THE EFFECTS OF MASS SELECTION FOR SEED SIZE IN HEXAPLOID TRITICALE

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Ian S. Ogilvie

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Mature Spike of Hexaploid Triticale

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ABSTRACT

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Effects of Mass Selection for Seed Size in Hexaploid Triticale.

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Three lines and two F3 segregating populations of hexaploid triticale (X *Triticosecale* Wittmack) were subjected to two cycles of ambidirectional mass selection for seed characteristics on the basis of size and density. No advance due to selection was observed in two contrasting environments. As neither seed size nor density were consistently correlated with plot yield, mass selection for these seed characteristics was ineffective in changing the yield of the populations studied. However, in seven crosses, plants resulting from large F2 seeds, selected on an individual F1 plant basis, outperformed those from small seeds. Similar selection in an advanced line yielded no significant differences. It is argued that the few genes which control seed size in these populations become fixed in the homozygous condition by the F3 generation, rendering further selection ineffective. This, coupled with a certain amount of outcrossing in triticale, suggests that mass selection techniques, suitable for wheat or other completely self-pollinated plants, would be ineffective in present early generations of hexaploid triticale, unless the techniques are modified, because of differences in the breeding system.

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INTRODUCTION

Selection for seed size and its effect on seed yield in triticale lines and segregating populations

Importance of selection from large populations

Large populations of the early segregating generations are required to recover all possible favourable recombinants, when working with characters controlled by a large number of genes, such as yield. Shebeski (1967) has calculated that in the F2 of a cross differing by 21 gene pairs (assuming only one gene difference on each chromosome of hexaploid wheat or triticale) only 0.237% of the plants would contain all the favourable alleles in either the homozygous or heterozygous condition. As environmental conditions would probably affect phenotypic expression of various genotypes, a much smaller proportion of the most favourable genotypes would exhibit superior phenotypes. This would necessitate using even larger F2 populations,than theoretically expected, to ensure a fair chance of selecting the desirable genotype.

Yield components and selection efficiency

To make selection for yield easier to manage, various characters associated with it have been used as its predictors. These characters, considered to be parts of yield, are known as its components and are thought to be under the control of a simpler genetic system. For crop plants in which the harvested seed is the economic product, the major components of seed yield are: (1) the number of plants harvested in a given unit area, (2) the average number of fertile or seed-bearing inflorescences per plant, (3) the average number of seeds per inflorescence and (4) the average weight of the individual seed (Langer, 1967).

All these yield components have been used in plant breeding programmes; however, some of them may be highly affected by environmental conditions and whether phenotypic selection actually indicates superior genotypes may, in many cases, be questionable.

To effectively deal with the large populations necessary for selection of the individuals with the largest possible number of genes for improved yield, a rapid method of handling must be used. The first three yield components depend on an extensive system of recording and labelling which would preclude the handling of a sufficiently large population to achieve significant improvement of the specific yield component.

Selection for seed size and yield improvement

Selection for seed size on a phenotypic basis could be achieved rather easily on a mass scale which would enable the use of mechanical methods and the rapid screening of reasonably large populations. A number of researchers have recorded evidence that seed size is positively correlated with seed yield in a number of cereal and other crops (see Literature Review). When different seed sizes of an inbred line are selected, the size differences should be due only to environmental differences or other factors such as the position of the seed in the inflorescence. When selecting from segregating populations, however, there will be both a genetic and an environmental component of seed size, and selection for a specific seed size should shift the mean seed size of the progeny towards the mean of the selected individuals with a corresponding shift in associated yield characters.

Problems in triticale breeding

The pedigree method and mass selection techniques for seed size selection, as a component of seed yield, have been widely used with positive results in hexaploid wheat and many other crop plants. However, for the object of this triticale investigation, some of the problems encountered are different from those associated with hexaploid wheat or any of the other more important cereal crops.

Hexaploid triticale has its origin from amphidiploids produced by colchicine or other chromosome doubling treatments of crosses between tetraploid wheats of various species (*Triticum* sp.), which are all naturally inbreeding, and diploid rye (*Secale cereale* L.) which is a naturally outcrossing species. The combination of an outcrossing species and a naturally inbreeding species in a new artificially synthesized hybrid appears to have created a number of problems which must be overcome before the new species can compete economically with established varieties of the traditional cereals. Many of the present triticale lines have very low fertility and produce varying amounts of shrivelled seed, especially in the early segregating generations. In this specific area, the problem of low fertility has been further complicated by the high susceptibility of most triticale lines to infection by ergot (*Claviceps purpurea* (Fr.) Tul.). Most florets which do not form seed are then infected by the fungal spores and produce a fungal body (sclerotium) in the place of the seed. Many seeds which do form are also infected by fungal spores at an early stage, with, in most cases, the embryo and much of the endosperm being destroyed by fungal growth.

These problems complicate the simple mechanical selection or separation of triticale lines on the basis of seed size as compared with hexaploid wheat or other cytologically stable crops. When there is a high degree of sterility on a given spike, only a few seeds may form. The possibility exists then that all the available nutrients could be translocated into these few seeds, resulting in much larger seeds than would be the case when the available nutrients are distributed to the much larger number of growing kernels in a highly fertile spike. Shrivelled, twisted seeds may be retained in the same class as large sound, plump seed when a bulk population is passed through a set of seed screens or sieves. These shrivelled seeds will have a much lower density than normal seeds, and will have a much lower weight and lower endosperm reserves for the nutrition of the developing embryo during germination and early development. Some method is therefore needed to compensate for this variation in seed density or weight in the mechanical separation on a size basis for most segregating triticale populations.

Because of these problems, mass selection screening techniques which have been used for increasing seed size and yield in other cereal crops may not be directly applicable to triticale breeding. Modifications therefore may have to be made to these methods to achieve any effective improvements.

Seed size selection in triticale

Some of the larger seeded lines of triticale have generally higher seed quality and indications of good yield combined with certain undesirable agronomic characters such as excessive plant height. An effective breeding programme should combine the reasonably good seed quality and large seed size of these lines with the short straw length of the semi-dwarf lines which have smaller seeds, a high degree of seed shrivelling and rather poor fertility.

When triticale lines of diverse origin and type are crossed there is some difficulty in obtaining sufficient amounts of seed from which to obtain, through mechanical separation, at least three different seed classes for a replicated yield trial. A preliminary experiment was first undertaken on F2 seed, using visiual selection for seed size and its effects on single plant and plot yields. Eventually two segregating populations of F2 plants were obtained from the winter nurseries growing at Ciudad Obregon, Sonora (Mexico), which gave sufficient F3 bulk seed for a replicated yield trial. Additionally, three advanced lines which differed widely in genetic origin and seed size were obtained. These five populations were subjected to two cycles of mass selection for seed size and were grown at two contrasting environments with a view to ascertaining: (1) the effectiveness of mechanical mass selection for seed size in segregating (F3 and F4) and pure triticale lines, (2) the correlated response, if any, of yield to selection for larger seed size and (3) the effect, in any, of the type of environment on the magnitude of the selection response.

This series of selection experiments, along with some growth studies of embryos cultured from seeds of various sizes from the lines and populations used in the F3 bulk selection experiments should give some definite information on the effectiveness of mass selection for seed size in increasing the yield of hexaploid triticale.

LITERATURE REVIEW

Genetic segregation in self-pollinated plants

When selecting for a quantitative character such as seed yield, in which a large number of genes may control its expression, large populations need to be evaluated. Shebeski (1967) has calculated that in a cross differing by 21 genes (one for each chromosome pair for hexaploid wheat or triticale) only 0.238% of all plants in the F2 generation would have all favourable genes in either the homozygous or heterozygous condition and that this would decrease to 0.0052% in the F3 and 0.00057% in the F4 generation. The difficulty of handling such large numbers of plants in order to obtain the most favourable possible genotype obviously makes it impossible to use the conventional pedigree system. This necessitates the use of certain screening techniques to eliminate obviously inferior genotypes and increase the possibility of selecting superior genotypes at the earliest possible generation.

Yield components as indicators of yield

Yield, in any crop where the seed is the desired economic product, may be resolved into four main components: (1) the number of plants per unit area, (2) the number of inflorescences or heads per plant, (3) the number of seeds per head and (4) the average weight per seed (Lander, 1967). All of these components can be used as a selection index in breeding for total seed yield, but it is necessary to choose one which can be used for populations consisting of many thousands of plants.

The first three components all require a process of observation and recording which would limit the size of populations which could be handled by a given amount of labour, while seed weight or size can be effectively handled by mechanical means and the populations separated into a range of classes from which positive or negative selection can be made.

The effectiveness of seed size as a component of yield, its effect on development of vegetative and reproductive structures of the plants, the heritability of seed size and the contribution of the embryo and the nutrient reserves in the seed are all factors which must be taken into consideration when attempting to initiate a programme of mass selection for seed size to improve yield. The accompanying review of previous investigations in a wide variety of economic plants, with a more detailed examination of similar work in cereals, has been done in order to apply these results to the present investigation of mass selection for seed size in hexaploid triticale.

Forage grasses

Rogler (1954), working with six depths of seeding and six seed sizes in crested wheatgrass (*Agropyron cristatum* L.), found a significant correlation between seed weight and emergence from depths greater than five centimetres. Leaf development was also greater for the larger seed sizes.

Kneebone and Cremer (1955) found that large seed size was associated with seedling vigour in five native American range grass species (*Buchloe dactyloides* (Nutt.) Engelm., *Bouteloua curtipendula* (Michx.) Torr., *Andropogon hallii* Hack., *Sorghastrum nutans* (L.) Nash. and

Panicum virgatum L.) but that germination was decreased in smaller seeds only in Panicum virgatum L. Kneebone (1956) made single plant selections in Andropogon hallii Hack. and found a correlation of 0.88 between seed weight and percentage stand. One cycle of selection in Bouteloua curtipendula (Michx.) Torr. for seedling vigour resulted in increased seed size and more vigourous progeny.

Thomas (1966), studying populations of perennial ryegrass (Lolium perenne L.), found that seed weight was positively correlated with seedling vigour (within a population) but that these correlations decrease with age. Arnott (1975) found that seedlings from large seeds of S24 perennial ryegrass produced longer and heavier roots, as well as having longer coleoptiles which enabled them to emerge from greater depths.

Trupp and Coulson (1971) found that early seedling vigour was correlated with seed size in smooth bromegrass (Bromus inermis Leyss.). This correlation decreased with time but was still evident 93 days after seeding.

Forage legumes

Twamley (1971) found that there was no negative correlation between seed size and seed yield in Lotus corniculatus L. (birdsfoot trefoil). Conje and Carlson (1973) reported that seedling dry weight and length were positively correlated with seed size in F1 plants of a cross between two diverse strains of birdsfoot trefoil. Twamley (1974) made three cycles of selection for seedling size and vigour in lines of birdsfoot trefoil in which an increase of seedling weight by 40% also resulted in a seed weight increase of 36%. Carleton and Cooper (1972) found that correlation of average seed size of a clone with its seedling vigour was significant in birdsfoot trefoil, not significant in alfalfa (_Medicago sativa_ L.) and approached significance in sainfoin (_Onobrychis sativa_ Lam.).

Townsend (1972) found large and medium seeds to be significantly superior to small seeds for emergence in _Astragalus cicer_ L. but not significantly greater for _Astragalus falcatus_ Lam.

Haskins and Gorz (1975) selected small, medium and large seeds in two lines of sweet clover (_Melilotus alba_ Desr.). Increased seed size improved both seed emergence and dry matter production.

Grain legumes

Fehr and Probst (1971) found that for 10 different strains of soybeans (_Glycine max_ Mer.) at 14 locations, yield, height and seed size were all positively correlated with the size of the seed sown. Fontes (1971) showed that plants grown from large seed had higher yield, greater height, fewer barren plants and were better competitors than those from small seed of the same two varieties. Singh, Tripathi and Negi (1972) demonstrated that plants from large seeds of three soybean varieties produced more dry matter than those from small seeds but that seed yield and yield components were not affected by seed size. Lal, Mehta and Nigam (1973) found that small and medium seeded varieties of soybeans were superior in emergence and seed yield than large seeded ones. Johnson and Luedders (1974) showed no effect of seed size on emergence or seed yield.

Coffelt and Hammons (1973) graded groundnut (_Arachis hypogea_ L.) seeds by 1/64 inch intervals from 22/64 to 14/64 inches and found that an excess of albino seedlings were produced by the small seed sizes but that the defect 'sterile brachytic' was inherited independently of seed size. Seed yields were lower for the smaller seeds (less than 15/64 inches). Sivasubramanian and Ramakrishnan (1974) noted the superiority in field emergence and dry matter production to 90 days of plants originating from large groundnut seed over those from small and shrivelled seeds and attributed this to the increased amounts of proteins and amino acids stored in the cotyledons.

Meuhlbauer (1973) noted that seed weight was negatively correlated with yield in 45 cultivars of lentil (*Lens esculenta* Moench.) Muehlbauer (1975) stated that there is a negative association between seed size and yield in lentils and that extensive backcrossing would be needed to increase the yield in large seeded cultivars.

Singh and Singh (1972) reported that the main yield contributing factors in field peas (*Pisum sativum* L.) were seeds per pod, branches per plant and seed size.

Pinthus , Bar-Am and Muhasen (1973) isolated large and small seeded lines from one cultivar of chick peas (*Cicer arietinum* L.). Bulks from the large seeded line produced higher yields and those from the small seeded line lower yields than the original cultivar.

Hamblin (1975), in a competition study of seven varieties of beans (*Phaseolus vulgaris* L.), found that large seeded high yielding lines would tend to be eliminated in mixtures with lower yielding small seeded types which produce a larger number of seeds per plant if the mixtures were maintained as bulks.

Miscellaneous economic plants

Gorina (1971) stated that selection by seed size in buckwheat

(Fagopyrum esculentum Moench.) increased the yield of the progeny by 8-12%, with the greatest increase in medium sized lines.

Harper and Obeid (1967) found that seedlings from small flax (Linum usitatissimum L.) seeds emerge fastest from one centimetre sowings and those from large seeds at six centimetres in depth. Large seeds had a competitive disadvantage in mixtures.

Dabral and Holker (1971) reported that capsule length and 1000 seed weight were correlated with yield in sesame (Sesamum indicum L.)

Ahmed and Zuberi (1973) found that in four varieties of rapeseed (Brassica campestris L.), large seeds (100 seeds = 56-63 mg) produced higher seed yields per plant, more fruits per plant, larger fruits and heavier seeds than small seeds (100 seeds = 23-29 mg) but had fewer seeds per fruit.

Kubka, Hortynski and Hulewicz (1974) reported that the correlation between the seed weight of a mother plant in radish (Raphanus sativus L.) with the root yield of its progeny was high and significant.

MacLachlan (1972) separated sugar beet (Beta vulgaris L.) seeds into six sizes from 7/64 inches to 12/64 inches and found that a yield increase of 0.4 tons of roots per acre without any effect of sugar percentage was obtained for each 1/64 inch increase in seed size. Scott, Harper, Wood and Jaggard (1974) reported that increasing sugar beet seed size caused a progressively greater percentage of emergence and root/shoot ratio.

Halsey (1971) found significantly greater yields of mature green and marketable size tomatoes (Lycopersicum esculentum Mill.) from plantings of heavy seed over those from light and unsized seed.

Cochran (1973) reported that large and medium seeds of the pepper (Capsicum annuum L.) "Truhard Perfection" emerged two days earlier than small seeds and had sufficient growth for transplanting while those from small seeds were not ready at 75 days.

El Zahab, Abo and Zahran (1974) tested four different seed sizes in three varieties of cotton (Gossypium hirsutum L.). Large seeds produced plants with 37% more dry matter than those from small seeds and 12% more than those from unselected bulks at 71 days but the yield of seed cotton did not differ between seed sizes.

