall, D. R. and A. H. D. Brown. 1973. Stability of performance of mixture and multilines. Euphytica 22:405-412.

Montgomery, E. G. 1912. Competition in cereals. Nebr. Agr. Exp. Sta. Bull. p. 4-22.

Nuding. J. 1936. Lerstug undertragstruktur von winter weizen sorten in reainsaat und munchung in verschiedenen deutschen anbaugebieten. Pflanzenbau 12:382-447.

Qualset, C. O. and R. M. Granger. 1970. Frequency dependent stability of performance in oats. Crop Sci. 10:386-389.

Rasmusson, D. C. 1968. Yield and stability of yield of barley populations. Crop Sci. 8:600-602.

Scott, P. R. and A. Bainbridge. 1978. Plant Disease Epidemiology. Blackwell Scientific Publications. Oxford, London, Edinburgh, Melbourne. p. 329.

Schlehuber, A. M. and B. C. Curtis. 1961. Grain yield of four varieties of hard red winter wheat in pure stands compared to a mixture. Okla. Agr. Exp. Sta. Processed series.

Shorter, R. and K. J. Frey. 1979. Relative yield of mixture and monocultures of oat genotypes. Crop Sci. 4:548-553.

Simmonds, N. W. 1962. Variability in crop plants, its use and conservation. Biol. Rev. 37:422-465.

Suneson, C. A. and G. A. Wiebe. 1942. Survival of barley and wheat varieties in mixtures. J. Amer. Soc. Agron. 34:1052-1056.

Suneson, C. A. 1949. Survival of four barley varieties in a mixture. Agron. Jour. 41:459-461.

Suneson, C. A. 1956. An evolutionary plant breeding method. Agron. Jour. 48:188-190.

Suneson, C. A. and R. T. Ramage. 1962. Competition between near isogenic genotypes. Crop Sci. 2:249-250.

APPENDIX

Appendix Table 1. Pedigrees and descriptions of four spring cultivars and their reaction type to leaf rust (*Puccinia recondita* f. sp. *tritici*).

JUPATECO

Pedigree: 12300 X Lerma Rojo S 64-8159/Norteno M 67.

This is a cultivar developed in 1973 by the International Maize and Wheat Improvement Center (CIMMYT) and the National Institute of Agriculture Research (INIA) in Mexico. It is a semidwarf (90-100 cm) with a strong stem. It is a midseason wheat (82 days to heading) with white, bearded and fusiform spikes. The kernels are small to medium in size. It is a high yielding cultivar and resistant to stem and leaf rust under conditions observed in Mexico before 1976-77.

SIETE CERROS

Pedigree: (Frontana X Kenya 58-Newthatch/Norin 10-Baart)Gabo 55.

This cultivar is midseason (82 days to heading) and has a short and strong white stem. The height varies from 100-110 cm. The spike is brown, bearded, oblong to clavate and resistant to shattering. The kernel is white, hard and small to medium in size. It is a high yielding cultivar with good adaptation. However, it is susceptible to races of stem and leaf rust found in Mexico. It was developed in 1966 by CIMMYT and INIA in Mexico.

NURI

Pedigree: Ciano"S" X Sonora F 64-Klein Rendidor/8156B.

This cultivar is hard, white and midseason (81 days to heading). It has a short, strong, white stem. The height varies from 100-110 cm. The spike is white, bearded, fusiform and resistant to shattering. The kernel is white, hard and varies from small to medium in size. It is

Appendix Table 1. (continued)

a high yielding cultivar, resistant to leaf and stem rust. It was developed in 1970 by CIMMYT and INIA in Mexico.

LERMA ROJO

Pedigree: (Yaqui 50 X Norin 10-Baart/Lerma 52)Lerma $Rojo^2$.

This cultivar is midseason (78 days to heading) with a white stem which is short and strong. The height varies from 110-120 cm. The spike is brown, bearded, fusiform and resistant to shattering. The kernel is soft, red and medium in size. It is a high yielding cultivar, moderately resistant to stem rust and susceptible to leaf rust. It was developed in 1964 by CIMMYT and INIA in Mexico.

