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RELATIONSHIP OF AGRONOMIC AND QUALITY CHARACTERISTICS TO YIELD OF TRITICALE

by

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ABSTRACT

Three advanced lines of hexaploid triticale (*X Triticosecale* Wittmack) with diverse genetic background and one Utility Grade red spring wheat (*Triticum aestivum* L. em. Thell. cv Glenlea) were investigated for interrelationships of fertility, kernel development, and the three principal yield components (kernel weight, kernel number/spike, spikes/plant). In addition, protein and lysine values were included in the comparisons. The three triticale lines included the cultivar 'Rosner' in addition to a line of Armadillo (70HN458) and 6TA204 (FasGro 204). The study was carried out using three plant population densities, viz., 140, 280, and 420 seeds/m^2, respectively, at three locations in 1973.

Highly significant differences were found among the three triticale lines for all characters investigated. Yields were significantly different at the 5% level.

Glenlea wheat and the three triticale strains when analysed collectively, showed significant differences due to seeding rates in all variables examined except kernel development, test weight, protein content, lysine content, and yield. Seeding rates had a linear effect on most traits. However, non-linear response to seeding rate was detected for tillers/

plant, spike length, days to heading and days to maturity. Most of these parameters showed substantial reduction as plant population density increased. However, analyses within triticales only showed a significant yield response to seeding rate.

The locations x varieties interaction was highly significant for all characters, while a highly significant interaction between varieties and rates was observed only for 1000-kernel weight, tillers/plant and days to heading.

The yield of Rosner and Armadillo were found to be positively correlated with plant height (r=0.81), kernels/spikelet (0.59), kernels/spike (0.57), days to maturity (0.44), lysine content (0.44), and spike length (0.38). All correlations were significant at the 1% level of probability. In contrast, yield was negatively correlated with protein content (-0.78), test weight (-0.46), tillers/plant (-0.41) and kernel development (-0.33), whereas 1000-kernel weight and fertile heads/plant were not correlated with yield.

Multiple regression analysis indicated plant height to be the most important independent variable in reducing the residual sum of squares for plot yield (65.1%). Other independent variables which further reduced the residual sum of squares were in order of importance, test weight, tillers per plant,

days to maturity, spike length and kernels/spikelet.

Glenlea was found to be superior to triticales in most of the characters studied whereas triticales were significantly higher in lysine content. The implications of the inter-relationships of these characters in triticale breeding are discussed.

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INTRODUCTION

The potential value of triticale (*X Triticosecale* Wittmack) as a human and livestock food is gaining recognition in many areas of the world. Considerably more work has still to be done however, to improve yields and adaptation of the species. This will be accomplished with time and while the major potential use of triticale in North America is as livestock grain, its value as a protein cereal crop for human consumption is becoming well established. (Larter, 1968; Pinto, 1973). Promising results from Ethiopia and other countries in terms of the crop's yielding ability, adaptability and its possible utilization for human consumption have convinced many workers that the development of this man-made species is progressing rapidly.

Grain yield in triticale, as in other crops, is a complex character which is a summation of a number of sub-characters. Breeding for improved yielding ability therefore, involves the search for a plant type capable of producing efficiently the agronomically important character(s) under given environmental conditions. This emphasizes the importance of competition that occurs among genotypes under different levels of plant population density (Donald, 1963).

Exploiting these morphological characteristics and yield components for purposes of plant improvement, however, is difficult because they are greatly influenced by environment and are often negatively correlated among themselves. In addition, yield parameters are determined at different stages of plant growth and the compensatory effects observed among yield components and related agronomic characters make the use of these traits as selection indices more difficult (Adams, 1967).

Plant breeders have studied yield in various ways to attain their goals in improving yield and quality (Donald, 1968). To date, however, the precise definition of yield in terms of its genetic, physiologic and morphologic nature is not yet known. This is particularly true for a new species such as triticale.

The present study was carried out in triticale with the following objectives:

(1) to determine the degree to which triticale cultivars were able to compensate in seed-yield for differences in plant population density;

(2) to clarify the effect of plant density on fertility, tillering capacity, yield and other related agronomic and quality characters;

(3) to investigate the interrelationships between plant characters and yield; and

(4) to assess the usefulness of the various yield components as selection criteria in triticale breeding programs.

LITERATURE REVIEW

This literature review is presented in the following four sections:

(1) pertinent results relative to fertility of triticale,

(2) a discussion of tillering and yield in cereal crops as influenced by plant population density and environment,

(3) a review of correlation studies of yield components and related agronomic characters in some cereal crops, and

(4) a review of studies on triticale protein and seed shrivelling.

1. Fertility

One of the characteristics with which low seed yield of triticale has been correlated is reduced fertility (Quinones, 1972). In both primary hexaploid and octoploid triticales, partial fertility has been observed by many workers (Larter et al., 1969; Müntzing, 1939; O'Mara, 1953). Müntzing and co-workers (Müntzing, 1939; Müntzing et al., 1963) observed highly irregular meiotic chromosome behaviour in octoploid triticales and suggested that it resulted from inbreeding depression of the rye component when incorporated into an otherwise inbreeding species. O'Mara (1953), however, felt that this was not entirely true and based his conclusion on the observation that hybrids between octoploid triticales - in which there would not be inbreeding depression - were sometimes more meiotically irregular and sterile than their octoploid parents.

Riley and Chapman (1957) proposed that cytological instability and low fertility of triticale were two unrelated phenomena. Their contention was that infertility was the result of a general incompatibility between wheat which is an inbreeder and rye an outbreeding species. Supporting this contention, Boyd, Sisodia and Larter (1970) reported that although they observed more meiotic abnormalities in triticale cv 'Rosner' than in wheat cv 'Pitic', these abnormalities were not necessarily reflected in reduced fertility. Based on observations of the relatively high fertility of 'Rosner' which was derived by selection from the progeny of crosses between wheat-rye amphiploids, they concluded that selection for increased fertility had been effective without a concurrent improvement in meiotic stability. Riley and Bell (1959) also demonstrated a low correlation coefficient between univalent frequency and fertility in amphiploids.

Müntzing (1966) and Müntzing et al. (1963) concluded that most chromosomes observed as univalents in metaphase I of triticale were rye chromosomes. This was particularly true in octoploid triticales in which reversion to wheat due to loss of rye chromosomes was observed. The existence of cytological instability and partial fertility is also reported in primary hexaploid triticales (Larter et al., 1969; Sanchez-Monge, 1959). In hexaploid triticale, Shigenaga, Larter and McGinnis (1971) and more recently Merker (1973) reported that both wheat and rye chromosomes contribute to the aneuploid condition.

Sisodia, Larter and Boyd (1970) studied the effect of planting date on the meiotic and reproductive behaviour of three primary and two secondary advanced hexaploid triticale lines. They concluded that meiotic irregularities increased with delayed planting date. Notwithstanding meiotic irregularities, pollen production was reasonably normal (70-75%) and spikelet fertility was equivalent to that of hexaploid wheat. Thus they confirmed that meiotic irregularity had little or no effect on percent seed-set. The investigation of Boyd, Sisodia and Larter (1970) on the cytological and reproductive behaviour of wheat and triticale in response to two temperature regimes (15^{o} and 30^{o} C.), also revealed that temperature had little influence on spikelet number within either species.

Tsuchiya (1972) studied chromosome association and fertility in five advanced strains of hexaploid triticale and suggested that chromosome association may not be the only factor influencing seed-set. He implied that abnormal meiotic behaviour may be directly reflected in a lower fertility only when abnormality is beyond a certain thresh-hold level.

Recently, Hsam and Larter (1973a) statistically demonstrated the absence of association between seed-set and certain parameters of meiotic instability including univalents and lagging (or excluded) chromosomes at telo-phase I. Later, Hsam and Larter (1973b) observed that the correlation between meiotic stability and seed-set disappeared with the advancement of generation of amphi-ploids and selection pressure. As a result, they concluded that because these two conditions were influenced by different casual factors, improving meiotic stability would not concomitantly improve fertility. They suggested selecting simultaneously for both characters in early generations and separately for each character in advanced lines. Although the basic cause of infertility can be related to meiotic instability, no statistical relationship was found between univalents and fertility whereas a very high significant correlation was observed between fertility and pollen viability (Gustafson, pers. comm.).

2. Tillering and Plant Population Density

Kirby (1967) examined growth and development, as well as yield and its components in barley grown over a wide range of population densities. He found that although density did not affect seedling establishment, increasing density resulted in the initiation of maximum tiller number per unit area which reached an equilibrium point as determined by different rates of tiller lethality. Increasing density depressed growth rate so that possible differences in dry matter production were masked. Grain yield rose to a maximum at the 70 lb/acre rate, and then declined as density increased resulting in the lowest yield at the highest density (280 lb/acre).

Jones and Hayes (1967) investigated the effect of seeding rate on yield of grain and its components in four diverse oat cultivars and reported that at the high (206 lb/acre) and medium (137 lb/acre) seeding rates, there was no significant difference in grain yield over a three-year period. However, the low seed rate (69 lb/acre) gave significantly lower yields than the other two rates. A significant variety x rate interaction was observed in one season.

Bremner (1969) carried out an experiment using three varieties of wheat of widely different tillering capacities to test the response to nitrogen fertilization and to assess the effects of unproductive tillers. He reported that the presence of a high number of unproductive tillers apparently had only a transitory effect on the growth of productive shoots.

Guitard *et al.* (1961) investigated the varietal response of two wheat, three oat and three barley varieties to six seeding rates over three years. They found that variety and season did not alter significantly the effect of seeding rate on yield. By studying the four yield components, viz., number of plants per acre, number of fertile heads per plant, number of kernels per head and 1000-kernel weight, they concluded that although these components explain certain responses due to genotypic and environmental differences, they did not provide an absolute measure of yielding ability. They also found a linear increase in the number of plants per acre and a curvi-linear decrease in number of fertile heads per plant as seeding rate was increased. In contrast, Finlay *et al.* (1971) found seeding rate to have no effect on yield of barley. They observed no relationship between the relative size of the various yield components (1000-kernel weight, kernels/spike, and spikes/m^2) and differences in yield.

Zeven (1972) stated that plant density had no effect on the expression of heterosis for yield and its components in early generations of wheat. He implied that the influence of plant density could be buffered by the genetic background of the species. Similar results were reported by Pandey and Torrie (1973) who found in soybeans (*Glycine max*) differences in plant density were compensated for by a variation in pod number. In flax, (*L. usitatissimum* L.) Albrechtsen and Dybing (1973) found that several characters including seed yield, oil content, iodine value, seed size, seeds per boll, bolls per area, and test weight were not significantly affected by variations in seeding rate. Height and boll number per plant were reduced with increased seeding rate, while rate of maturity was accelerated. Chapman, Allard and Adams (1969) found that seed size in mixtures of two wheat varieties increased significantly at lower population densities.

Larter *et al*. (1971) reported a comparative study of the performance of triticale cv 'Rosner' and *T. aestivum* cv 'Manitou' under different dates of planting and rates of seeding. According to their findings, the optimum rate of seeding for triticale was 100 kg/ha. The kernel weight of both species was reduced significantly with increased seeding rate while protein content remained unchanged.

A number of workers have reported on the influence of seeding rates on the yield of cereals and genotype-population density interactions (Guitard, 1961; Woodard, 1956). Different relations between yield and plant population density in several species is reviewed by Holliday (1960).

3. Yield Components and Related Characters

Adams (1967) studying the field bean (*Phaseolus vulgaris* L.) concluded that negative correlations among the different yield components were widespread phenomenon among the major crop plant species. He stressed that the correlations are developmental, varying with environmental stress, rather than being genetic *per se*. He also postulated that they are caused by genetically independent components that are free to fluctuate in response to either a limited or varying input of metabolites, such that a certain input is limiting at certain critical developmental stages. Other workers (Fonseca and Patterson, 1968; Knott and Talukdar, 1971; Adams and Grafius, 1971; Pandey and Torrie, 1973; Rasmusson and Cannell, 1970; and Duarte and Adams, 1972) have reported negative correlations among various yield components and different degrees of compensation between components.

On the other hand, Fonesca and Patterson (1968) found that the three yield components, viz., spikes per unit area, kernels per spike and kernel weight, were highly correlated with yield in winter wheat (*T. aestivum* L.). Reddi *et al.*, (1969) studying the heritability and interrelationships of plant height, spike length, tillering ability and kernel weight in two wheat crosses reported that culm length and kernel weight were positively and significantly correlated. Spike length and kernel weight, however, were negatively correlated. Hsu *et al.* (1970) found spike number per plant to be the most important component in determining yield per plant in wheat varieties and crosses, while Albrechtsen and Dybing (1973) showed bolls per unit area to be the most important component determining seed and oil yields in flax.