Griffin (1972) graded a half-sib seed lot of Monterrey pine (Pinus radiata D. Don) into large and small seeds. The seedlings from large seeds were 18% taller and had a 45% greater dry weight at 32 weeks than those from small seeds.

Tropical cereals

Abdullah and Vanderlip (1972) reported that large (over 10/64 inches) and medium (10/64 to 9/64 inches) seeds of sorghum (Sorghum vulgare Pers.) taken from a hybrid grown at nine different locations were similar and superior to small (less than 9/64 inches) seeds in all tests of seedling vigour and field establishment but that grain yield did not differ significantly between seed sizes.

Gubbels (1974) found that seed size was positively correlated with the emergence of the first five seedlings and with green weight of maize (Zea mays L.) genotypes planted at low temperatures. Hunter and Kannenberg (1972) reported that there was no difference in grain yield or in days to 50% emergence in maize seeds within a line between those with a 100 seed weight of 39 g and those of 23 g. Sevov and Mitev (1974) found a direct positive correlation between the size of the seed and the yield of the plants grown from them in popcorn.

Herrmann (1969) classified 20 different cultivars of rice (*Oryza sativa* L.) by seed size and found that increased seed size improved the germination and early development of the rice plant independent of the geographical origin of the cultivar or environmental conditions.

Oats (*Avena sativa* L.)

Frey and Wiggins (1956) tested seeds of various test weights from four oat varieties. The dry weight of the seedlings was correlated with the test weight of the seed from which they were grown, but the difference disappeared at maturity. However, low test weight samples did not produce as high grain yields as those from high test weights, indicating a lower grain/straw ratio. Kernels from plants grown from the low test weight seed were lower in 100 kernel weight than those grown from high test weight seed in three of the four varieties. Murphy and Frey (1962) found that seed width was more closely correlated with seed weight than was seed length. Heritability was 51.1% for length, 35.1% for width and 36% for weight. Bowman and Rothman (1967) reported no significant difference in yield between eight different test weights ranging from 28.3 to 46.3 kg/hl in the winter oat variety "Victorgrain 48-93". 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.

Barley (*Hordeum vulgare* L.)

Kaufman and McFadden (1960) reported higher yields of plants grown from larger seeds due to a higher number of heads produced per plant. Dermirlicakmak, Kaufman and Johnson (1963) found that lower rates of seeding produced higher 1000 kernel weights within a variety. There was no effect of seed size on emergence, but increased tillering produced higher yields from large seeds, although tillering capacity alone was a poor indicator of yield. Kaufman and McFadden (1963) reported greater tiller numbers for large seeds over medium, bulk and small in four different varieties. Kaufman and Guitard (1967) found that large seeds produced superior seedling growth and leaf size for the first two leaves than small seeds (one half the size of the large seeds) but that results were inconsistent for subsequent growth. McDaniel (1969) reported that heavy seeds contained a greater initial quantity of mitochondrial protein than the light seeds and therefore produced seedlings with a greater energy production potential, resulting in faster growth. Rasmusson and Cannell (1970) found that heads per plant was the most effective index for selection for yield but that selection for high kernel weight was also effective. Malhotra and Jain (1972), in analysing 30 strains of barley, found that yield was positively associated with 1000 kernel weight and seeds per spike.

Wheat (*Triticum aestivum* L.)

Waldron (1941) found that within spring wheat varieties, heavy seeds (40.0 mg per seed) outyielded light seeds (26.6 mg per seed) by 12% when equal numbers of seed were planted per row and by 10% when equal weights of seed were planted per row. Marchetti (1948) reported contrasting results with large (24,900 grains per kg) and medium (31,600 grains per kg) seeds of the Italian wheat variety "Libero." Medium seeds sown at 154 kg/ha (equal seed number) and at 195 kg/ha (equal seed weight) outyielded large seeds sown at 195 kg/ha in both cases by 18%.

Quisenberry and Reitz (1967) reported that seed weight has been found to be under monogenic control in some crosses and in others by two to four genes. Heritability estimates ranged from 0.370 to 0.693. Sharma and Knott (1964) estimated that four genes controlled seed size differences in the cross between the spring wheat varieties "Selkirk" (large) and "Chagot" (small). Heritability was high with estimates of 0.370 to 0.695. Selection in the F2 indicated that the higher estimate was correct.

Bremner, Eckersall and Scott (1963) found that small embryos in the variety "Cappelle" had a higher initial growth rate than large embryos due to a larger scutellum/embryo ratio. Larger seeds were found to produce larger seedlings due to larger endosperm reserves and especially a larger source of magnesium. Embryo size had no significant effects when endosperm was equalised.

Fasoulas (1963) reported that large seeds produced plants with greater numbers of seminal roots, longer first three leaves, earlier tillering and heading, greater number of spikes per plant and spikelets per spike and higher yields of grain and straw. Larger embryos were also found to be superior than small embryos and varieties with large embryos were found to have a greater competitive advantage in mixtures. MacKey (1973) stated that seminal roots are deeper and more efficient per unit of weight than crown roots but that high seminal root number is not automatically associated with large embryo size. Seed size influences shoot and root development equally. Both are reduced by dwarfing genes.

Fonseca and Patterson (1968) reported that yield in a seven parent diallel was correlated with kernel weight. Borojevic and Cupina (1969) found a positive correlation between 1000 grain weight and yield in quintals per hectare of 0.771 and with yield in grams per plant of 0.524 for nine Central European wheat varieties. Austenson and Walton (1970) reported that the size of the individual seed accounted for 2.5-4.5% of the variation in yield of spring wheat plants of three different varieties. Goydani and Singh (1971) found that plants from small seeds (1000 grains = 20-29 g) of four varieties produced low yields due to a decrease in germination, low numbers of fertile tillers per plant and a low survival to harvest.

Khadi (1971) found transgressive segregation for both small and large seed size in six wheat crosses. Heritability for kernel weight was 70%. Knott and Talukdar (1971) reported a negative correlation between high seed weight and kernels per plot and a positive correlation between seed weight and yield.

Karamalishoev (1972) reported a positive correlation between seed size and root penetration in two wheat cultivars. Kir'yan and Dashevs'skii (1972) found the highest number and growth of embryonic roots in wheat was from the largest seeds and that it was also affected by the location of the ear, being highest for those from the middle of the ear.

Bagnara, Poukhalski and Rossi (1972), in crosses of four mutant lines and two cultivars of durum wheat (Triticum durum Desf.) reported that dominant alleles are more frequent than recessive and act mainly to increase kernel size. Small seed size was recessive in one variety and semi-dominant in another line. There was a positive association between culm length and kernel weight in some crosses.

Derera and Bhatt (1972,1973) compared mass selection for seed size in four varieties and three segregating F2 bulks as compared with unselected controls in all populations. Large seed selections in the heterogeneous bulks showed higher 100 kernel weight, grains per ear and yield per plot than the controls, while the small seed selections were in all cases lower. There were no significant differences between either size and controls for three of the four varieties, with only a significant difference (decrease) for small seeds in one variety. Selection appeared to be for genetic differences in size for the segregating bulks and for non-genetic differences in the varieties.

Dasgupta and Austenson (1973), in testing 83 seed samples of the variety "Manitou" at three different locations, determined that 1000 kernel weight was the only character associated with yield at all three stations.

Chebib, Helgason and Kaltsikes (1973) tested small, large and unselected bulk seeds of a pure line and a segregating population at three different row spacings. Wide plant spacing was the main cause of intraplot variance. The effect of genotype did not approach the 5% significance level for any of the 11 yield components. It was concluded that sorting seeds into equal sizes would increase the effectiveness of single plant selection by 10% while decreasing spacings from 15 cm to 5 cm would increase it by 51%.

Bhatt and Derera (1973) found that phenotypes from large seed selections produced highly significant increases in mean tiller number and grain yield per plant in two of three crosses. Quality factors were independent of seed size. Roy (1973) planted large and small seeds of two varieties in both pure and mixed (size) stands at spacings of 1.7 cm X 3.0 cm. In mixed stands the large seeds gave higher yields per plant than the small seeds, but the yield per plant from small seed plants was higher in pure stands.

Kikot (1973) attributed decreases in yield from small seeds compared with large and unselected bulks to decreases in tillering and 1000 grain weight. They also had reduced germination and vigour. Randhawa, Anand and Jolly (1974) reported an average yield increase of 16.4% for large seeds over small and 7.4% over bulk in the dwarf wheat "Kalyansona" at seed rates of 40,60, 80 and 100 kg/ha.

Kir'yan (1974) reported that the number of seminal roots depended on the cultivar and on seed size. In winter wheat, 80% of the seedlings from large seeds had four to five roots while only 45% of those from medium seedlings had four to five roots.

Rye (<u>Secale cereale</u> L.)

Vageler (1927) reported that plot yield in Petkuser rye increased with the size of the seed used, but that there was no relation between the size of the kernels used for seed and those of the harvest. Kuvarin (1974) noted that small defective seeds were over half aneuploids in a tetraploid rye population. Selection of only plants containing none of these defective seeds reduced aneuploids in this population from 13.67% to 6.81%. Pfahler (1974) found that early seedling growth as measured by coleoptile length was not closely associated with vigour expressed at later stages of growth.

Miscellaneous cereals

Kiesselbach (1924) presented data on sized seed of several varieties of spring wheat, winter wheat and oats grown over several seasons. Upon space planting, small seeds gave rise to plants which yielded 19% less than those originating from small seed, but this difference decreased to less than 10% at optimum rates of seeding. It was concluded that sizing within a variety was not practical for commercial production

Guitard, Newman and Hoyt (1961) found that 1000 kernel weight was not highly affected by different seeding rates in wheat and barley. Tillering was of little use in selection for yield, and most progress was made in selecting heads with the highest 1000 kernel weight and maximum number of kernels.

Landenmark (1972) reported on the germination of sized samples of oats, barley and spring wheat over two years. When all seed was of good quality, in the first year, there was no significant difference in germination between seed sizes. The second year showed poorer seed quality and large sizes showed higher germination than medium, with both being significantly higher than small sizes. Koval'chuk (1973) found that the decrease in germination and viability during long storage was greater in small seeds than in large seeds of wheat and barley.

Triticale (X *Triticosecale* Wittmack)

Bishnoi and Sapra (1975) reported that in three hexaploid triticales, large seeds (greater than 7½/64 inches) gave 51% higher field stand, 62% more seedling dry weight and 37% higher grain yield than small (less than 6/64 inches) seeds.

Kaltsikes and Larter (1970) found the percentage of aneuploids ranged from three to nine times in shrivelled seeds as in plump seeds of three cultivars of hexaploid triticale but only slightly higher in a fourth. Reitz (1970) reported that seeds set in the higher part of the spikelet were often only half the size of those set at the base in hexaploid triticale. Tsuchiya (1972) found that the percentage of euploid plants was higher from large seeds in five of six hexaploid triticale strains. Kaltsikes (1974) reported that 1000 grain weight was positively correlated with yield while width of flag leaf was negatively correlated with yield in a 5 X 5 F3 diallel of hexaploid triticale lines.

Weimarck (1975) found that the percentage of euploid plants from large smooth seeds with a 1000 kernel weight of over 55 g was double that of smaller seeds in the octoploid triticale cultivar "Kagawa."

General trend of seed size selection

The various investigations on selection for increased seed size (Table 1) have generally shown an increase in the yield of seed from the selected individuals, as well as other desired economic characters. Even in cross-pollinated species, selection for large seed size has usually had the effect of increasing seedling characters, such as vigour, although the weight of seed produced was not increased to the same degree as in self-pollinated species.

Although seed yield and vegetative characters such as an increase in early seedling growth have generally been associated with large seed size, there have been some exceptions. The investigations on lentils (*Lens esculenta* Moench.) have demonstrated a negative correlation between seed size and seed yield (Muehlbauer, 1974, 1975). Other species

TABLE 1. Response to Increased Seed Size Selection in Various Economic Plants

Species	Character	Response to Increased Seed Size Selection: Positive	None	Negative	Author	Breeding System	Authority
<u>Grasses</u>							
Lolium perenne	Seedling weight	+			Arnott (1975)	cross	Allard (1966)
	Early seedling development	+			Thomas (1966)		
Bromus inermis	Early seedling development	+			Trupp & Carlson (1974)	cross	Allard (1966)
	Seed,forage yield		0				
Agropyron cristatum	Early seedling	+			Rogler (1954)	cross	Hughes *et al.* (1951)
Andropogon hallii	Seedling vigour	+			Kneebone & Cremer (1955,1956)	cross	
	% stand	+					
Bouteloua curtipendula	Seedling vigour	+			Kneebone & Cremer (1955,1956)	cross	Hughes *et al.* (1951)
Buchloe dactyloides	Seedling vigour	+			Kneebone & Cremer (1955,1956)	cross	Allard (1966)
Panicum virgatum	Seedling vigour	+			Kneebone & Cremer (1955,1956)	cross	Hughes *et al.* (1951)
Sorghastrum nutans	Seedling vigour	+			Kneebone & Cremer (1955,1956)	cross	

TABLE 1. (Continued) Response to Increased Seed Size Selection in Various Economic Plants

Species	Character	Response to Increased Seed Size Selection Positive	None	Negative	Author	Breeding System	Authority
Forage Legumes							
Astragalus cicer	Seed emergence	+			Townsend (1972)	cross	Scheetz et al. (1971)
Astragalus falcatus	Seed emergence		0		Townsend (1972)	cross	
Lotus corniculatus	Seedling vigour	+			Twamley (1974)	cross	Allard (1966)
	Seedling vigour	+			Carleton & Cooper (1972)		
	Seedling weight	+			Conje & Carlson (1973)		
	Seed yield		0		Twamley (1971)		
Medicago sativa	Seedling vigour		0		Carleton & Cooper (1972)	cross	Brauer (1969)
Melilotus alba	Dry matter production	+			Haskins & Gorz (1975)	cross	Brauer (1969)
Onobrychis sativa	Seedling vigour		0		Carleton & Cooper (1972)	cross	
Grain Legumes							
Arachis hypogea	Seed yield	+			Coffelt & Hammons (1973)	self	Brauer (1969)
	Field emergence	+			Sivasubramanian & Ramakrishnan (1974)		
	Dry matter production	+					

TABLE 1. (Continued) Response to Increased Seed Size Selection in Various Economic Plants

Species	Character	Response to Increased Seed Size Selection Positive	None	Negative	Author	Breeding System	Authority
Grain Legumes							
Glycine max	Yield, height, seed size	+			Fehr & Probst (1971)	self	Allard (1966)
	Dry matter, seed yield		0		Singh et al. (1972)		
	Seed yield, emergence		0		Johnson & Luedders (1974)		
	Seed yield, emergence			-	Lal et al. (1973)		
Lens esculenta	Seed yield			-	Muehlbauer (1974, 1975)	self	Arnon (1972)
Cicer arietinum	Seed yield	+			Pinthus et al. (1973)	self	Brauer (1969)
Pisum sativum	Seed yield	+			Singh & Singh (1972)	self	Brauer (1969)
Phaseolus vulgaris	Seed yield	+			Hamblin (1975)	self	Brauer (1969)
Miscellaneous species							
Fagopyrum esculentum	Seed yield	+			Gorina (1971)	cross	Brauer (1969)
Sesamum indicum	Seed yield	+			Dabral & Holker (1971)	self	Brauer (1969)
Brassica campestris	Seed yield/plant	+			Ahmed & Zuberi (1973)	cross	Williams (1964)

TABLE 1. (Continued) Response to Increased Seed Size Selection in Various Economic Plants