Appendix Table 2. Percentage and type of disease reaction to leaf rust (*Puccinia recondita* f. sp. *tritici*) for four cultivars grown in the Yaqui Valley from 1975 to 1978.

VARIETY	Leaf Rust Reaction Type 1975-76 (March 5)	1976-77 (March 21)	1977-78 (March 21)
Jupateco	TR	100S	20MS-S
Siete Cerros	40S-MS	60S-MS	40S-MS
Nuri	60S	80S	60S
Lerma Rojo	100S	100S	80S

S = Susceptible
R = Resistant
MS = Moderately susceptible
T = Trace

Appendix Table 3. Temperature and precipitation data for the Center of Agriculture Investigations of Northwest Mexico during 1975-76, 1976-77 and 1977-78 growing seasons.

		Temperature (C°)		Precipitation (mm)
Year	Month	Max.	Min.	Min.
1975-76	October	34.1	15.4	0.0
	November	29.9	10.9	0.2
	December	24.0	7.8	0.0
	January	24.1	7.1	3.9
	February	25.0	9.0	0.0
	March	26.3	8.1	0.0
	April	29.5	11.3	0.0
	May	33.1	15.0	0.4
1976-77	October	31.8	17.6	62.0
	November	29.2	13.1	5.1
	December	25.5	9.3	5.4
	January	30.3	9.5	10.5
	February	27.1	7.6	0.0
	March	25.6	8.0	2.0
	April	30.3	11.2	0.0
	May	33.1	13.8	0.0
1977-78	October	35.4	22.3	6.9
	November	31.7	14.0	0.3
	December	28.4	11.4	0.0
	January	25.2	9.6	0.0
	February	25.2	8.1	0.0
	March	28.3	12.3	0.0
	April	30.8	10.6	0.0
	May	--	--	---

Appendix Table 4. Observed mean square values from individual analysis of variance for the base population grown in 1975-76, 1976-77 and 1977-78, first and second derived populations grown in 1976-77 and 1977-78, respectively.

Source of Variation	DF	Grain Yield	Spike Number	Spikelets per Spike	Kernels per Spike	100 Kernel Weight	Plant Height
1975-76 Base Population							
Block	3	6819.74	1191.48	0.59	6.09	0.10	2.2
Treatments	14	16066.60**	4280.20**	6.33**	85.91**	0.10	55.46**
Treatments X Block	42	3355.76	842.66	0.49	8.86	0.07	9.69
C.V.		14.9	12.8	7.5	10.9	6.7	6.7
1976-77 Base Population							
Block	3	2338.62	721.20	1.28**	25.71**	0.022	9.84**
Treatments	14	4140.98**	2674.89**	1.65**	113.94**	0.043	84.48**
Treatments X Block	42	1463.64	504.77	0.36	6.52	0.035	2.73
C.V.		11.6	11.4	4.3	10.5	5.3	5.3
1977-78 Base Population							
Block	3	3598.99	185.35	0.51	43.96**	0.10	10.37
Treatments	14	4427.82**	2578.11**	1.49**	81.92**	0.11	38.51
Treatments X Block	42	1543.37	693.74	0.60	5.68	0.08	5.87
C.V.		9.9	11.0	4.7	12.8	7.2	3.9
1976-77 First Derived Population							
Block	3	6949.70*	1727.62	8.81**	5.2	0.20	18.97
Treatments	14	2501.72	2769.82**	2.06*	83.44**	0.07	86.10
Treatments X Block	42	2152.47	954.18	1.03	17.81	0.10	2.58
C.V.		13.23	13.78	6.6	10.74	8.5	5.38
1977-78 Second Derived Population							
Block	3	4308.08*	1381.39	0.56	91.91**	0.88	63.60**
Treatments	14	4135.96**	3302.77**	2.73**	66.51**	0.36	29.09**
Treatments X Block	42	1467.87	502.83	0.29	9.87	0.07	4.37
C.V.		9.65	11.62	4.95	14.07	9.51	3.8

*Significant at 5% level **Significant at 1% level

Appendix Table 5. Phenotypic correlation coefficients between yield and the yield components for the composite involving Jupateco and Siete Cerros in the base population in 1977-78.

