THE INFLUENCE OF KERNEL-TYPE AND FERTILIZER ON THE PERFORMANCE OF TRITICALE (X *Triticosecale* Wittmack)

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ABSTRACT

Three advanced and genetically diverse lines of triticale were used to test the influence of parental seed size and fertilizer response on yield components, yield and quality of kernel. Seed of each line was sub-divided into three size classes, large, small and unsorted, based on test weight and density. The experiment was grown at two locations in the North Central Region of Chile in 1975-76.

Parental seed size did not affect germination rate although plants derived from small seed were generally weaker throughout their developmental cycle. Yield and yield components were positively influenced by parental kernel type in that progeny of the large kernel class possessed a large spike number and kernel number per plant and a higher kernel weight (density) relative to progeny produced from small seeds. Grain yields of plants grown from the small seed class were significantly below those obtained from progeny of the large-seed class. In general, the grain from plants grown from small seeds had a higher protein content than grain grown from subclasses comprised of larger seeds. Small parental seeds also gave rise to plants with relatively poorer post harvest seed development. Plant vigor was positively and significantly associated with fertilizer application at the stages of tillering and anthesis. However, seedling vigor as well as kernel weights, test weights and post-harvest seed development were maximum at the intermediate rates of fertilizer application. In contrast, yield and yield components, and grain protein content were significantly improved with increasing fertilizer levels.

INTRODUCTION

Triticale (X *Triticosecale* Wittmack) has the potential to produce high grain yields associated with comparatively high levels of protein content. Thus, it may become an important commercial crop in many countries of the world, especially the less privileged areas where it will provide a source of increased income for the farmers and an improved level of nutrition for the population.

Information on triticale collected in Chile over the past few years corroborates the above statements. Several triticale lines are presently being tested throughout the country, and are favorably competing with wheat in yield, protein content, adaptation, and disease resistance. The main agronomic drawback of the species as a crop for Chile, rests with its tendency to produce shrivelled kernels resulting in low test weight. This limitation is a major reason for rejection of triticale by farmers, and also by the milling and baking industries. For industrial use, well developed plump kernels are required with a test-weight of 72 k/hl or above. The basic cause for seed shrivelling resulting from incomplete endosperm development is still not fully known.

Among the objectives of triticale breeding programs, the improvement of kernel type and test weight has taken a high priority. To this end, considerable progress has been made within the last few years. If these problems are solved without adversely affecting either agronomic attributes or protein content, triticale may achieve even higher yield levels thus becoming more attractive to farmers and processers. It is also recognized that the specific response of the species to management practices must be defined under a broad range of environmental conditions. By so doing, the most favorable cultural practices that allow the full expression of the crop's genetic potential will be known and recommended to the producer.

Hence, this study was undertaken as a preliminary investigation of the effects of genotype, environment, kernel type, and fertilizer levels on the yield, yield components, protein content and kernel characteristics of triticale.

LITERATURE REVIEW

The occurrence of abnormal, shrivelled kernels found in several triticale lines of otherwise good performance is one of the major problems inherent to the species. As a result of this deficiency, yield potential and industrial quality are limited. In addition, the relatively poorly developed kernels make the crop less attractive to the farmer and miller.

Parodi, et al. (1976) reported that the main deficiency found in triticale germplasm in Chile was low test-weight ranging from 7 to 17% lower than that of wheat. Low test weight resulted in a reduced percentage of flour extraction. Test weight was found to interact with environmental conditions, a feature that was also exhibited by the wheat cultivars used as controls in their experiments.

Efforts to improve test weight have been successful and there has been a clear trend towards obtaining higher test weights in most newly developed triticales. Zillinsky (1974) has indicated that grain development in triticale is more sensitive to environmental condition than the parental species, wheat and rye. The shrivelled grains have usually higher protein content than plump grains. He indicated that the approach used to overcome endosperm shrivelling has included the use of density gradient solutions, visual selection, mutation induction, selection for high fertility, the use of both air column separation and the gravity table separation. Zillinsky is of the opinion that as a result of the presence of a negative association between dwarfing and plump grain, visual screening has tended to eliminate the dwarf type from breeding populations. Best results have been obtained from visual selection for plumpness in the most fertile populations. As a consequence of these efforts, CIMMYT (1974) reported a significant improvement on the hectolitre weight of their best triticale lines, which increased from 68 k/hl in 1968 to 76 k/hl in 1973.

Effect of seed size and weight on plant development and performance

The effect of seed size and weight on plant development and performance has been studied for a number of crop species by several scientists. The following review of literature will deal mainly with wheat, oats, barley, rye and triticale.

Wheat, oats, rye and barley

McDaniel (1969) reported that heavy barley seeds contained a greater initial quantity of mitochondrial protein than light seeds, and therefore produced seedlings with a greater energy production potential. This was reflected in a faster growth rate. Kneebone and Cremer (1955) evaluated seed vigor on seedlings from various species grown under greenhouse and field conditions. They found that seed size did not affect germination rate. Large seeds, however, produced more vigorous seedlings with a faster growth rate than that of smaller seeds.

Waldron (1941) found that within spring wheat cultivars, heavy seeds (40.0 mg/kernel) produced plants that out yielded light seeds (26.6 mg/kernel) by 12% when equal numbers of seeds were planted per row, and by 10% with equal weights of seeds per row. Knott and Talukdar (1971) transferred the high seed weight from Triticum aestivum L em Tell cv. "Selkirk" to cv. "Thatcher" spring wheat by backcrossing. On average, the backcross lines with high seed weight outyielded Thatcher. However, their yields varied considerably depending on the degree of compensation of other yield components, specifically seeds per spike and spikes per plot. Weight per seed was positively correlated with number of kernels per plot.

Kikot (1973) attributed a decrease in yield from small seed to a reduction in tillering and 1000-kernel weights. Pinthus (1966) reported that seed size did not influence seedling emergence in wheat, but plants from large seeds produced 24% more grain than plants derived from small seeds. The increase yield was due almost equally to a higher number of spikes per plant and an increased number of kernels per spike. Goydani and Singh (1971) found that wheat plants derived from small seeds (1000 seeds = 20-29 g) of four cultivars produced comparatively lower yields due to a decrease in germination percentage, a lower number of fertile tillers per plant, and a lower survival to harvest as compared to plants derived from large (1000 seeds = 41-46 g), medium sized (1000 seeds = 30-40 g) and bulk (1000 seeds = 35-50 g) seeds. Dasgupta and Austenson (1973) in testing 83 seed samples of the *Triticum aestivum* L em Tell. cv. "Manitou" at three different locations, determined that 1000-kernel weight was the only character positively associated with yield at all locations. Chebib *et al* (1973) studied the effect of seed size on genotypic variation in wheat and determined that differences in initial seed size had a direct effect on the interplot variability and an indirect effect on interplant competition.

Frey and Wiggans (1956) reported that the test-weight of seed oats was positively correlated with the dry weight of seedlings produced. Except in limited instances, the weights of plants from light test-weight seed reached the same weight as those from heavy seeds sometime before maturity. However, in some cases this equality was not attained until heading time. Oat kernels produced on plants from light test-weight seed weighed less than those grown from heavy seed. Frey and Huang (1969) found that the relationship between yield and 100-seed weight was curvilinear. Maximum yields were recorded from lines with a 100-seed weight of 2.75 to 3.10 g.

Kaufmann and Guitard (1967) indicated that large seeds of barley were superior to small seeds both in the rate of seedling growth and size of the first two leaves. The lengths of these leaves were positively related to both spike length and floret number. Kaufmann and McFadden (1960) demonstrated the effect on yield of barley plants grown from large and small seeds both in greenhouse and field tests. Plants from small seeds yielded approximately 77 and 57% of those grown from large seeds in the greenhouse and field respectively, the latter under interplant competition. With inter-row competition, the percentages were 70 and 54% under greenhouse and field conditions respectively, while with no competition, 89 and 83 percent respectively. It was further shown that increased competition favoured plants from large seeds. Superior production resulted mainly from a greater number of heads on plants grown from large seeds.

Triticale

Kaltsikes (1974) reported that in a 5 x 5 F_3 diallel cross of hexaploid triticale lines, 1000-kernel weight was positively correlated with yield. Ogilvie (1976) working with seven triticale crosses, found that plants resulting from large F_2 seeds selected on an individual F_1 plant basis, yielded higher than those from small seeds. However, similar selection on advanced lines produced no significant differences.

Tankowski and Kolodziejczyk (1974) studied seven triticale hexaploids and one octoploid type, classifying seed samples into five grades according to the degree of shrivelling of the seed. Germination percentage and vigor of germination were lowest in the most shrivelled grades, but both the distribution of grades and the viability of seed of a given grade varied from one triticale to another. The octoploid type had the lowest incidence of shrivelling, being comparable with rye and superior to three wheat cultivars included for comparison. The same authors showed that germination percentage varied inversely with the degree of shrivelling. They concluded that the wide variation found in the degree of shrivelling makes it possible to select forms with uniform and high germination. Bishnoi and Sapra (1975) stated that seedling vigor and field performance can be considered an important characteristic of seed quality of some species. They studied four seed size classes from three triticale genotypes (6TA131, 6TA385, and 6TA419) and showed that plants derived from large seeds were superior in total germination, seedling dry weight, and seedling establishment to those derived from small seeds. Plants derived from large seeds from a given line produced 51% higher field stand, 62% more seedling dry weight, and 37.8% higher grain yield than plants from small seeds. Increased yield was apparently due to an increase in seedling dry weight and an increased seedling establishment rate.

Physiological and Cytological causes for kernel shrivelling in triticale

The physiological basis for the occurrence of shrunken endosperm and kernel shrivelling in triticale have been studied by numerous investigators. Simmonds (1974) described the kernel morphology and development of hexaploid triticale and compared them with that of its wheat and rye parents. In triticale, because of irregularities in cell division of the endosperm periperal layer, grain shrivelling commonly occurs leading to a highly irregular arrangement of cells in the aleurone and adjacent endosperm tissue. These irregularities occur as early as six to seven days after anthesis. D'Appolonio (1974) reported that triticale (AABBRR) has a higher percent of nitrogen content in its starch than does its durum wheat (AABB) parent, but a lower content than its rye (RR) parent. He concluded that there does not appear to be any physical, chemical or structural properties in triticale starch than are not found in the starch of one of the parent species. Kaltsikes, _et al_. (1975) investigated the development of the embryo sac in triticale, common wheat, durum wheat, and rye. Generalized antipodal disintegration occurred earlier in rye and in shrivelled triticale grains than in either wheat or triticale with plump seeds. Triticale with shrivelled seeds as well as rye were also characterized by a higher number of aberrant endorsperm nuclei and delayed endosperm cellularization when compared with lines with plump kernels or with wheat. They consider that the rye parent is responsible for the early degeneration of the antipodals, the formation of the aberrant endosperm nuclei, and the kernel shrivelling observed in triticale. Shealy and Simmonds (1973) studied grain shrivelling in triticale in which grain was examined at daily intervals between 0 and 14 days after anthesis. Malformed aleurone and associated forms in the endosperm were apparently responsible for shrivelled areas of the grain. Precocious release of α-amylase which leads to premature digestion of starch granules and loss of kernel weight was also considered to be a factor in grain shrivelling.

Hill, et al. (1974), found a negative significant correlation between amylase activity and grain density in eight triticale genotypes varying in their test weight. Starch content was positively correlated with test weight. Starch deposition in some shrivelled grain genotypes was slower and the maximum starch content per unit of kernel volume was lower than in the plump-grain genotypes. 14C-sucrose feeding experiments indicated that the line 6A190 which has shrivelled grain, was less efficient in transporting sucrose to the spike than the plump-grain line 6531. In addition, 6A190 deposited a larger proportion of sucrose to the pericarp than line 6531. Studies on the development of α-amylase activity in four triticale lines, showed that it reached a maximum within the pericarp at approximately 12-15 days after anthesis and declined to a minimum at approximately 20 days past anthesis. Aleurone and endosperm α-amylase increased from approximately 20 days to a maximum at 28-31 days in all genotypes except 6A190. In 6A190, α-amylase continued to increase as the grain matured. Dedio et al. (1975) determined α-amylase activity in the embryo, pericarp, aleurone and endosperm of the seed of four triticale lines, two wheat, and one rye cultivar, harvested at 4-day intervals from 60 to 42 days after anthesis. Alpha-amylase activity in the embryo was low in all cases while activity in the pericarp reached a maximum in all samples at about 10-15 days after anthesis. Activity in the aleurone and endosperm remained low throughout the developmental period in all genotypes except triticale 6A190. In this line, α-amylase level of the endosperm and aleurone remained low until about 20-25 days after anthesis, after which it increased dramatically in the later stages of development. Light microscope examination of triticale 6A190 at 10 days after anthesis showed that the starch in the inner portion of the pericarp was digested and at 22 days, all pericarp starch had disappeared. Specific lesions in the endosperm and aleurone cells were observed after 22 days. Areas of the endosperm in which starch damage was induced by α-amylase activity were often associated with regions possessing necrotic tissue located between the aleurone and the endosperm. In some areas, aleurone cells were completely absent.