Rasmusson and Cannell (1970) reported that a selection experiment for yield and components of yield in barley gave useful evaluation of selection on the basis of yield components. They reported that while selection for number of heads per plant and kernel weight were highly effective in positively altering yield, selection on the basis of kernels per head actually reduced yield in one of two populations that they studied. Therefore, they concluded that although selection for yield on the basis of yield components was effective in certain situations, it could not be recommended as a general routine procedure in practical breeding programs. Genetic and environmental factors are jointly responsible for many of the phenotypic correlations observed to occur between agronomic characters which makes them unreliable as an indicator of true yield responses. The study of variation and covariation of agronomic traits in durum wheat T. durum Desf. in F_2, F_3 and F_4 generations of four crosses (Lebsock and Amaya, 1969) revealed that selection for short, early-maturing plants in segregating populations may result in lines with lower kernel weight and test weight. This study showed significant positive correlations of kernel weight and grain yield with test weight. These workers implied that kernel weight could be used effectively for rapid selection of high test weight and even possibly higher yield in F_2 and F_3 populations. This was supported by their findings that the heritabilities for kernel weight, test weight and number of kernels per spike were 72, 67, and 69% respectively.

Grafius (1972) in an attempt to answer whether component traits compete for the same environmental resources, came to the conclusion that they shared a common resource pool. However, certain resources were found to be trait specific. In this regard, Frey (1959) reported 50 to 65 percent yield increases in oat varieties due to nitrogen stimulation of numbers of heads/plant and seeds/spike. Earlier, Grafius (1956) by representing the three components of yield as the edges of a rectangular parallelepiped with the yield as the volume of the geometric figure, postulated a universal variety to have a certain set of properties. By applying this hypothesis to data on corn (Grafius, 1960) and oats (Grafius, 1965), he concluded that theoretically no yield component is more important than the other. On the other hand, when four hard red spring wheat varieties having different plant heights were compared in a four year field study in two locations (Johnson et al., 1966), the taller varieties were found to be less productive than the short ones. In turn, the high number of kernels per spike of the highest yielding variety was associated with a high number of spikelets per spike and kernels per spikelet. Lee and Kaltsikes (1973), however, found a high positive correlation (r=0.80) between plant height and yield per plant in F_2 of durum wheat.

Recently Das (1972), by employing the tools of phenotypic and genotypic correlations, path-coefficient analysis and discriminant functions, investigated the relative importance of certain selection units in selection for yield of wheat. He found that grain-weight and ear number were the two most important component characters and suggested the desirability of selecting those plants which produce a large number of tillers and large grain. Hsu and Walton (1970), Singh *et al.*, (1970) and Walton (1971) have reported similar results.

Kaltsikes (1973) studied the relationship between yield and its components in an 8 x 8 diallel cross in spring rye (*Secale cereale* L.). He obtained no significant correlations between yield and certain flag leaf characters. However, on a plot basis, the following components were positively and significantly correlated with yield: plants per plot, number of tillers per plant, spikes per plant and 250-kernel weight.

Recently 22 cultivars of spring wheat were investigated by Nass (1973) over a two year period. He found that yield per ear and number of ears per plant contributed greatest to reducing yield variance in a stepwise multiple regression analysis, whereas these two components were negatively correlated with each other.

He found positive association between kernels per ear, harvest index and yield per ear with yield per plot, and similar associations between kernels per ear and kernel weight with yield per ear. He concluded that ears/plant, yield/ear and harvest index could be effectively utilized towards selecting for increased yield.

An experiment was carried out by Utz *et al.* (1973) using two winter wheat crosses with which they studied the effectiveness of selection within individual F_2 plants and F_3 plant rows by means of trait correlations between generations. Their work revealed high positive correlation between yield and plant height from generation to generation.

The stability of yield performance in triticale and in common and durum wheats was investigated by Kaltsikes (1971). Stability of yield, as measured by the contribution of cultivars to the interaction sum of squares, was not correlated with yield. The triticale cv 'Rosner' was the least stable whereas the bread wheats exhibited the highest stability.

4. Protein and Kernel Development

a) Protein

Chemical evaluation of protein quality carried out on several advanced generation lines of hexaploid triticales at Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT), Mexico, revealed ranges of 11.7% to 22.5% with an average value of 17.5% protein (Villegas, 1973). Lysine content ranged from 2.5 to 3.7% with an average of 3.2%. To some extent, the high protein values were exaggerated by kernel shriveledness which occurs regularly in primary amphiploid triticales. As kernel plumpness improves through intensive selection for this character and for higher grain yield, the protein percent tends to decrease (Larter, pers. comm.). According to Villegas, in 2,381 lines studied in 1972, protein content ranged from 10.9 to 19.1% with a mean value of 13.4%. Lysine content ranged from 2.0% to 3.9% with an average of 3.4%. These tests showed that lysine content of protein was inversely correlated with protein content.

Villegas *et al*. (1970) investigated lysine content of spring wheat, durum wheat, rye, triticale and other wheat species. Results obtained showed that lysine content of triticale and rye was about 20% and 30% higher respectively than the spring and durum wheats. Spring wheat and durum wheat were about equal in lysine content. There was a significant inverse relationship between protein content and content of lysine in protein of wheat, triticale and rye.

Bragg and Sharby (1970) used broiler chicks to study nutritive value of triticale in comparison to wheat. Results indicated that triticale could replace wheat without adverse effect on growth. They reported an average protein (N x 6.25) value of 14.9% for triticale and 14.4% for wheat. The average availability of different amino acids was 93.6 $\pm$ 4.66 percent for triticale and 92.1 $\pm$ 1.90 percent for wheat.

b) Kernel Development

One of the major problems in the development and utilization of triticale is its relatively poor kernel character (Klassen, Hill and Larter, 1971). The basic cause of seed shrivelling resulting from incomplete endosperm development is not known. Klassen and co-workers analysed eight lines of hexaploid triticale during development and at maturity for alpha-amylase activity, reducing sugars, and starch content. Alpha-amylase was found to be inversely correlated with grain density, the index used for estimating degree of seed shrivelling. Mature grain starch content ranged from 49.1 to 57.1% and was significantly associated with grain density. Their observation of starch development patterns indicated that in triticale lines with poor kernel character, starch deposition was terminated prematurely. They reported a seed density of 1.0810 to 1.2967 g/cc for the triticale lines, 1.3560 g/cc and 1.3612 g/cc for bread and durum wheats, respectively, and 1.2307 g/cc for rye.

Recently, Shealy and Simmonds (1973) studied seed shrivelling in triticale by examining the developmental morphology of triticale from anthesis to maturity. They examined the pericarp, integumentary, nucellar, and embryo-sac tissues. The endosperm, the embryo-sac tissues and the aleurone were found to be pertinent morphological structures related with seed shrivelling. Malformation of cells of the aleurone and endosperm tissue, also precocious alpha-amylase release, were considered to be the factors responsible for grain shrivelling in triticale.

MATERIAL AND METHODS

This study was designed to investigate the interrelationships of various plant characteristics as influenced by plant population density. Three advanced lines of hexaploid triticale (*X Triticosecale* Wittmack; 2*n*=6*X*=42) of diverse genetic background and one utility red spring wheat (*T. aestivum* L. em. Thell. cv Glenlea) were used in this study. The three triticale lines included the cultivar Rosner, an Armadillo line (70HN458) and 6TA204 (FasGro 204). The parentage and source of these lines is shown in Table I.

In 1973, a six replicate, split-plot experiment was grown at each of three locations, with the experimental design consisting of varieties (or strains) as main plots and rate of seeding (plant density) as sub-plots. Plots consisted of four rows each 5.6 m in length with a row spacing of 20 cm. Seeding rates for each of the four strains were adjusted in accordance with seed weight to produce plant population densities of 140, 280 and 420 viable seeds/m^2 (approx. 70, 140 & 210 kg/ha, respectively).

The sites at which the experiment was conducted included two at the University of Manitoba, Winnipeg, Manitoba (Plant Science Department's experimental nursery at the "Point" and "Westfield") and the third at the Canada Department of Agriculture Research Station, Swift Current, Saskatchewan. The

Table 1. Pedigree and source of the three advanced strains of triticale and one Utility Grade red spring wheat

STRAIN	PEDIGREE[+]	SOURCE
Glenlea	2* Pembina/Bage /2/ CB100	U. of Manitoba, Canada
Rosner	Tcl. 6A189 (*T. turgidum* var. *durum* (cv. Ghiza))/ Tcl. 6A20 (*T. turgidum* var. *durum* (cv. Carleton)) *2/Tcl. 6A69 (*T. turgidum* var. *persicum*) /Tcl. 6A67 (4x Triticum sp.).	U. of Manitoba, Canada
6TA204	*T. aestivum* (P4160E) /Tcl Bulk (4x triticum sp.) /2/ Tcl. 6A274 Tc. 8x (*T. aestivum*)/Tcl. 6x (*T. turgidum* var. *durum*)	Jenkins Foundation for Research, U.S.A.
Armadillo	Rosner /2/Tcl. 6A66 (*T. dicoccoides*)/Tcl. 6A250 (*T. Persicum*)	CIMMYT, Mexico

\+ In the Pedigree column, Tcl. stands for triticale; next is U. of Manitoba accession number followed by identity of the Triticum parent within parentheses. Method of illustrating pedigrees is according to Purdy *et al*. (1968). The pedigree of CB100 is Sonora 64/Tezanos Pintos Precoz /2/ Nainari 60.

Swift Current plots were fertilized with 44.8 Kg of 11-48-0 per hectare while the other two locations were unfertilized. The average rainfall during the crop cycle (May to August) was 358 mm (14.1 in.) at the Point and Westfield and 190 mm (7.5 in.) at Swift Current.

The following characters were measured from each plot at each location:

(1) 1000-kernel weight (g).

(2) Kernel development (seed density) (g/cc) as determined by measuring the volume of light parafin oil displaced by a 5.0 g sample of seed.

(3) Number of kernels per spike based on counts on 10 plants of each plot.

(4) Number of kernels per spikelet (fertility) using the spike material of (3) above. For fertility determinations, all fully developed spikelets were counted.

(5) Number of fertile heads per plant as determined from material of (3) above.

(6) Number of tillers per plant as determined from a one m length of each of the two harvested centre rows of each plot and in which the total number of plants were known from previous counts at the seedling stage.

(7) Number of plants per unit row length.

(8) Spike length (cm) based on measurements of 8 spikes taken at random from each plot (excluding awns).

(9) Days to heading estimated as the number of days from planting to the time when approximately 75% of the spikes of any plot had emerged from the boot.

(10) Days to maturity, as the number of days from planting to a time when approximately 75% of the plants from any plot exhibited a yellow coloration on the "neck" for a distance of about 10 cm from the base of the spike.

(11) Plant height (cm) at maturity recorded as a mean of 8 measurements per plot from the ground level to the tip of the tallest spike (excluding awns).

(12) Test weight (kg/hl) as determined on harvested grain samples adjusted to a 12% moisture level.

(13) Protein content (%) as per the Kjeldahl method using a N x 5.7 conversion factor and a moisture basis of <u>0.0%</u>.

(14) Lysine content (%) as expressed on a g lysine/100g protein basis.

(15) Grain yield (g/plot). A 5m length of the two center rows of each plot was harvested for yield. The harvested plot area therefore, was 0.4 m x 5.0 m = 2.0 m^2 for all locations. Grain yield data were adjusted to a 12% moisture basis.

Analyses of variance were computed for each character studied. Sums of squares for varieties were subdivided into a comparison between wheat and triticale and a comparison among the three triticale lines. The effect of plant population density was partitioned into linear and non-linear responses and were tested for significance (Steel and Torrie, 1960).

Simple phenotypic correlation coefficients were computed between all combinations of characters for two triticale lines grown at the three locations. Stepwise multiple regression and multilinear regression analyses were carried out for selected characters of these two triticale lines.