	Grain Yield Per plot	No. of Spikes per Unit Area	No. of Spikelets per Spike	No. of Kernels per Spike	100 Kernel Weight
Grain Yield per Plot	1.00+ 1.00	0.8413** 0.8879**	0.1792 0.0479	0.5910 0.2938	0.3479 -0.2000
No. of Spikes per Unit Area		1.00 1.00	0.0966 0.1132	0.2082 0.0390	0.3101 -0.5549
No. Spikelets per Spike			1.00 1.00	0.1204 0.0524	-0.0198 -0.2107
No. of Kernels per Spike				1.00 1.00	0.0734 -0.3932
100 Kernel Weight					1.00 1.00

n=28

**Significant at the 1% level.
+The upper and the lower coorelation coefficient within each cell represent Jupateco and Siete Cerros, respectively.

Appendix Table 6. Phenotypic correlation coefficients between yield and the yield components for the composite involving Jupateco and Siete Cerros in the second derived population in 1977-78.

	Grain Yield per Plot	No. of Spikes per Unit Area	No. of Spikelets per Spike	No. of Kernels per Spike	100 Kernel Weight
Grain yield per Plot	1.00+ 1.00	0.8778** 0.9387**	0.7320** 0.0818	0.5803 -0.0526	-0.5141 0.2145
No. of Spikes per Unit Area		1.00 1.00	0.6486* -0.0687	0.3147 0.1369	-0.4495 -0.8786**
No. Spikelets per Spike			1.00 1.00	0.1951 -0.2365	-0.3965 0.1129
No. of Kernels per Spike				1.00 1.00	-0.5755 0.2396
100 Kernel Weight					1.00 1.00

n=28

*,** Significant at the 5% and 1% levels of probability, respectively.

+The upper and the lower correlation coefficient within each cell represent Jupateco and Siete Cerros, respectively.

Appendix Table 7. Phenotypic correlation coefficients between yield and the yield components for the composite involving Siete Cerros and Lerma Rojo in the base population in 1977-78.

	Grain Yield per Plot	No. of Spikes per Unit Area	No. of Spikelets per Spike	No. of Kernels per Spike	100 Kernel Weight
Grain Yield per Plot	1.00[+] 1.00	0.8356** 0.8461**	-0.0892 0.2513	0.3894 0.3447	-0.2009 -0.0940
No. of Spikes per Unit Area		1.00 1.00	-0.1447 0.0895	0.3203 0.1835	-0.4678 -0.0454
No. Spikelets per Spike			1.00 1.00	-0.0018 -0.1119	-0.2835 0.0267
No. of Kernels per Spike				1.00 1.00	-0.3317 -0.3612
100 Kernel Weight					1.00 1.00

n=28

**Significant at the 1% level.
+The upper and lower correlation coefficient within each cell represent Siete Cerros and Lerma Rojo, respectively.

Appendix Table 8. Phenotypic correlation coefficients between yield and yield components for the composite involving Siete Cerros and Lerma Rojo in the second derived population 1977-78.

	Grain Yield per Plot	No. of Spikes per Unit Area	No. of Spikelets per Spike	No. of Kernels per Spike	100 Kernel Weight
Grain yield per Plot	1.00 1.00	0.9276* 0.9460*	-0.3166 0.2661	-0.7833** 0.1083	-0.0762 -0.1153
No. of Spikes per Unit Area		1.00 1.00	-0.3537 0.1825	-0.1290 0.3998	0.3477 -0.6657
No. Spikelets per Spike			1.00 1.00	0.1403 -0.1493	0.1740 -0.3728
No. of Kernels per Spike				1.00 1.00	-0.0898 -0.0769
100 Kernel Weight					1.00 1.00

n=28

*, ** Significant at 5% and 1% levels of probability, respectively.
+ The upper and lower correlation coefficient within each cell represent Siete Cerros and Lerma Rojo, respectively.