Species	Character	Response to Increased Seed Size Selection Positive	None	Negative	Author	Breeding System	Authority
Miscellaneous species							
Raphanus sativus	Progeny root yield	+			Kubka et al.(1973)	cross	Allard (1966)
Beta vulgaris	Root yield	+			MacLachlan (1972)	cross	Brauer (1969)
	Emergence	+			Harper et al(1974)		
	Root/shoot ratio	+					
Lycopersicum esculentum	Mature fruit yield	+			Halsey (1971)	self	Allard (1966)
Capsicum annuum	Seedling growth	+			Cochran (1973)	self	Allard (1966)
Gossypium hirsutum	Dry matter	+			El Zahab et al. (1974)	self	Allard (1966)
	Seed cotton yield		0				
Pinus radiata	Seedling height and weight	+			Griffin (1972)	cross	Brauer (1969)
Tropical cereals							
Sorghum vulgare	Seedling vigour	+			Abdullah & Vanderlip (1972)	self	Allard (1966)
	Grain yield		0				
Zea mays	Emergence, green weight	+			Gubbels (1974)	cross	Allard (1966)
	Days to 50% emergence, grain yield		0		Hunter & Kannenberg (1972)		

TABLE 1. (Continued) Response to Increased Seed Size Selection in Various Economic Plants

Species	Character	Response to Increased Seed Size Selection Positive	None	Negative	Author	Breeding System	Authority
Tropical Cereals							
Zea mays	Individual plant yield	+			Sevov & Mitev (1974)	cross	Allard (1966)
Oryza sativa	Germination, early seedling development	+			Herrmann (1969)	self	Allard (1966)
Temperate Cereals							
Avena sativa	Seed yield	+			Frey & Wiggins (1956)	self	Allard (1966)
	Seed yield	+			Murphy & Frey (1962)		
	Seed yield	+			Bowman & Rothman (1967)		
	Seed yield	+ (curvilinear)			Frey & Huang (1969)		
Hordeum vulgare	Seed yield	+			Kaufman & McFadden (1960)	self	Allard (1966)
	Seed emergence		0		Dermirlicakmak & al (1963)		
	Seed yield	+			Dermirlicakmak & al (1963)		
	Tillering	+			Dermirlicakmak & al (1963)		
	Tillering	+			Kaufman & McFadden (1963)		

TABLE 1. (Continued) Response to Increased Seed Size Selection in Various Economic Plants

Species	Character	Response to Increased Seed Size Selection: Positive	None	Negative	Author	Breeding System	Authority
Temperate Cereals							
Hordeum vulgare	Seed yield	+			Rasmusson & Cannell (1970)	self	Allard (1966)
	Seed yield	+			Malhotra & Jain (1972)		
Triticum aestivum	Seed yield	+			Waldron (1941)	self	Allard (1966)
	Seed yield			-	Marchetti (1950)		
	Grain and straw yield	+			Fasoulas (1963)		
	Grain yield	+			Fonseca & Patterson (1968)		
	Yield/unit area	+			Borojevic & Cupina (1969)		
	Plant survival	+			Goydani & Singh (1971)		
	Germination	+			Goydani & Singh (1971)		
	Tillers/plant	+			Goydani & Singh (1971)		
	Seed yield	+			Knott & Talukdar (1971)		
	Root penetration	+			Karamalishoev (1972)		

TABLE 1. (Continued) Response to Increased Seed Size Selection in Various Economic Plants

Species	Character	Response to Increased Seed Size Selection Positive	None	Negative	Author	Breeding System	Authority
<u>Temperate Cereals</u>							
Triticum aestivum	Plot yield	+			Derera & Bhatt (1972,1973)	self	Allard (1966)
	Grains/ear	+			Derera & Bhatt (1972,1973)		
	Tiller number	+			Bhatt & Derera (1973)		
	Grain yield/plant	+			Bhatt & Derera (1973)		
	Individual plant yield (mixed stands)	+			Roy (1973)		
	Individual plant yield (pure stands)			-	Roy (1973)		
	Grain yield	+			Kikot (1973)		
	Grain yield	+			Randhawa & al (1972)		
	Number of seminal roots	+			Kir'yan (1974)		
	Number of seminal roots		0		MacKey (1974)		

TABLE 1. (Continued) Response to Increased Seed Size Selection in Various Economic Plants

Species	Character	Response to Increased Seed Size Selection Positive	 None	 Negative	Author	Breeding System	Authority
Temperate Cereals							
Secale cereale	Plot yield	+			Vageler (1927)	cross	Allard (1926)
	Seed size from harvested plots		0		Vageler (1927)		
Various Cereals							
Triticum aestivum and Avena sativa	Plot yield	+			Kiesselbach (1924)	self	Allard (1966)
Triticum aestivum, Avena sativa and Hordeum vulgare	Seed germination	+			Landenmark	self	Allard (1966)
Triticum aestivum and Hordeum vulgare	Seed viability in long storage	+			Loval'chuk (1973)	self	Allard (1966)
X Triticosecale	Field stand	+			Bishnoi & Sapra (1975)	$\pm$self	Yeung & Larter (1973)
	Grain yield	+			Bishnoi & Sapra (1975)		
	Seed yield	+			Kaltsikes (1974)		

such as soybeans (Glycine max Mer.) have shown wide variations within the species, with both positive and negative associations between seed size and seed yield for different genotypes (Fehr and Probst, 1971:Lal, Mehta and Nigam, 1973).

Investigations in the cereal crops have generally demonstrated increased seed yields when selection has been made for increased seed size. An exception has been the oat selection of Frey and Huang (1969), where a curvilinear response was obtained, with the highest yields being recorded for lines selected which have an intermediate seed size. All references to selection for seed size in wheat showed seed size to be positively correlated with seed yield and yield components with the exception of the work of Marchetti (1950) for size selection within one variety. The limited investigations in rye (Secale cereale L.) have not shown increased seed size from the progeny of large seed size selections (Vageler, 1926). The fact that rye is the only cross-pollinated cereal of the temperate small grains would in all probability decrease the efficiency of selection where only the female parent was selected, pollination being completely at random.

The investigations on triticale have indicated that seed weight is positively correlated with seed yield (Kaltsikes, 1974) and some advantages in yield in preliminary field experiments have been demonstrated for the selection of large seed sizes within segregating populations (Bishnoi and Sapra, 1975). The heritability of seed size within the specific triticale population and the genetic background of the triticale lines used in the specific cross would have an important effect on the advance obtained from seed size selection. From the results of previous investigators, it would appear that selection for large seed should improve seed yield in triticale, provided that modifications in technique are made to prevent uncontrolled outcrossing and provided sufficiently large populations are available so that a high degree of selection intensity can be applied.

MATERIALS AND METHODS

Visual seed size selection of F2 seed from crosses of lines differing in seed size and other characters

A preliminary investigation on selection at the F2 seed level was undertaken in order to determine if selection for seed size in segregating hexaploid triticale populations was an effective method of increasing grain yield. As only F3 and later generations were available from already existing segregating populations, in which the parental lines did not differ as much in seed size as desired, a series of crosses were made between lines with widely differing seed sizes and other characters.

The following lines were used as parents:

Line	Characters	Average 100 seed weight
6531	Large seed, excellent seed quality, tall straw	7.100 g
6A405	Large seed, fair seed quality, tall straw	5.995 "
ITSN73	Medium seed, good seed quality, medium height	4.820 "
6TA204*	Small seed, poor seed quality, dwarf	3.400 "
ITSN52	Small seed, fair seed quality, medium height	3.200 "

Crosses were made among all the selected lines, but many failed to produce any seed due to ergot infection and other causes. All F1 seed was harvested and each seed was planted in a four inch plastic pot. Each F1 plant provided 200-300 seeds for selection on the basis of seed size.

* All references to 6TA204 refer to the EMS dwarf mutant of this line.

In order to avoid any effects caused by seed shrivelling, only plump full seeds were selected. The 10 largest and 10 smallest seeds were then selected by visual means from the progeny of each F1 plant. This was also done for a number of different plants of the line 6531 which was used as an advanced line control.

To obtain the average weight of the large and small F2 seeds selected from each F1 plant, each selected lot of 10 large and 10 small seeds was weighed separately. The large and small selected seeds from each F1 plants were sown in plots consisting of paired 2.5 metre rows for the progeny of each F1 plant (Figure 1). This was a selection intensity of approximately 5% of the population for both the large and the small seed class. Data were recorded on germination and survival to harvest. Each plant surviving to harvest was pulled, tagged and recorded for agronomic characteristics which would give an estimate of fertility. All plants were individually threshed and their yield of grain was recorded.

A number of paired progeny rows were discarded due to the loss of all plants in a row. The remaining paired rows for F2 progeny and controls were analysed by the paired t-test.

<u>Mass selection for seed size in F3 and F4 material</u>

Because of positive indications from selection in the F2 and insufficient seed for yield trials at the F2 generation, a series of replicated yield trials were set up for mass selection over two cycles or generations of selection. Selection was made in the F3 and F4 generations in two segregating populations, with a similar two cycles of selection in three advanced lines serving as controls. The two

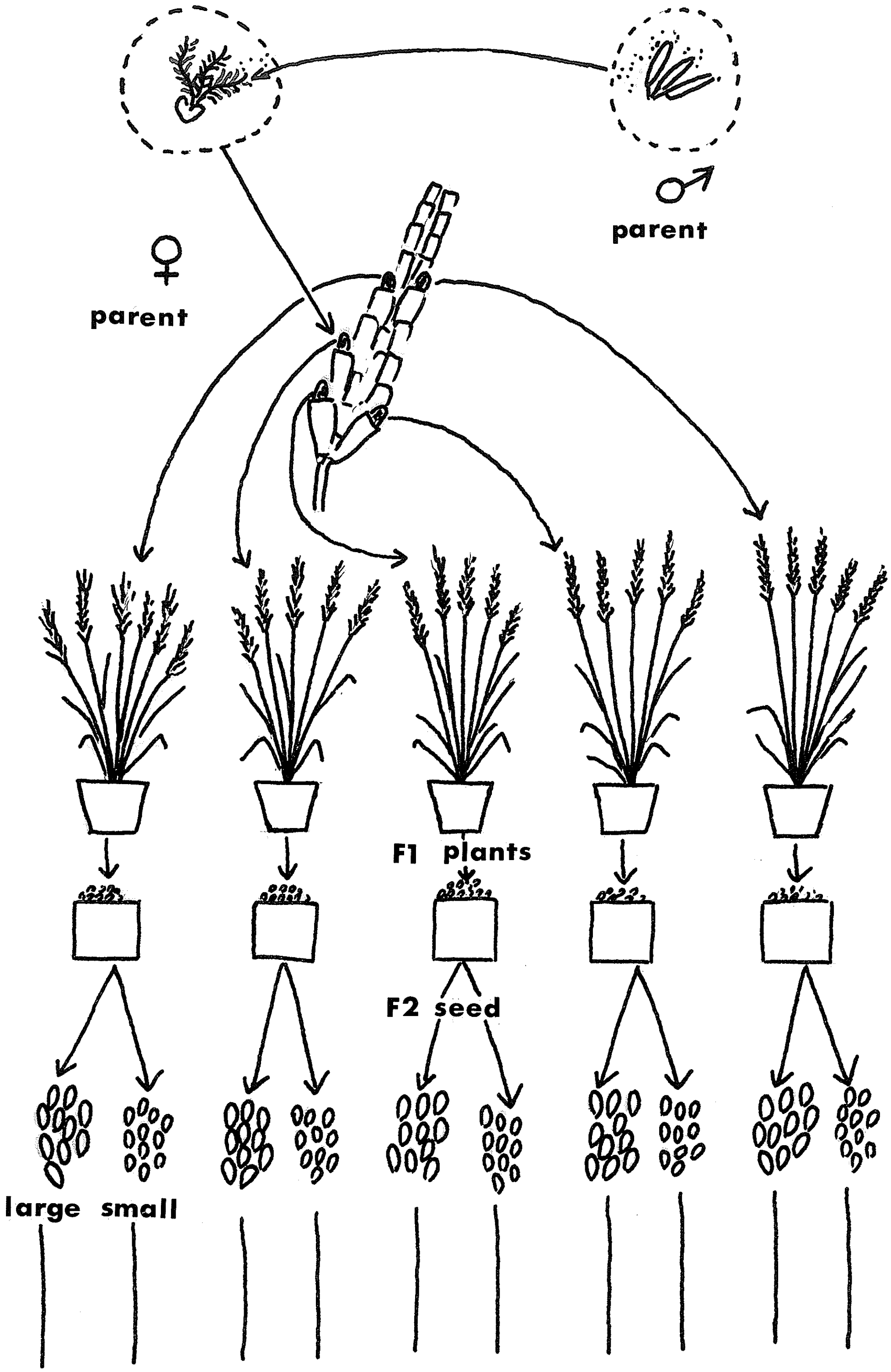


Figure 1. Experimental design: paired progeny rows of F2 plants

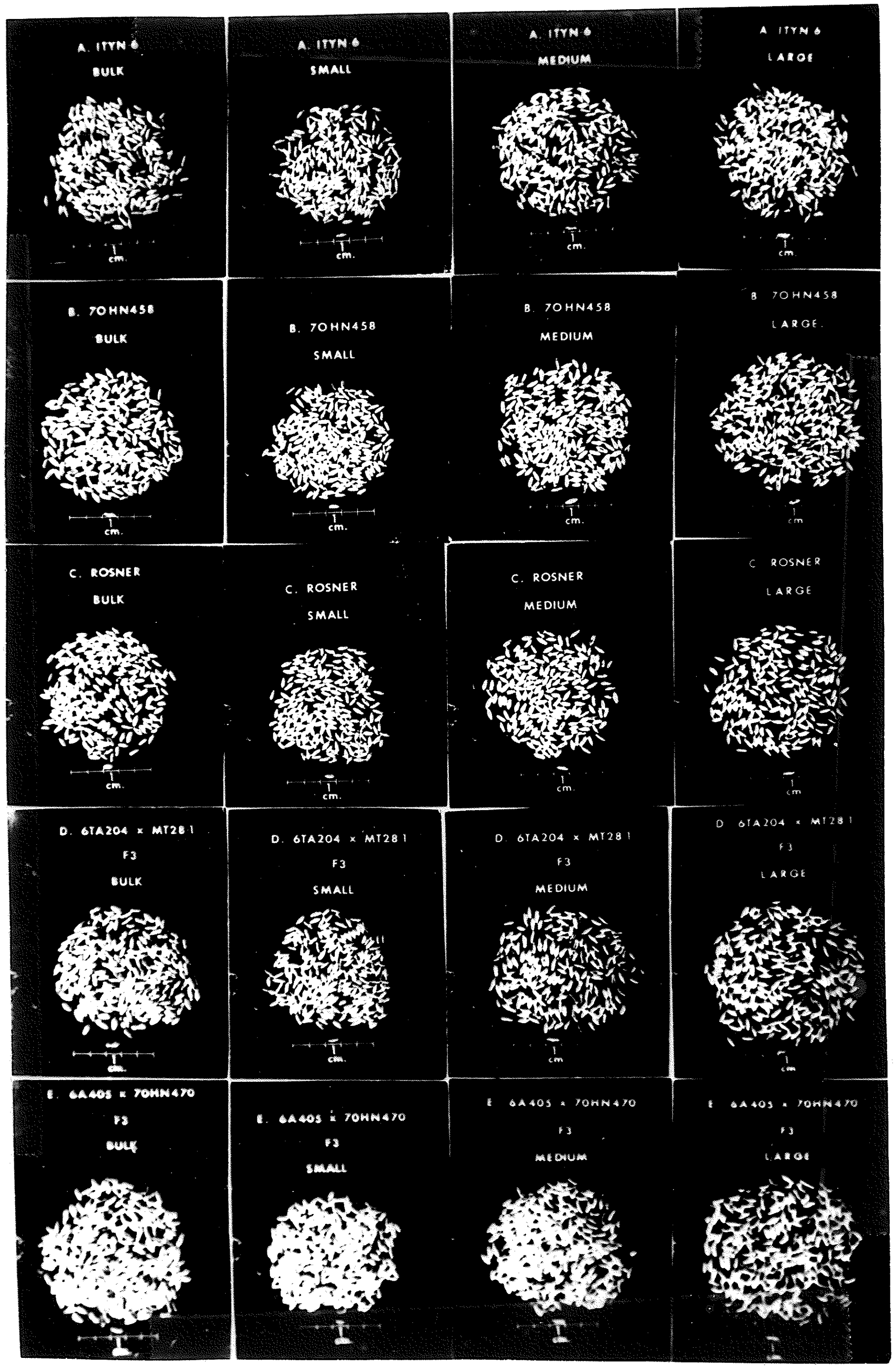


Plate I. Seed Size Selections in Three Advanced Lines and Two Segregating Populations.

segregating populations were chosen on the basis of sufficient seed availability for a four replicate trial at each of two locations and the fact that two of the parental lines had also been used in the production of crosses which had been selected at the F2 level. The advanced lines were selected on the basis of contrasting seed size and differences in other agronomic characteristics.