RESULTS

A total of 14 individual plant characters of wheat and triticale grown at three locations and under three population densities were evaluated in the present study. The mean square values for each parameter as influenced by variety, seeding rate, and location, as well as their interactions are shown in Table 2. Location and variety effects resulted in highly significant differences ($P \leq 0.01$) for all parameters while the locations x varieties interaction was either significant ($P \leq 0.05$) or highly significant ($P \leq 0.01$). When the varieties sums of squares were subdivided into a comparison between wheat and triticales and a comparison among the three triticale lines, the wheat vs. triticales mean square values were significant ($P \leq 0.05$) for all plant characters with the exception of tillers/plant and plant height. All parameters with the exception of kernel development were significantly different ($P \leq 0.01$) among triticales. Seeding rate was responsible for highly significant differences in all parameters with the exception of seed density, seed test weight, protein, lysine content, and yield. A significant varieties x rates interaction was found for only 4 of the 14 parameters, viz., 1000-kernel weight, tillers/plant days to heading, and yield. The effect of seeding rate was mostly linear. Similarly, the location x rates interaction was

Table 2. Analysis of variance for agronomic and quality characters of one wheat and three hexaploid triticale varieties grown under three plant densities at three locations

Source of variation	Degrees of freedom	MEAN SQUARES						
		1000 Kernel weight (g)	Kernel development (g/cc)	No. of kernels/ spike	No. of kernels/ spikelet	No.of fertile heads/plant	Tillers/ plant	Spike length
Locations	2	385.169**	0.027**	2760.656**	2.659**	4.325*	24.005**	70.300**
Reps.in locations	15	13.855	0.004	22.127	0.051	0.931	0.732	1.066
Varieties	3	1017.656**	0.144**	1696.354**	2.629**	1.703**	1.543**	79.513**
wheat vs triticales	(1)	1210.320**	0.427**	748.845**	5.445**	2.205*	0.080	68.445**
among triticales	(2)	921.329**	0.003	2170.108**	1.221**	1.453*	2.274**	85.047**
Varieties x locations	6	306.985**	0.004*	214.225**	0.526**	1.313**	0.567*	1.900**
Main-plot error	45	7.025	0.002	15.590	0.029	0.386	0.188	0.273
Seeding rates	2	64.853**	(ns)	217.689**	0.120**	7.867**	15.032**	11.212**
linear component	(1)	129.705**	-	435.377**	0.238**	15.733**	29.160**	17.640**
non-linear component	(1)	(ns)	-	(ns)	(ns)	(ns)	0.903**	4.785**
Varieties x rates	6	18.929**	0.001	15.191	0.039	0.069	0.354*	0.108
Locations x rates	4	4.289	0.001	4.779	0.009	0.325	3.079**	0.472**
Locations x varieties x rates	12	3.876	0.001	5.345	0.015	0.300	0.184	0.268
Subplot error	120	2.238	0.001	8.817	0.024	0.312	0.120	0.166

* Significant at the 5% level
** Significant at the 1% level
(ns) Non-significant mean squares

Table 2 (continued)

Source of variation	Degrees of freedom	Days to heading	Days to maturity	Plant height (cm)	Test weight (kg/hl)	Protein content (%)	Lysine content (%)	Grain yield (g/plot)
		MEAN SQUARES						
Locations	2	586.347**	5031.437**	54601.312**	417.144**	210.543**	0.507**	1,290,675.000**
Reps. in locations	15	1.520	10.150	48.646	9.862	5.795	0.041	35,289.599
Varieties	3	1415.595**	1607.807**	3185.568**	3007.707**	11.841**	7.801**	500,517.312**
wheat vs triticales	(1)	162.000**	178.605**	11.52	8719.515**	8.820*	22.579**	1,443,640.320**
among triticales	(2)	2042.392**	2322.408**	4772.591**	151.804**	13.351**	0.412**	28,955.809*
Varieties x locations	6	33.511**	110.993**	766.112**	84.041**	14.950**	0.094**	154,118.812**
Main-plot error	45	1.706	1.850	37.046	2.270	1.472	0.015	6,535.111
Seeding rates	2	29.847**	56.014**	54.460*	3.133	0.508	0.014	1,512.096
linear component	(1)	51.840**	104.040**	81.000**	5.038	0.360	0.004	416.160
non-linear component	(1)	7.854**	7.988**	27.921	1.228	0.656	0.025	2,608.033
Varieties x rates	6	0.919*	0.655	12.489	1.096	0.549	0.013	16,683.957**
Location x rates	4	1.486**	1.354*	3.363	3.639*	0.420	0.019	2,798.951
Location x var. x rates	12	0.635	1.510**	18.318	1.564	0.517	0.008	7,938.117*
Subplot error	120	0.393	0.519	11.711	1.393	0.351	0.010	3,593.521

* Significant at the 5% level

** Significant at the 1% level

significant for 5 parameters, viz., days to heading, and maturity, test weight, tillers/plant, and spike-length. The locations x varieties x rates interaction was significant only for days to maturity and yield.

In the presentation of more detailed results which follows, the various parameters are grouped into four classes, viz., (1) fertility, (2) tillering and plant population density, (3) yield components and related characters, and (4) kernel development, test weight, protein and yield. Each class will be discussed separately.

1. Fertility

The effect of plant population density on fertility of wheat and triticale varieties is shown in Table 3. Considering first the trend of mean fertility levels over all locations, it is seen that within a particular variety, the higher rates of seeding slightly reduced mean seed-set. Whereas a mean of 2.0 kernels/spikelet was obtained at the 140 seeds/m^2 rate, mean fertility at both of the two higher rates of seeding was 1.9 seeds/spikelet. This indicated that at all locations there was a trend toward decreased plant fertility with increased plant population density. Statistically this difference was shown to be highly significant ($P \leq 0.01$,

Table 3. The effect of plant population density on fertility (kernels per spikelet) of Glenlea wheat and three hexaploid triticale lines grown at three locations

LOCATION	VARIETY												Overall location means
	Glenlea			Rosner			6TA204			Armadillo			
	No. of viable seeds per m^2												
	140	280	420	140	280	420	140	280	420	140	280	420	
Point	2.3	2.1	2.2	2.3	2.3	2.2	1.8	1.8	1.8	2.1	2.0	1.9	2.1
Swift Current	2.2	2.1	2.1	1.7	1.5	1.6	1.6	1.8	1.6	1.5	1.4	1.4	1.7
Westfield	2.3	2.2	2.3	2.2	2.1	2.0	1.7	1.7	1.7	2.0	2.0	2.0	2.0
Rate means	2.3	2.2	2.2	2.1	2.0	1.9	1.7	1.8	1.7	1.9	1.8	1.8	
Overall variety means		2.2			2.0			1.7			1.8		
Seeding rate means (overall)	140 seeds/m^2 : 2.0												
	280 seeds/m^2 : 1.9												
	420 seeds/m^2 : 1.9												

CV (mainplot) = 8.8% CV (subplot) = 8.0%

LSD:	5%	1%
Between two overall variety means	0.07	0.09
Between two overall location means	0.08	0.11
Between two overall seeding rate means	0.05	0.07
Between two seeding rate means in the same variety	0.10	0.13
Between any two other variety means	0.11	0.14

LSD = 0.07; Table 3). The effect of plant population density on the variance of fertility, when partitioned into linear and non-linear effects, was expressed as a linear relationship indicating linear reduction in fertility with increased plant density (Table 2).

A highly significant difference existed in fertility between crop varieties (Table 3). Glenlea wheat and Rosner triticale expressed the highest fertility level (2.2 and 2.0 kernels/spikelet respectively) while 6TA204 and Armadillo were less fertile for all locations with an average of 1.7 and 1.8 kernels/spikelet, respectively. As shown in Table 2, differences in fertility within triticales were also highly significant ($MS = 1.221$; $P \leq 0.01$) with Rosner exhibiting the highest seed-set of the three strains. Location also had a highly significant effect on fertility (Table 3) with the overall mean seed-set at Swift Current being 1.7 seeds/spikelet compared with 2.0 and 2.1 seeds obtained at "Westfield" and "Point" locations, respectively. The varieties x locations interaction mean squares was also highly significant. This environmental effect on fertility is depicted in Fig. 1. together with the influence of location on varieties for fertile heads/plant for three of the four varieties. Armadillo triticale showed a similar trend but was not included in the chart. These two variables exhibited an interesting inverse relationship for the four varieties

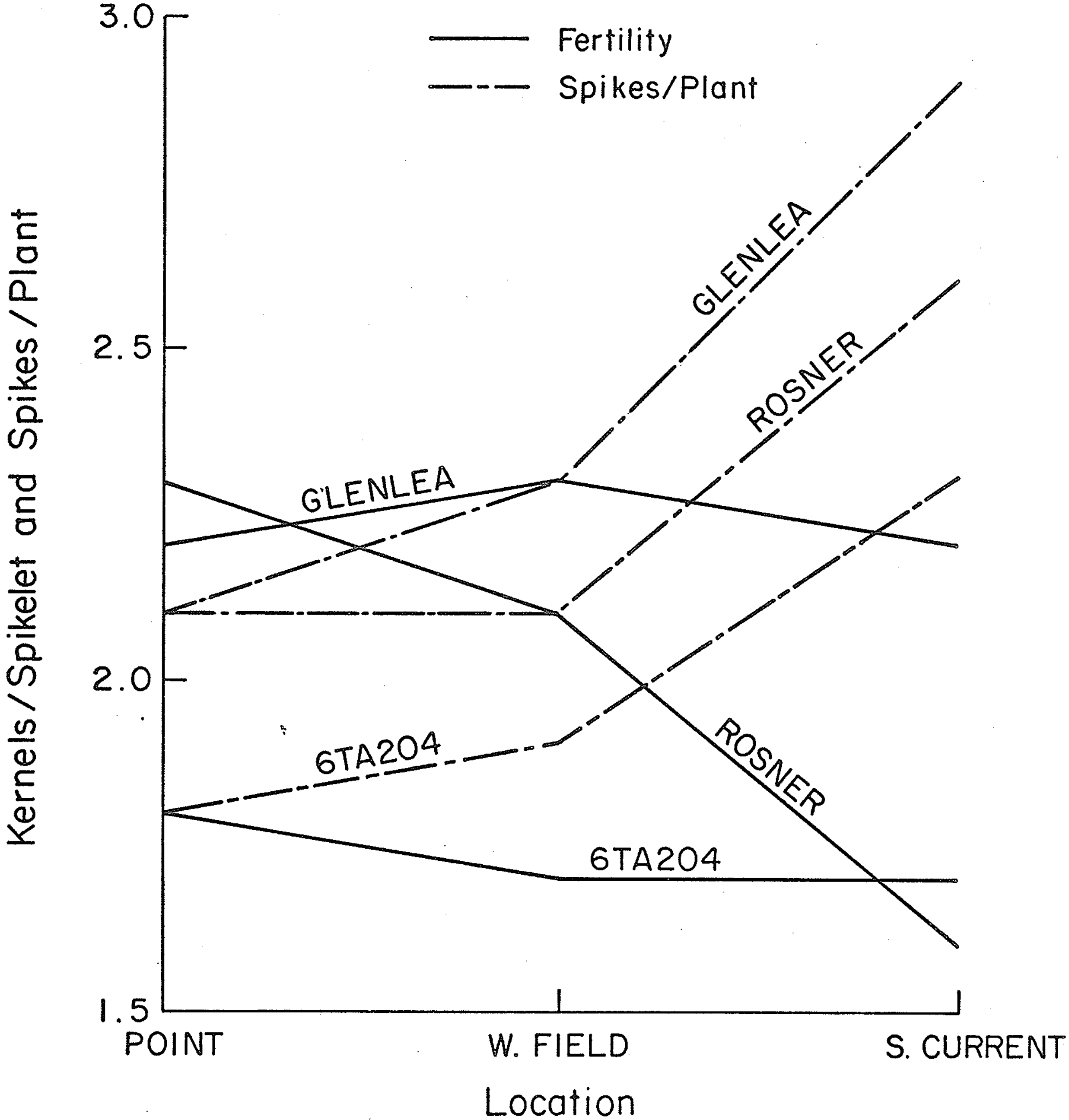

Figure 1. Fertility and spike number/plant of Glenlea wheat, Rosner and 6TA204 triticales (overall seeding rates) grown at 3 locations.

used in the study. For Glenlea, Rosner, and 6TA204, the parameters fertility and fertile head/plant were numerically equal (or nearly so) at one of the three locations. For example, Rosner showed 2.1 kernels/spikelet and 2.1 spikes/plant at Westfield.

Correlation coefficients were calculated for the 15 characters of the two triticale varieties, viz., Rosner and Armadillo (Table 4). The triticale line 6TA204 was excluded from correlation analysis because there was a possible accidental loss of grain from the "Westfield" 6TA204 plots while machine-threshing. Therefore, although most of the correlation coefficients were of similar magnitude, when analysis was carried out for the three triticales, only correlation values based on the two lines are reported. On the basis of their direct practical contribution to yield however, only specific characters will be discussed as they relate to their association with each respective character.