Appendix Table 9. Phenotypic correlation coefficients between yield and yield components for the composite involving Jupateco, Siete Cerros and Lerma Rojo in the base population in 1977-78.

	Grain Yield per Plot	No. of Spikes per Unit Area	No. of Spikelets per Spike	No. of Kernels per Spike	100 Kernel Weight
Grain Yield per Plot	1.00+ 1.00 1.00	0.8550** 0.9142** 0.6728*	-0.0206 -0.0571 0.2531	0.3365 -0.0566 0.0092	0.0418 -0.0813 0.2160
No. of Spikes per Unit Area		1.00 1.00 1.00	-0.0826 -0.1179 -0.0655	0.1426 0.2359 0.3461	0.0956 -0.1849 -0.4868
No. Spikelets per Spike			1.00 1.00 1.00	-0.0834 -0.3838 -0.0881	-0.0836 0.0334 0.1140
No. of Kernels per Spike				1.00 1.00 1.00	-0.3018 -0.1730 -0.4028
100 Kernel Weight					1.00 1.00 1.00

n=28

*, ** Significant at 5% and 1% levels of probability, respectively.

+ The upper, middle and lower correlation coefficients within each cell represent Jupateco, Siete Cerros and Lerma Rojo, respectively.

Appendix Table 10. Phenotypic correlation coefficients between yield and the yield components for the composite involving Jupateco, Siete Cerros and Lerma Rojo in the second derived population in 1977-78.

	Grain Yield per Plot	No. of Spikes per Unit Area	No. of Spikelets per Spike	No. of Kernels per Spike	100 Kernel Weight
Grain Yield per Plot	1.00 + 1.00 1.00	0.7358** 0.9065** 0.8224**	0.2996 0.1988 0.0880	0.3375 0.2604 0.3336	-0.3162 -0.1260 -0.5758
No. of Spikes per Unit Area		1.00 1.00 1.00	0.1852 0.0358 -0.1345	0.2312 -0.1070 0.2414	-0.2330 -0.3557 -0.1978
No. Spikelets per Spike			1.00 1.00 1.00	-0.2185 0.0031 0.0004	-0.1608 0.5694 0.3334
No. of Kernels per Spike				1.00 1.00 1.00	-0.5338 -0.3448 -0.6457*
100 Kernel Weight					1.00 1.00 1.00

n=28

*, ** Significant at 5% and 1% levels of probability, respectively.
+ The upper, middle and lower correlation coefficients within each cell represent Jupateco, Siete Cerros and Lerma Rojo, respectively.

Appendix Table 11. Phenotypic correlation coefficients between yield and the yield components for the composite involving Jupateco, Siete Cerros, Nuri and Lerma Rojo in the base population in 1977-78.

	Grain Yield per Plot	No. of Spikes per Unit Area	No. of Spikelets per Spike	No. of Kernels per Spike	100 Kernel Weight
Grain Yield per Plot	1.00 +	0.9265**	0.1500	0.0348	-0.3318
	1.00	0.9221**	0.4886	0.1270	-0.2061
	1.00	0.8694**	0.0548	0.4769	-0.2590
	1.00	0.6858*	0.1803	0.3845	-0.0626
No. of Spikes per Unit Area		1.00	-0.0149	0.3580	-0.1961
		1.00	0.4093	0.2816	-0.1494
		1.00	0.0663	0.1087	-0.1629
		1.00	-0.0194	0.0857	-0.0204
No. Spikelets per Spike			1.00	-0.2418	0.1595
			1.00	-0.1738	-0.2276
			1.00	0.0946	-0.1193
			1.00	-0.2916	0.2000
No. of Kernels per Spike				1.00	-0.4344
				1.00	-0.3540
				1.00	-0.4930
				1.00	-0.3792
100 Kernel Weight					1.00
					1.00
					1.00
n=28					1.00

*,** Significant at 5% and 1% level of probability, respectively.