The selected material used was as follows:

Advanced lines

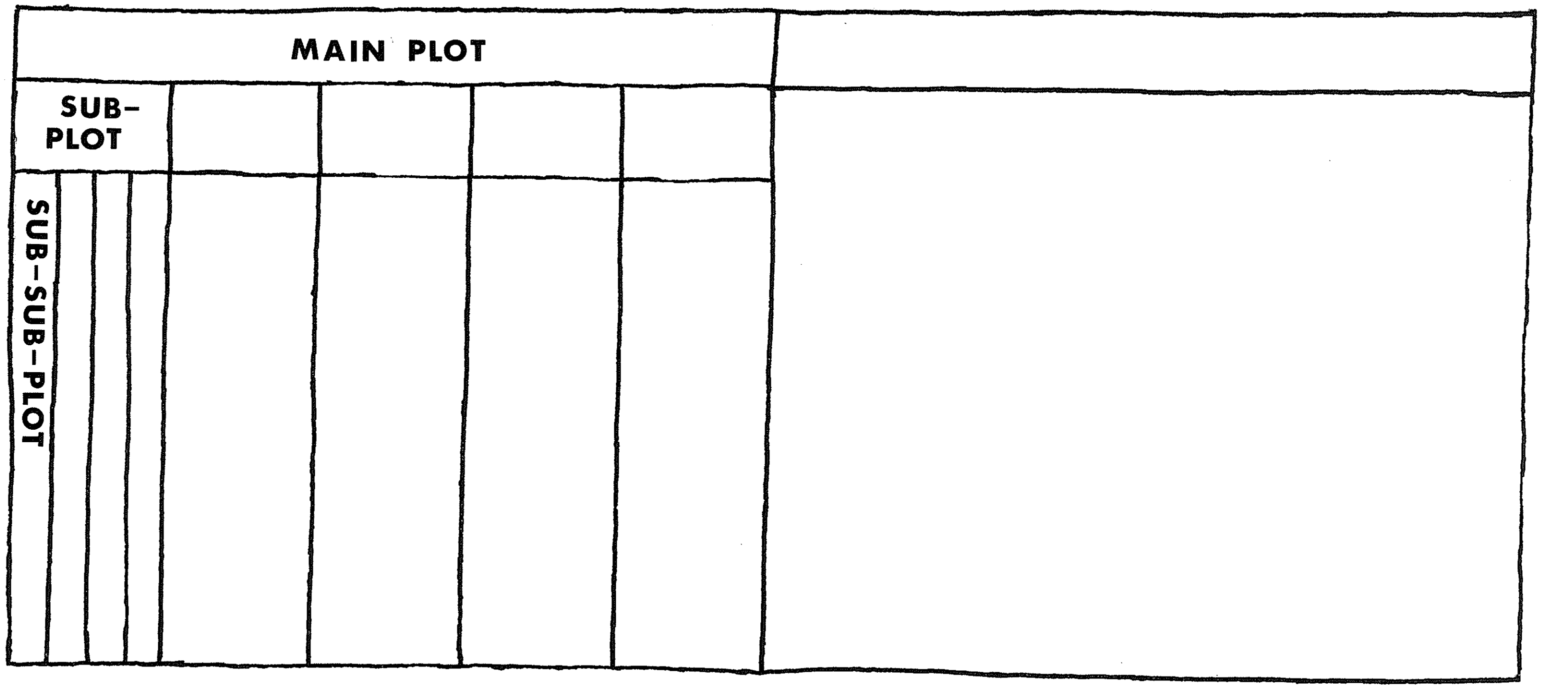
1. ITYN-6 (1972): small seeded line, wrinkled seeds
2. 70HN458 (Armadillo): medium sized seeds, good quality, short straw
3. Rosner: medium to large seeds, taller straw

Segregating populations (F3 and F4)

A.	6TA204 dwarf small shrivelled seed	X	MT28-1 medium height small to medium seed
B.	6A405 tall large seed	X	70HN470 short straw medium sized seed

Seed bulks of all populations and lines were separated by the use of standard seed sieves into portions of small, medium and large seed sizes. Large seeds were those retained by a 10/64 inch standard seed sieve. Medium seeds were all those which passed through the 10/64 inch sieve but were retained by a 9/64 inch sieve, while small seeds were classed as all those which passed through the 9/64 inch sieve. Unselected bulk seed was used as a control with all five groups (See Plate I for comparative seed sizes of all groups used). All this material which was selected from the original source of seed (F3 material in the case of the two segregating populations) was designated 'Cycle 1.' All material of the first cycle of selection was grown in a preliminary four replicate yield trial. From the material harvested from the preliminary yield trial, a further cycle of selection was carried out for each size in each of the five different groups- i.e. the harvested plots from large seed origin again subjected to selection for size and the large seeds retained and planted as the second cycle of selection. This second cycle of selection was designated 'Cycle 2' (F4 in the case of the segregating material). In the second year both cycles of selection were planted together in replicated yield trials at two locations (Figure 2).

The main section of this investigation consists of a series of four replicate yield trials in a split-split plot experimental design. The main plot consisted of the cycle of selection for a specified seed size (first or second cycle of selection). The sub-plot in all of this series of experiments consisted of the variety (advanced line or segregating population) and the sub-sub-plot of the selected seed size. All sub-plots were randomised within main plots and all sub-sub-plots were randomised within sub-plots. The basic unit (sub-sub-plot) consisted of a three row 5.5 metre plot adjusted by seeding rate (based on laboratory seed germination tests of all material for all sizes separately) to produce a theoretical number of 165 plants per plot, 55 plants per row with an average spacing of 10 cm between plants. The experimental design is illustrated in Figure 3. This design was used at two different locations: (1) University of Manitoba Point Field- a sheltered location on the University Fort Garry Campus located in a bend of the Red River which could be considered an optimum environment for cereal crops and (2) West Field- an open location about 4 km west of the University



Sub-plots randomized within main plots and sub-sub-plots randomized within sub-plots

Figure 2. Experimental design: split-split-plot

Main plots: 2 selection cycles or seed densities

Sub-plots: 5 varieties (3 advanced lines and 2 segregating populations)

Sub-sub-plots: 4 seed sizes

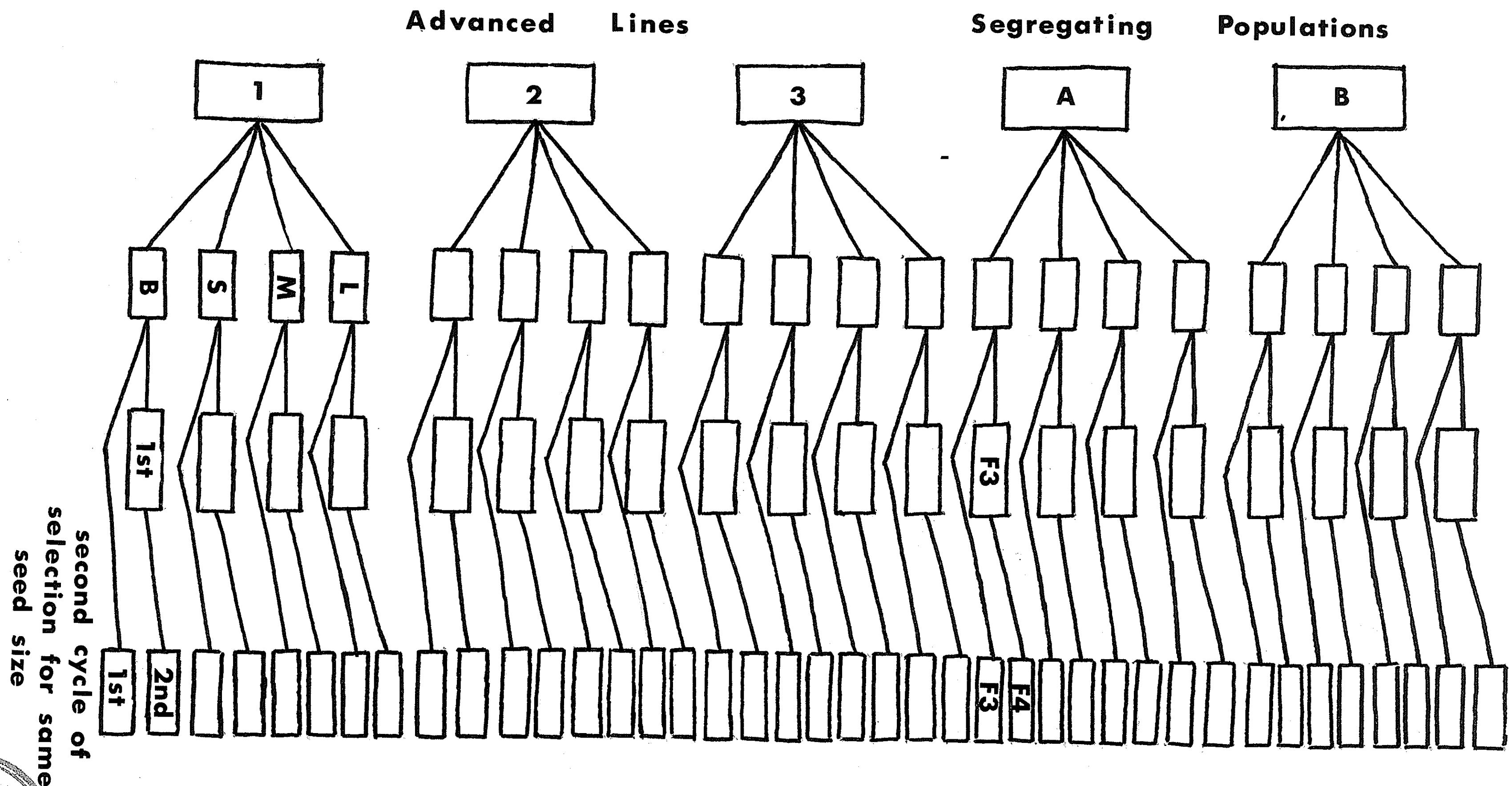


Figure 3. Experimental design. Two cycles of selection

Seed size: B = bulk S = small M = medium L = large which could be considered an average environment for cereal crops. Both locations were on heavy Red River clay soil.

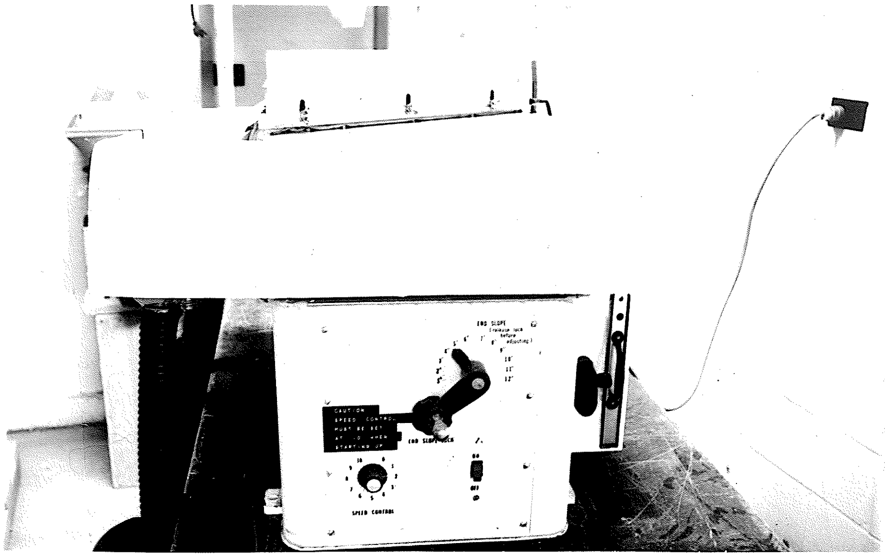
All plots were sown with a modified three-row John Deere horticultural plot type seeder. Seedling emergence was recorded for each plot. At harvest, the total number of plants growing in each plot was recorded. From each plot, 10 plants were selected at random and tagged to provide a random sample of individual plant yield and measurements of plant height and other agronomic characteristics (from which an estimate or indication of fertility could be determined) after the remaining plants had been harvested to provide the yield of grain per plot.

<u>Seed separation on the basis of gravity</u>

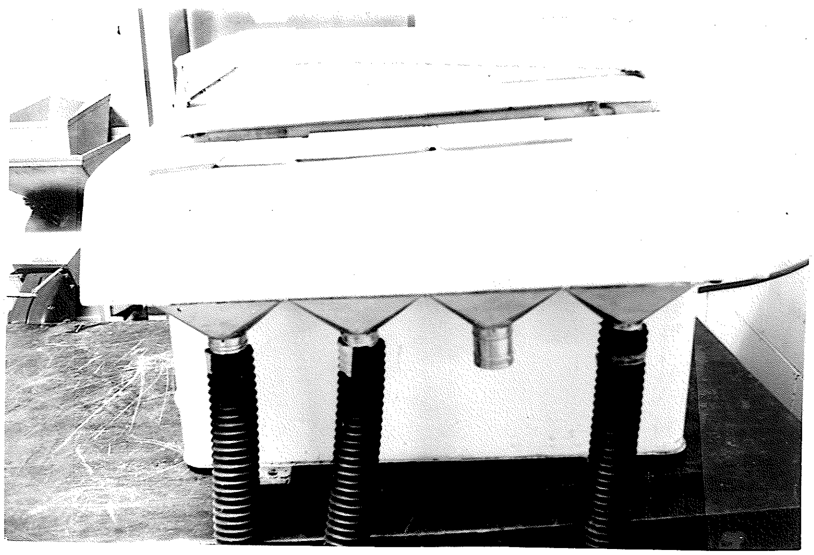
In order to obtain some estimate of the effects of specific gravity or density on the yield and other characters of plants grown from seeds of various sizes and origins, a "Kipp-Kelly" specific gravity separator, Model V-1358 (See Plate II), was used. The machine was adjusted so that approximately one half of a seed sample (unselected bulk of Rosner was used as a control) separated into a 'high density' fraction and half into a 'low density' fraction (machine setting was a speed of 3.5 on the speed setting, an air vent setting of 7.0 and an angle of elevation of 7).

All seed sizes of all the lines and populations (previously described in 'mass selection for seed size') were run over the specific gravity separator at the indicated setting for separation into 'high' and 'low' density fractions.

A four replicate yield trial with seed density as the main plot, variety or population as the sub-plot and seed size as the sub-sub-plot



a. Controls for Machine Speed, Elevation and Fan Speed



Light Fraction Heavy or Dense Fraction

b. Separation Table of Machine

Plate II. Specific Gravity Separator

was set up under similar conditions of germination testing and field conditions as the mechanical mass selection cycle experiment. The design is illustrated in Figure 4. Data recorded and analysis were similar to that of the previous experiment on two cycles of selection for seed size.