Within triticale lines fertility showed highly significant positive correlations with the following characters (Table 4): kernels/spike, days to maturity, plant height and yield. Thousand kernel weight and test weight were negatively correlated with fertility. The high positive correlation of fertility with yield was consistent when data were computed for individual locations and rates.

Table 4. Simple phenotypic correlation coefficients between pairs of variables for two triticale lines grown under three plant densities at three locations

No. of Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. 1000-kernel weight		.18	-.49**	-.39**	.03	.01	-.20	-.42**	-.82**	-.66**	-.23*	.60**	-.15	.34**	.02
2. Kernel development			-.38**	-.31**	-.03	.17	-.26*	-.47**	-.30**	-.33**	-.42**	.51**	.22*	-.29**	-.33**
3. Kernels/spike				.95**	-.06	-.22*	.36**	.74**	.72**	.83**	.80**	-.82**	-.56**	.26*	.57**
4. Kernels/spikelet					-.18	-.34**	.44**	.61**	.60**	.77**	.77**	-.74**	-.60**	.28**	.59**
5. No. of fertile heads/plant						.36**	-.30**	.08	.00	-.08	-.05	.10	.08	.07	-.06
6. Tillers/plant							-.82**	.02	.03	-.24*	-.49**	.30**	.50**	-.30**	-.41**
7. Plant/m row								.10	.16	.40**	.64**	-.44**	-.59**	.28**	.61**
8. Spike length									.58**	.61**	.56**	-.75**	-.24*	.14	.38**
9. Days to heading										.88**	.45**	-.69**	-.15	-.10	.17
10. Days to maturity											.75**	-.83**	-.46**	.11	.44**
11. Plant height												.77**	-.81**	.47**	.81**
12. Test weight													.41**	-.21*	-.46**
13. Protein content														-.58**	-.78**
14. Lysine content															.44**
15. Yield/plot															

N = 108

* Significant at the 5% level

** Significant at the 1% level

2. Tillering and Plant Population Density

The relationship between tillering capacity and yield in cereals as influenced by plant density varies according to environmental stress. In the present experiment, the highest overall mean number of tillers per plant was produced at the Swift Current location (2.7 tillers) followed by the "Point" location with 1.8 tillers. The "Westfield" test produced 1.6 tillers per plant. The comparison among varieties showed that Rosner had the highest mean tiller number of all four varieties tested (2.2) while Glenlea wheat and the two triticale lines, Armadillo and 6TA204 averaged 2.0, and 1.9 tillers per plant, respectively (Table 5).

The tillering ability of all the varieties was substantially reduced as plant population density increased. On an overall average, the seeding rate of 140 seeds/m^2 resulted in the maximum (highest) tiller number per plant (2.5) compared to 1.9 and 1.6 tillers per plant for the 280 and 420 seeds/m^2 rates, respectively (Table 5). However, Rosner suffered relatively less in tiller reduction due to high plant competition. The effect of plant density on tiller number per plant, and the response of varieties to environmental stress in tiller production is shown in Fig. 2 for Glenlea wheat and Rosner triticale, and for the "Point"

Table 5. The effect of plant population density on the number of tillers per plant for Glenlea wheat and three hexaploid triticale lines grown at three locations

LOCATION	VARIETY												Overall location means
	Glenlea			Rosner			6TA204			Armadillo			
	No. of viable seeds per m^2												
	140	280	420	140	280	420	140	280	420	140	280	420	
Point	3.2	1.5	1.2	2.6	1.7	1.3	2.1	1.5	1.1	2.7	1.5	1.1	1.8
Swift Current	2.6	2.3	2.6	3.2	2.9	3.0	2.8	2.8	2.5	2.4	2.4	2.3	2.7
Westfield	2.2	1.4	1.1	2.4	1.7	1.2	1.7	1.4	1.0	2.1	1.3	1.1	1.6
Rate means	2.7	1.8	1.6	2.8	2.1	1.8	2.2	1.9	1.5	2.4	1.7	1.5	
Overall variety means		2.0			2.2			1.9			1.9		
Seeding rate means (Overall)					140 seeds/m^2 : 2.5								
					280 seeds/m^2 : 1.9								
					420 seeds/m^2 : 1.6								

CV (Main-plot) = 21.7% CV (Subplot) = 17.3%

LSD:	5%	1%
Between two overall variety means	0.2	0.2
Between two overall location means	0.3	0.4
Between two overall seeding rate means	0.1	0.2
Between two seeding rate means in the same variety	0.2	0.3
Between any two other variety means	0.3	0.3

and Swift Current locations. The other varieties and location showed a similar trend.

The analysis of variance for tillering showed highly significant differences due to locations, varieties and seeding rates (Table 2). In addition locations x seeding rates interaction was significant ($P \leq 0.01$). Also, the interactions for varieties x locations and for varieties x seeding rates were significant at the 5% level of probability (Fig. 2). A comparison analysis among varieties for tillering capacity revealed highly statistical differences among triticales but no significant difference between wheat and the triticale lines collectively (Table 2). By partitioning the tillers per plant mean squares due to plant population density into its linear and non-linear components, it was shown that both components were of importance. The contribution of the linear effect was highly significant ($P \leq 0.005$) while the non-linear effect was significant at the 1% level of probability.

The simple phenotypic correlation analyses within the triticale lines showed tillers per plant to be negatively correlated with kernels/spike, plant density, maturity, plant height, and yield. Conversely, tiller number was positively correlated with spikes/plant and test weight.

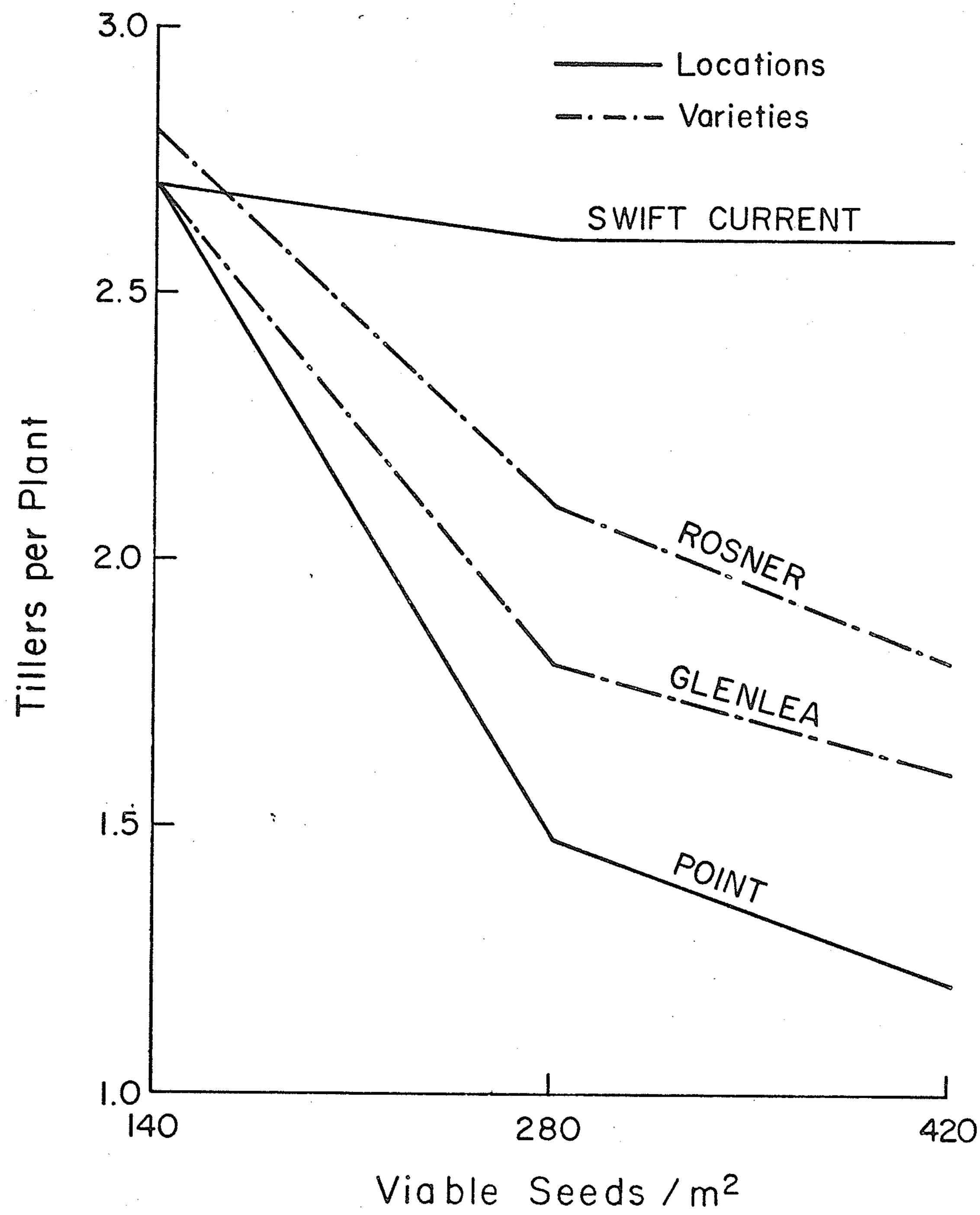

Figure 2. Effect of plant density on tillering of Glenlea wheat and Rosner triticale, also response in tiller number of 4 varieties at Point and Swift Current locations.

3. Yield Components and Related Characters

The means and LSD values of the three conventional yield components, viz., 1000-kernel weight (1000 KW), kernels/spike, and fertile heads per plant are shown in Tables 6, 7 and 8, respectively. Significant differences ($P \leq 0.01$) in 1000 KW were observed for locations, varieties and seeding rates. Also the interaction terms between locations and varieties, and between varieties and seeding rates were significant ($P \leq 0.01$; Table 2). In Fig. 3, the effect of environmental stress on 1000 KW and kernel number/spike for 3 of the 4 varieties is shown.

To determine whether there were significant differences among the triticale lines in kernel weight, kernels/spike and fertile heads per plant, the varieties sum of squares of the respective variables was partitioned. As a result, in addition to significant differences between wheat and triticales, the three triticale lines showed highly significant differences ($P \leq 0.01$) in 1000 KW and kernels/spike. Examining the overall means of varieties, the triticale 6TA204 and Armadillo were higher in 1000 KW (39.2 and 38.4 g, respectively) than Rosner (31.7 g). The kernel weight of Glenlea was 41.9 g/1000 kernels. Material grown on the Plant Science "Point" location produced the highest 1000 KW (39.5 g), while the Swift Current

Table 6. The effect of plant population density on 1000 kernel weight (g) of Glenlea Wheat and three hexaploid triticale lines grown at three locations

LOCATION	VARIETY												Overall location means
	Glenlea			Rosner			6TA204			Armadillo			
	No. of viable seeds per m^2												
	140	280	420	140	280	420	140	280	420	140	280	420	
Point	48.2	47.7	48.3	31.3	29.9	28.7	43.8	41.7	39.9	38.3	37.5	38.0	39.5
Swift Current	34.4	34.0	32.9	32.7	33.6	32.9	36.9	34.8	32.0	38.7	40.0	38.6	35.1
Westfield	44.6	43.5	43.4	34.7	30.6	30.4	43.5	41.2	38.7	37.5	38.8	37.9	38.7
Rate means	42.4	41.8	41.5	32.9	31.4	30.7	41.4	39.3	36.9	38.2	38.8	38.2	
Overall variety means		41.9			31.7			39.2			38.4		

Seeding rate means (Overall)

140 seeds/m^2	:	38.7
280 seeds/m^2	:	37.8
420 seeds/m^2	:	36.8

CV (Main-plot) = 7.0% CV (Subplot) = 4.0%

LSD:	5%	1%
Between two overall variety means	1.0	1.3
Between two overall location means	1.3	1.8
Between two overall seeding rate means	0.5	0.6
Between two seeding rate means in the same variety	0.9	1.3
Between any two other variety means	1.6	2.1

Table 7. The effect of plant population density on the number of kernels per spike for Glenlea wheat and three hexaploid triticale lines grown at three locations

LOCATION	VARIETY												Overall location means
	Glenlea			Rosner			6TA204			Armadillo			
	No. of viable seeds per m^2												
	140	280	420	140	280	420	140	280	420	140	280	420	
Point	32.7	29.9	32.7	45.1	43.6	40.2	49.2	47.3	46.0	36.9	34.7	32.0	39.2
Swift Current	28.5	27.3	26.0	27.9	24.4	23.3	37.2	37.9	33.2	20.1	18.9	17.9	26.9
Westfield	33.1	30.3	31.4	39.6	36.0	33.6	40.3	37.6	36.8	32.6	29.8	28.7	34.2
Rate means	31.4	29.2	30.0	37.6	34.7	32.4	42.3	40.9	38.7	29.9	27.8	26.2	
Overall variety means		30.2			34.9			40.6			28.0		