Darvey (1973) reported that the chromosomes having the least effect on seed shrivelling in addition lines of wheat cultivars Chinese Spring, Holdfast, and Kharkov were 2R and 3R, while chromosomes 7R/4R and 1R caused intermediate shrivelling. Major genes responsible for shrivelling appear to be located on chromosomes 4R/7R, 5R and 6R, with the degree of shrivelling affected differentially depending upon the wheat cultivar used. Some accessions of _Secale africanum_ and _S. montanum_ as well as triticale lines involving S _montanum_ did not have shrivelled seed. Darvey suggested that the incorporation of chromosomes from these species may help to overcome the seed shrivelling problem in triticale.

Kaltsikes and Roupakias (1975) investigated the relationship between kernel shrivelling and endosperm, embryo and antipodal development in wheat-rye substitution lines. A positive relationship between mature kernel shrivelling and number of aberrant endosperm was observed during the first 10-15 divisions after fertilization. The rye chromosomes 5R, 4R, 6T, 3R and 1R, in descending order of magnitude, were found to be responsible for aberrant nuclei induction. A negative relationship between only starch deposition in the endosperm and kernel shrivelling was indicated.

Kaltsikes and Larter (1970) found that the frequency of aneuploids in four cultivars of hexaploid triticale (separated into classes containing either shrivelled or plump kernels) was much higher in shrivelled seed than plump seed. Weimarch (1975) reported that in octoploid triticale cv "Kagawa", the percentage of euploid plants from large smooth seeds with a 1000-kernel weight of 55 g or more was twice as large as that of smaller seeds.

Yield and Yield Components

The yield of a plant species has been defined by Parodi (1977) as the result of the action of all the genetic mechanisms of the plant and of the interaction of these mechanisms *per se* and with the environment. The expression of yield potential may not, therefore, be attributed to neither specific genes nor to specific chromosomes, but to all the genes in the entire chromosome complement.

Grafius' (1965) theory describes yield as the volume (W) of a rectangular parallelepiped in which the number of spikes per unit area (X), number of kernels per spike (Y), and kernel weight (Z), represent the edges. The volume of the parallelepiped reaches its maximum when the best combination of components is found.

Even though a review of the literature indicates an active interest by workers in yield components, it is evident that these factors are generally ignored by plant breeders as selection criteria except when visual selection is practiced. Parodi (1977), Frankel (1935), and Adams (1967), have proposed explanations for yield components not having been extensively used as might be expected. Both scientists point out that yield components are significantly affected by environmental factors, and indicate that negative correlations among components are frequently found. Therefore, the results of selection on the basis of yield components are determined by the interactions and associations among components in a given population (Parodi, 1977). Seed weight as a yield component, has frequently been reported as the most stable component (Sharma and Knott, 1964; Vera and Parodi, 1977).

Fonseca and Patterson (1968) concluded that within the germ plasm which they studied, the progress that could be obtained by selecting on a component basis was somehow limited by negative correlations among components. The authors questioned whether the correlations found were of genetic origin and could therefore be modified, or if they were in fact a result of limitations in the total physiological potential of the plants. Rasmussen and Cannell (1970) found that phenotypic correlations were not a satisfactory basis to conclude whether or not selection for yield could be made on the basis of yield components. Fonseca and Patterson (1968) and Parodi _et al_. (1970) reached a similar conclusion and suggested the use of the pathcoefficient analysis to evaluate the true association existing among yield and yield components.

Rasmussen and Cannell (1970) believe that the occasional negative response found when selecting for yield components may be due to genetic linkage. If so, the obvious route to obtaining higher yield would be to break the negative linkages and to identify the superior recombinants. Adams and Grafius (1971) proposed an alternative explanation to Rasmussen and Cannell's (1970) theory. It was based on the oscilatory response of the components due to the sequential nature of their development and to a limitation in the amount of environmental resources. If that is true, a high flux of environmental resources should be available at all times during plant development so as to allow for the full expression of each of the yield components.

Fertilizer responses

Nitrogen (N) For satisfactory crop development, the nitrogen requirements of most nonleguminous plants is large compared to the demand for most other nutrients. Relatively large amounts of inorganic N must be supplied either from the soil or in the form of commercial fertilizer. Nitrate is frequently the most available form of nitrogen that prevails in aerated soils. The initial nitrate concentration in the soil may exceed the requirement of the young plant with the level gradually decreasing during the growth cycle, reaching a minimum at maturity. The effectiveness of nitrate uptake by the plant root may determine the nitrate concentration needed in the soil for maximum production, as well as the residual left in the soil after the crop matures.

It is well known that the application of nitrogen fertilizer to cereals generally increases yield. Stickler and Pauli (1964) and Pendleton and Duncan (1960) found that wheat cultivars have different N absorption capacities. This absorption capacities did not seem to be correlated with any morphological characteristics of the varieties. Rohde (1963) found that nitrogen fertilizer produced increases in the grain yield, number of spikes and straw weight on 49 varieties of wheat studied during a 9-year period. Nitrogen fertilizer had no effect on the number of kernels per spike, but on 100-kernel weight and test weight the effects were variable. Hobbs (1953), McNeal and Davis (1954) and Johonson, et al. (1973) showed that although the test weight in spring wheat was unaffected by nitrogen fertilizer, improved yields were obtained as a result of an increase in spike number per plot.

Syme (1972) grew five wheat cultivars under different seeding rates and nitrogen levels. Variation in protein content resulting from fertilizer use was proportionally less than that for yields so that the highest yielding wheats also yielded the most protein per hectare. Johnson et al. (1973) found significant positive and linear responses of protein to nitrogen fertilizer in wheat. Hucklesby et al. (1971) produced evidence for challenging the concept that grain yield and grain protein content are negatively correlated. McNeal and Davis (1954) found that high nitrogen availability late in the growth period was essential for maximum protein content. Ridley (personal comm.) found triticale, wheat and barley responded to added nutrients when soil levels of nitrogen and phosphorous were low. They showed that these species were similar in their response to fertilizers, however, barley tended to respond to a slightly higher amount of fertilizer nitrogen than either wheat or triticale. CIMMYT (1976) reported that triticale was not as responsive to nitrogen fertilizer as wheat and that applications of nitrogen over 80 k/ha produced lodging in triticale.

Nitrogen (N) x Phosphorous (P) - Phosphorous is another important macroelement in cereal crops. The importance of phosphorous in plant growth may be appreciated from the quantitative ratio of the main elements that go to make up the chemical composition of various agricultural plants. Phosphorous enters into the composition of various protein compounds (phospho-proteins) which are essential for cellular nuclei, cytoplasm, enzymes etc. Phosphorous also plays an important part in the formation of chlorophyll and in the process of fruit formation. Numerous reports of the effects of P on cereals have been made by all cereal growing countries of the world. For Chile's North Central Region where nitrogen and phosphorous are limiting, Volke and Inostroza (1967), Diaz and Parodi (1973) and Norero (1972) reported on the effect of fertilizer on wheat. N and P improved tillering but reduced the number of grains per spike. Phosphorous alone increased 100-kernels weight while nitrogen application decreased it. Both N and P increased yield, which was positively correlated with tillering and plant height and negatively correlated with number of grains per spike. A decreased kernel-weight was associated with the higher rates of fertilizer. Norero (1972) found the best kernel-weight was obtained with a zero dose of nitrogen fertilizer. Phosphorous had a negative effect on the number of kernels per spike, but a positive effect on kernel-weight.

Mitchell (1953) found that barley and oats respond better than wheat to P, but that variation in response may also occur as a result of inherent varietal characteristics. McLean (1971) studying the influence of phosphorous and nitrogen found that the application of 250 kg of N per ha alone produced little increment in yield, while applications of both N and P gave 23 and 88% yield increases at the low and high rates respectively.

MATERIAL AND METHODS

The study was designed to investigate the effects of seed size and fertilizer on the expression of plant vigor, yield components, yield, protein content, and kernel characters of three spring hexaploid triticale (X *Triticosecale* Wittmack) lines. The seed of each line was divided into three size classes; large, small, and unsorted and the experiment was conducted at two locations in Chile's North Central region during the 1975-76 season.

Locations

The two locations in Chile's North Central Spring wheat growing region included, Pirque, Santiago and San Felipe, Aconcagua. The geographic and climatic characteristics of these locations are shown in Table 1.

Table 1 Geographic and climatic characteristics of the experimental locations.

Location	Latitude south	Longitude west	Altitude m	Average annual Rainfall mm	Average annual Temperature °C
Pirque	33° 42'	70° 35'	654	380	12.24
San Felipe	32° 45'	70° 44'	580	320	14.30

Soil analysis conducted at both locations previous to planting, provided the following information.

	Pirque	San Felipe
$(NH_4 + NH_3) = N$	22.17 ppm	8.19 ppm
P (olsen)	7.67 ppm	5.00 ppm
K	195.14 ppm	109.48 ppm
Organic matter	3.5%	2.8%
pH	8.1	7.8

The soil at both locations was representative of a well-drained sandy or fine sandy clay - loam type. The previous crop was safflower (Carthamus tinctorius) at Pirque and durum wheat (Triticum turgidum var. durum) at San Felipe.

Genotypes

Three spring hexaploid (2n = 42 = AABBRR) triticale lines, INIA / rye // Armadillo "S" ($\underline{X}$ 2142-12N-2M-4N-1M-1Y-0M); Navajoa (Maya $\overline{\underline{II}}$/ Armadillo "S" = $\underline{X}$ 2802-38N-3M-6N-5M-0Y); and Maya $\overline{\underline{II}}$ / Armadillo "S" ($\underline{X}$ 1802-37N-2M-1N-0M) were studied. In the results and discussion to follow, they will be identified as lines; 1, 2, and 3 respectively.

Parental kernel-type

Three seed-size classes of each line were obtained by sieving bulk lots of grain through a variable size screen. The three classes derived represented samples with (1) large kernels of high test-weights, (2) small kernels of low test-weight and (3) unsorted kernels of medium test-weight. These classes were designated as large, small and unsorted respectively.

Fertilizer rates

Four fertilizer treatments were applied to each seed class, namely: 0; 45; 90; 180k/ha of both N and P_2O_5. The nitrogen source was Chilian nitrate, N_aNO_3 (15% N) and Triple Super-phosphate (45% P_2O_5). Each nitrogen treatment was applied at three stages, viz., one third of the total application at planting, one third at tillering, and one third at anthesis. All the phosphorus was applied at the time of planting.

Field design

The experiment was arranged in the field as a split-split-plot (3 x 3 x 4) design with four replicates at two locations. Genotypes constituted the main plots, kernel-types the sub-plots, and fertilizer rates the sub-sub-plots. Each sub-sub-plot was 2m long and 1.5m wide with five rows spaced 0.30m apart. A uniform seeding rate of 202 seeds per row was used representing an equivalent rate of 200 k/ha.

General maintenance of plots

No disease problems were observed at either location.

Aphids (Metopolophium dirhodum Walker and Macrosiphum (Sitobium) avenae Fabricius) were controlled at both locations in October by air spraying Phosphomidon 50% in solution at 150 cc active ingredient per ha. A second application was applied when aphid numbers approximated 5 to 10 insects per plant in the border rows. The second application was made with a CO_2 pressure pump.

At both locations, weeds Brassica sp, Raphanus sp, Polygonum persicaria and Paspalum distichum, were controlled at post emergence with a herbicide mixture of 24% Picloram + 72% 2,4-D amine (0.65 kg/ha + 0.60 kg/ha respectively) in 300 l/ha of water.