Relation of seed size, embryo size and plant development

Whether the relationship between seed size and yield is due to the initial size of the embryo or to the size of the nutrient reserves in the endosperm has been an important point of discussion (See Literature Review). In order to try to separate the effects of embryo size and endosperm size from different sized seed, an embryo culture experiment was set up to equalise the effect of nutrient reserves from seed of different size classes.

Seed from the three advanced lines and two segregating populations described earlier, which had been mechanically mass selected for small, medium and large seed sizes, was used. All seeds were uniformly soaked for five hours in sterile distilled water, disinfected and prepared for dissection in a sterile room under a "Wild" dissecting microscope. Prior to the actual dissection of each individual embryo, each seed was measured for length and width by means of a calibrated micrometer eyepiece on the dissecting microscope. Immediately on dissection, the length and width of each embryo and the length of the scutellum were also measured with the micrometer.

After dissection, each embryo was placed on a slanted surface of "Nitsch" orchid agar in a 100 ml screw cap vial (equal measured amounts of agar in each vial). Each vial with embryo was sealed and then incub-

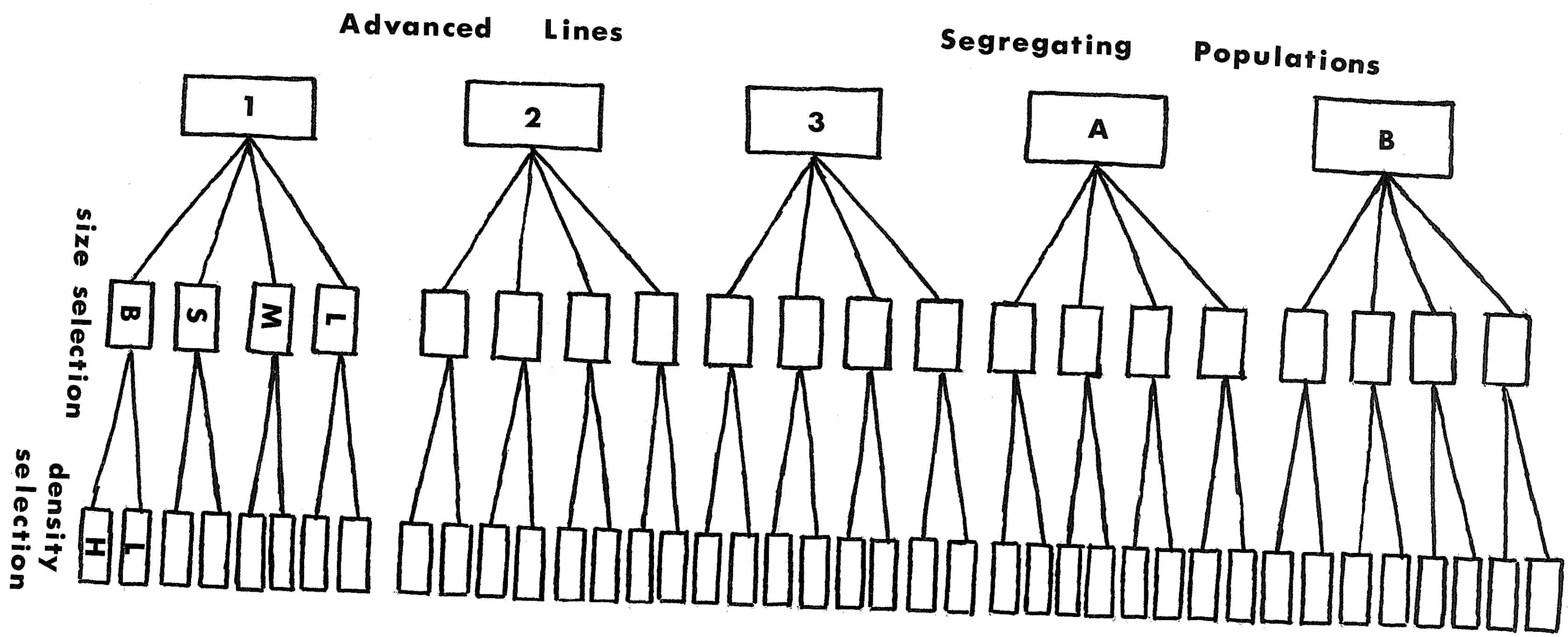


Figure 4. Selection for seed size at high and low seed density

Seed size: B = bulk S = small M = medium L = large

Seed density: H = high L = low

ated under a bank of three fluorescent tubes for 10 days with 24 hour per day lighting. Approximately 50 embryos were dissected from each size of each variety or population in order to obtain sufficient seedlings for further measurements of growth after any losses due to failure of growth or contamination.

After 10 days of growth on the nutrient agar media, all developing plants were removed from the vials, agar was washed off the roots and the numbers and measurements of shoots (leaves) and roots were recorded. All normally developed plants were then transplanted to a standard potting mixture of two parts loam, one part peat moss and one part sand in individually labelled four inch plastic pots. The transplanted seedlings were then grown in the greenhouse at approximately 20° C. with supplemental lighting to provide 16 hours of daylight.

All plants surviving were harvested at 13 weeks from the beginning of culture. Each plant was tagged and all soil washed from the roots. All tagged harvested plants were air dried for a period of 90 days at 20 C. Each plant was then separated into head, leaf, stem and root material and weighed. All mature plant part weights were then recorded for correlation with initial seed and embryo measurements.

RESULTS

Visual selection for seed size in F2 populations

Comparison of large and small F2 seeds

The grain yield and agronomic characteristics for plants originating from the 10 largest seeds (L) and the 10 smallest seeds (S) for progeny of each cross are presented in Table 2. The paired row t test for significance betweeen paired large and small seed rows from each progeny group is presented for each cross.

The F2 progeny of the cross 6531 X 6A405 showed higher values for plant survival and spikelets per spike for plants from large seeds. Average plant grain yield for plants from large seeds was 148% of that from small seeds while average plot yield for plants from large seed was 166.5% of that from small seeds. Plant height, tillers per plant, fertile tillers per plant and seeds per spike were higher for plants from small seed. Most values did not show statistical significance, with significant differences only shown for the superiority of the individual plant yields from plants originating from large seeds (P=0.05), although plot yield also approached a significant difference (P=0.063) in favour of plants from large seeds.

The F2 progeny of ITSN73 X 6TA204 exhibited higher values for plants grown from large seeds for all characteristics than for those grown from small seeds. The plants grown from large seeds were significantly higher for plant survival (P=0.05) and spikelets per spike (P=0.05)

TABLE 2. Agronomic Characteristics of Plants Grown from Large and Small F2 Seeds from a Number of Crosses

Cross	Number of Paired Progeny Rows	Seed Size	Average Seed Weight (g)	Plant Survival	Plant Height (cm)	Tillers/ Plant	Fertile Tillers/ Plant	Spikelets/ Spike	Seeds/ Spike	Plant Yield (g)	Plot Yield (g)
6531	6	L	0.0766	5.5	71.0	7.4	3.9	23.1	9.5	5.18	31.96
X		S	0.0490	4.7	71.6	8.1	4.2	21.9	12.5	3.50	19.19
6A405		t test		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	0.05	0.063
ITSN73	5	L	0.0584	5.8	66.1	12.3	5.2	22.7	22.3	5.58	32.58
X		S	0.0326	3.6	57.1	7.9	4.0	20.0	19.2	3.23	12.10
6TA204		t test		0.05	N.S.	N.S.	N.S.	0.05	N.S.	N.S.	0.07
ITSN52	4	L	0.0563	5.0	59.3	7.7	4.5	19.4	25.0	3.33	17.24
X		S	0.0333	3.8	51.8	4.1	2.1	17.5	26.4	2.00	7.33
6531		t test		N.S.	N.S.	0.05	0.05	N.S.	N.S.	0.05	0.05
6531	6	L	0.0598	7.0	77.2	12.5	9.7	21.2	32.7	11.74	85.15
X		S	0.0345	3.7	69.1	11.0	7.6	18.8	24.3	7.18	26.55
ITSN73		t test		0.05	N.S.	N.S.	N.S.	N.S.	0.05	0.05	0.01
Above	8	L	0.0604	7.0	74.8	12.2	9.2	21.0	31.9	10.72	77.20
with		S	0.0345	4.1	69.1	10.3	6.7	19.2	23.9	7.09	29.33
Reciprocals		t test		0.01	N.S.	N.S.	N.S.	N.S.	0.01	0.05	0.01
ITSN52	11	L	0.0495	6.2	61.5	14.9	10.6	21.2	29.5	9.80	58.35
X		S	0.0270	4.9	59.7	10.8	7.2	20.5	20.9	7.00	40.11
6TA204		t test		0.077	N.S.	0.01	0.01	N.S.	0.05	0.082	N.S.
6531	11	L	0.0668	4.1	92.9	14.3	11.2	23.4	50.9	17.97	75.89
(Selfs)		S	0.0352	4.9	94.6	16.4	12.7	23.3	51.6	19.89	105.29
		t test		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

and approached the 5% level for plot yield (P=0.07)

The F2 progeny of ITSN52 X 6531 had all characters higher for plants originating from large seeds, with significance shown for tillers per plant (P=0.05), fertile tillers per plant (P=0.05), average plant yield (P=0.05) and plot yield (P=0.05).

In F2 progeny of 6531 X ITSN73, plants from large seeds were higher for all characters, with significance shown for plant survival (P=0.05), seeds per spike (P=0.05), average plant yield (P=0.05) and plot yield (P=0.01). Average plant yield for plants originating from large seed was 163.5% of that of those from small seed, while plot yield for plants from large seed was 324.5% that of those from small seed. With the reciprocal cross included, values were higher from plants originating from large seeds for all characteristics, with statistical significant higher values shown for plant survival (P=0.01), seeds per spike (P=0.01), average plant yield (P=0.05) and average plant yield (P=0.01). Average plant yield from large seed origin plants was 140% of that from small seeds and plot yield was 263.2% for large seed origin plants over those from small seeds.

With F2 plants from ITSN52 X 6TA204 there were higher values for plants grown from large seeds for all characters, with significance shown for tillers per plant (P=0.01), fertile tillers per plant (P=0.01), and seeds per spike (P=0.05). Plant survival (P=0.077) and average plant yield (P=0.082) approached the 5% level of significance. Average plant yield for plants from large seed was 140% of that from small seed plants while average plot yield for large seed plants was 145.5% of that for small seed plants.

The progeny from different plants of line 6531 did not show any consistent trend. Plants from large seeds were below those from small seeds for all characters except spikelets per spike. However, none of these differences was significant or closely approached significant levels. Average plant yield for plants from large seeds was 90.3% of that from small seeds, while plot yield for plants from large seeds was 72% of that from small seeds.

Correlation of seed weight with agronomic characteristics

Correlations were run between the average seed weight for each plot (single row- large or small seed) and the agronomic characteristics of the plants grown from them (Table 3).

Seed weight in the F2 progeny of 6531 X 6A405 was not significantly correlated with any of the agronomic characteristics measured.

The F2 progeny of ITSN73 X 6TA204 showed significant correlations between seed weight and plant survival (P=0.01), tillers per plant (P=0.01), average plant yield (P=0.05) and plot yield (P=0.01).

For the F2 progeny from ITSN52 X 6531, there were significant correlations of seed weight with tillers per plant (P=0.01), fertile tillers per plant (P=0.01) and plot yield (P=0.05).

With F2 progeny of 6531 X ITSN73 there was significant correlation between seed weight and plant survival (P=0.01), spikelets per spike (P=0.05), seeds per spike (P=0.01), average plant yield (P=0.01) and plot yield (P=0.01). When combined with the reciprocal cross there were significant correlations between seed weight and plant survival (P=0.01), seeds per spike (P=0.01), plant yield (P=0.05) and plot yield (P=0.01)

The F2 progeny of ITSN52 X 6TA204 showed significant correlation

TABLE 3. Correlation Coefficients (x 100) of Average Initial Seed Weight with Various Agronomic Characteristics in F2 Plants of a Number of Different Crosses

Cross or Line	Number of Plots (Equal number of Large and Small)	Plant Survival	Plant Height (cm)	Tillers/Plant	Fertile Tillers/Plant	Spikelets/Spike	Seeds/Spike	Plant Yield (g)	Plot Yield (g)
6531 X 6A405	12	7	- 1	-19	- 5	55	-16	26	23
ITSN73 X 6TA204	10	71**	44	72**	39	51	17	59*	74**
ITSN52 X 6531	8	43	51	88**	93**	44	- 8	60	66
6531 X ITSN73	12	63**	49	33	40	57*	71**	72**	77**
6531 X ITSN73 and reciprocal	16	59**	36	34	40	49	64**	58*	68**
ITSN52 X 6TA204	22	30	18	58**	50*	27	39	36	26
6531 (selfs)	22	-21	-21	-38	-28	4	3	-10	-21

* significant at 0.05 level

** significant at 0.01 level

of seed weight with tillers per plant (P=0.01) and fertile tillers per plant (P=0.05).

The progeny of individual plants of line 6531 showed no significant correlation between seed weight and any of the selected agronomic characteristics. Correlation coefficients were lower than in any of the segregating populations for most characters and showed negative values for all characters except spikelets per spike and seeds per spike.

The effect of mass selection for seed size in three advanced lines and two segregating populations

Preliminary selection cycle

Advanced lines

Regarding plot yield of the small and large seeded selections, generally all three lines reacted in a similar manner (Table 4). Thus all small seeded selections showed a reduction in yield over the control, ITYN-6 and 70HN458 being significant at the 1% level, whereas all three lines had highly significant positive responses (P=0.01) in the large seeded selections. On the other hand, the medium selections indicated that the three lines responded differently. ITYN-6 had a non-significant negative value while 70HN458 and Rosner had positive values (P=0.01).

The number of plants per plot showed no differences among the small seeded selections and the controls. Medium selections showed no response in ITYN-6, while increases were shown for 70HN458 (P=0.05) and Rosner (P=0.01). Similar trends were demonstrated for large selections with no difference for ITYN-6 and increases for 70HN458 and Rosner (P=0.01).

Average plant height for small seed selections was reduced in ITYN-6 (P=0.01) and 70HN458 (P=0.05), with no difference in Rosner. In

TABLE 4. The Effect of Selection for Seed Size on Several Agronomic Characteristics in Three Advanced Lines of Hexaploid Triticale- Preliminary Selection- Point Field

Line and Size Comparison	Plot Yield (g)	Plants/ Plot	Plant Height (cm)	Tillers/ Plant	Fertile Tillers/ Plant	Spikelets/ Spike	Seeds/ Spike	Selected Plant Yield (g)
1. ITYN-6								
Bulk	661.0	93.5	88.95	8.93	7.30	17.6	50.4	9.16
S - B	- 69.0**	- 4.3	- 2.00**	-0.63	-0.80*	- 0.3	- 4.4**	-0.57
M - B	- 10.0	4.0	- 0.60	-0.83*	-1.13**	- 0.7**	- 3.1*	-1.07*
L - B	91.0**	2.3	- 0.06	0.13	-0.33	0.2	- 0.3	-0.56
2. 70HN458								
Bulk	601.0	89.8	86.75	8.90	7.18	17.5	46.3	8.46
S - B	- 72.3**	- 3.3	- 1.35*	-0.58	-0.53	0.5*	- 3.3**	-0.48
M - B	86.3**	5.3*	1.25*	-0.98*	-0.63*	0.5*	- 3.3**	-0.09
L - B	156.3**	13.3**	1.00	-0.58	-0.43	0.5*	1.2	0.21
3. Rosner								
Bulk	577.0	79.5	94.50	10.45	9.03	19.5	57.7	11.78
S - B	- 5.8	4.5	- 0.73	-0.95*	-0.98**	0.6*	- 2.6*	-2.38**
M - B	132.5**	11.3**	0.95*	-1.35**	-1.25**	1.0**	- 5.3**	-1.33**
L - B	93.0**	22.8**	- 1.60*	-0.70	-0.68*	- 0.6*	- 2.2	-1.29**
LSD (P=0.05)	34.2	4.6	1.25	0.77	0.62	0.4	2.5	0.91
LSD (P=0.01)	45.4	6.1	1.66	1.02	0.82	0.7	3.3	1.21

medium selections there was an increase for 70HN458 (P=0.05), with no significant change for the other two lines. There was a differing response in large selections, a decrease being present in Rosner (P=0.05), but no difference in the first two lines.