+ From the upper to the lower correlation coefficients within each cell Jupateco, Siete Cerros, Nuri and Lerma Rojo are represented, respectively.

Appendix Table 12. Phenotypic correlation coefficients between yield and the yield components for the composite involving Jupateco, Siete Cerros, Nuri and Lerma Rojo in the second derived population in 1977-78.

	Grain Yield per Plot	No. of Spikes per Unit Area	No. of Spikelets per Spike	No. of Kernels per Spike	100 Kernel Weight
Grain Yield per Plot	1.00 + 1.00 1.00 1.00	0.5958 0.9522** 0.8683** 0.9686**	0.0804 0.0363 -0.4782 0.3300	0.1327 0.1385 0.0236 -0.1872	-0.3281 -0.1344 0.3753 -0.2212
No. of Spikes per Unit Area		1.00 1.00 1.00 1.00	-0.1144 0.1213 -0.1957 0.3189	0.4798 -0.0730 -0.5437 0.2583	-0.3334 -0.3390 0.4009 -0.1150
No. Spikelets per Spike			1.00 1.00 1.00 1.00	-0.0543 -0.0666 -0.2957 -0.3146	-0.1406 -0.2316 -0.5845 -0.2194
No. of Kernels per Spike				1.00 1.00 1.00 1.00	-0.7165** -0.2728 0.1428 -0.3603
100 Kernel Weight					1.00 1.00 1.00 1.00
n=28					

*,** Significant at 5% and 1% levels of probability, respectively.
+ From the upper to the lower correlation coefficients within each cell Jupateco, Siete Cerros, Nuri and Lerma Rojo are represented, respectively.

Appendix Table 13. Direct and indirect effects between yield and yield components for Jupateco and Siete Cerros composite in the base population grown in 1977-78.

Path way of association	Jupateco	Siete Cerros
Yield/plot vs No. of spikes per unit area		
Direct effect	0.7749	1.0585
Indirect effect via No. of spikelets per spike	0.0014	0.0017
Indirect effect via No. of kernels per spike	0.0539	0.0272
Indirect effect via kernel weight	0.0112	-0.1995
Total correlation	0.8414	0.8879
Yield/plot vs No. of spikelets per spike		
Direct effect	0.0142	0.0147
Indirect effect via No. of spikes per unit area	0.0749	0.1198
Indirect effect via No. of kernels per spike	0.0932	0.0203
Indirect effect via kernel weight	-0.0030	-0.1069
Total correlation	0.1793	0.0479
Yield/plot vs No. of kernels per spike		
Direct effect	0.4475	0.5194
Indirect effect via No. of spikes per unit area	0.0933	0.0555
Indirect effect via No. of spikelets per spike	0.0030	0.0006
Indirect effect via kernel weight	0.0473	-0.2816
Total correlation	0.5911	0.2939
Yield/plot vs kernel weight		
Direct effect	0.1525	0.5075
Indirect effect via No. of spikes per unit area	0.0569	-0.4162
Indirect effect via No. of spikelets per spike	-0.0003	-0.0031
Indirect effect via No. of kernels per spike	0.1388	-0.2882
Total correlation	0.3479	-0.2000
Coefficient of determination R^2	97.21	99.16

Appendix Table 14. Direct and indirect effects between yield and yield components for Jupateco and Siete Cerros composite in the second derived population grown in 1977-78.