Bird damage was controlled at Pirque by using an electronic sound device. No such control was necessary at San Felipe, where no bird damage occurred.

The material was irrigated throughout the growing period. Irrigation was carried out at 15-day intervals at both locations.

Characters observed

The ten plant characters studied and the stage of development at which each character was observed at each location are shown in Table 2. Vigor was recorded as a visual comparative estimation of the rate of development of the plants measured on a 1 to 5 scale with 1 representing the least vigorous plants. The number of spikes per plot was an actual count from the three centre rows in each sub-sub-plot. The number of kernels per spike was subsequently determined by the formula:

$$\text{Number of kernels per spike} = \frac{\text{Grain yield (g)}}{\text{Number of spikes} \times \text{weight of one kernel (g)}}$$

TABLE 2. Observations made on the experimental material.

Observation	Stage of development when observation was made	Scale
Emergence vigor	25 days after planting	1-5[1]
Tillering vigor	57 days after planting	1-5
Anthesis vigor	104 days after planting	1-5
Number of spikes per plot	at maturity	
Number of kernels per spike	after harvest	
100-kernel weight	after harvest	g
Grain yield	after harvest	kg/ha
Test-weight	after harvest	kg/hl
Protein content	after harvest	%
Post-harvest kernel type	after harvest	1-5[2]

[1] 1-5 scale, 1 representing the least vigorous and, 5 the most vigorous plants.

[2] 1-5 scale, 1 representing completely shrivelled, and 5 fully plump kernels.

Hundred-kernel weight, expressed in grams, was expressed as the mean of two random samples of 100 kernels each. Yield was calculated as grams per plot for each sub-sub-plot and transformed to kilograms per hectare by multiplying by the conversion factor 5.556.

Test-weight was measured with the appropriate equipment and expressed as kilograms per hectoliter. Protein content was determined using the dye-binding capacity method on duplicate samples from each sub-sub-plot expressing the final result as the mean of the two samples. Post-harvest kernel type evaluation was based on a visual estimate of the kernel development on a 1 to 5 scale; 1 representing completely shrivelled kernels and 5, fully plump and normal kernels.

Statistical analysis

Each set of data was subjected to an analysis of variance, as a split-split-plot design. Differences among means were estimated through Duncan's new multiple range test at the 0.05 level. The data were divided into three groups; the first contains information on the characteristics of the parent material. The second group includes preliminary information on seedling and plant vigor with the first measurement made at the 25-day-old seedling stage, the second after 57 days at the time of tillering and the third at anthesis. The third group is considered to be the main body of information obtained for this thesis and describes the genotypes, parental kernel-type and fertilizer effects on the expression of yield components and yield. Three additional variables are considered within this group, viz., test-weight, protein content, and post-harvest kernel type which are important considerations in furthering the triticale breeding program at the Catholic University of Chile.

RESULTS

Characteristics of the parental material

Evaluation of the parental material was made on the basis of three kernel characteristics, namely; germination, test weight, and protein content (Table 3). Comparison of the three seed-size classes within each genotype showed that germination percentage did not differ significantly either between seed classes within a genotype or between genotypes. A range of 93 to 99% germination was found to exist over all seed classes and genotypes.

As expected, test weights of seed classes differed significantly with the large, unsorted, and small classes reflecting progressively lighter seed weights. Genotypic differences within seed size classes were non significant.

Protein contents were significantly different between kernel classes with the small seed groups within each genotype exhibiting the highest protein percentage, followed by the unsorted and large classes respectively.

Factors affecting seedling vigor at Pirque and San Felipe

Analysis of variance of the factors affecting seedling vigor (Table 4) showed that kernel type and fertilizer application both exhibited a highly significant effect on

TABLE 3. Test-weight (k/hl), percent germination (%), and protein content (%) of each seed-size class derived from each of three triticale genotypes.

Genotype	Seed-size class	Test weight (k/hl)	Germination (%)	Protein content (%)
1	Unsorted	67.10 b[1]	99 a	9.33 b
	Large	69.83 a	98 a	8.80 b
	Small	50.61 c	99 a	15.53 a
	Mean	62.51	99	11.22
2	Unsorted	65.90 b	99 a	12.06 b
	Large	73.93 a	96 a	9.55 c
	Small	51.28 c	93 a	14.47 a
	Mean	63.64	96	12.03
3	Unsorted	70.96 b	98 a	9.55 b
	Large	72.88 a	98 a	8.01 c
	Small	53.73 c	94 a	12.25 a
	Mean	65.83	97	9.94

[1]Values designated by different letters are statistically different (0.05).

plant vigor at both locations. This effect expressed as early as 25 days after seeding, was carried through the plant's growth cycle to the anthesis stage which was the final measurement made for vigor response. The effect of vigor due to genotypes was not significant at both locations.

<u>Individual factors affecting vigor at Pirque and San Felipe</u>

Further analysis of the effects of individual factors on plant vigor as measured at the three progressive stages of plant growth viz: emergence, tillering, and anthesis at Pirque and San Felipe (Tables 5 to 10) showed no differences in emergence vigor between the three triticale lines as

TABLE 4. Mean squares from analyses of variance for vigor of three triticale lines grown at two locations.

		Mean squares					
		Emergence vigor (25 days)		Tillering vigor (57 days)		Anthesis vigor (104 days)	
Source of variation	d.f.	Pirque	San Felipe	Pirque	San Felipe	Pirque	San Felipe
Replications	3	5.139	2,859	3.340	0.192	5.528	0,278
Genotypes (A)	2	1.188	1.188	2,799	0.965	6.465	1,396
Error A	6	1.410	0.567	0,576	0.817	1.354	1,063
Total A	11	2.386	1.305	1.734	0.674	3.422	0,909
Parental kernel type (B)	2	29.021*	15.396*	36.549*	28.049*	5,257*	5.646*
AB	4	1.177	0.458	0.507	0.215	0,726	0,292
Error B	18	0.431	0.706	0,428	0.623	0,634	0.558
Total AB	35	2.764	1.705	2,912	2.159	1,785	0,929
Fertilizer rates (C)	3	29,806*	22,248*	9,563*	16,285*	29.972*	49.352*
AC	6	0.215	0.206	0,299	0.132	0,354	0,276
BC	6	1.131	0.498	0.271	0.215	0.340	0.192
ABC	12	0.094	0.602	0.174	0.354	0.295	0.157
Error C	81	0,252	0.309	0,217	0.346	0.344	0.182
TOTAL ABC	143	1.509	1.139	1.075	1.111	1.315	1.399

* Significant at the 0.01 level.

recorded at the three stages of growth.

Parental kernel type clearly had an influence on the vigor of the plants grown. Plants produced from small seeds exhibited a consistently reduced vigor relative to those grown from either unsorted or large seeds at both locations. Moreover, this reduced vigor was expressed throughout the three stages of the plant's development as evaluated in this study. These trends held true for all the three lines and for most comparisons the differences were not statistically different.

At both locations fertilizer responses varied depending upon the stage of plant growth (Figures 1 and 2). Emergence vigor was progressively suppressed with increased rates of fertilizer application. This effect was expressed within each seed size class for the three lines of triticale at both locations. Vigor as measured at tillering and anthesis, however, was generally expressed as a positive effect to increased fertilizer rates. At the tillering stage, only the highest rates of fertilizer (180-180 k/ha of N and P_2O_5) consistently resulted in a significantly increased vigor at Pirque (Figure 3). At San Felipe, tillering reacted positively to increased fertilizer rates (Figure 4). At anthesis, however, the response to fertilizer was more closely associated with application rate whereby each increment of N and P resulted in a corresponding improvement in vigor rating at Pirque and San Felipe (Figures 5 and 6).

Figure 1. Mean emergence vigor of 3 lines of triticale at Pirque 25 days after planting.

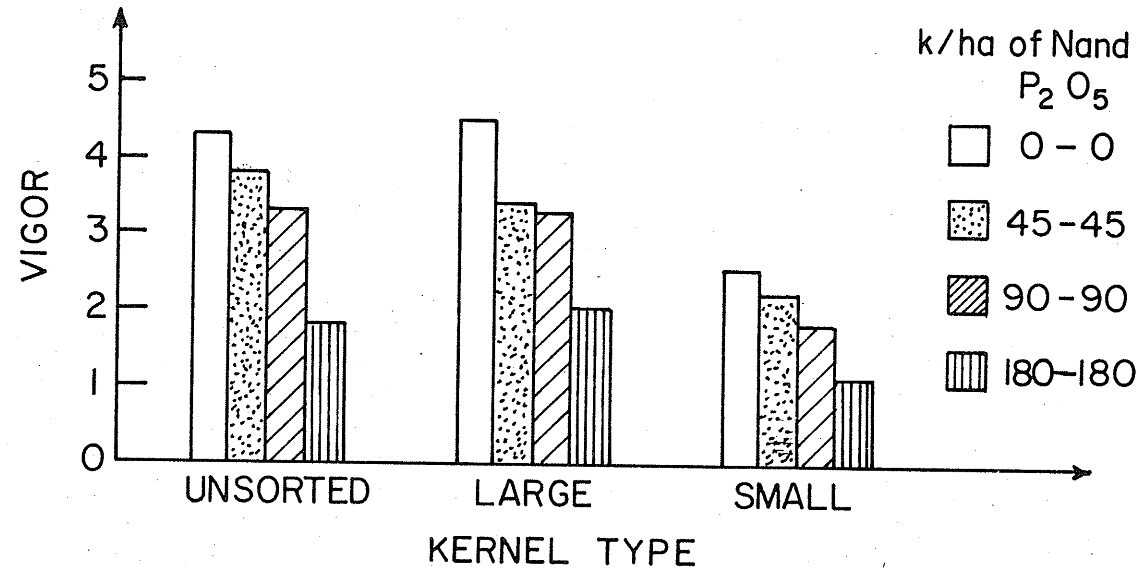

Figure 2. Mean emergence vigor of 3 lines of triticale at San Felipe 25 days after planting.

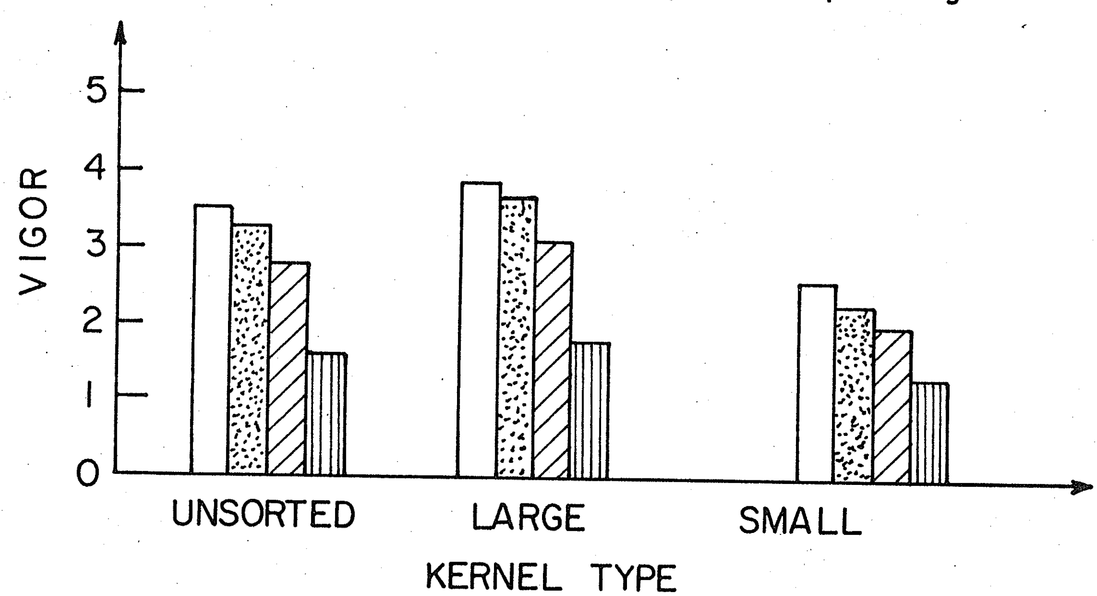

TABLE 5. Emergence vigor measured at Pirque 25 days after planting as affected by genotype parental kernel-type, and fertilizer application.