The number of tillers per plant in small seed selections did not change significantly in the first two lines while there was a decrease (P=0.05) in Rosner. A similar response was found in all three lines for medium seed selections, with decreases in ITYN-6 (P=0.05), 70HN458 (P=0.05) and Rosner (P=0.01). All three lines showed a similar response in the large seed selections, with no differences from the controls.

There were differences in response for the number of fertile tillers for small seed selections, with decreases being shown in ITYN-6 (P=0.05) and Rosner (P=0.01), but not in 70HN458. All lines showed a decrease for medium size selections, at the 1% level for ITYN-6 and Rosner, and at the 5% level for 70HN458. In the large seed selections, there was a similar trend in the first two lines, which showed no change, while there was a decrease (P=0.05) for Rosner.

Selection for small seed size increased (P=0.05) the number of spikelets per spike in both 70HN458 and Rosner, with no change for ITYN-6. Medium seed selections showed an increase for 70HN458 (P=0.05) and Rosner (P=0.01) and a decrease (P=0.01) for ITYN-6. Large seeded selections showed a contrasting response, with an increase for 70HN458 (P=0.05), a decrease for Rosner (P=0.05), and no significant difference for ITYN-6.

Small seed size selections demonstrated decreases from bulk controls in ITYN-6 (P=0.01), 70HN458 (P=0.01) and Rosner (P=0.05) for the number of seeds per primary spike. A similar trend was shown for the medium selections, with decreases in ITYN-6 (P=0.05), 70HN458 (P=0.01) and Rosner (P=0.01). There were no significant differences from unselected bulk controls for large seed selections in any of the three lines.

For the average yield of the 10 plants selected from each plot, selection for small seeds produced no significant difference from unselected bulks for ITYN-6 or 70HN458, while there was a decrease for Rosner (P=0.01). Medium seed size selections demonstrated decreases in both ITYN-6 (P=0.05) and Rosner (P=0.01), while there was no change for 70HN458. Large seed selections showed a similar trend for ITYN-6 and 70HN458, which did not show any significant differences, while Rosner had a decrease (P=0.05).

Segregating populations

For the first cycle of selection (Table 5), the two segregating F3 populations responded in a similar manner for average plot yields, with decreases for small (P=0.01) and medium (P=0.01) and an increase for large (P=0.05) seed selections.

The number of plants per plot showed a decrease (P=0.01) for both populations in the small seed selections but differed for medium size selections, with decreases (P=0.01) in population B (6A405 X 70HN458), but no significant difference for population A (6TA204 X MT28-1). Neither population demonstrated significant differences from the bulk seed for large seed selections.

Average plant height exhibited similar trends in both populations, with no difference in small seed selections and increases (P=0.01) for medium seed selections. There were increases in large seed selections for populations A (P=0.01) and B (P=0.05).

A differing response was shown for tillers per plant in small size selections, with increases (P=0.01) in A and no significant difference

TABLE 5. The Effect of Selection for Seed Size on Several Agronomic Characteristics in Two Segregating Populations (F3) of Hexaploid Triticale: Preliminary Selection- Point Field

Size Comparison Population	Plot Yield (g)	Plants/ Plot	Plant Height (cm)	Tillers/ Plant	Fertile Tillers/ Plant	Spikelets/ Spike	Seeds/ Spike	Selected Plant Yield (g)
A. 6TA204 X MT28-1								
Bulk	509.8	87.8	82.40	9.23	7.83	21.9	50.4	8.92
S - B	- 74.0**	- 8.8**	1.10	2.30**	1.35**	- 0.8**	- 2.0	3.07
M - B	- 50.3**	1.5	3.90**	1.65**	0.48	1.0**	- 5.3**	0.10
L - B	40.0*	- 2.3	2.98**	1.15**	1.00**	- 0.5	- 6.5**	0.81
B. 6A405 X 70HN470								
Bulk	348.5	89.8	80.78	10.50	8.90	19.9	29.6	6.83
S - B	-177.5**	-27.5**	0.03	0.48	0.30	- 0.5	4.1	-0.34
M - B	- 77.8**	-14.5**	2.60**	1.40**	0.63*	1.0**	3.2*	1.36**
L - B	34.5*	3.5	1.35*	1.63**	0.65*	- 1.5**	- 1.8	-0.42
LSD (P=0.05)	34.2	4.6	1.25	0.77	0.62	0.4	2.5	0.91
LSD (P=0.01)	45.4	6.1	1.66	1.02	0.82	0.7	3.3	1.21

in B. Both populations showed increases (P=0.01) for medium and large size selections.

Fertile tillers per plant differed for small seed selections, with increases (P=0.01) in A and no significant differences in B. Medium sizes demonstrated a different trend, with increases in B (P=0.05) and no significant difference in A. Both populations showed an increase for large seed selections, that for A (P=0.01) being greater than that for B (P=0.05).

Spikelets per spike showed similar trends for both populations, with decreases in A (P=0.01) and B (P=0.05) for small seed sizes. A similar increase (P=0.01) was shown for both populations for medium seed size selections. Decreases were demonstrated for both A (P=0.05) and B (P=0.01) for large seed size selections.

Seeds per spike showed opposite trends for the two populations. Small seed size selections demonstrated no difference for A and an increase (P=0.01) for B. Medium sizes exhibited a decrease (P=0.01) for A and an increase (P=0.05) for B. Large sizes demonstrated a decrease for A (P=0.01) and no significant difference from bulk controls in B.

Average plant yield for the selected plants showed differences between the two populations. Population A exhibited an increase (P=0.01) in small seed selections while there was no significant difference for B. Medium size selections demonstrated no difference for A and an increase (P=0.01) for B, while large seed selections showed no significant difference for either population.

Correlation of plot yields with agronomic characters

The advanced lines showed different trends with respect to the correlation of plot yields with measured agronomic characters, for all seed sizes combined, in preliminary selections (Table 6). Plot yield in ITYN-6 was not significantly correlated with any of the measured agronomic characters. Both 70HN458 and Rosner demonstrated a significant positive correlation between plot yield and the number of plants per plot (P=0.01), but no significant correlations between plot yield and any other character.

The two segregating populations exhibited contrasting trends. Both A and B showed a positive correlation between plot yield and the number of plants per plot (P=0.01). However, A demonstrated a positive correlation between plot yield and the number of seeds per spike (P=0.05), while B exhibited a negative correlation for seeds per spike (P=0.05) and also for the number of spikelets per spike (P=0.05) with plot yield.

Two cycles of selection

Advanced lines at Point Field

Plot yield showed a similar trend for all three lines with a decrease for bulk selections from the first to second cycle of selection (Table 7). Small seed selections demonstrated a significant decrease from bulks for all lines at the first cycle, being at the 1% level for ITYN-6 and Rosner, and at the 5% level for 70HN458. The second cycle showed a similar decrease from bulk for Rosner, but a non-significant decrease for ITYN-6 and a significant decrease (P=0.01) for 70HN458. The medium sized selections differed among lines and between cycles. No significant difference between bulk and medium was demonstrated during the first cycle for ITYN-6 and Rosner, while an increase (P=0.01) was shown for 70HN458. The second cycle revealed a different response, with a decrease for ITYN-6 (P=0.01), no significant difference for 70HN458 and an increase

TABLE 6. Correlation of Plot Yields with Agronomic Characteristics in Hexaploid Triticale- All Seed Sizes: Preliminary Cycle of Selection (Coefficients x 100)

	ITYN-6	Advanced Lines 70HN458	Rosner	Segregating Populations 6TA204 X MT28-1 F3	6A405 X 70HN470 F3
1. Plants/plot	15	74**	61**	67**	74**
2. Plant height (cm)	41	5	-26	16	-21
3. Tillers/plant	23	-11	-21	15	13
4. Fertile Tillers/plant	12	- 4	-15	10	-19
5. Spikelets/ Primary spike	39	15	4	-17	-58*
6. Seeds/ Primary spike	35	6	- 5	52*	-49*
7. Average Selected Plant yield (g)	39	14	- 3	15	-13

* significant at 0.05 level

** significant at 0.01 level

TABLE 7. Advanced Lines: Two Cycles of Selection- Point Field

Line and Size Comparison	Cycle	Plot Yield	Plants/ Plot	Seed Emergence	Plant Height (cm)	Tillers/ Plant	Fertile Tillers/ Plant	Spikelets/ Spike	Seeds/ Spike	Selected Plant Yield (g)
ITYN-6										
Bulk	1	571.0	104.8	118.3	67.05	5.63	4.95	17.3	32.5	5.07
	2	501.0	101.3	117.0	66.82	5.48	4.98	17.5	39.8	6.48
S - B	1	- 54.0**	- 0.3	0.8	0.03	0.15	0.08	0.4	5.1**	1.30**
	2	- 29.3	17.5	18.5	-0.10	0.43	0.10	0.6**	-5.3**	-0.63*
M - B	1	- 4.0	0.8	2.5	1.50*	0.13	0.10	0.7**	5.4**	1.09**
	2	- 50.0**	- 2.0	0.0	-1.32	-0.13	-0.13	0.3	-3.0*	-0.70
L - B	1	- 11.8	- 2.5	- 1.3	0.43	0.85**	0.65**	0.1	5.3**	1.57**
	2	77.5**	9.5*	8.5*	-0.02	0.13	-0.03	-0.3	-6.1**	-1.17**
70HN458										
Bulk	1	604.5	96.8	109.0	69.23	6.42	5.43	18.4	43.9	7.32
	2	576.8	99.5	115.3	67.73	6.23	5.50	18.2	40.9	7.21
S - B	1	- 34.5*	- 1.0	5.3	1.40*	-0.50	-0.18	-0.4	- 7.5**	-1.04**
	2	- 57.5**	- 4.3	- 3.8	-0.78	-1.08**	-1.03**	-0.4	- 0.7	-1.55**
M - B	1	68.8**	11.8**	19.3**	-0.10	-0.73**	-0.28	-0.5*	- 3.5*	-1.40**
	2	7.0	- 7.5	- 8.8*	0.83	-0.18	0.23	-0.6*	- 1.2	-0.32
L - B	1	116.5**	13.8**	17.5**	1.88**	0.23	0.58*	-0.5*	- 4.3**	-0.52
	2	114.0**	13.8**	14.5**	-0.58	-0.03	0.18	-0.6**	- 1.3	-1.01**
Rosner										
Bulk	1	694.0	104.2	121.3	69.73	6.58	6.13	19.3	50.0	8.00
	2	625.3	91.3	108.5	70.80	6.23	5.60	20.4	42.6	7.38
S - B	1	-192.0**	-11.0**	-14.5**	-0.30	-0.20	-0.20	0.1	- 0.9	-0.61*
	2	-175.0**	-18.0	-19.5**	-1.43	1.38**	1.28**	-1.4**	-4.6	1.76**
M - B	1	26.5	12.0**	9.0*	1.83*	0.83*	0.63**	0.9**	3.6**	1.34**
	2	103.5**	17.3**	16.5**	-0.70	-0.13	-0.05	-0.7**	-5.7**	-0.04
L - B	1	- 91.0**	3.0	- 1.5	2.13**	0.70**	0.25	0.3	-0.4	0.10
	2	76.0**	42.8**	43.0**	-0.48	-0.03	0.23	-0.7**	-5.4**	-0.11
LSD (P=0.05)		34.3	7.8	8.2	1.40	0.51	0.44	0.5	2.6	0.60
LSD (P=0.01)		45.4	10.4	10.8	1.86	0.66	0.59	0.6	3.5	0.79

for Rosner (P=0.01). Large seed selections again showed differing responses. For the first cycle there was no change for ITYN-6, an increase for 70HN458 (P=0.01), and a decrease for Rosner (P=0.01), while the second cycle showed increases for all three lines (P=0.01), with the greatest increase in 70HN458.

The number of plants per plot demonstrated similar trends with decreases in ITYN-6 and Rosner from the first to the second cycle for unselected bulks. Small seed selections showed a similar trend for ITYN-6 and 70HN458 for the first cycle, with no change from the bulk, Rosner exhibiting a significant decrease (P=0.01), while during the second cycle there was an increase for ITYN-6 (P=0.01), no change for 70HN458 and a decrease for Rosner (P=0.01). Medium seed selections demonstrated no change in the first cycle for ITYN-6 and an increase for 70HN458 (P=0.01) and Rosner (P=0.01), while the second cycle showed no change for ITYN-6 or 70HN458 and an increase for Rosner (P=0.01). Large seed selections produced no change in the first cycle for ITYN-6 or Rosner and an increase in 70HN458 (P=0.01), while the second cycle showed increases in ITYN-6 (P=0.05), 70HN458 (P=0.05) and Rosner (P=0.01). Seed emergence showed similar differences to those exhibited for final number of plants per plot.

Average plant height in small seed selections was not different from bulk selections in ITYN-6 or Rosner, but showed a decrease in 70HN458 (P=0.05) in the first cycle, while for the second cycle there was no change in the first two lines and a decrease in Rosner (P=0.05). Medium selections produced increases in the first cycle for ITYN-6 (P=0.05) and Rosner (P=0.05), while there was no effect in any line in the second cycle. Large selections demonstrated increases for 70HN458

(P=0.01) and Rosner (P=0.01) for the first cycle but no effect on any line for the second cycle.

Small seed selections in the first cycle produced a decrease in 70HN458 (P=0.05), while in the second cycle there was a decrease for 70HN458 (P=0.01) and an increase for Rosner (P=0.01) for the number of tillers per plant. Medium seed selections demonstrated a decrease in 70HN458 (P=0.01) and an increase in Rosner (P=0.05) for the first cycle and no significant change in the second cycle for any line. Large seed selections exhibited an increase for ITYN-6 (P=0.01) and Rosner (P=0.01) in the first cycle cycle and no change in the second cycle for any line.

Fertile tillers per plant in small seed selections were not different from bulk in the first cycle for any line while the second cycle produced a decrease in 70HN458 (P=0.01) and an increase in Rosner (P=0.01). Medium size seed selections did not show any differences for either cycle in ITYN-6 or 70HN458 but there was an increase in Rosner (P=0.01) in the first cycle. Large selections produced increases over bulk in ITYN-6 (P=0.01) and 70HN458 (P=0.05) for the first cycle but no differences for any of the lines in the second cycle.

Spikelets per spike in small seed selections showed no change in any of the three lines in the first cycle, an increase for ITYN-6 (P=0.01) and a decrease for Rosner (P=0.01) in the second cycle. Medium sized seed demonstrated increases for ITYN-6 (P=0.01) and Rosner (P=0.01) and a decrease for 70HN458 (P=0.05) in the first cycle, with decreases for 70HN458 (P=0.05) and Rosner (P=0.01) in the second cycle. Large seed selections demonstrated a decrease in 70HN458 (P=0.05) in the first cycle and for Rosner (P=0.01) in the second cycle.