Seeding rate means (Overall)

140 seeds/m^2 : 35.3
280 seeds/m^2 : 33.1
420 seeds/m^2 : 31.8

CV (Main-plot) = 11.8% CV (Subplot) = 8.9%

LSD:	5%	1%
Between two overall variety means	1.5	2.0
Between two overall location means	1.7	2.3
Between two overall seeding rate means	1.0	1.3
Between two seeding rate means in the same variety	2.0	2.6
Between any two other variety means	2.2	2.9

Table 8. The effect of plant population density on the number of fertile heads per plant for Glenlea Wheat and three hexaploid triticale lines grown at three locations

LOCATION	VARIETY												Overall location means
	Glenlea			Rosner			6TA204			Armadillo			
	No. of viable seeds per m^2												
	140	280	420	140	280	420	140	280	420	140	280	420	
Point	2.4	2.0	1.8	2.4	2.2	1.8	2.2	1.7	1.6	2.7	2.5	2.5	2.2
Swift Current	3.1	2.8	2.7	3.2	2.5	2.0	2.6	2.5	1.8	3.0	2.1	1.7	2.5
Westfield	2.9	2.2	1.9	2.2	2.1	2.0	2.1	1.9	1.6	2.2	1.7	1.6	2.0
Rate means	2.8	2.3	2.2	2.6	2.3	2.0	2.3	2.0	1.7	2.7	2.1	1.9	
Overall variety means		2.4			2.3			2.0			2.2		

Seeding rate means (Overall)

140 seeds/m^2	:	2.6
280 seeds/m^2	:	2.2
420 seeds/m^2	:	1.9

CV (Main-plot = 28.2% CV (Subplot) = 25.4%

LSD:	5%	1%
Between two overall variety means	0.2	0.3
Between two overall location means	0.3	0.5
Between two overall seeding rate means	0.2	0.2
Between two seeding rate means in the same variety	0.4	0.5
Between any two other variety means	0.4	0.5

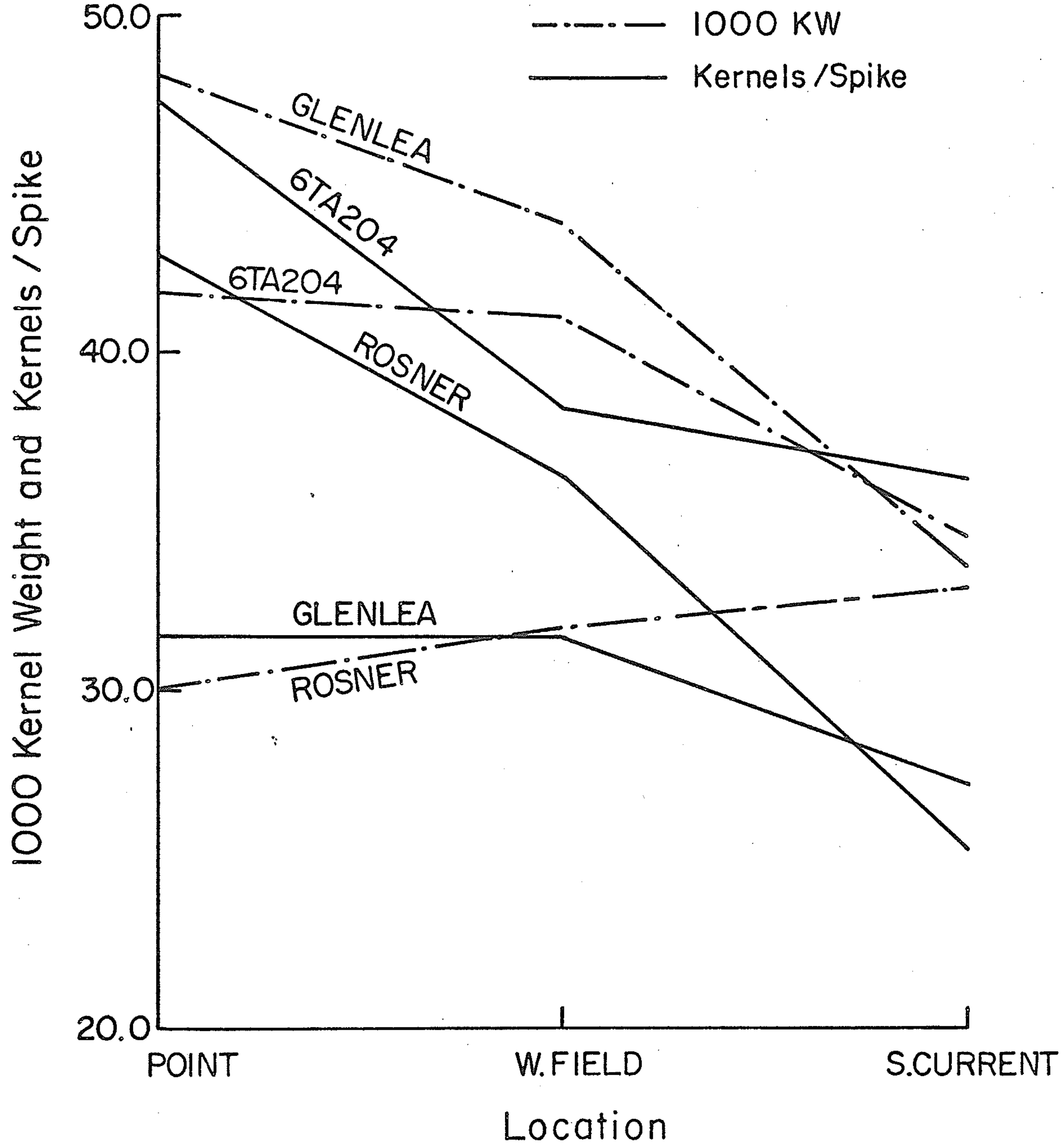

Figure 3. Effect of environment on 1000 KW and kernel number/spike of Glenlea wheat, Rosner and 6TA204 triticales (overall seeding rates).

nursery resulted in the lowest mean value (35.1 g). The lowest plant population density (140 seeds/m^2) gave slightly higher 1000 KW (38.7 g) than either seeding rates of 280 seeds/m^2 (37.8 g/1000 kernels) or 420 seeds/m^2 (36.8 g/1000 kernels).

Kernels/spike and fertile heads/plant were highly significantly different for varieties and seeding rates (Table 2). Furthermore, the interaction between varieties and locations was significant ($P \leq 0.01$) for these two variables (Fig. 1 and 3). Although an increase in plant density resulted in a subsequent reduction in the number of kernels/spike and fertile heads/plant, the interaction terms involving seeding rates for these same two parameters were non-significant. The contrast analysis indicated differences among the triticale lines in kernels/spike and heads/plant (Table 2). For the three components of yield, viz., 1000 KW, kernels/spike and heads/plant the seeding rates sum of squares was due to a linear effect indicating a linear reduction in kernel number and number of heads as plant density increased. Among triticale lines the number of kernels/spike was positively correlated with yield ($r = 0.57$) while 1000 KW and heads/plant were not correlated with kernel number (Table 4). Thousand kernel weight was negatively associated with most other plant characters investigated but positively correlated with test weight (kg/hl) and lysine content. Conversely, the number of kernels/spike was found to be highly and positively correlated with most agronomic characters. This was not generally true for the number of heads/plant.

The 4 agronomic characters including days to heading, days to maturity, plant height and spike length will be discussed jointly (Tables 9, 10 and 11). These factors were significantly different among varieties, locations, seeding rates, and varieties x locations interaction. Days to heading and spike length showed highly significant F-values for locations x rates interaction ($P \leq 0.01$). Comparison of subdivided mean squares indicated highly significant differences for all four characters among triticale varieties (Table 2). Even though there was no statistical difference in height between wheat and triticales, variation was observed for number of days to heading, days to maturity and spike length.

The effect of seeding rates on height was due to its linear component, indicating that each increase in seeding rate produced approximately correspondingly equal decreases in height. The contribution of the non-linear component was also highly significant in the cases of days to heading, days to maturity, and spike length, indicating curvi-linear changes in these traits as the severity of plant competition increased.

Comparing all the various agronomic characters within the two triticales, height was most strongly correlated with yield ($r = 0.81$); Table 4). Days to maturity and spike length were

Table 9. The effect of plant population density on the number of days to maturity for Glenlea wheat and three hexaploid triticale lines grown at three locations

LOCATION	VARIETY												Overall location means
	Glenlea			Rosner			6TA204			Armadillo			
	No. of viable seeds per m^2												
	140	280	420	140	280	420	140	280	420	140	280	420	
Point	107.2	106.2	105.8	108.0	107.7	107.2	110.2	109.7	109.0	97.5	96.3	95.2	105.0
Swift Current	91.3	90.8	89.3	93.3	91.2	89.7	94.7	93.5	92.8	87.2	86.5	85.5	90.5
Westfield	108.3	108.5	107.7	109.5	108.5	107.7	110.8	109.3	108.2	94.3	93.3	93.2	104.9
Rate means	102.3	101.8	100.9	103.6	102.4	101.5	105.2	104.2	103.3	93.0	92.1	91.3	
Overall variety means		101.7			102.5			104.2			92.1		
Seeding rate means (Overall)					140 seeds/m^2 :			101.0					
					280 seeds/m^2 :			100.1					
					420 seeds/m^2 :			99.3					

CV (Main-plot) = 1.4% CV (Subplot) = 0.7%

LSD:	5%	1%
Between two overall variety means	0.5	0.7
Between two overall location means	1.1	1.6
Between two overall seeding rate means	0.2	0.3
Between two seeding rate means in the same variety	0.5	0.6
Between any two other variety means	0.7	0.9

Table 10. The effect of plant population density on plant height (cm) of Glenlea Wheat and three hexaploid triticale lines grown at three locations

LOCATION	VARIETY												Overall location means
	Glenlea			Rosner			6TA204			Armadillo			
	No. of viable seeds per m^2												
	140	280	420	140	280	420	140	280	420	140	280	420	
Point	109.3	106.3	105.6	104.8	104.7	104.9	129.5	122.7	123.3	107.0	108.0	108.3	111.2
Swift Current	62.8	61.5	62.3	62.8	60.5	57.7	62.0	61.8	64.7	59.8	59.2	57.8	61.1
Westfield	108.8	107.9	106.6	100.9	101.7	101.6	125.0	121.4	122.0	92.0	92.0	91.0	105.9
Rate means	93.6	91.9	91.5	89.5	89.0	88.1	105.5	102.0	103.3	86.3	86.4	85.7	
Overall variety means		92.3			88.8			103.6			86.1		
Seeding rate means (Overall)					140 seeds/m^2	:		93.7					
					280 seeds/m^2	:		92.3					
					420 seeds/m^2	:		92.2					

CV (Main-plot) = 6.6%   CV (Subplot) = 3.7%

LSD:	5%	1%
Between two overall variety means	2.4	3.2
Between two overall location means	2.5	3.4
Between two overall seeding rate means	1.1	1.5
Between two seeding rate means in the same variety	2.3	3.0
Between any two other variety means	3.0	4.0

Table 11. The effect of plant population density on spike length (cm) of Glenlea Wheat and three hexaploid triticale lines grown at three locations

LOCATION	VARIETY												Overall location means
	Glenlea			Rosner			6TA204			Armadillo			
	No. of viable seeds per m^2												
	140	280	420	140	280	420	140	280	420	140	280	420	
Point	11.6	10.8	10.8	10.0	9.2	9.0	12.1	11.0	11.2	8.6	8.0	8.0	10.0
Swift Current	9.9	9.1	8.4	7.9	7.4	7.2	9.1	8.9	8.5	7.2	7.2	6.6	8.1
Westfield	9.7	9.5	9.3	8.3	7.7	7.2	9.8	9.8	9.3	7.9	7.4	7.2	8.6
Rate means	10.4	9.8	9.5	8.7	8.1	7.8	10.4	9.9	9.7	7.9	7.5	7.3	
Overall variety means		9.9			8.2			10.0			7.6		

Seeding rate means (Overall)

140 seeds/m^2 : 9.3
280 seeds/m^2 : 8.8
420 seeds/m^2 : 8.6

CV (Main-plot) = 5.9% CV (Subplot) = 4.6%

LSD:	5%	1%
Between two overall variety means	0.2	0.3
Between two overall location means	0.4	0.5
Between two overall seeding rate means	0.1	0.2
Between two seeding rate means in the same variety	0.3	0.4
Between any two other variety means	0.5	0.7

correlated with yield at the 1% level of probability (r = 0.44 and 0.38, respectively), whereas, days to heading was not correlated with grain yield.