		LINES			
		1	2	3	
			Genotypic effect		
Genotypes		2.94 a[1]	2.63 a	2.81 a	
			Parental kernel-type effect		
Unsorted		3.69 a	2.88 d	3.00 cd	
Large		3.31 bc	3.19 bc	3.78 ab	
Small		1.81 c	1.81 e	2.06 e	
			Fertilizer effect		
	N - P (k/ha)				Mean
Unsorted	0-0	5.00 a	4.00 b	4.00 b	4.3
	45-45	4.25 b	3.50 c	3.50 c	3.8
	90-90	3.50 c	2.50 de	2.75 d	3.3
	180-180	2.00 fg	1.50 hi	1.75 gh	1.8
Large	0-0	4.75 a	4.00 b	4.75 a	4.5
	45-45	3.25 c	3.50 c	3.50 c	3.4
	90-90	3.25 c	3.25 c	3.25 c	3.3
	180-180	2.00 fg	2.00 fg	2.00 fg	2.0
Small	0-0	2.50 de	2.25 ef	2.75 d	2.5
	45-45	2.00 fg	2.25 ef	2.25 ef	2.2
	90-90	1.75 gh	1.75 gh	2.00 fg	1.8
	180-180	1.00 j	1.00 j	1.25 i	1.1

[1]Values designated by different letters are statistically different (0.05).

TABLE 6. Emergence vigor estimated at San Felipe 25 days after planting, as affected by genotype, parental kernel-type, and fertilizer application.

Variables		Lines 1	Lines 2	Lines 3	
			Genotypic effect		
Genotypes		2.67 a[1]	2.48 a	2.79 a	
		Parental kernel-type effect			
Unsorted		3.00 ab	2.63 bc	2.75 b	
Large		3.00 ab	3.00 ab	3.38 a	
Small		2.00 de	1.81 e	2.25 cd	
	N - P (k/ha)		Fertilizer effect		Mean
Unsorted	0-0	3.75 bc	3.00 ef	3.75 bc	3.5
	45-45	3.75 bc	3.00 ef	3.25 de	3.3
	90-90	3.00 ef	2.75 fg	2.50 gh	2.8
	180-180	1.50 kl	1.75 jk	1.50 kl	1.6
Large	0-0	3.75 bc	4.25 a	3.75 bc	3.9
	45-45	3.50 cd	3.50 cd	4.00 ab	3.7
	90-90	2.50 gh	3.00 ef	3.75 bc	3.1
	180-180	2.25 hi	1.25 lm	2.00 ij	1.8
Small	0-0	2.75 fg	2.25 hi	2.75 fg	2.6
	45-45	2.25 hi	2.25 hi	2.25 hi	2.3
	90-90	1.75 jk	1.75 jk	2.50 gh	2.0
	180-180	1.25 lm	1.00 m	1.50 kl	1.3

[1]Values designated by different letters are statistically different (0.05).

Figure 3. Mean tillering vigor of 3 lines of triticale at Pirque 57 days after planting.

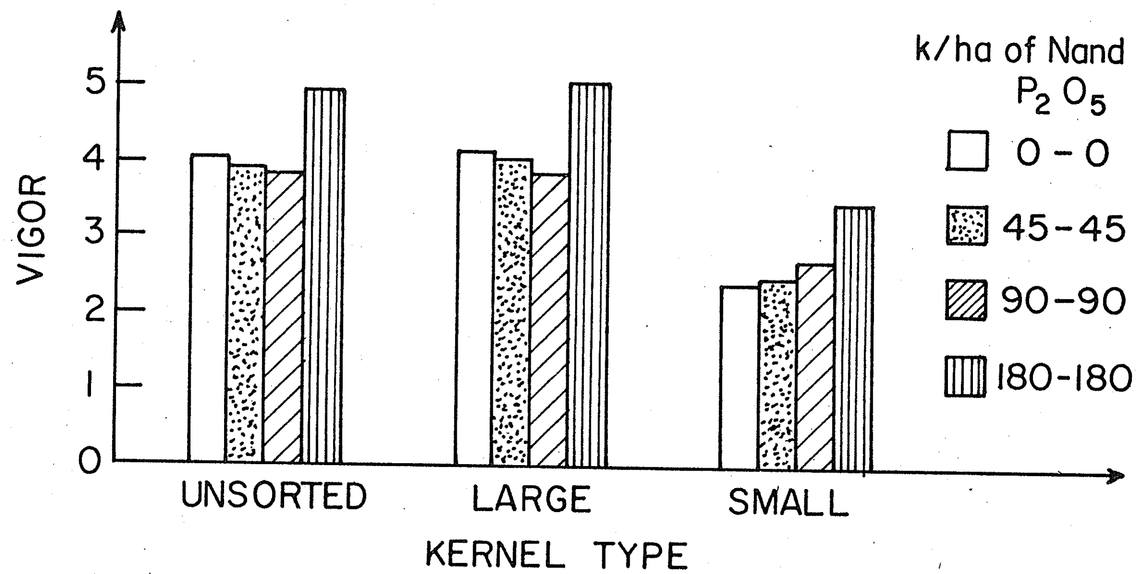

Figure 4. Mean tillering vigor of 3 lines of triticale at San Felipe 57 days after planting.

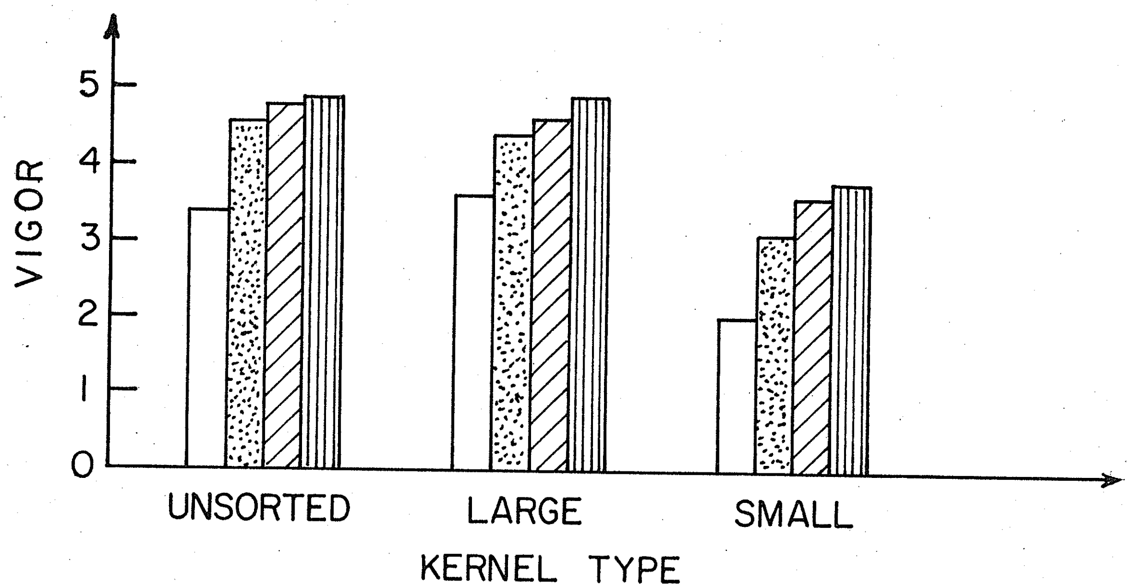

TABLE 7. Tillering vigor estimated at Pirque 57 days after planting, as affected by genotype, parental kernel-type, and fertilizer application.

Variables		Lines 1	2	3	
			Genotypic effect		
Genotypes		3.83 a[1]	3.40 a	3.79 a	
		Parental kernel-type effect			
Unsorted		4.50 a	3.81 c	4.12 bc	
Large		4.19 ab	4.06 bc	4.38 ab	
Small		2.81 d	2.31 e	2.88 d	
	N - P (k/ha)		Fertilizer effect		Mean
Unsorted	0-0	4.50 bc	3.50 fg	4.00 de	4.0
	45-45	4.25 cd	3.75 ef	3.75 ef	3.9
	90-90	4.25 cd	3.25 g	3.75 ef	3.8
	180-180	5.00 a	4.75 ab	5.00 a	4.9
Large	0-0	3.75 ef	4.00 de	4.50 bc	4.1
	45-45	4.00 de	3.75 ef	4.25 cd	4.0
	90-90	4.00 de	3.50 fg	3.75 ef	3.8
	180-180	5.00 a	5.00 a	5.00 a	5.0
Small	0-0	2.50 h	1.50 j	2.75 h	2.3
	45-45	2.50 h	2.25 i	2.50 h	2.4
	90-90	2.75 h	2.25 i	2.75 h	2.6
	180-180	3.50 fg	3.25 g	3.50 fg	3.4

[1]Values designated by different letters are statistically different (0.05).

TABLE 8. Tillering vigor estimated at San Felipe 57 days after planting, as affected by genotype, parental kernel-type, and fertilizer application.

Variables	N - P (k/ha)	Lines 1	2	3	Mean
		Genotypic effect			
Genotypes		3.92 a[1]	3.85 a	4.13 a	
		Parental kernel-type effect			
Unsorted		4.50 a	4.31 a	4.50 a	
Large		4.31 a	4.31 a	4.50 a	
Small		2.94 c	2.94 c	3.38 b	
		Fertilizer effect			
Unsorted	0-0	3.25 g	3.25 g	3.75 ef	3.4
	45-45	4.75 ab	4.50 bc	4.50 bc	4.6
	90-90	5.00 a	4.75 ab	4.75 ab	4.8
	180-180	5.00 a	4.75 ab	5.00 a	4.9
Large	0-0	3.75 ef	3.50 fg	3.50 fg	3.6
	45-45	4.25 cd	4.25 cd	4.75 ab	4.4
	90-90	4.25 cd	4.50 bc	5.00 a	4.6
	180-180	5.00 a	5.00 a	4.75 ab	4.9
Small	0-0	2.25 i	1.75 i	2.00 ij	2.0
	45-45	2.75 h	3.25 g	3.25 g	3.1
	90-90	3.25 g	3.50 fg	4.00 de	3.6
	180-180	3.50 fg	3.25 g	4.25 cd	3.8

[1]Values designated by different letters are statistically different (0.05).

Figure 5. Mean anthesis vigor of 3 lines of triticale at Pirque 104 days after planting.

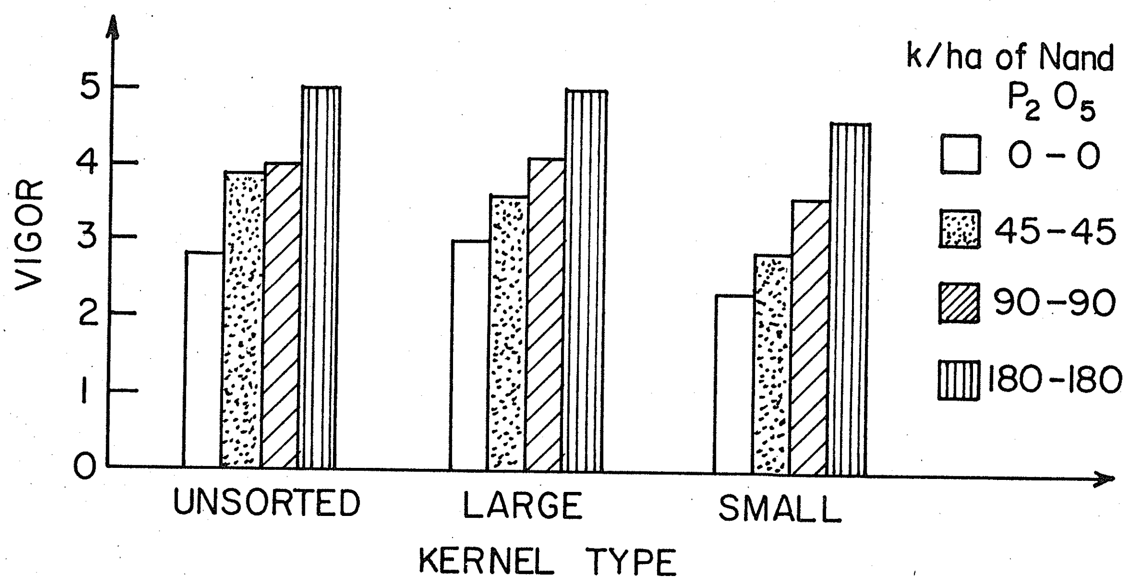

Figure 6. Mean anthesis vigor of 3 lines of triticale at San Felipe 104 days after planting.