Seeds per spike in small seed selections were higher than bulk (P=0.01) for ITYN-6 and lower (P=0.01) in 70HN458 in the first cycle of selection and were lower for ITYN-6 (P=0.01) and Rosner (P=0.01) in the second cycle. Medium selections produced increases in ITYN-6 (P=0.01) and Rosner (P=0.01) and a decrease in 70HN458 (P=0.05) for the first cycle and decreases for ITYN-6 (P=0.05) and Rosner (P=0.01) in the second cycle. Large selections showed an increase in ITYN-6 (P=0.01) and a decrease in 70HN458 (P=0.01) in the first selection cycle, with decreases for ITYN-6 (P=0.01) and Rosner (P=0.01) in the second cycle.

Average plant yield in small seed selections increased in the first cycle for ITYN-6 (P=0.01) and decreased in 70HN458 (P=0.01) and Rosner (P=0.05), while in the second cycle there were decreases in ITYN-6 (P=0.05) and 70HN458 (P=0.01) with an increase in Rosner (P=0.01). Medium seed sizes in the first cycle showed increases in ITYN-6 (P=0.01) and Rosner (P=0.01) and a decrease in 70HN458 (P=0.01), while there was a decrease in ITYN-6 (P=0.05) in the second cycle. Large size selections had an increased yield in ITYN-6 (P=0.01) in the first cycle, while the second cycle showed decreases in ITYN-6 (P=0.01) and 70HN458 (P=0.01).

Segregating populations at Point Field

Plot yields (Table 8) in bulk selections increased in cycle 2 over cycle 1 in population A (6TA204 X MT28-1) while there was no change in population B (6A405 X 70HN470). Small seed selections showed a decrease compared with bulks for both A and B (P=0.01) in the first cycle, while in the second cycle only A had a decrease (P=0.01). Medium seed selections in the first cycle were lower in B (P=0.01), but in the second cycle produced increases in both A and B (P=0.01). Large seed showed an increase for A (P=0.05) at the first cycle, but a decrease for B (P=0.01), while

TABLE 8. Segregating Populations: Two Cycles of Selection- Point Field Effect of Selection on Agronomic Characteristics

Line and Size Comparison	Cycle	Plot Yield (g)	Plants/ Plot	Seed Emergence	Plant Height (cm)	Tillers/ Plant	Fertile Tillers/ Plant	Spikelets/ Spike	Seeds/ Spike	Selected Plant Yield (g)
6TA204 X MT28-1										
Bulk	1	345.5	108.8	123.8	63.43	6.35	4.68	21.5	30.3	4.83
	2	422.5	110.8	126.5	60.75	6.53	4.85	20.2	28.5	5.35
S - B	1	- 49.8**	- 6.3	- 9.3*	-1.75*	-1.00**	-1.18**	-0.6**	-4.0**	-1.28**
	2	-110.8**	-23.0**	-23.5**	1.03	0.60*	0.08	0.8**	7.7**	0.89**
M - B	1	23.5	-13.5**	-13.8**	-0.70	1.28**	0.80**	0.0	-1.5	0.31
	2	62.0**	2.3	0.8	6.65**	0.13	0.30	1.5**	5.6**	-0.03
L - B	1	37.8*	6.0	7.5	-2.73**	-0.38	-1.15**	-1.3**	0.7	0.12
	2	- 34.3*	- 3.3	- 2.2	5.53**	0.23	0.05	2.6**	4.3**	-0.20
6A405 X 70HN470										
Bulk	1	363.3	121.0	138.5	63.40	5.80	4.38	20.1	28.5	4.33
	2	360.3	95.0	108.5	67.15	6.63	5.45	20.0	37.4	5.60
S - B	1	-100.3**	-22.0**	-24.5**	-4.55**	-0.23	-0.15	-1.6**	-1.8	0.39
	2	8.5	1.5	4.3	-5.43**	-0.65*	-0.60**	-0.4	-8.0**	-0.68*
M - B	1	- 79.5**	-11.5**	-12.5**	-1.63*	-0.15	-0.58*	0.2	5.9**	-1.13**
	2	42.0**	22.3**	23.3**	-3.08**	0.48	0.25	-0.4	-5.7**	0.13
L - B	1	- 49.0**	-13.5**	-14.3**	3.40**	1.50**	1.10**	0.3	0.9	-0.53
	2	28.0	21.0**	23.5**	-3.08**	-0.28	-0.90**	0.2	-4.5**	-0.19
LSD (P=0.05)		34.3	7.8	8.2	1.40	0.51	0.44	0.5	2.6	0.60
LSD (P=0.01)		45.4	10.4	10.8	1.86	0.66	0.59	0.6	3.5	0.79

at the second cycle there was an decrease for A (P=0.05), but no significant change for B.

Plants per plot and seed emergence demonstrated similar trends. Small seed selections at the first selection cycle produced only a slight decrease for A (P=0.05 for seed emergence, no significance for plants per plot) with a large decrease for B (P=0.01), while at the second cycle this was reversed with a large decrease for A (P=0.01) and no significant change for B. Medium selections showed a decrease for both populations (P=0.01) at the first cycle, while at the second cycle there was no change for A and an increase for B (P=0.01). Large seed selections produced no significant change for either cycle in A, while with B there was a decrease in the first cycle (P=0.01) and an increase (P=0.01) in the second.

Average plant height in unselected bulks decreased from the first to the second cycle in A and increased in B. In small seed size selections there was a decrease in height compared with bulks in the first cycle for both A (P=0.05) and B (P=0.01), while the second cycle produced no significant change in A but a decrease (P=0.01) in B. Medium selections did not change in A for the first cyle of selection and there was a decrease in B (P=0.05), while the second cycle showed an increase in A (P=0.01) and a decrease in B (P=0.01). Large seed selections demonstrated opposing trends for the two populations as the first cycle showed a decrease for A (P=0.01) and an increase for B (P=0.01), while the reverse occurred in the second cycle.

Tillers per plant in the small seed selections showed a decrease from bulk in A (P=0.01) but no change in B for the first cycle, while the second cycle demonstrated an increase in A (P=0.05) and a decrease in B (P=0.05). Medium selections demonstrated an increase for A (P=0.01) in the first cycle with no change for either population at the second cycle. Large seed selections showed no change in A over either cycle, while there was an increase for B (P=0.01) only in the first cycle.

Fertile tillers per plant in small seed selections decreased in A (P=0.01) and did not change in B at the first cycle while the reverse occurred at the second cycle. Medium sizes produced an increase in A (P=0.01) and a decrease in B (P=0.05) at the first cycle, with no change at the second cycle for either population. Large selections showed a decrease for A (P=0.01) and an increase for B (P=0.01) at the first cycle, with no change for A and a decrease for B (P=0.01) at the second cycle.

Spikelets per spike for small seed selections decreased from the bulk at the first cycle for both populations (P=0.01), while the second cycle revealed an increase in A (P=0.01) and no significant change in B. Medium selections did not show any significant change for either population at the first cycle and an increase for A (P=0.01) at the second cycle. Large seed selections produced no significant change in B for either cycle, while A showed a decrease (P=0.01) at the first cycle and an increase (P=0.01) at the second.

Seeds per spike produced an increase in bulk selections of B for the second cycle over the first, with little change in A. Small seed selections decreased from the bulks in the first cyle in both A (P=0.01) and B (P=0.05), while there was an increase in A (P=0.01) and a decrease in B (P=0.01) in the second cycle. Medium seed selections produced no change in A and an increase in B (P=0.01) at the first cycle and an increase in A (P=0.01) and a decrease in B (P=0.01) at the second cycle. Large seed selections showed no change in either population at the first cycle and an increase in A (P=0.01) and a decrease in B (P=0.01) at the second cycle.

Average selected plant yield in bulk selections increased in both populations from the first to the second cycle. Small seed selections produced a decrease in A (P=0.01) and no change in B at the first cycle, with an increase in A (P=0.01) and a decrease in B (P=0.05) at the second cycle. Medium seed selections produced no change in A for either cycle and a decrease in B (P=0.01) only for the first cycle. Large seed selections produced no change in either population at either cycle.

Correlation of plot yields with agronomic characters

Correlation of plot yields with the measured agronomic characters for all seed sizes combined are presented in Table 9 for both the advanced lines and the segregating populations.

All advanced lines showed significant positive correlations for plot yields, with seed emergence and the number of plants per plot over both cycles. Both characters showed correlation at the 5% level for the first cycle in ITYN-6 and at the 1% level for the second cycle in ITYN-6 and for both cycles in 70HN458 and Rosner.

Plant height showed positive correlations with plot yield in the second cycle of ITYN-6 (P=0.01), both cycles of 70HN458 (P=0.01) and the first (P=0.05) and second (P=0.01) cycles of Rosner.

Tillers per plant demonstrated positive correlations with plot yield in both cycles of 70HN458 (P=0.01). Fertile tillers per plant and spikelets per spike only showed a significant positive correlation in

TABLE 9. Correlation Coefficients (x 100) of Plot Yields with Agronomic Characteristics- Point Field: Two Cycles of Selection All Seed Sizes Combined

	Advanced Lines						Segregating Populations			
	ITYN-6		70HN458		Rosner		6TA204 X MT28-1		6A405 X 70HN470	
Cycle of Selection	1	2	1	2	1	2	1 F3	2 F4	1 F3	2 F4
1. Plants/plot	57*	69**	83**	60**	60**	60**	52*	60**	50*	60**
2. Seed Emergence	52*	68**	81**	68**	65**	64**	55*	58*	42	58*
3. Plant Height (cm)	46	80**	65**	82**	49*	71**	27	19	10	43
4. Tillers/ Plant	6	32	66**	68**	47	-24	-11	0	15	32
5. Fertile Tillers/ Plant	9	43	72**	18	54*	3	- 2	26	8	24
6. Spikelets/ Primary Spike	41	54*	71**	37	-12	20	-38	- 4	- 8	52*
7. Seeds/ Primary Spike	23	10	44	16	66**	57**	23	11	- 6	18
8. Selected Plant Yield (g)	23	41	71**	28	72**	34	57*	33	- 8	51*

* significant at 0.05 level

** significant at 0.01 level

the first cycle of 70HN458 (P=0.01) and in the first cycle of Rosner (P=0.05) for fertile tillers only. Selected plant yield was significantly correlated with plot yield in the first cycle of 70HN458 (P=0.01) and Rosner (P=0.01).

There were fewer significant correlations between agronomic characters and plot yield in the two segregating populations. Plot yield was significantly correlated with numbers of plants per plot in the first cycle for both populations (P=0.05), and also in the second cycle for both populations (P=0.01). Seed emergence showed significant correlation with plot yield in both cycles in population A (P=0.05), and for only the second cycle for population B (P=0.05).

No other agronomic characters showed any significant correlation with yield with the exception of average plant yield for the first cycle in population A (P=0.05).

Effect of two cycles of selection

There was a general decrease in plot yield from the first cycle to the second cycle in the three advanced lines (Table 10), although this decline was not present in large seed selection for ITYN-6 and Rosner. The two segregating populations generally showed an increase for the second cycle (F4) over the first (F3). However, none of these differences showed significance for the level of cycle (main plot in the split-split-plot experimental design).

There was no consistent trend for agronomic characters. A significant increase in seed emergence and plants per plot was present for the second cycle of selection for large seed in Rosner (P=0.05). Plant height and seeds per spike generally decreased in the second cycle of

TABLE 10. Agronomic Characteristics in Hexaploid Triticale-Difference of Second Cycle over First Cycle of Selection-Advanced Lines: Point Field

Line and Size	Plot Yield (g)	Plants/ Plot	Seed Emergence	Plant Height (cm)	Tillers/ Plant	Fertile Tillers/ Plant	Spikelets/ Spike	Seeds/ Spike	Selected Plant Yield (g)
1. ITYN-6									
Bulk	- 70.0	- 3.5	- 1.3	-0.23	-0.15	0.03	0.2	7.2	1.41
Small	- 45.3	14.3	14.3	0.35	0.13	-0.05	0.4	-3.2	-0.53
Medium	-124.0	- 6.3	- 3.8	-3.05	-0.40	-0.20	-0.2	-1.2	-0.38
Large	19.3	8.5	8.5	-0.68	-0.88	-0.60	-0.2	-4.2	-1.32
2. 70HN458									
Bulk	- 27.8	2.8	6.3	-1.50	-2.85**	0.08	-0.2	-3.0	-0.12
Small	- 50.8	- 0.5	- 2.8	-0.88	0.78	-0.78	-0.2	3.8	-0.63
Medium	- 89.5	-16.5	-21.8	-0.58	0.35	0.58	-0.3	-0.8	0.96
Large	- 30.3	2.8	2.8	-3.95	-0.45	-0.33	-0.3	0.0	-0.61
3. Rosner									
Bulk	- 68.8	-13.0	-13.3	1.08	-0.35	-0.53	1.1	-7.4	-0.59
Small	- 51.8	-20.0	-20.0	-0.05	1.03	0.95	-0.4	-2.0	1.78
Medium	8.3	- 3.3	- 5.3	-1.45	-1.30	-1.20	-0.6	-5.3	-1.96
Large	98.3	32.8*	31.8*	-1.53	-1.08	-0.55	0.1	-1.6	-0.79
LSD (P=0.05)	214.4	26.9	28.6	5.87	1.84	1.79	1.5	9.7	3.00
LSD (P=0.01)	284.4	35.7	37.9	7.78	2.45	2.38	1.9	12.9	3.98

TABLE 10. (Continued) Agronomic Characteristics in Hexaploid Triticale- Difference of Second Cycle over First Cycle of Selection- Segregating Populations: Point Field

Population and Size	Plot Yield (g)	Plants/ Plot	Seed Emergence	Plant Height (cm)	Tillers/ Plant	Fertile Tillers/ Plant	Spikelets/ Spike	Seeds/ Spike	Selected Plant Yield (g)
A. 6TA204 X MT28-1									
Bulk	77.0	2.0	- 2.8	-2.68	0.18	0.18	-1.4	- 1.8	0.51
Small	16.0	-14.8	-11.5	0.10	1.78	1.43	0.0	10.1*	2.68
Medium	162.5	17.8	17.3	4.69	-0.98	-0.33	0.1	5.4	0.18
Large	5.0	- 7.3	- 7.0	5.58	0.78	1.38	2.5**	1.8	0.20
B. 6A405 X 70HN470									
Bulk	- 3.0	-26.0	-30.0*	3.75	0.83	1.08	-0.1	8.8	1.28
Small	105.8	- 2.5	- 1.3	2.85	0.40	0.63	1.2	2.6	0.22
Medium	118.5	7.8	5.8	2.30	1.45	1.90*	-0.7	9.1	2.54
Large	74.0	8.5	8.8	2.73	-0.95	-0.93	-0.2	5.3	0.56
LSD (P=0.05)	214.4	26.9	28.6	5.87	1.84	1.79	1.5	9.7	3.00
LSD (P=0.01)	284.4	35.7	37.9	7.78	2.45	2.38	1.9	12.9	3.98

selection for advanced lines and increased for the segregating populations. There was a significant decrease in the number of tillers per plant for the second cycle of the bulk of 70HN458 (P=0.01). There were increases in the number of fertile tillers per plant for the second cycle of selection for medium seed size in population B (P=0.05) and in the number of seeds per spike in the second cycle of selection for small seed size in A (P=0.05). The number of spikelets per spike was significantly larger in the second cycle of selection for large seeds in A (P=0.01)..

Advanced lines at West Field

Plot yields for small seed selections in the first cycle of selection (Table 11) were less than the bulks in ITYN-6 (P=0.01) and Rosner (P=0.01), while in the second cycle there was a greater decrease for ITYN-6 (P=0.01) and a decrease in 70HN458 (P=0.01), with no significant change in Rosner. Medium selections showed an increase for 70HN458 (P=0.01) and Rosner (P=0.01) in the first cycle, with increases in ITYN-6 (P=0.01) and Rosner (P=0.05) and a decrease for 70HN458 (P=0.05) for the second. Large seed size selections produced increases in 70HN458 (P=0.01) and Rosner (P=0.01) in the first cycle and for ITYN-6 (P=0.05) and Rosner (P=0.05) for the second.