Path way of association	Jupateco	Siete Cerros
Yield/plot vs No. of spikes per unit area		
Direct effect	0.8317	0.9591
Indirect effect via No. of spikelets per spike	0.0868	0.0016
Indirect effect via No. of kernels per spike	0.0938	-0.1724
Indirect effect via kernel weight	-0.1346	0.1504
Total correlation	0.8777	0.9387
Yield/plot vs No. of spikelets per spike		
Direct effect	0.1338	-0.0229
Indirect effect via No. of spikes per unit area	0.5394	-0.0659
Indirect effect via No. of kernels per spike	0.1514	0.0998
Indirect effect via kernel weight	-0.1346	0.0709
Total correlation	0.6900	0.0819
Yield/plot vs No. of kernels per spike		
Direct effect	0.4810	0.7288
Indirect effect via No. of spikes per unit area	0.1623	-0.2268
Indirect effect via No. of spikelets per spike	0.0421	-0.0031
Indirect effect via kernel weight	-0.1051	-0.5514
Total correlation	0.5803	-0.0525
Yield/plot vs kernel weight		
Direct effect	0.2338	0.6276
Indirect effect via No. of spikes per unit area	-0.4786	0.2298
Indirect effect via No. of spikelets per spike	-0.0531	-0.0026
Indirect effect via no. of kernels per spike	-0.2162	-0.6403
Total correlation	-0.5141	0.2145
Coefficient of determination R^2	98.12	97.6

Appendix Table 15. Direct and indirect effects between yield and yield components for Siete Cerros and Lerma Rojo composite in the base population grown in 1977-78.

Path way of association	Siete Cerros	Lerma Rojo
Yield/plot vs No. of spikes per unit area		
Direct effect	0.9579	0.9932
Indirect effect via No. of spikelets per spike	0.0039	0.0064
Indirect effect via No. of kernels per spike	-0.0010	-0.0510
Indirect effect via kernel weight	-0.1252	-0.1024
Total correlation	0.8356	0.8462
Yield/plot vs No. of spikelets per spike		
Direct effect	-0.0272	0.0712
Indirect effect via No. of spikes per unit area	-0.1386	0.0889
Indirect effect via No. of kernels per spike	0.1837	0.0836
Indirect effect via kernel weight	-0.1070	0.0076
Total correlation	-0.0891	0.2513
Yield/plot vs No. of kernels per spike		
Direct effect	0.5734	0.4556
Indirect effect via No. of spikes per unit area	-0.0017	-0.1111
Indirect effect via No. of spikelets per spike	-0.0087	0.0131
Indirect effect via kernel weight	-0.1765	-0.0129
Total correlation	0.3865	0.3447
Yield/plot vs kernel weight		
Direct effect	0.3773	0.2834
Indirect effect via No. of spikes per unit area	-0.3177	-0.3587
Indirect effect via No. of spikelets per spike	0.0077	0.0019
Indirect effect via No. of kernels per spike	-0.2682	-0.0207
Total correlation	-0.2009	-0.0941
Coefficient of determination R^2	94.86	98.87

Appendix Table 16. Direct and indirect effects between yield and yield components for Siete Cerros and Lerma Rojo composite in the second derived population grown in 1977-78.

Path way of association	Siete Cerros	Lerma Rojo
Yield/plot vs No. of spikes per unit area		
Direct effect	0.8838	1.0289
Indirect effect via No. of spikelets per spike	0.0033	0.0003
Indirect effect via No. of kernels per spike	0.0821	-0.0638
Indirect effect via kernel weight	-0.0416	-0.0191
Total correlation	0.9276	0.9460
Yield/plot vs No. of spikelets per spike		
Direct effect	-0.0093	0.0002
Indirect effect via No. of spikes per unit area	-0.3126	0.1878
Indirect effect via No. of kernels per spike	-0.0755	0.1708
Indirect effect via kernel weight	0.0808	-0.0926
Total correlation	-0.3166	0.2662
Yield/plot vs No. of kernels per spike		
Direct effect	0.5855	0.4272
Indirect effect via No. of spikes per unit area	0.1240	-0.1536
Indirect effect via No. of spikelets per spike	0.0012	0.0001
Indirect effect via kernel weight	-0.3631	-0.1653
Total correlation	0.3476	0.1084
Yield/plot vs kernel weight		
Direct effect	0.4635	0.2483
Indirect effect via No. of spikes per unit area	-0.0794	-0.0791
Indirect effect via No. of spikelets per spike	-0.0016	-0.0001
Indirect effect via No. of kernels per spike	-0.4586	-0.2844
Total correlation	-0.0761	-0.1152
Coefficient of determination R^2	99.1	99.1

Appendix Table 17. Direct and indirect effects between yield and yield components for the Jupateco, Siete Cerros and Lerma Rojo composite in the base population grown in 1977-78.