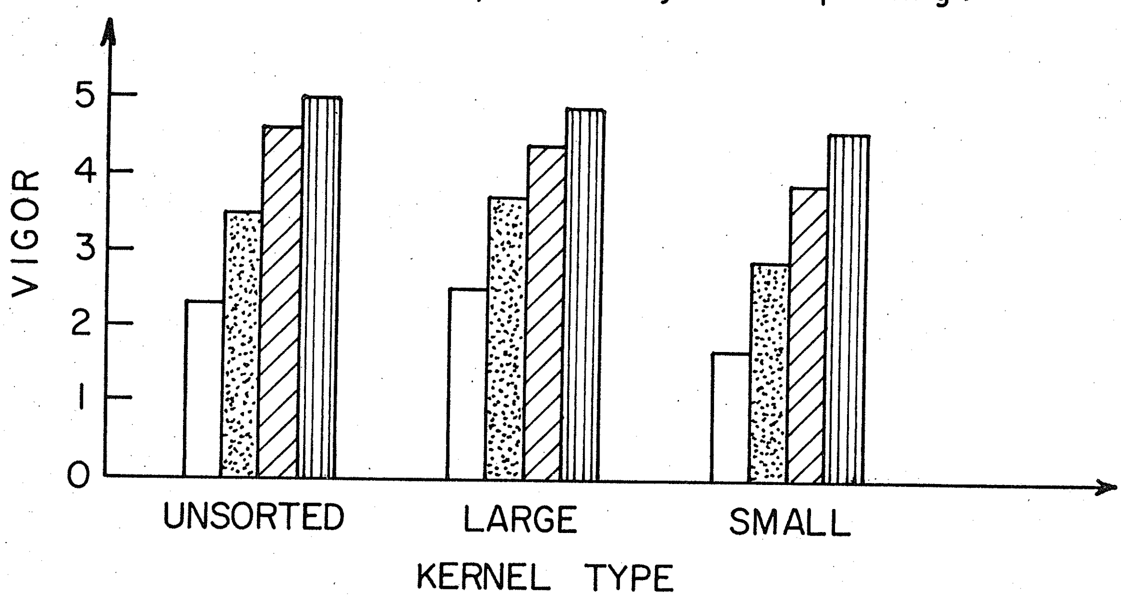

TABLE 9. Vigor at anthesis estimated at Pirque 104 days after planting, as affected by genotype, parental kernel-type, and fertilizer application.

Variables		Lines 1	2	3	
		Genotypic effect			
Genotypes		3.96 a[1]	3.31 a	3.94 a	
		Parental kernel-type effect			
Unsorted		4.13 a	3.50 c	4.13 a	
Large		4.00 ab	3.75 abc	4.06 a	
Small		3.75 abc	2.69 d	3.63 bc	
	N - P (k/ha)	Fertilizer effect			Mean
Unsorted	0-0	2.75 h	2.25 i	3.25 fg	2.8
	45-45	4.25 bc	3.50 ef	4.00 cd	3.9
	90-90	4.50 b	3.25 fg	4.25 bc	4.0
	180-180	5.00 a	5.00 a	5.00 a	5.0
Large	0-0	2.75 h	3.00 gh	3.25 fg	3.0
	45-45	4.00 cd	3.50 ef	3.50 ef	3.6
	90-90	4.25 bc	3.50 ef	4.50 b	4.1
	180-180	5.00 a	5.00 a	5.00 a	5.0
Small	0-0	2.75 h	1.75 j	2.25 i	2.3
	45-45	3.25 fg	2.25 i	3.25 fg	2.9
	90-90	4.00 cd	3.00 gh	4.00 cd	3.6
	180-180	5.00 a	3.75 de	5.00 a	4.6

[1]Values designated by different letters are statistically different (0.05).

TABLE 10. Vigor at anthesis estimated at San Felipe 104 days after planting, as affected by genotype, parental kernel-type, and fertilizer application.

Variables		Lines 1	Lines 2	Lines 3	
			Genotypic effect		
Genotypes		3.81 a[1]	3.48 a	3.71 a	
			Parental kernel-type effect		
Unsorted		3.94 a	3.75 abc	3.88 ab	
Large		4.00 a	3.56 bc	4.06 a	
Small		3.50 cd	3.13 f	3.19 df	
	N - P (k/ha)		Fertilizer effect		Mean
Unsorted	0-0	2.25 l	2.50 k	2.25 l	2.3
	45-45	3.75 f	3.25 h	3.50 g	3.5
	90-90	4.75 b	4.25 d	4.75 b	4.6
	180-180	5.00 a	5.00 a	5.00 a	5.0
Large	0-0	2.50 k	2.25 l	2.75 j	2.5
	45-45	4.00 e	3.25 h	3.75 f	3.7
	90-90	4.50 c	4.00 e	4.75 b	4.4
	180-180	5.00 a	4.75 b	5.00 a	4.9
Small	0-0	2.00 m	1.75 m	1.25 o	1.7
	45-45	3.00 i	3.00 i	2.75 j	2.9
	90-90	4.25 d	3.50 g	4.00 e	3.9
	180-180	4.75 b	4.25 d	4.75 b	4.6

[1]Values designated by different letters are statistically different (0.05).

Yield and quality components

A total of seven characters pertaining to yield and kernel quality components were analysed from the experimental material as described previously. These factors were:

(1) Number of spikes per plot

(2) Number of kernels per spike

(3) Hundred-kernel weight

(4) Yield

(5) Test-weight

(6) Protein content

(7) Post-harvest kernel type

The mean squares from analyses of variance (Tables 11 and 12) indicate that at both locations genotypic (triticale lines) differences had a significant influence on the number of spikes per plot, 100-kernel weight, overall yield, and kernel test-weight. Kernel number per spike was influenced by genotype at San Felipe, while significant differences in protein were found to exist between lines at Pirque only. At both locations genotypic differences had non-significant influence on post-harvest kernel type. Highly significant effects of parental kernel type were expressed by all characters at Pirque, but at San Felipe, protein content was the only character exhibiting non significant differences. Fertilizer rates significantly affected all characters at both locations except post harvest kernel type which was the only character found to be non significant at Pirque.

TABLE 11. Mean squares from analyses of variance for specific components of yield and kernel quality at Pirque.

		Mean squares						
Source of variation	d.f.	Spikes per plot	Kernels per spike	100-kernel weight (g)	Yield (k/hl)	Test weight (k/hl)	Protein Content (%)	Post-harvest kernel type
Replications	3	52616.0	133.70	0.465	156370.0	3.623	6.427	0.363
Genotypes (A)	2	252660.0**	118.67	2.246**	342930.0**	50.768**	16.231*	2.443
Error A	6	15902.0	26.46	0.166	12989.0	2.136	2.779	0.637
Total A	11	68961.0	72.48	0.626	112082.0	11.384	6.220	0.891
Parental kernel-type (B)	2	57625.0*	147.70**	1.443**	658190.0**	66.760**	8.028**	2.099*
AB	4	11354.0	51.57	0.105	48260.0	1.285	2.948	0.760
Error B	18	10828.0	22.69	0.151	28290.0	3.316	1.280	0.445
Total AB	35	31831.0	48.78	0.369	92903.0	9.245	3.409	0.716
Fertilizer rate (C)	3	504920.0**	468.27**	0.062	1726600.0**	12.085**	56.832**	0.492
AC	6	5625.8	34.13*	0.101	14766.0	2.594	3.533*	0.142
BC	6	15330.0**	60.79**	0.137	26468.0*	0.738	0.459	0.117
ABC	12	3606.1	17.33	0.060	13026.0	2.209	1.463	0.074
Error C	81	3753.0	13.57	0.080	8706.0	1.460	0.864	0.193
Total ABC	143	21692.0	34.88	0.152	66714.0	3.668	2.806	0.312

*, ** Significant at the 0.05 and 0.01 levels, respectively.

TABLE 12. Mean squares from analyses of variance for specific components of yield and kernel quality at San Felipe.

		Mean squares						
Source of variation	d.f.	Spikes per plot	Kernels per spike	100 kernel weight (g)	Yield (k/ha)	Test weight (k/hl	Protein content (%)	Post-harvest kernel type
Replications	3	14385.0	13.48	0.292	52360.0	0.538	0.205	1.766
Genotypes (A)	2	76181.0**	860.85**	2.951**	300620.0*	133.910**	0.646	0.398
Error A	6	5661.0	29.49	0.059	45709.0	1.130	1.185	0.939
Total A	11	20861.8	176.27	0.644	93872.7	25.111	0.820	1.066
Parental kernel-type (B)	2	31290.0**	221.80**	1.076**	470160.0**	8.531**	2.303	2.325*
AB	4	1282.0	12.67	0.068	9217.9	9.435	1.396	0.484
Error B	18	3150.8	28.10	0.046	18181.0	3.222	1.672	0.366
Total AB	35	10111.7	83.98	0.296	66771.4	15.502	1.409	0.711
Fertilizer rate (C)	3	251230.0**	501.42**	0.763**	948240.0**	41.281**	74.281**	0.432**
AC	6	4757.9	17.68	0.096	8204.4	0.864	0.631	0.896
BC	6	5455.1	15.95	0.119	7500.4	0.905	0.302	0.186
ABC	12	4742.7	38.87	0.054	15767.0*	2.731	0.692	0.261
Error C	81	3142.0	15.20	0.075	8067.6	2.540	0.711	0.203
Total ABC	143	10251.8	44.36	0.144	42787.4	6.402	2.403	0.521

*, ** Significant at the 0.05 and 0.01 levels, respectively.

Significant single interactions were obtained only at Pirque affecting a few of the seven characters. These included a genotype x fertilizer interaction affecting number of kernels per spike and protein content. Similarly, a significant parental kernel type x fertilizer interaction affecting the number of spikes per plot, number of kernels per spike, and overall yield at Pirque. The triple interaction was significant for number of kernels per spike and overall yield at San Felipe, (Table 12).

Individual factors affecting yield and quality components

Number of spikes per plot - Comparing the three lines of triticale for number of spikes produced showed that line 1 was significantly more productive than either lines 2 or 3 at both locations. This was also reflected within parental kernel type at both locations (Tables 13 and 14). At Pirque plants derived from the three parental kernel types produced non significant numbers of spikes per plot in lines 1 and 3. In line 2, plants derived from small kernels produced significantly fewer spikes per plot than plants derived from large or unsorted kernel types. At San Felipe a significantly lower number of spikes were produced by the small seed class, while the large and unsorted parental kernel types were non significantly different in the production of spikes. Fertilizer response was clearly expressed in increments of spike number per plot. In all instances, the highest

TABLE 13. Number of spikes per plot at Pirque as modified by genotype parental kernel-type, and fertilizer application.

Variable		Lines 1	2	3
		Genotypic effect		
Genotypes		743.25 a[1]	599.75 b	652.88 b
		Parental kernel-type effect		
Unsorted		746.13 a	633.75 b	665.44 b
Large		760.94 a	640.63 b	664.31 b
Small		722.69 a	524.88 c	628.88 b
	N - P (k/ha)	Fertilizer effect		
Unsorted	0-0	563.50 p	526.25 g	566.50 op
	45-45	652.00 hi	597.25 lmno	593.50 mnop
	90-90	839.00 cd	631.50 ijkl	722.25 e
	180-180	930.00 a	780.00 d	779.50 d
Large	0-0	640.75 ijk	565.50 op	578.00 nop
	45-45	719.00 ef	605.75 lmn	684.25 fgh
	90-90	799.25 d	615.75 ijklm	646.00 ij
	180-180	890.75 b	775.50 d	785.00 d
Small	0-0	570.25 op	345.25 t	427.00 s
	45-45	654.25 hi	474.25 r	609.00 klm
	90-90	804.50 d	599.00 lmno	694.75 efg
	180-180	861.75 bc	681.00 gh	784.75 d

[1] Values designated by different letters are statistically different (0.05).

TABLE 14. Number of spikes per plot at San Felipe as modified by genotype parental kernel-type, and fertilizer application.