4. Kernel Development, Test Weight, Protein and Yield

The analysis of variance for kernel development as measured by seed density revealed no statistical significant difference due either to seeding rate or its interaction terms (Table 2 and 12). However, kernel development was significantly affected by differences in locations and varieties. The partitioning of variety mean squares showed no differences in kernel development among triticale lines, while wheat was highly superior to triticales ($P \leq 0.005$). Test weight, another measure of kernel development, was found to be positively correlated with kernel density. Almost all the other traits including yield were negatively correlated with kernel development. Seeding rates had no influence on test weight, although variations occured due to locations and varieties. The interactions of varieties and locations, and locations and rates were significant for this character. In addition, test weight showed negative correlation with grain yield.

Table 12. The effect of plant population density on kernel development (g/cc) of Glenlea wheat and three hexaploid triticale lines grown at three locations

LOCATION	VARIETY												Overall location means
	Glenlea			Rosner			6TA204			Armadillo			
	No. of viable seeds per m^2												
	140	280	420	140	280	420	140	280	420	140	280	420	
Point	1.310	1.322	1.317	1.163	1.173	1.178	1.186	1.172	1.196	1.196	1.210	1.186	1.217
Swift Current	1.299	1.322	1.328	1.245	1.230	1.240	1.230	1.205	1.220	1.242	1.240	1.240	1.254
Westfield	1.311	1.322	1.317	1.221	1.243	1.223	1.230	1.202	1.217	1.246	1.226	1.225	1.249
Rate means	1.307	1.322	1.321	1.210	1.215	1.213	1.216	1.193	1.211	1.228	1.225	1.217	
Overall variety means		1.317			1.213			1.206			1.224		

Seeding rate means (Overall)

140 seeds/m^2	:	1.240
280 seeds/m^2	:	1.239
420 seeds/m^2	:	1.241

CV (Main-plot) = 3.3% CV (Subplot) = 2.5%

LSD:	5%	1%
Between two overall variety means	0.016	0.021
Between two overall location means	0.021	0.029
Between two overall seeding rate means	0.011	0.014
Between two seeding rate means in the same variety	0.021	0.028
Between any two other variety means	0.023	0.031

Correlation of protein content of triticales with the various other variables was also investigated. It was found that a positive association of protein content occurred with tillers/plant and test weight. On the other hand, protein content was negatively correlated at the 1% level with kernels/spike, kernels/spikelet, maturity, height, lysine content and yield (Table 4). In contrast, lysine content was positively correlated with 1000 KW, kernels/spike, height and yield at 1% level of probability. A negative association was found to exist between lysine, and kernel development and protein content.

There were significant differences ($P \leq 0.01$) for protein and lysine content among locations and varieties (Table 2) and a significant varieties x locations interaction was obtained for these two quality factors. The effect of environment on lysine and protein contents of Glenlea wheat and 6TA204 triticale is shown in Fig. 4. Armadillo and Rosner showed a similar trend as 6TA204 in their protein and lysine level. Seeding rate had no significant effect on either protein content or lysine level. A difference in protein and lysine contents existed between wheat and triticale as well as within triticales (Table 2). Glenlea and Rosner were approximately equal in protein content (15.9 and 16.0% respectively) while Armadillo and 6TA204 were slightly lower (15.0 and 15.3, respectively; Table 13). The triticale lines were significantly higher in lysine content compared to

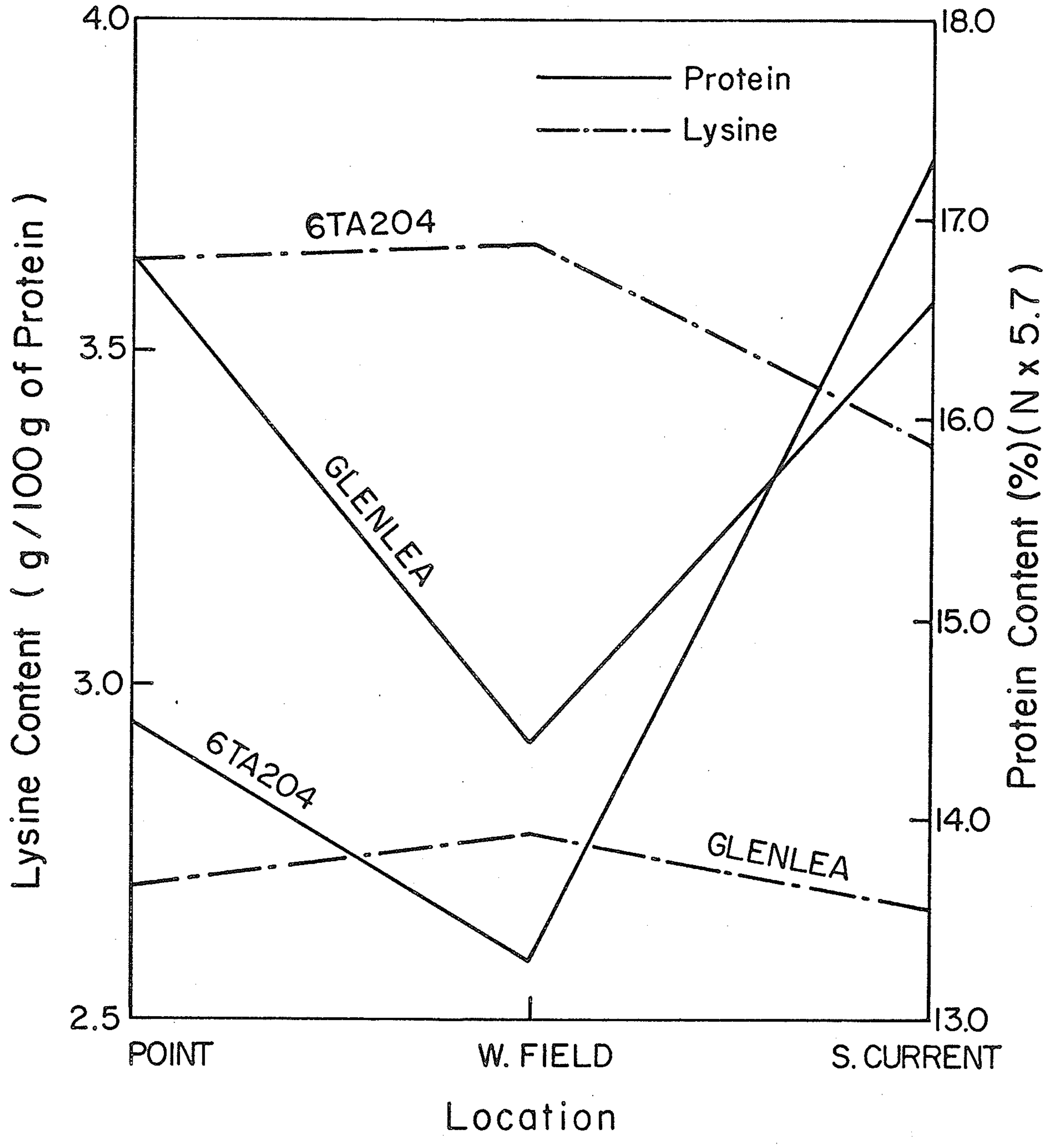

Figure 4. Protein (N x 5.7) and lysine (g / 100 g protein) contents of Glenlea wheat and 6TA204 triticale grown at 3 locations.

Table 13. The effect of plant population density on protein content (N x 5.7) (%) on a zero percent moisture basis for Glenlea wheat and three hexaploid triticale lines grown at three locations

LOCATION	VARIETY												Overall location means
	Glenlea			Rosner			6TA204			Armadillo			
	No. of viable seeds per m^2												
	140	280	420	140	280	420	140	280	420	140	280	420	
Point	16.4	17.0	17.1	15.6	15.4	15.4	14.3	14.6	14.7	14.0	13.9	13.8	15.2
Swift Current	16.4	16.6	16.7	17.7	17.9	18.1	17.5	17.0	17.3	17.6	18.0	18.1	17.4
Westfield	14.2	14.6	14.4	13.9	15.0	14.5	13.8	13.2	13.0	14.1	14.1	13.7	14.0
Rate means	15.6	16.1	16.1	15.8	16.1	16.0	15.2	14.9	15.0	15.2	15.3	15.2	
Overall Variety means		15.9			16.0			15.0			15.3		

Seeding rate means (Overall)

140 seeds/m^2	:	15.5
280 seeds/m^2	:	15.6
420 seeds/m^2	:	15.6

CV (Main-plot) = 7.8% CV (Subplot) = 3.8%

LSD:	5%	1%
Between two overall variety means	0.5	0.6
Between two overall location means	0.9	1.2
Between two seeding rate means	0.2	0.3
Between two seeding rate means in the same variety	0.4	0.5
Between any two other variety means	0.6	0.8

Glenlea wheat (Table 14). Triticales ranged in mean lysine content from 3.38% to 3.55% for all locations, whereas Glenlea averaged 2.72%.

Means and LSD values for grain yield are shown in Table 15. Differences in yielding ability were observed among locations, and varieties (Table 2). In addition, the locations x varieties and varieties x rates interactions were significant (Fig. 5). Seeding rate (plant density) significantly affected yield among triticale strains ($P \leq 0.05$), but not between wheat and triticale as a group. The major difference in yield was between wheat and triticales ($P \leq 0.005$; Table 2) with Glenlea outyielding the average of the three triticales by 31.3% (Table 15). At all locations, Glenlea showed a reduction in yield as seeding rate increased from 140 seeds/m^2 to 420 seeds/m^2. In contrast, Armadillo triticale yielded higher at the 420 seeds/m^2 rate than at the lower rates of seeding at two of the three locations. For Rosner triticale, no significant differences in yield due to seeding rate occurred at the "Point" and Swift Current, although at "Westfield", the 280 seeds/m^2 rate gave significantly higher yield than the 140 seeds/m^2 rate. Considering the overall mean values, the Swift Current test yielded only 55% of the "Point" location. Generally, while the lowest plant density was optimum for Glenlea wheat, the highest rate was optimum for Armadillo triticale. The 280

Table 14. The effect of plant population density on lysine content of protein (g/100g of protein) for Glenlea wheat and three hexaploid triticale lines grown at three locations

LOCATION	VARIETY												
	Glenlea			Rosner			6TA204			Armadillo			
	No. of viable seeds per m^2												Overall location means
	140	280	420	140	280	420	140	280	420	140	280	420	
Point	2.73	2.70	2.68	3.46	3.43	3.45	3.62	3.66	3.63	3.58	3.53	3.54	3.34
Swift Current	2.67	2.66	2.69	3.32	3.27	3.26	3.36	3.36	3.36	3.41	3.38	3.44	3.18
Westfield	2.76	2.71	2.88	3.46	3.33	3.39	3.59	3.66	3.73	3.36	3.46	3.48	3.32
Rate means	2.72	2.69	2.75	3.41	3.35	3.37	3.53	3.56	3.57	3.45	3.46	3.49	
Overall variety means		2.72			3.38			3.55			3.47		
Seeding rate means (Overall)					140 seeds/m^2		:	3.28					
					280 seeds/m^2		:	3.27					
					420 seeds/m^2		:	3.29					

CV (Main-plot) = 3.7% CV (Subplot) = 3.1%

LSD:	5%	1%
Between two overall variety means	0.05	0.06
Between two overall location means	0.07	0.10
Between two overall seeding rate means	0.03	0.04
Between two seeding rate means in the same variety	0.07	0.09
Between any two other variety means	0.07	0.10

Table 15. The effect of plant population density on grain yield (g/plot)* of Glenlea wheat and three hexaploid triticale lines grown at three locations

LOCATION	VARIETY												Overall location means
	Glenlea			Rosner			6TA204			Armadillo			
	No. of viable seeds per m^2												
	140	280	420	140	280	420	140	280	420	140	280	420	
Point	847.3	732.5	773.0	468.0	482.2	440.3	442.5	489.0	475.2	530.7	561.0	614.0	571.3
Swift Current	357.3	323.3	328.3	282.2	298.7	296.2	335.3	386.5	391.7	258.7	255.2	229.3	311.9
Westfield	737.2	671.7	650.5	426.5	486.5	446.2	397.2	371.8	288.8	437.2	529.8	545.8	499.1
Rate means	647.3	575.8	583.9	392.2	422.4	394.2	391.7	415.8	385.2	408.8	448.7	463.1	
Overall variety means		602.4			403.0			397.6			440.2		