Path way of association		Jupateco	Siete Cerros	Lerma Rojo
Yield/plot vs No. of spikes per unit area				
Direct effect		0.9814	1.0987	1.0900
Indirect effect via No. of spikelets per spike		-0.0026	0.0035	-0.0022
Indirect effect via No. of kernels per spike		-0.0321	-0.1559	-0.0474
Indirect effect via kernel weight		-0.0917	-0.0320	-0.3677
Total correlation		0.8551	0.9143	0.6727
Yield/plot vs No. of spikelets per spike				
Direct effect		0.0310	-0.0296	0.0343
Indirect effect via No. of spikes per unit area		-0.0811	-0.1295	-0.0714
Indirect effect via No. of kernels per spike		0.0549	0.0958	-0.1861
Indirect effect via kernel weight		-0.0254	0.0062	0.1041
Total correlation		-0.0206	-0.0571	0.2531
Yield/plot vs No. of kernels per spike				
Direct effect		0.3849	0.4062	0.5378
Indirect effect via No. of spikes per unit area		-0.0818	-0.4217	-0.0960
Indirect effect via No. of spikelets per spike		0.0044	-0.0070	0.0119
Indirect effect via kernel weight		0.0290	-0.0342	-0.4444
Total correlation		0.3365	-0.0567	0.0093
Yield/plot vs kernel weight				
Direct effect		0.3038	0.1849	0.9128
Indirect effect via No. of spikes per unit area		-0.2962	-0.1901	-0.4391
Indirect effect via No. of spikelets per spike		-0.0026	0.0010	0.0029
Indirect effect via No. of kernels per spike		0.0368	-0.0751	-0.2618
Total correlation		0.0418	-0.0813	0.2159
Coefficient of determination	R^2	98.08	96.82	94.4

Appendix Table 18. Direct and indirect effects between yield and yield components for the Jupateco, Siete Cerros and Lerma Rojo composite in the second derived population grown in 1977-78.

Path way of association		Jupateco	Siete Cerros	Lerma Rojo
Yield/plot vs No. of spikes per unit area				
Direct effect		1.1204	1.0351	0.8136
Indirect effect via No. of spikelets per spike		0.0009	-0.0004	-0.0190
Indirect effect via No. of kernels per spike		-0.1495	0.0012	0.0001
Indirect effect via kernel weight		-0.2360	-0.1295	0.0278
Total correlation		0.7358	0.9064	0.8225
Yield/plot vs No. of spikelets per spike				
Direct effect		0.0050	-0.0114	0.1416
Indirect effect via No. of spikes per unit area		0.2075	0.0371	-0.1094
Indirect effect via No. of kernels per spike		0.1582	-0.0417	0.0702
Indirect effect via kernel weight		-0.0711	0.2138	0.0144
Total correlation		0.2996	0.1987	0.0880
Yield/plot vs No. of kernels per spike				
Direct effect		0.6841	0.3896	0.2910
Indirect effect via No. of spikes per unit area		-0.2448	0.0032	0.0003
Indirect effect via No. of spikelets per spike		0.0012	0.0011	0.0342
Indirect effect via kernel weight		-0.1030	-0.1336	0.0081
Total correlation		0.3374	0.2603	0.3336
Yield/plot vs kernel weight				
Direct effect		0.4421	0.3755	-0.0431
Indirect effect via No. of spikes per unit area		-0.5981	-0.3569	-0.5235
Indirect effect via No. of spikelets per spike		-0.0008	-0.0059	0.0473
Indirect effect via No. of kernels per spike		-0.1594	-0.1386	-0.0546
Total correlation		-0.3152	-0.1259	-0.5757
Coefficient of determination	R^2	91.69	99.03	80.35