Variable		Lines 1	2	3
		Genotypic effect		
Genotypes		626.56 a[1]	548.35 b	574.27 b
		Parental kernel-type effect		
Unsorted		640.38 a	563.06 de	584.00 cd
Large		639.69 ab	569.00 d	597.44 c
Small		606.63 bc	513.00 f	541.38 e
	N - P (k/ha)	Fertilizer effect		
Unsorted	0-0	506.00 n	541.75 op	507.25 n
	45-45	637.00 de	546.75 jklm	524.75 mn
	90-90	685.25 bc	652.50 cd	615.25 efg
	180-180	733.25 a	601.25 fgh	688.75 a
Large	0-0	463.25 o	472.50 o	433.50 p
	45-45	690.00 b	535.50 klmn	563.25 ijk
	90-90	683.75 bc	641.25 de	693.25 b
	180-180	693.75 b	626.75 def	699.75 ab
Small	0-0	531.00 lmn	403.25 q	456.50 o
	45-45	584.00 ghi	516.50 n	549.00 jklm
	90-90	627.25 def	571.00 hij	572.50 hij
	180-180	684.25 bc	561.25 ijkl	587.50 ghij

[1]Values designated by different letters are statistically different (0.05).

fertilizer treatment (180-180 k/ha of N and P_2O_5) resulted in the largest spike number. The control treatment (0-0 k/ha of N and P_2O_5) produced the lowest number of spikes per plot at Pirque but were less clearly defined at San Felipe. It is of interest to note the percent increase in number of spikes per plot in response to fertilizer treatment. At Pirque within the unsorted class of line 1 a 65.0% increase in kernel number per spike occurred when comparing the control fertilizer treatment with the highest rate used. A similar comparison within the large seed class of this same line revealed a 30.0% increase and within the small seed class, a 51.1% increase. In lines 2 and 3 the largest increase in kernel number came within the small seed class giving 97.2% and 83.7% increases respectively. At San Felipe the overall increment in number of spikes per plot due to fertilizer was less than at Pirque. The largest increment (61.4%) occurred in line 3 within the large seed class.

<u>Numbers of kernels per spike</u> - Comparison of the three lines of triticale for number of kernels per spike showed that at both locations lines 2 and 3 produced significantly more kernels per spike than line 1 (Tables 15 and 16). The effects of parental kernel type showed that in lines 1 and 3, plants derived from unsorted and large kernels produced statistically similar number of kernels per spike at both locations. Line 2 at Pirque where plants derived from

large kernels produced significantly more kernels per spike than plants derived from unsorted and small kernels. Parental kernel type had no effect on kernel number per spike in line 2 at San Felipe. Plant derived from unsorted and large kernels produced more kernels per spike than small kernels at both locations. Fertilizer effects at both locations showed that, in general, the nonfertilized plots produced the lowest number of kernels per spike. As the level of fertilizer was increased (0-0, 45-45, 90-90, and 180-180 k/ha of N and P_2O_5), the number of kernels per spike also increased significantly within each line. An observation of interest is the percent increase in number of kernels per spike in response to the fertilizer treatments. At Pirque for example, the increase in kernel number per spike between the highest and lowest fertilizer treatments (0-0 and 180-180 k/ha of N and P_2O_5) within the small seed class of line 1 amounted to only 8.5% while similar comparisons within the large and unsorted seed classes of this same line revealed a 32.1% and a 33.2% increase respectively. Line 2 showed an increase of 24.1%, 41.7%, and 73.0% for the small, large and unsorted seed classes respectively. Line 3 exhibited a striking difference in the number of kernels per spike ranging from a 3.8% increase within the small seed class to a 71.0% increase within the large seed class.

At San Felipe similar comparisons in kernel number per spike between the lowest and highest fertilizer treatments

TABLE 15. Number of kernels per spike at Pirque as modified by genotype, parental kernel-type, and fertilizer application.

Variables		Lines 1	2	3
			Genotypic effect	
Genotypes		27.91 b[1]	30.55 a	30.74 a
			Parental kernel-type effect	
Unsorted		27.69 d	28.06 de	32.23 ab
Large		29.49 cd	34.07 a	31.42 bc
Small		26.59 e	29.52 cd	28.56 de
	N - P (k/ha)		Fertilizer effect	
Unsorted	0-0	22.44 r	20.56 s	27.63 lmno
	45-45	27.12 lmno	26.28 nop	33.82 de
	90-90	31.35 fgh	29.83 hijk	30.63 hi
	180-180	29.88 hijk	35.56 cd	36.83 c
Large	0-0	24.86 pq	30.41 hij	23.68 qr
	45-45	30.26 hijk	30.02 hijk	28.23 klmn
	90-90	29.97 hijk	32.76 efg	33.29 ef
	180-180	32.85 efg	43.09 a	40.50 b
Small	0-0	24.80 pq	26.67 mnop	28.11 klmn
	45-45	28.74 ijklm	28.48 ijklm	28.31 jklmn
	90-90	25.93 op	29.86 hijk	28.63 ijklm
	180-180	26.90 mno	33.09 ef	29.19 hijkl

[1]Values designated by different letters are statistically different (0.05).

TABLE 16. Number of kernels per spike at San Felipe as modified by genotype, parental kernel-type, and fertilizer application.

Variable	N - P (k/ha)	Lines 1	2	3
		Genotypic effect		
Genotypes		29.23 b[1]	37.10 a	35.88 a
		Parental kernel-type effect		
Unsorted		29.90 d	38.45 a	38.37 a
Large		30.73 cd	37.71 ab	36.68 ab
Small		27.08 e	35.15 b	32.60 c
		Fertilizer effect		
Unsorted	0-0	24.07 p	36.09 fghi	34.18 ijkl
	45-45	29.86 no	33.61 jklm	37.12 defg
	90-90	33.25 jklm	37.97 def	39.17 cd
	180-180	32.41 klm	46.12 a	43.01 b
Large	0-0	29.11 o	29.56 o	35.12 ghij
	45-45	28.96 o	34.42 hijk	35.91 fghi
	90-90	32.01 lmn	40.64 c	36.94 defg
	180-180	32.82 klm	46.21 a	38.74 cde
Small	0-0	24.52 p	28.56 o	24.50 p
	45-45	25.70 p	38.46 de	31.81 mn
	90-90	28.17 o	37.07 defg	36.07 fghi
	180-180	29.92 no	36.53 efgh	38.00 def

[1]Values designated by different letters are statistically different (0.05).

for line 1 showed an increase of only 12.8% within the large seed class while increases of 22.0% and 34.7% were observed within the small and unsorted classes respectively. Line 2 showed increases of 27.8%, 56.3% and 28.0% within the unsorted, large, and small seed classes respectively. Line 3, on the other hand, exhibited a large increase (55.1%) within the small seed class, while the large and unsorted seed classes showed a 10.3% and 25.8% increase in kernel number per spike in response to high fertilizer rate.

Hundred-kernel weight - Kernel density was characterised by significant differences among genotypes with lines 1 and 3 producing significantly heavier kernels than line 2 at Pirque. At San Felipe, all three lines were significantly different, line 3 producing the heaviest kernels and line 2 the lightest (Tables 17 and 18). Parental kernel type effects were significantly different for the three lines. At Pirque the plants produced from the unsorted and large kernel types in lines 1 and 2 produced significantly heavier kernels than plants derived from small kernels. In line 3 there were no significant differences in kernel weight resulting from the three parental kernel types. At San Felipe, plants from unsorted and large kernel types produced significantly heavier kernels than plants derived from small kernels in all three lines. Fertilizer effects were not consistent in modifying kernel weight at each of the two locations. In general, the highest fertilizer rate (180-180 k/ha of N and

TABLE 17. Hundred-kernel weight at Pirque as modified by genotype, parental kernel-type, and fertilizer application.

Variable		Lines 1	Lines 2	Lines 3
		Genotypic effect		
Genotypes		3.95 a[1]	3.59 b	3.97 a
		Parental kernel-type effect		
Unsorted		4.01 abc	3.56 e	4.01 abc
Large		4.51 a	3.84 cd	4.04 ab
Small		3.74 d	3.36 f	3.86 bcd
	N - P (k/ha)	Fertilizer effect		
Unsorted	0-0	3.95 defghi	3.45 r	3.98 defghi
	45-45	4.23 ab	3.62 nopq	4.09 bcde
	90-90	3.87 hijk	3.67 mnop	4.11 abcd
	180-180	4.02 defgh	3.52 pqr	3.85 hijkl
Large	0-0	4.07 bcdef	3.88 hijk	4.19 abc
	45-45	4.09 abcde	3.94 efghij	3.92 fghij
	90-90	4.22 ab	3.91 ghij	4.25 a
	180-180	4.06 cdefg	3.62 opq	3.82 ijklm
Small	0-0	3.78 jklmn	3.21 s	3.92 fghij
	45-45	3.49 qr	3.55 pqr	3.71 lmno
	90-90	3.73 klmno	3.42 r	3.82 ijklm
	180-180	3.96 defghi	3.28 s	3.98 defgh

[1]Values designated by different tillers are statistically different (0.05).

TABLE 18. Hundred-kernel weight at San Felipe, as modified by genotype, parental kernel-type and fertilizer application.

Variable	N - P (k/ha)	Lines 1	Lines 2	Lines 3
		Genotypic effect		
Genotypes		3.46 b[1]	3.33 c	3.81 a
		Parental kernel-type effect		
Unsorted		3.59 c	3.36 ef	3.83 b
Large		3.49 d	3.46 de	3.96 a
Small		3.29 fg	3.17 g	3.62 c
		Fertilizer effect		
Sorted	0-0	3.57 hijk	3.17 rst	3.90 bcd
	45-45	3.80 cde	3.60 ghij	3.91 bc
	90-90	3.67 efghi	3.49 jklmn	3.96 b
	180-180	3.35 mnopq	3.17 rst	3.57 hijk
Large	0-0	3.36 lmnopq	3.54 ijk	3.92 b
	45-45	3.63 fghij	3.78 cdef	4.13 a
	90-90	3.54 ijk	3.38 lmnop	4.27 a
	180-180	3.43 klmno	3.13 st	3.54 ijk
Small	0-0	3.16 rst	3.04 st	3.50 jklm
	45-45	3.23 pqrs	3.30 opqr	3.72 efgh
	90-90	3.43 klmno	3.11 st	3.75 defg
	180-180	3.34 opqr	3.22 qrs	3.50 jkl

[1]Value designated by different letters are statistically different (0.05).

P_2O_5) had a tendency to reduce kernel weight relative to the intermediate rates used in this study.

Yield - Grain yield data from both locations are shown in Tables 19 and 20. At Pirque, lines 1 and 3 produced significantly higher yields than line 2 while at San Felipe line 3 was the significantly highest yielding line. Significantly higher yields were produced on plants derived from large and unsorted seeds at both locations. Fertilizer treatment was significant in all treatment combinations with the control producing the lowest yield within the three parental classes at both locations. At Pirque, the yield increased in accordance with fertilizer rates. For example, in line 1 within the large kernel type the increments in fertilizer rates (45-45, 90-90, and 180-180 k/ha of N and P_2O_5) produced yield increments of 37.2%, 54.23%, and 81.2% respectively. Line 2 had the greatest yield increase (162%) at Pirque in response to the highest fertilizer rate (180-180 k/ha of N and P_2O_5) within the unsorted kernel type, and an increase of 84.0% was obtained with the large seed class while the small seed class showed a 153.7% increase in yield. At San Felipe, the highest yields were not necessarily produced by the highest fertilizer rates. For example, in line 1 within the unsorted seed class, a yield increment of 63.1% resulted from a 45-45 fertilizer rate, while the 90-90 fertilizer rate resulted in the highest increment of yield

TABLE 19. Grain yield (k/ha) at Pirque as modified by genotype, parental kernel-type, and fertilizer application.

Variable		Lines 1	2	3
		Genotypic effects		
Genotypes		4609.26 a[1]	3728.36 b	4450.81 a
		Parental kernel-type effect		
Unsorted		4702.43 a	3623.26 c	4798.61 ab
Large		5169.44 a	4673.61 b	4707.29 b
Small		3955.90 c	2888.19 d	3846.53 c
	N - P (k/ha)	Fertilizer effect		
Unsorted	0-0	2762.50 pq	2072.22 r	3454.17 klm
	45-45	4127.78 fgh	3151.89 no	4579.17 e
	90-90	5700.00 c	3838.89 hij	5026.39 d
	180-180	6219.44 b	5430.55 c	6134.72 b
Large	0-0	3611.11 jk	3679.17 ijk	3173.61 mno
	45-45	4955.55 d	3962.50 ghi	3965.28 ghi
	90-90	5569.44 c	4284.72 ef	5061.11 d
	180-180	6541.67 a	6768.06 a	6629.17 a
Small	0-0	2968.05 op	1611.11 s	2619.44 q
	45-45	3587.50 jkl	2550.00 q	3541.67 kl
	90-90	4266.67 f	3304.17 lmn	4190.28 fg
	180-180	5001.39 d	4087.50 fgh	5034.72 d

[1]Values designated by different letters are statistically different (0.05).