Seeding rate means (Overall)

140 seeds/m^2	:	460.0
280 seeds/m^2	:	465.7
420 seeds/m^2	:	456.6

* Factor for conversion of g/plot to kg/ha = x5

CV (Main-plot) = 17.5% CV (Subplot) = 13.0%

LSD:	5%	1%
Between two overall variety means	31.8	41.8
Between two overall location means	66.7	92.3
Between two overall seeding rate means	19.8	26.1
Between two seeding rate means in the same variety	39.6	52.3
Between any two other variety means	45.0	59.8

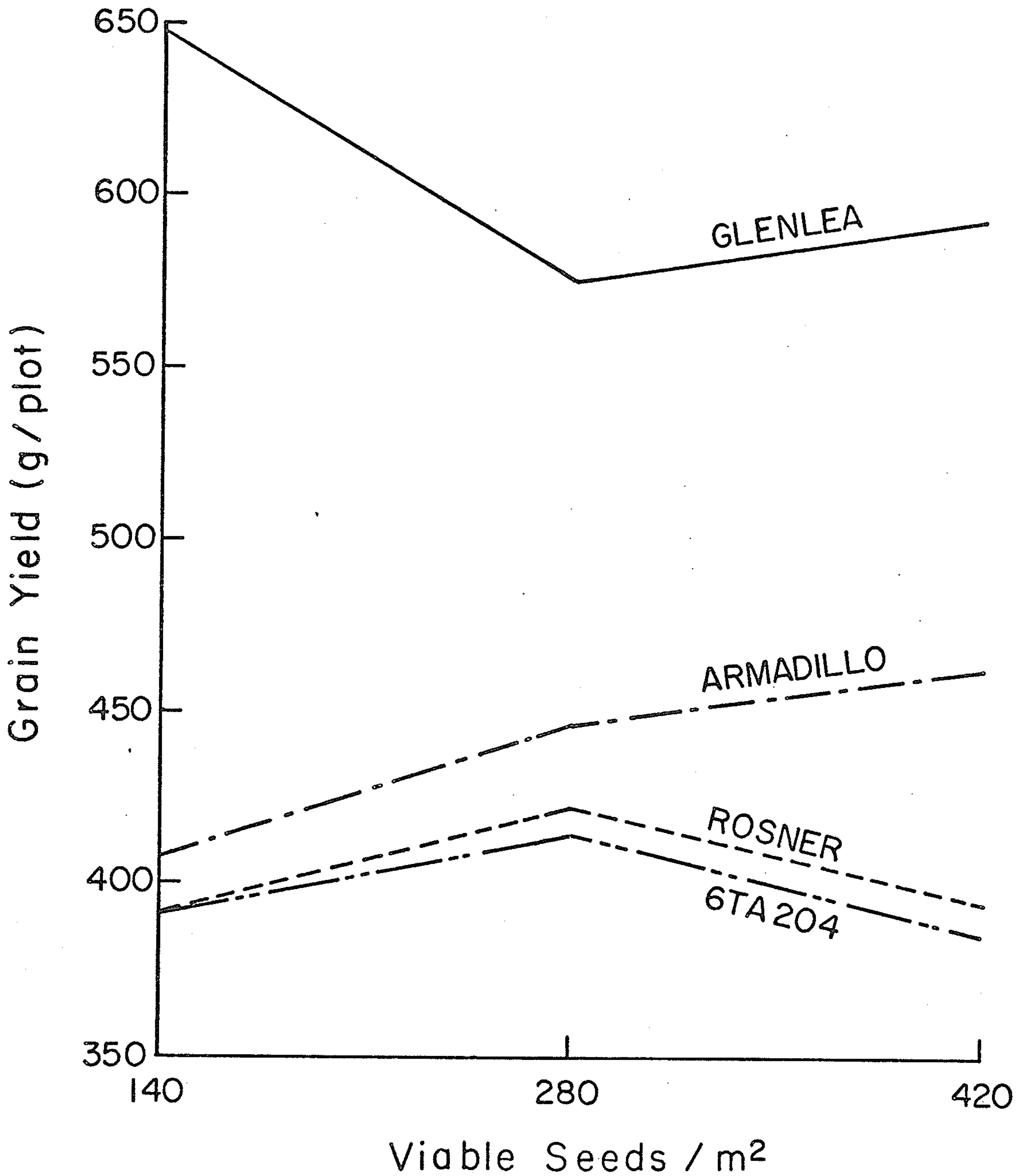

Figure 5. Effect of plant population density on grain yield (g/plot) of Glenlea wheat and 3 hexaploid triticale lines grown at 3 locations.

seeds/m^2 rate was optimum for Rosner and 6TA204 (Fig. 5).

One of the objectives of this study was to assess the usefulness of the various yield components and plant characters in determining yield. This was attempted by using multilinear regression and stepwise multiple regression analyses. For this purpose only those triticale lines used in correlation analysis were included. Multilinear regression analysis gave a standardized regression coefficient (b) of 0.79 for plant height and 0.48, 0.32 and -0.30 for plant population density, test weight, and tillers/plant, respectively. This indicated the very high contribution of height to yield. Also stepwise multiple regression analysis indicated strongly the importance of plant height in reducing the residual sum of squares of plot yield (Table 16). Plant height alone accounted for 65.1% of grain yield. Other independent variables which further reduced the residual sum of squares of plot yield were, in order of importance, test weight, tillers/plant, days to maturity, spike length, plant density, fertility, and 1000 KW. Test weight contributed 6.5% towards this reduction of sum of squares of yield, whereas tillers/plant, number of days to maturity and spike length contributed 2.3, 1.4 and 1.2%, respectively. However, the contributions of plant density, fertility, and 1000 KW were non-significant. These three variables contributed 0.8, 0.6 and 0.4% respectively. This was substantiated by computing and testing the regression coefficients and corre-

Table 16. Stepwise multiple regression analysis of mean plot grain yields on selected plant variables for two hexaploid triticale lines grown under three plant densities at three locations

Variable added to equation	Total reduction in residual sum of squares (%)	Regression coefficients								Multiple correlatio coefficien (R)
		b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	
1. Height	65.1	5.23								0.807**
2. Test weight	71.6	7.25	16.60							0.846**
3. Maturity	73.0	7.65	10.72	-3.70						0.854*
4. Plant density	73.8	7.06	10.50	-3.41	0.65					0.859
5. Tillers/plant	76.1	7.13	10.47	-4.01	1.96	45.54				0.872**
6. Spike length	77.3	6.82	16.14	-3.73	2.20	40.87	25.38			0.879*
7. Kernels/spikelet	77.9	6.47	16.10	-4.60	2.24	43.69	21.64	57.39		0.883
8. 1000-kernel weight	78.3	5.72	13.57	-2.98	2.56	48.70	22.31	55.47	3.92	0.885

N = 108

* Significantly different from the previous R at the 5% level

** Significantly different from the previous R at the 1% level lation coefficients for individual locations. The correlation coefficients of plant height from each location, although they were lower in magnitude, were not statistically different.

In summary, grain yield in triticale lines was positively correlated at the 1% level of probability with number of kernels/spike, fertility, spike length, days to maturity, plant height, and lysine content. On the other hand, kernel development, number of tillers/plant, test weight, and protein content were negatively correlated with grain yield at the 1% level of probability. There were no associations between yield and 1000-Kernel Weight, fertile heads/plant, and days to heading.

DISCUSSION

1. Fertility

Although the problem of poor fertility in triticale has been partially overcome by the breeding of secondary triticales, it still poses as one of the major problems in the exploitation of this man-made grain (Quinones, 1972). This observation was supported by the present study. Glenlea wheat was found superior in seed-set to all of the advanced strains of triticale included in the present experiment. Variation in fertility had an important effect on the yielding ability of triticale lines since seeds/spikelet showed consistently high positive correlation with grain yield at all locations and at all plant population densities. A major advance in triticale breeding was the development of the highly fertile Armadillo strains (Zillinsky and Borlaug, 1971). This improved fertility was found to be genetically controlled and could be transmitted readily to their progenies. The high fertility together with other desirable characters of the Armadillo type triticale has resulted in yield increases of 50% to 60% above those obtained from triticale strains grown prior to 1969 in the CIMMYT program in Mexico (Zillinsky and Lopez B., 1973).

An interesting observation in the present study was the tendency of Glenlea wheat and 6TA204 triticale to exhibit a relatively consistent fertility level over all locations while the fertility of Rosner and Armadillo triticales was substantially reduced under moisture stress at Swift Current. The relatively high yields of Glenlea wheat and 6TA204 triticale under the semi-arid conditions of the Swift Current location, point to the fact that these genotypes possess the desirable tolerance necessary for the breeding of cultivars for areas of drought stress. The high productivity of these two varieties is apparently due to their consistently high fertility. However, these varieties are late maturing compared to the other two lines of triticale. Earliness, especially rapid development from emergence to heading, has been found to be important in escaping drought (Hurd, 1971). Derera et al. (1968) found that 40 to 90% of the variation in drought tolerance observed in their varieties was due to earliness.

In addition to the relationship of fertility with grain yield, its interrelationship with other yield components and agronomic characters is an important consideration. Correlation coefficient values showed that this variable was positively correlated with most of the characters under study which were, in turn, significantly directly related to grain yield. In durum wheat, Kaltsikes and Lee (1971) found that kernels/spikelet was highly correlated (r=0.71) with yield per plant. This observation together with the regression analysis results, substantiated the importance of this parameter in triticale. The emphasis of selecting for increased fertility can be a useful criterion to follow in triticale breeding (Tsuchiya, 1972).

Both the wheat and the triticale varieties tended to exhibit equal number of kernels/spikelet and heads/plant at a particular location (Fig. 1). For example, Glenlea exhibited 2.3 kernels/spikelet and 2.3 heads/plant at "Westfield" location. However, if it is not coincidental, the mechanism controlling this tendency towards an equilibrium point between these two quantitative variables under a certain environment could not be explained by the present data. The very strong inverse relationship observed at Swift Current between kernels/spikelet and heads/plant is assumed to be due to high number of heads per plant because of low competition as a result of poor seedling survival percent. At any rate, knowing the high spike potential of 6TA204, the low fertility level it showed has resulted in a substantial reduction of its yield.

2. <u>Tillering and Plant Population Density</u>

The response of genotype to plant competition has been previously investigated (Donald, 1963). In the present study, although varieties showed highly significant differences in tiller number, the variation between Glenlea wheat and the triticale strains as a group was non-significant. However, Rosner was significantly superior in tiller number per plant to Glenlea wheat as well as to the other two triticale strains studied. The substantial reduction in tillering ability under plant competition (or high plant density) was less for Rosner indicating that this triticale cultivar has a better competitive ability than Glenlea wheat in respect to its tillering capacity (Fig. 2). Similarly, Jones and Hayes (1967) found non-significant differences in grain yield between 137 lb/acre and 206 lb/acre even though a 69 lb/acre rate yielded comparatively lower. Guitard et al. (1961) reported that in wheat, oats and barley, number of fertile heads per plant decreased curvi-linearly as seeding rate was increased.

As indicated earlier, tillering was decreased with increased seeding rates at two of the three locations. The exception was at Swift Current where severe moisture stress resulted in a reduction in seedling survival, i. e. number of plants per unit area. Surviving plants were thus able to utilize more efficiently available soil moisture. This may or may not result in a final yield reduction depending on the optimum density level for a specific genotype under a given environment. Thorne (1966) found an inverse relationship between tiller number and yield provided the tillers that were produced were fertile. Under the semi-arid conditions at Swift Current Research Station selection has been for plants having a few number of tillers of uniform maturity (Hurd, 1971). Nevertheless, Rosner did not show an advantage in yield notwithstanding its relatively high tillering capacity.

The negative association of tillers per plant and most yield parameters in relation to plant population density has been reported by many workers (e.g. Kirby, 1967; Bremner, 1969). On the other hand, Kaltsikes (1973) found a highly significant positive correlation (r=0.40) between tillers/plant and plot yield in spring rye. Although the presence of high numbers of unproductive tillers can have only a transitory effect on productivity of the plant under high fertilization and moisture levels (Bremner, 1969), under conditions of nutrient and/or water stress, competition by unproductive tillers may result in reduction of yield. The substantial reduction in fertility (kernels/spikelet) at Swift Current when varieties exhibited high numbers of heads per plant implied that the limiting environmental resource was exploited by early developing yield components at the expense of late ones. This point is discussed by Rasmusson and Cannell (1970) for barley. In an environment where the moisture supply is ample in early stages of plant growth but inadequate in later stages, high genetic ceilings for ear number/plant and kernel number/head could result in low kernel weight. This can occur at a given plant population level over and above the optimum density for any cultivar or species in a given environment. In the present study the optimum level of plant density varied according to genotype and location. Hence, Bunting _et al_. (1964) refer to tillering as a "plasticity in the plant" enabling it to adapt to environmental differences. Nonetheless, the importance of optimum plant density in the present study was indicated by both its positive correlation coefficients with important yield determinants such as kernels/spike, fertility, days to maturity, plant height and yield _per se_ and its role in reducing the residual sum of squares for plot yield according to stepwise multiple regression analysis (Table 16).

3. Yield Components and Related Characters

Nass (1973) stated that ears per plant was the most important variable in influencing yields of the spring wheat cultivars that he studied. However, according to the present study, number of ears per plant contributed very little towards triticale yield. It has been widely accepted that yield is the direct and/or indirect function of the three principal yield components, viz., kernel weight, number of kernels per spike and number of spikes per plant. Whether or not this concept is a universally accepted physiological phenomenon for all grain crops has a practical implication in plant breeding. The view supported by Rasmusson and Cannell (1970) is that since the optimal level for number of spikes/plant and number of kernels/spike will differ depending on environment, kernel size should be the only parameter whose genetic ceiling is near its maximum.

Based on the present data, 1000 KW *per se* may not be important in determining yielding ability in triticale. This is not in agreement with other reports on the importance of kernel weight in many cereal crops. Rasmusson and Cannell (1970) after studying selection for yield and components of yield in barley, concluded that selection for high genetic potential for kernel weight would be advantageous in all environments. They stated that since kernel mass is the last component to be synthesized by the plant, its level of expression should not result in a compensating change in the other components. The 1000 KW values within the two triticales studied herein were not correlated with yield ($r=0.02$). A specific example is Armadillo which yielded less than Rosner at the Swift Current location but was significantly higher in 1000 KW ($P \leq 0.01$). Similarly, triticale 6TA204, while being equal to Armadillo in kernel weight was superior to it in yield. Under conditions of stress, wheat and triticales showed a differential reaction of the various yield components. Whereas Glenlea exhibited a reduction in 1000 KW and kernel number per spike, the triticales were most seriously affected by reduced kernel number while kernel weight either remained unchanged or even somewhat improved.

Evidence for negative relationships between components of yield in cereals has been reported by many workers (e. g. Knott and Talukdar, 1971; Fonseca and Patterson, 1968). In the present study, these findings are supported by the high negative correlation coefficient values obtained for 1000 KW and other yield determinants such as kernels/spike, kernels/spikelet, and the "time-morphological" factors, (days to heading, days to maturity, plant height and spike length). Knott and Talukdar (1971) found 1000-kernel weight in wheat to be positively correlated with yield per plot and negatively correlated with kernel number per plot. Also kernels per spike showed a high negative correlation with spikes per plot.

In contrast, kernel number per spike appeared to be a very important yield component in triticale. The correlation coefficient between kernel number per spike and fertility was 0.95. Moreover, the high positive correlation of this component with spike length, days to maturity, plant height and yield _per se_ substantiates the influence of this variable on yield as reported by other workers (e. g. Fonseca and Patterson, 1968; Nass, 1973). Considering the three principal yield components in triticale, therefore, number of kernels/spike was found to have the most influence on potential yielding ability while heads/plant was not correlated with either yield *per se* or with any of the important yield-determining variables.

The two morphological plant characters, viz., plant height and spike length were found positively associated with yield in triticale (r = 0.81 and 0.38, respectively). In addition, high correlation coefficient values were obtained between height and kernels/spike (r = 0.80), kernels/spikelet (r = 0.77), days to maturity (r = 0.75) and spike length (r = 0.56). The positive correlation found between height and yield is in agreement with reports by Lebsock and Amaya (1969), Utz *et al*. (1973), and Lee and Kaltsikes (1973). Lee and Kaltsikes (1973) obtained correlation coefficients of 0.58 and 0.80 between plant height and yield per plot of durum wheat F_1 and F_2 generations, respectively. Lebsock and Amaya (1969) also found a correlation between plant height and yield in some of their crosses in durum wheat. Kaltsikes and Larter (1970) studied five inbreds of durum wheat grown in the Canadian Western Cooperative test. They found significant correlation between these two characters. Such positive correlation between plant height and yield can be a handicap in breeding since lodging is one of the major problems in cereal crop production (Zillinsky and Borlaug, 1971; and Utz et al., 1973). Furthermore, the importance of plant height in contributing towards triticale yield in the present study, has been substantiated by multilinear regression and stepwise multiple regression analyses. The analyses of data for separate locations gave similar results to those determined for combined locations. As mentioned earlier, plant height alone contributed 65.1% towards the reduction of residual sum of squares of yield per plot. Notwithstanding the apparent strong association of plant height with yield of triticale, the problem of lodging cannot be ignored and efforts are being made to reduce straw length yet maintain yields. In addition, this relationship between height and yield could be merely phenotypic due to environmental stress.

4. Kernel Development, Test Weight, Protein and Yield

The problem of kernel development which is also a measure of test weight, is the major area of research in triticale (Zillinsky and Borlaug, 1971). The basic objective of successfully attaining plump triticale grain while still maintaining the present seed size and yielding potential of this new crop may not as yet been achieved. There seems to exist an inverse relationship between kernel development (seed density) and other determinants of yield. Kernel development, while positively correlated with test weight, is negatively correlated with most yield parameters and yield. This suggests that in triticale the improvement of grain development may result in loss of some important components with concomitant reduction in yield. To fully exploit the potential of triticale, this relationship must be understood and eventually be circumvented. On the other hand, substantial improvement has been achieved in grain type with the isolation of the fertile Armadillo strains in the International Wheat and Maize Improvement Centre, Mexico (Zillinsky and Borlaug, 1971). To date, the cause of seed shrivelling in triticale has not been defined. Shealy and Simmonds (1973) reported malformation of cells of the aleurone and endosperm tissue, also precocious alpha-amylase release to be responsible for poor kernel development.

By studying the location means and mean squares, it could be implied that as size of kernel is reduced due to moisture stress at Swift Current, improvement in plumpness is attained. However, this resulted in lower yield. Furthermore, the utilization of multivariate statistical analysis indicated the minor contribution of kernel development towards yield.

Protein and its amino acids, in particular lysine, is one of the most promising attributes of triticale. Comparing the protein content of the varieties of the present study, Glenlea and Rosner were about equal and higher than 6TA204 and Armadillo. Ruckman _et al_. (1973) compared protein and lysine levels of a hard red spring wheat, Inia 66, a white spring wheat, Siete Cerros 66, a durum spring wheat, Oviachic 65, and three triticales, viz., 6TA204, Rosner and T-1324. On the average, triticales had higher whole-grain protein content than the wheats. Triticales had a protein content (N x 5.7) of 16.3% versus 14.3% for wheats on a dry weight basis, also a higher lysine level (2.63 vs 2.14%, respectively). In the present study, plant population density had no effect on protein percentage. This is in agreement with a similar report on the absence of influence of plant population density on protein by Larter _et al_. (1971). An inverse relationship of protein to grain yield was obtained ($r = -0.78$); but was positively correlated with those parameters found to be non-significantly associated with grain yield. This inverse relationship between protein content and grain yield is found to exist in wheat (Williams, 1966). Williams (1966) carried out a series of 24 trials from 1961 to 1963 throughout the Australian wheat belt. He reported that the wheat variety 'Festival' was consistently low in yield and high in protein while the variety 'Heron' was low in protein and high in yield.

The relatively high level of lysine in triticale has always been a strong incentive for the development of this species as a commercial crop. This relationship has been confirmed by other reports (e. g. Villegas *et al.*, 1970). In the present investigation, the mean lysine content of the triticales ranged from 3.38% to 3.55% while Glenlea wheat averaged 2.72%, a 20 to 23% increase. The presence of a significant inverse relationship between protein and lysine was apparent from the present study. These data agree with other reports of high negative correlation between protein content and lysine content of protein in bread and durum wheats, rye and triticale. Villegas *et al.* (1970) found correlation coefficients of -0.69 and -0.50 between protein and lysine contents of rye and triticale, respectively. At the Westfield test site, 6TA204 triticale produced a very low protein percent (13.3%) due to lack of application of commercial fertilization or other unknown environmental factors, but produced the highest lysine value (3.66%). That such an inverse relationship may be based on a varietal difference is suggested by the finding that in the triticale breeding program at the University of Manitoba, a low percentage of hybrids have been selected for high protein without accompanying loss of lysine (Larter, pers. comm.). In the present study, lysine content was not influenced by plant population density. Thus, if the present results can be applied to the breeding program in general, selection on the basis of yield will result in the maintenance of favorable lysine levels.

The lack of significant difference in yield due to variation in plant density illustrated the wide adaptability of the variety Glenlea. In line with this, Zeven (1972) found that in wheat plant density had no effect on the expression of heterosis for yield. This was implied to be due to the buffering capacity of genotypes (also see Pandey and Torrie, 1973). In contrast, differences in yield among triticale lines due to plant density were significant. The relatively better yield performance of Armadillo at the 420 seeds/m^2 plant density indicated that this line requires higher plant density to reach its optimum productivity. This was also suggested by its lower tillering capacity relative to other triticale strains, even under optimum conditions. The improved performance of 6TA204 and Glenlea compared to the other two triticale lines under Swift Current conditions may be attributed to their higher kernel number/spike and fertility, respectively.

Finally, in the present data, there was a clear-cut trend in triticale for high negative correlation of yield with protein, test weight, kernel development and tiller number per plant. Absence of correlation of yield with 1000 KW and fertile heads/plant implied that it is not always possible to extract yield component relationships from cereal crops in general and apply them directly to triticale.

SUMMARY

In this experiment highly significant differences were found among the three triticale lines for all characters investigated. Yields were significantly different at the 5% level. Triticales showed significant differences due to plant population density in all variables examined except kernel development, test weight, protein content, and lysine content. For most characters, the seeding rates variance was due to a linear effect. The locations x varieties interaction was highly significant for all characters, whereas a highly significant interaction between varieties and seeding rates was observed only for 1000 KW, tiller number and days to heading.

Generally, the following findings were obtained by the present study:

(1) Glenlea wheat was superior to the triticale lines in fertility. Fertility decreased linearly as plant population density increased.

(2) Fertility in triticales was positively correlated with kernel number per plant, spike length, days to heading and maturity, plant height and yield _per se_, whereas it was negatively correlated with 1000 KW, kernel development, test weight, and protein content.

(3) Rosner triticale was superior to Glenlea wheat in tillering ability. Tillering ability of all varieties investigated decreased as plant population density increased. The lowest seeding rate (140 seeds/m^2) resulted in the highest tiller number. The effects were both linear and non-linear. However, Rosner suffered less than Glenlea wheat in tiller reduction due to high plant competition.

(4) Tillering in triticale was negatively correlated with kernels/spike, plant density, days to maturity, plant height and yield. However, tillers/plant contributed 2.3% of the yield variance which was significant at the 1% level.

(5) Among the 3 principal yield components only kernel number was found to be of importance in determining yield in triticale. 1000 KW was negatively correlated with most plant characters.

(6) Plant height was positively correlated with yield in triticale and was found to be the most important contributor towards the yield variance (65.1%). Test weight, days to maturity and spike length were also found to be important.

(7) Kernel development was negatively correlated with most plant traits studied. Although test weight

contributed 6.5% of the yield variance, it was negatively correlated with yield.

(8) Rosner triticale and Glenlea wheat were equal in protein while all the triticales were superior to Glenlea in lysine content. Protein was negatively correlated with yield and major yield determinants whereas lysine was positively correlated with yield and major yield components.

(9) Glenlea was superior to triticales in yield and most traits with Glenlea outyielding the average yield of the three triticale lines by 31.3%. The locations x varieties and varieties x seeding rates interactions for yield were significant. Among triticales plant density affected yield significantly, while optimum levels varied with lines.

(10) In summary, in triticale, yield was positively correlated with kernel number/plant, fertility, spike length, days to maturity, plant height and lysine content. Conversely, yield was negatively associated with kernel development, tiller number, test weight and protein content. No associations of yield with 1000 KW, ears/plant and days to heading were observed.

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