TABLE 20. Grain yield (k/ha) at San Felipe as modified by genotype, parental kernel-type, and fertilizer application.

Variables		Lines 1	Lines 2	Lines 3
		Genotypic effect		
Genotypes		3558.68 b[1]	3807.75 b	4413.56 a
		Parental kernel-type effect		
Unsorted		3824.31 bc	4081.25 b	4793.05 a
Large		3805.90 bc	4119.79 b	4839.93 a
Small		3045.83 d	3222.22 d	3607.64 c
	N - P (k/ha)	Fertilizer effect		
Unsorted	0-0	2418.05 rs	2890.28 p	3827.78 jkl
	45-45	3943.05 ijk	3823.61 jkl	4216.67 ghi
	90-90	4622.22 de	4802.78 d	5300.00 b
	180-180	4313.89 g	4805.55 d	5827.78 a
Large	0-0	2606.94 qr	2761.11 pq	3337.50 o
	45-45	4016.67 hij	3850.00 jkl	4613.89 def
	90-90	4277.78 g	5112.50 c	6123.61 a
	180-180	4322.22 fg	4973.61 cd	5284.72 b
Small	0-0	2270.83 s	1940.28 t	2186.11 s
	45-45	2694.44 pq	3636.11 lmn	3531.95 mno
	90-90	3405.55 no	3640.28 lmn	4365.28 efg
	180-180	3812.50 jklm	3672.22 klmn	4347.22 efg

[1]Values designated by different letters are statistically different (0.05).

(91.2%) and with 180-180 the increase was only of 78.4%. The overall increment in yield at San Felipe was lower than at Pirque.

<u>Test weight</u> - Comparing the three lines of triticale for test-weight showed lines 2 and 3 to have significantly better test weight than line 1 at both locations (Tables 21 and 22). Parental kernel type effect was also expressed in that plants derived from large kernels produced seeds with significantly higher test weight than progeny of small kernel at Pirque. At San Felipe, plants derived from unsorted and large kernel types produced better test weights than plants derived from small kernel type. Fertilizer effects on test weight were inconsistent and no clear pattern of response was expressed. It was apparent however, that the highest fertilizer rates tended to suppress test weight below that of the control. This tendency was general for all seed size classes.

<u>Protein content</u> - The three genotypes exhibited no statistical difference in protein content at San Felipe, while at Pirque, lines 2 and 3 showed significantly higher protein than line 1 (Tables 23 and 24). Parental kernel type effect was also expressed in line 1 in that plants derived from small kernels had significantly higher protein content at both locations than those derived from large and unsorted kernels. Lines 2 and 3 did not exhibit a consistent pattern with respect to seed size in protein content. Without exception, the highest

TABLE 21. Test-weight (k/hl) at Pirque, as modified by genotype, parental kernel-type, and fertilizer application.

Variables		Lines 1	2	3
		Genotypic effect		
Genotypes		64.62 b[1]	66.60 a	66.09 a
		Parental kernel-type effect		
Unsorted		64.24 e	66.76 b	65.93 bc
Large		66.17 bc	67.57 a	67.30 a
Small		63.46 f	65.48 cd	65.05 de
	N - P (k/ha)	Fertilizer effect		
Unsorted	0-0	64.94 ijkl	67.43 b	66.50 efg
	45-45	65.55 hi	67-76 b	65.38 hij
	90-90	62.46 q	65.94 fgh	66.75 cde
	180-180	64.03 nop	65.90 gh	65.10 ijk
Large	0-0	66.45 efg	67.41 b	67.59 b
	45-45	66.56 defg	68.55 a	67.40 bc
	90-90	65.66 h	67.69 b	66.96 bcde
	180-180	66.00 fgh	66.63 def	67.25 bcd
Small	0-0	64.70 jklm	65.10 ijk	65.66 h
	45-45	63.98 nop	65.78 h	65.99 fgh
	90-90	62.69 opq	66.46 efg	64.31 lmn
	180-180	62.46 pq	64.60 klmn	64.25 mno

[1]Values designated by different letters are statistically different (0.05).

TABLE 22. Test-weight (k/hl) at San Felipe, as modified by genotype, parental kernel-type, and fertilizer application.

Variables		Lines 1	2	3
		Genotypic effect		
Genotypes		68.86 b[1]	66.71 a	66.79 a
		Parental kernel-type effect		
Unsorted		65.44 c	66.83 b	67.32 b
Large		64.00 d	68.29 a	67.80 b
Small		62.15 e	65.02 c	65.59 c
	N - P (k/ha)	Fertilizer effect		
Unsorted	0-0	65.71 jkl	66.45 ghijk	67.99 cde
	45-45	66.56 ghijk	67.01 fgh	66.91 fghi
	90-90	66.24 hijkl	68.60 abc	67.53 def
	180-180	63.23 qr	65.26 mno	66.84 fghi
Large	0-0	63.76 pq	69.44 a	67.18 efg
	45-45	65.65 klmn	69.23 ab	68.04 cde
	90-90	64.42 op	68.31 bcd	68.61 abc
	180-180	62.18 s	66.20 hijkl	66.08 ijklm
Small	0-0	62.42 rs	65.38 lmn	65.11 no
	45-45	61.96 s	66.00 ijklmn	66.63 fghij
	90-90	63.35 p	65.16 no	66.69 fghi
	180-180	60.86 t	63.53 q	63.93 pq

[1]Value designated by different letters are statistically different (0.05).

protein content was produced with the highest fertilizer rate. At Pirque, for example, line 1 within the three parental seed size classes, the highest fertilizer rate produced 30.1%, 39.8%, and 34.3% more protein content in the seed respectively than the control. In line 2 the highest fertilizer rate produced relatively smaller increases of 7.2%, 20.2%, and 13.3% in protein content within the unsorted, large and small seed classes respectively. In line 3 the increase in protein content at the highest fertilizer rate was 26.7%, 17.25%, and 5.8% respectively for the three parental seed classes. At San Felipe, the increment in protein content was higher than at Pirque. In line 1 the highest fertilizer rate increased the protein content by 37.9%, 31.6%, and 41.5% respectively in the three parental seed classes over that of the control. Similarly, in line 3 the small parental seed class exhibited the largest increase (36.2%) in protein content, while in line 2 the large parental seed class showed the greatest increase in protein content (33.7%).

Post-harvest kernel type - Comparing the three lines of triticale for kernel type after harvest showed lines 1 and 3 to have the best kernel type at Pirque. At San Felipe, however, the three lines were non significantly different for this character (Tables 25 and 26). The parental kernel type effect was not well defined within the lines, however, there was a trend for small parental kernels to result in

TABLE 23. Protein content (%) at Pirque as modified by genotype, parental kernel-type, and fertilizer application.

Variables	N - P (k/ha)	Lines 1	Lines 2	Lines 3
		Genotypic effect		
Genotypes		12.18 b[1]	13.19 a	13.19 a
		Parental kernel-type effect		
Unsorted		12.07 e	13.13 bc	13.90 a
Large		11.72 e	12.69 d	12.74 d
Small		12.76 d	13.56 ab	12.93 cd
		Fertilizer effect		
Unsorted	0-0	11.29 mop	13.14 hi	12.31 jk
	45-45	10.25 q	12.26 jk	13.42 gh
	90-90	12.00 kl	13.85 fg	14.27 def
	180-180	14.69 cd	14.09 ef	15.60 a
Large	0-0	10.23 q	11.97 klm	12.25 jk
	45-45	10.85 p	11.30 nop	11.60 lmn
	90-90	11.50 mno	13.10 hi	12.71 ij
	180-180	14.30 def	14.39 de	14.40 de
Small	0-0	11.45 nop	13.20 hi	12.68 ij
	45-45	11.08 op	13.08 hi	12.38 jk
	90-90	13.14 hi	13.00 hi	13.26 h
	180-180	15.38 ab	14.95 bc	13.41 gh

[1]Values designated by different letters are statistically different (0.05).

TABLE 24. Protein content (%) at San Felipe, as modified by genotype, parental kernel-type, and fertilizer application.

Variables	N - P (k/ha)	Lines 1	Lines 2	Lines 3
		Genotypic effect		
Genotypes		11.23 a[1]	11.05 a	11.27 a
		Parental kernel-type effect		
Unsorted		10.98 bc	10.87 c	11.23 abc
Large		10.92 bc	11.27 abc	11.09 bc
Small		11.78 a	11.02 bc	11.50 ab
		Fertilizer effect		
Unsorted	0-0	9.83 nopq	9.79 opq	10.16 klmno
	45-45	9.40 q	10.28 klmn	10.48 k
	90-90	11.14 ghi	11.21 fghi	11.00 ij
	180-180	13.56 bc	12.20 e	13.27 c
Large	0-0	9.56 pq	9.99 lmnop	9.98 mnop
	45-45	10.20 klmno	10.16 klmno	10.58 jk
	90-90	11.33 fghi	11.58 fg	11.09 hi
	180-180	12.58 de	13.36 c	12.71 d
Small	0-0	10.16 klmno	9.88 mnop	10.18 klmno
	45-45	11.06 hij	10.47 kl	10.35 klm
	90-90	11.53 fgh	11.19 fghi	11.63 f
	180-180	14.38 a	12.54 de	13.86 b

[1]Values designated by different letters are statistically different (0.05).

progenies with poorer kernels relative to large parental kernels. This was consistently so at San Felipe (Table 26). The influence of fertilizer application on post harvest kernel type was most marked at the highest rate. Although differences were not always significant, there existed a consistent trend towards low post-harvest kernel type ratings at the high fertilizer level. This occurred irrespective of parental kernel type or location.

TABLE 25. Post harvest kernel-type at Pirque, as modified by genotype, parental kernel-type, and fertilizer application.

Variables	N - P (k/ha)	Lines 1	Lines 2	Lines 3
			Genotypic effect	
Genotypes		3.60 a[1]	3.16 b	3.33 ab
			Parental kernel-type effect	
Unsorted		3.44 bc	3.41 bc	3.19 c
Large		3.81 a	3.31 bc	3.63 ab
Small		3.56 ab	2.75 d	3.19 c
			Fertilizer effect	
Unsorted	0-0	3.13 fg	3.38 def	3.13 fg
	45-45	3.50 cde	3.63 bcd	3.38 def
	90-90	3.75 abc	3.13 fg	3.13 fg
	180-180	3.38 def	3.50 cde	3.13 fg
Large	0-0	3.75 abc	3.25 ef	3.63 bcd
	45-45	4.00 abc	3.38 def	3.75 abc
	90-90	4.00 a	3.38 def	3.63 bcd
	180-180	3.50 cde	3.25 ef	3.50 cde
Small	0-0	3.50 cde	2.88 hi	3.38 def
	45-45	3.88 ab	2.75 i	3.25 ef
	90-90	3.63 bcd	2.88 hi	3.13 fg
	180-180	3.25 ef	2.50 j	3.00 gh

[1]Values designated by different letters are statistically different (0.05).

TABLE 26. Post harvest kernel-type after harvest at San Felipe as modified by genotype, parental kernel-type, and fertilizer application.

Variables		Lines 1	2	3
			Genotypie effect	
Genotypes		3.15 a[1]	3.02 a	2.97 a
			Parental kernel-type effect	
Unsorted		3.41 a	3.06 b	3.00 c
Large		3.06 b	3.25 ab	3.25 ab
Small		2.97 bc	2.75 cd	2.66 d
	N - P (k/ha)		Fertilizer effect	
Unsorted	0-0	3.63 bcd	3.00 ghi	3.25 efg
	45-45	4.00 a	3.38 def	3.50 cde
	90-90	3.75 abcd	3.38 def	3.13 fgh
	180-180	2.25 lm	2.50 jk	2.13 mn
Large	0-0	3.25 efg	3.88 ab	3.38 def
	45-45	3.38 def	3.50 cde	3.75 abc
	90-90	3.25 efg	3.25 efg	3.00 ghi
	180-180	2.38 kl	2.38 kl	2.88 hi
Small	0-0	3.38 def	2.75 ij	2.88 hi
	45-45	3.25 efg	3.50 cde	3.00 ghi
	90-90	3.00 ghi	2.75 ij	2.75 ij
	180-180	2.25 lm	2.00 n	2.00 n

[1]Values designated by different letters are statistically different (0.05).

DISCUSSION

Characteristics of the parent material

The triticale genotypes used in this study exhibited sufficient variability of seed type to enable visual subdivision into three distinct classes, namely, large, small and unsorted. Goydani and Singh (1971) attributed part of the decrease in yield observed in wheat plants derived from small seeds to lower germination. Tankowski and Kolodziejczyk (1974) and Bishnoi and Sapra (1975) reported the same results for triticale. However, in the present study, no significant differences were observed in percentage of germination within and among genotypes. Differences found in characteristics of plants grown from this seed therefore, were not the result of differential in germination behavior.

The protein content of each seed-size class differed significantly, in that the small kernels were higher in protein content than large and unsorted classes. This finding is consistent with previous reports that showed comparatively higher protein contents in triticale lines that had shrunken kernels (Zillinsky, 1974). The improvement of kernel type of triticale through breeding has resulted in an increase in the carbohydrate fraction and a concomitant decrease in percentage protein.

Plant vigor as related to genotype, parental kernel-type, and fertilizer rates

The visual estimations of plant vigor at various stages of development, produced similar results at the two locations used in this study, Pirque and San Filipe. This may be regarded as an indication of stability of behavior of genotypes under different environmental conditions.

The influence of kernel size showed that plants derived from small kernels were weaker throughout the entire development cycle than plants derived from unsorted and large kernels. The latter two categories tended to be similar in regard to vigor. This observation suggests that among these three triticale lines, there would be no apparent benefits in selecting only large kernels for seed. Screening out the smaller kernels produced no advantages in terms of plant vigor. Plant vigor in response to fertilizer varied depending upon the stage of growth at which measurements were made. At the time of emergence, vigor was negatively associated with fertilizer rates, while at tillering and anthesis, an almost linear positive response was obtained between increasing rates of nitrogen and phosphorus, and vigor.

Yield component

The analysis of the three main yield components, number of spikes per plot, number of kernels per spike, and

100-kernel weight, suggested a rather uniform response at both locations. One of the most striking features of the data presented in this thesis is the positive influence of the parental kernel-type on the yield components of the progeny. Relative to the small kernel class, large kernels generally resulted in the progenies having a larger number of spikes per plot and kernels per spike, and higher 100-kernel weight. In most comparisons the differences obtained between large and unsorted kernels tended to be non-significant. This information confirms that obtained by Kikot (1973), Pinthus (1966) Goydani and Singh (1971). The kernel-weight was also affected by genotypic effects.

Fertilizer rates also had similar effects on yield components at the two locations. Obviously the expression of each component had the potential to improve with increasing fertilizer levels in a relatively uniform manner under different environmental conditions.

A distinct feature of fertilizer influence was the different response of kernel weight compared with that of either spike number or kernel number. Both the control as well as the highest fertilizer rates (180-180 K/ha of N and P_2O5) were generally associated with the development of light kernels while intermediate levels (45-45, 90-90 K/ha of N and P_2O5) of fertilizer tended to produce heavier kernels. This may be explained by assuming that when the plants were subjected to zero fertilizer, the general unthriftiness exhibited by such plants was also reflected in 100-kernel weight. On the other hand, the highest fertilizer rate favored the expression of the two components that are established early in the plants' ontogeny, i.e. number of spike and spikelet primordia. The level of nutrients utilized to allow maximum expression of the first of these may have resulted in a reduced availability of nutrients for the improvement of kernel weight, the third component in the sequence. In other words, "sink-size" appears to be fixed for any given genotype; an increase in one component may be compensated for by a decrease in another. This has been referred to as the oscilatory component behavior reported by Adams and Grafius (1971) and is consistent with Grafius and Thomas' (1971) postulates on yield component interrelationships.

Yield

One of the main objectives of plant breeding is to increase crop yields. It is generally accepted that yield is the result of the action and interaction of environmental factors with the three main yield components as postulated by Grafius (1965). Parodi (1977) suggested that there are neither specific genes, chromosome segments, nor whole chromosomes governing yield, but that yield is the result of the action of all the plants' genes modified by environmental factors. In the present experiment, it was evident that at both locations, yield was first an expression of genotype. Moreover, yield was closely related to the kernel-type from which the plants were derived. Plants produced from small kernels yielded significantly less than those derived from large or unsorted kernels. These results agree with those of several workers including Waldron (1941). Knott and Talukdar (1971), Kikot (1973), Pinthus (1966), Goydani and Singh (1971) and Dasgupta and Austenson (1973) working with wheat; Kaufmann and McFadden (1960), and Pinthus (1966) with barley; also Kaltsikes (1974), Ogilvie (1976) and Bishnoi and Sapra (1975) working with triticale. When discussing the effect of seed-weight, it was indicated previously that eliminating the small seeds by screening conferred no advantage to the developing plant in terms of germination vigor. From the standpoint of overall yield, however, it seems advisable to screen out the light seeds since plants derived from the heavier seeds did produce significantly higher yields.

Increased nutritional levels through fertilizer application resulted in a near-linear yield response at both locations. It may be assumed, therefore, that these genotypes were highly responsive to fertilizer application and the possibility of improving yields through fertilizer applications was apparent. These results coincide with Rhode (1963), Volke and Inostroza (1967), Diaz and Parodi (1973), and Norero (1972).

Test-weight

Results on test-weight from the two locations suggested that over and above genotypic effects, the kernel size of the parent was the main factor influencing weight of grain per measured volume. This being the case, to obtain improvements within this parameter it would be desireable to use only grain of the large seeds. In review of these data, it appears that seed-size is an important factor for obtaining high yields in triticale, at least until lines of uniformly improved test-weight become available. Unfortunately, it was not possible to conclude from these data the optimum level of nitrogen and phosphorus fertilizer for optimum test weight.

Protein content

The protein data showed that under the conditions of this experiment, genotypic effects vary with location. Genotypes affected the expression of protein content at Pirque but did not alter the character at San Felipe. The influence of kernel-type on protein level was also more evident at Pirque than at San Felipe. However, in most cases plants grown from small kernels tended to produce a higher protein percentage than that found in larger seed.

The most interesting feature about these data, is the definite and consistent ability of fertilizer application to modify grain protein content at both locations. The information points to the high genetic potential of the three lines for protein production and that to be able to fully utilize this potential, relatively high levels of fertilizer must be applied. It is important to emphasize that under the highest fertilizer level used in this experiment (180-180 k/ha of N and P_2O5), high protein contents were associated with high yields. Management practices, therefore, must be exercised in order to obtain the highest yields of protein with an economical fertilizer usage.

Post-harvest kernel-type

A visual estimation of kernel-type after harvest showed genotypic differences at Pirque but not at San Felipe. A general effect of kernel-type in the parent material was observed, with a tendency for the large and unsorted-kernel parent material to produce better kernels than kernels derived from a parent with small-kernels. Again, the data emphasizes the need to use large kernels as seed stock. Intermediate levels of fertilizer (90-90 k/ha of N and P_2O5) at Pirque and low-intermediate levels (45-45 to 90-90 k/ha of N and P_2O5) at San Felipe, were associated with the development of improved kernel type.

It should be noted that not withstanding the best treatment combination provided in this experiment, fully plump kernels were never obtained. This suggests that within this lines there are physiological and genetic limitations that precluded the formation of maximum kernel development.

SUMMARY

This study was designed to investigate the effects of two environments on the expression of plant vigor, yield components, yield, protein content and kernel characters of three spring hexaploid (2n = 6x = 42) triticale (x Triticosecale Wittmack) lines. The parental seed of each line was divided into three classes according to test-weight and size (large, small and unsorted) and four fertilizer treatments, namely; 0; 45; 90; 180 k/ha of both N and P_2O_5 were applied to each seed class. The experiment was conducted during the 1975-76 growing season at two locations in Chiles' North Cenral Region.

The following conclusions were derived from the study;

(1) Seed variability in the parent material allowed a subdivision into distinct seed classes. However, seed size did not effect germination. Protein content was significantly higher in the small seed class.

(2) Plant vigor was similar at both locations. Plants derived from small seeds were weak throughout the entire development cycle whereas plants grown from large and unsorted kernels had increased and similar vigor. Plant vigor at emergence was negatively and significantly associated with fertilizer rate, but was positively associated at the tillering and anthesis stages of plant

growth.

(3) Yield components, number of spikes per plot, number of kernels per spike and hundred-kernel weight responded in a rather uniform manner at both locations. Parental kernel-type positively influenced the yield components in the progeny, so that the large kernel class generally resulted in progenies that had a larger number of spikes per plot, kernels per spike, and a higher 100-kernel weight, relative to the smaller classes. Fertilizer effects were similar at both locations, being positively and significantly associated with higher numbers of spikes per plot and kernels per spike. However, kernel-weight was higher with intermediate fertilizer rates, and decreased with either zero fertilizer or at high doses (180 k/ha of N and P).

(4) At both locations yield was first affected by genotype. Moreover, yield was closely related to the kernel-type from which the plants were derived, in that plants produced from small kernels yielded significantly less than those derived from large or unsorted kernels. Increased nutritional levels through fertilizer applications resulted in higher yields in an almost linear fashion at Pirque, and with some limitations at San Felipe.

(5) Test-weight results from the two locations suggested that over and above genotypic effects, parental kernel size was the main factor influencing test-weight. The

effects of fertilizer level on test weight were inconsistent at both locations.

(6) Genotypic effects on protein content were not consistent at both locations. Lines differed in protein content at Pirque, but not at San Felipe. Kernel-type effects were more marked at Pirque than at San Felipe. In general, plants derived from small kernels tended to have higher protein contents in their grains than progeny grown from large kernels. Protein content increased significantly with fertilizer rates. Under the highest fertilizer rates used, high protein contents were associated with high yields.

(7) A visual estimation of post harvest kernel-type showed genotypic effects at Pirque, but not at San Felipe. Parental seed-type effects were observed; plants derived from large and unsorted seeds produced better developed kernels than those grown from small seeds. Intermediate fertilizer rates were associated with production of plumper kernels than either lowest or highest rates.

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Appendix I. Summary of management operations at both locations.

Operation	Location: Pirque	Location: San Felipe
Planting	6-20-75	7-23-75
Phosphorous	6-20-75	7-23-75
First nitrogen application	6-20-75	7-23-75
Second nitrogen application	9-8-75	9-16-75
Third nitrogen application	10-14-75	10-16-75
First irrigation	9-20-75	9-16-75
Second irrigation	10-13-75	9-30-75
Third irrigation	10-29-75	10-25-75
Fourth irrigation	11-21-75	11-15-75
Fifth irrigation	12-8-75	12-5-75
Sixth irrigation	12-18-75	
Herbicide application	8-22-75	9-17-75
First insecticide application	10-10-75	10-20-75
Second insecticide application	11-1-75	11-25-75
Harvest	1-5-76	12-29-75

Appendix II. Precipitation and average temperature at Pirque and San Felipe during the 1975-76 season.

Month	Location			
	Pirque		San Felipe	
	Precipitation mm	Temperature C	Precipitation mm	Temperature C
January	0.00	-	0.00	-
February	0.00	-	0.00	-
March	0.00	-	0.00	-
April	0.00	-	6.00	-
May	19.00	9.50	24.00	11.60
June	9.50	8.70	0.00	8.90
July	175.50	8.00	105.00	9.20
August	36.50	8.95	22.50	10.40
September	0.00	9.92	0.00	12.50
October	0.00	12.81	0.00	15.50
November	22.50	13.17	12.00	18.40
December	0.00	17.80	0.00	20.90
Total	263.00		169.50	

Appendix III. Mean squares from analyses of variance for characteristics of parental kernel-type.

Source of Variation	df	Mean square[1] test-weight k/hl	df	germination %	df	Protein %
Genotypes	2	26,22	2	43,06	2	16.71
Parental kernel-type	6	350,59**	6	40,28**	6	41.01**
Error	18	0,45	63	29,17	36	1.20

**Statistical significant at the 1% level.

[1]The statistical design used was that of a Nested design mixed model.