Plots grown from unselected bulk seed showed increases in the number of seeds emerging and the final number of plants per plot from the first to the second selection cycle for ITYN-6 and Rosner, and a corresponding decrease in 70HN458. Plants per plot and seed emergence in small seed selections were higher in ITYN-6 (P=0.01) and lower in 70HN458 (P=0.01) in the first cycle of selection, while the reverse response was shown in the second cycle. Medium size seeds were higher

TABLE 11. Advanced Lines: Two Cycles of Selection- West Field
Effect of Selection on Agronomic Characteristics

Line and Size Comparison	Cycle	Plot Yield (g)	Plants/ Plot	Seed Emergence	Plant Height (cm)	Tillers/ Plant	Fertile Tillers/ Plant	Spikelets/ Spike	Seeds/ Spike	Selected Plant Yield (g)
ITYN-6										
Bulk	1	511.3	100.3	110.3	67.45	7.60	6.73	17.3	33.6	6.76
	2	508.3	109.3	119.3	63.70	6.15	5.40	16.8	31.1	5.16
S - B	1	- 50.8**	8.3**	8.3**	-1.23	-1.10**	-0.98	0.0	-0.7	-1.16**
	2	-147.5**	-13.0**	-13.0**	0.65	0.43*	0.13	0.1	1.2	0.17
M - B	1	3.5	7.8**	7.8**	-3.76**	-0.98**	-1.00**	0.3	0.2	-1.16**
	2	93.8**	- 1.3	- 1.3	1.38	1.08**	0.60**	0.8**	2.7**	0.82**
L - B	1	- 12.5	3.3	3.3	-2.73**	-0.93**	-0.88**	-0.1	1.0	-0.59**
	2	81.0*	2.3	2.3	2.20**	0.28	0.10	0.2	1.1	0.36
70HN458										
Bulk	1	497.5	113.8	123.8	63.03	6.60	5.60	17.6	36.5	6.19
	2	526.0	91.0	101.0	63.55	6.45	5.73	17.1	34.9	5.92
S - B	1	- 29.3	- 12.3**	- 12.3**	-0.88	-0.20	-0.10	-0.4**	-0.6	-0.49*
	2	- 86.0**	11.5**	11.5**	-1.48*	-0.23	-0.38*	0.1	-0.3	-0.39
M - B	1	86.0**	6.3*	6.3*	1.00	-0.28	-0.35*	0.0	0.2	-0.40
	2	- 39.3*	3.8	3.8	0.23	-0.33	-0.33*	0.2	1.6*	0.09
L - B	1	110.8**	- 2.3	- 2.3	1.33	-0.83**	-0.33*	-0.3*	-1.3	-0.60**
	2	21.8	18.0**	18.0**	-0.50	0.08	-0.08	0.9**	1.7*	0.18
Rosner										
Bulk	1	506.0	97.5	107.5	74.58	7.28	7.00	19.1	39.4	6.87
	2	535.3	111.5	121.5	74.83	7.05	6.73	19.4	39.8	6.20
S - B	1	- 81.0**	- 2.3	- 2.3	1.13	0.15	0.13	-0.2	1.0	0.22
	2	- 19.3	- 1.5	- 1.5	3.38**	0.48	0.63**	-0.1	2.2**	1.89**
M - B	1	72.3**	11.8**	11.8**	1.63*	-0.60**	-0.35*	0.3*	2.9**	0.19
	2	36.6*	- 0.5	- 0.5	4.78**	0.20	0.48**	0.2	1.3	1.28**
L - B	1	150.0**	15.5**	15.5**	3.75**	-0.48**	-0.25	0.1	1.4	0.25
	2	41.8*	0.5	0.5	1.53*	0.80**	0.70**	0.1	-0.1	1.32**
LSD (P=0.05)		36.6	4.8	4.9	1.44	0.34	0.31	0.3	1.5	0.43
LSD (P=0.01)		48.6	6.4	6.5	1.91	0.45	0.41	0.4	2.0	0.56

at the first cycle for ITYN-6 (P=0.01), 70HN458 (P=0.05) and Rosner (P=0.01), while none of the lines were significantly different from the bulks at the second cycle. Large size selections did not differ from the bulks for either cycle in ITYN-6, but were higher only in the second cycle for 70HN458 (P=0.01) and in the first cycle for Rosner (P=0.01).

Average plant height for small seed selections showed no significant differences from the bulks for any of the three lines in the first cycle, while in the second cycle there was a decrease in 70HN458 (P=0.05) and an increase in Rosner (P=0.01). Medium selections had a decrease in ITYN-6 (P=0.01) and an increase for Rosner (P=0.05) in the first cycle, while in the second cycle the only change was an increase for Rosner (P=0.01). For large seed selections in the first cycle there was a decrease in ITYN-6 (P=0.01) and an increase for Rosner (P=0.01), while in the second cycle there was an increase in ITYN-6 (P=0.01) and Rosner (P=0.05).

There was a decrease in the number of tillers per plant for bulks in the second cycle of selection as compared with the first for ITYN-6. Tillers per plant in small seed selections at the first cycle only showed a change in ITYN-6, being lower (P=0.01) than bulks, while at the second cycle there were increases in ITYN-6 (P=0.05) and Rosner (P=0.01). Medium selections showed decreases for ITYN-6 (P=0.01) and Rosner (P=0.01) in the first cycle, while there was an increase for ITYN-6 (P=0.01) in the second cycle. With large seed selections there was a decrease in all three lines (P=0.01) at the first cycle, while the only change at the second cycle was an increase in Rosner (P=0.01).

There was a decrease in the number of fertile tillers per plant in bulks of ITYN-6 from the first to second cycle, with little change in the other two lines. Fertile tillers per plant in small seed selections were lower for ITYN-6 (P=0.01) at the first cycle, and higher for Rosner (P=0.01) and lower for 70HN458 (P=0.05) at the second cycle. Medium selections were lower at the first cycle for ITYN-6 (P=0.01), 70HN458 (P=0.05) and Rosner (P=0.05), while at the second cycle there were increases in ITYN-6 (P=0.01) and Rosner (P=0.05) and decreases in 70HN458 (P=0.05). Large seed sizes showed decreases in ITYN-6 (P=0.01) and 70HN458 (P=0.05) at the first cycle, while at the second cycle there was an increase for Rosner (P=0.01).

Spikelets per spike in small seed selections at the first cycle were lower in 70HN458 (P=0.01), while none of the lines showed any change from the bulks at the second cycle. Medium seed selections demonstrated an increase for Rosner (P=0.05) in the first cycle and for ITYN-6 (P=0.01) at the second cycle. Large selections showed a decrease for 70HN458 (P=0.05) in the first cycle and an increase (P=0.01) in the second cycle.

Seeds per spike in small selections only showed a change for Rosner, where there was an increase (P=0.01) in the second cycle. In medium seed size selections, there was an increase for Rosner (P=0.01) in the first cycle and for ITYN-6 (P=0.01) and 70HN458 (P=0.05) in the second cycle. Large seed sizes only demonstrated change in 70HN458, with an increase (P=0.05) in the second cycle.

Average plant yield in bulk selections decreased greatly from the first to the second cycle in ITYN-6, with small decreases in the other two lines. Small size selections demonstrated decreases for ITYN-6 (P=0.01) and 70HN458 (P=0.05) in the first cycle and an increase for Rosner (P=0.01) in the second cycle. Medium size selections were lower in the first cycle for ITYN-6 (P=0.01) and greater in the second cycle for ITYN-6 (P=0.01) and Rosner (P=0.01). Large seed size selections showed decreases in the first cycle for ITYN-6 (P=0.01) and 70HN458 (P=0.01) and an increase in the second cycle for Rosner (P=0.01).

Segregating populations at West Field

Plot yield in bulk selections (Table 12) showed little change over the two cycles in A, but an increase in the second cycle for B. Small seed selections demonstrated a decrease for both A (P=0.01) and B (P=0.05) in the first cycle, but increases for both A (P=0.01) and B (P=0.05) in the second cycle. The medium seed size selections of A showed a decrease in the first selection cycle (P=0.05) and no significant change in the second, while those of B demonstrated a large increase over the bulks (P=0.01) in both cycles. Large seed sizes showed a decrease in the second cycle for A (P=0.05) and no change from the bulks in either cycle for B.

The bulk seeds showed increases in the number of seeds emerging and the number of plants per plot for the second cycle over the first in A, while there was a decrease in B. Small seed size selections demonstrated significant decreases for both populations (P=0.01) at both cycles of selection. Medium selections did not change for A but in B decreased in the first cycle (P=0.05) and increased in the second cycle (P=0.01). Large selections showed opposing trends, with increases for A (P=0.01) and decreases for B (P=0.01) in the first cycle and an increase for B in the second cycle (P=0.01).

Average plant height in bulks of both populations increases from the first to the second cycle. Small seed selections showed decreases

TABLE 12. Segregating Populations: Two Cycles of Selection- West Field
Effect of Selection on Agronomic Characteristics

Line and Size Comparison	Cycle	Plot Yield (g)	Plants/ Plot	Seed Emergence	Plant Height (cm)	Tillers/ Plant	Fertile Tillers/ Plant	Spikelets/ Spike	Seeds/ Spike	Selected Plant Yield (g)
6TA204 X MT28-1										
Bulk	1	281.3	102.3	112.3	69.78	7.13	6.38	21.8	27.8	5.54
	2	292.3	110.8	120.8	72.35	6.55	5.60	22.0	31.0	5.07
S - B	1	- 68.5**	-12.0**	-12.0**	-3.05**	0.65**	-1.13**	0.0	-7.7**	-2.05**
	2	50.5**	-15.8**	-15.8**	-6.50**	-0.03	0.05	-1.1	2.8**	-0.32
M - B	1	- 40.3*	0.5	0.5	0.83	0.08	-0.30	-0.1	-2.1**	-0.78**
	2	18.0	- 0.3	- 0.3	0.40	1.05**	0.65**	-1.6	-2.9**	0.46*
L - B	1	0.3	7.3**	7.3**	-1.23	0.13	-0.20	-0.5**	-5.2**	-1.91**
	2	- 47.3**	- 1.3	- 1.3	0.83	-0.85**	-0.93**	-0.8**	-5.7**	-0.91**
6A405 X 70HN470										
Bulk	1	210.3	110.8	120.8	63.20	7.73	5.90	19.1	21.5	4.80
	2	271.3	102.3	112.3	66.88	7.10	6.05	19.0	22.7	4.92
S - B	1	- 44.3*	-19.8**	-19.8**	-0.60	0.38*	0.75**	-0.3*	1.2	-0.38
	2	37.8*	- 7.8**	- 7.8**	0.70	-0.10	0.28	-0.1	9.8**	0.73**
M - B	1	129.0**	- 5.8*	- 5.8*	0.98	-0.23	0.13	-0.5**	1.1	-0.54*
	2	147.3**	10.5**	10.5**	2.73**	-0.20	-0.10	0.2	3.7**	0.31
L - B	1	21.0	- 7.5**	- 7.5**	1.20	-0.48**	0.10	1.0**	1.6*	0.01
	2	9.0	14.5**	14.5**	-0.65	-0.63**	-0.28	-0.5**	0.9	-0.08
LSD (P=0.05)		36.6	4.8	4.9	1.44	0.34	0.31	0.3	1.5	0.43
LSD (P=0.01)		48.6	6.4	6.5	1.91	0.45	0.41	0.4	2.0	0.56

only in A in both cycles (P=0.01). Medium selections increased in B (P=0.01) in the second cycle. There was no significant change for large seed size selections in either population at either cycle.

The number of tillers per plant decreased from the first to the second cycle of selection in bulk seeds of both populations. For small seed size selections, there was an increase over bulk for A (P=0.01) and B (P=0.05) in the first cycle only. In medium selections there was an increase at the second cycle for A (P=0.01). Large seed selections demonstrated decreases in A (P=0.01) at the second cycle and for B (P=0.01) in both cycles.

The number of fertile tillers per plant in bulk selections of A decreased from the first to the second cycle. In small seed size selections there was a decrease in A (P=0.01) and an increase in B (P=0.01) at the first cycle with no significant change at the second. Medium seed sizes only produced an increase in A (P=0.01) at the second cycle, while large seeds only showed a decrease in A (P=0.01) at the second cycle.

Spikelets per spike in small seed selections demonstrated a decrease in B (P=0.05) at the first cycle and in A (P=0.01) at the second cycle. Medium selections were lower than bulk for B (P=0.01) in cycle one and for A (P=0.01) in cycle two. Large seeds demonstrated decreases in both cycles for A (P=0.01) and in B an increase in cycle one (P=0.01) and a decrease in cycle two (P=0.01).

Seeds per spike increased in bulks of A from the first to the second cycle with a very small increase in B. Small seed selections produced a decrease in the first cycle of A (P=0.01), while both populations showed an increase (P=0.01) at the second cycle. Medium selections decreased for both cycles in A (P=0.01) and increased in cycle two for B (P=0.01). Large seed size selections produced large decreases in both cycles for A (P=0.01), while there was an increase in the first cycle (P=0.05) for B.

Average plant yield for bulk selections showed a decrease from the first to the second cycle for A, with little change in B. There were contrasting trends in small seed selections, with a decrease in A (P=0.01) at the first cycle and an increase in B (P=0.01) at the second cycle. Medium seed size selections produced decreases for A (P=0.01) and B (P=0.05) at the first cycle of selection and an increase for A (P=0.05) at the second. Large selections demonstrated decreases for A (P=0.01) at both cycles, with no significant change for B at either cycle.

Correlation of plot yields with agronomic characters

Correlation of plot yields with selected agronomic characters is presented in Table 13 for both the advanced lines and the segregating populations over both cycles of selection at the West Field location.

Results at this location differed widely from those at the other location (Point Field). The number of plants per plot or seed emergence had little correlation with plot yields, both characters showing significance at the second cycle for Rosner (P=0.01) alone of the three lines and two segregating populations.

There was no consistency of correlations for characters with plot yield for the three lines. Plant height showed positive correlations with plot yield in the first cycle of ITYN-6 (P=0.05) and Rosner (P=0.01) and in the second cycle of 70HN458 (P=0.01). The only other character showing significant correlation with plot yield was the number of

TABLE 13. Correlation Coefficients (x 100) of Plot Yields with Agronomic Characteristics- West Field: Two Cycles of Selection All Seed Sizes Combined

	Advanced Lines						Segregating Populations			
	ITYN-6		70HN458		Rosner		6TA204 X MT28-1		6A405 X 70HN470	
Cycle of Selection	1	2	1	2	1	2	1 F3	2 F4	1 F3	2 F4
1. Plants/plot	-31	46	4	17	44	67**	47	14	15	47
2. Seed Emergence	-31	46	4	17	44	67**	47	14	15	47
3. Plant Height (cm)	51*	48	44	59*	62**	41	83**	40	11	37
4. Tillers/ Plant	30	- 4	2	9	-19	36	65**	58*	7	8
5. Fertile Tillers/ Plant	25	8	-13	40	-12	40	87**	68**	3	- 4
6. Spikelets/ Primary Spike	48	40	-34	62**	- 3	63**	34	42	10	19
7. Seeds/ Primary Spike	41	23	30	22	32	3	76**	14	5	-21
8. Selected Plant Yield (g)	28	8	17	40	27	36	67**	58*	22	- 6

* significant at 0.05 level

** significant at 0.01 level

spikelets per spike, which was positively correlated with plot yield in the second cycle of 70HN458 and Rosner (P=0.01).

The two segregating populations showed different trends. There was no significant correlation between plot yield and any agronomic character for population B. Population showed significant positive correlations of plot yield with plant height, tillers per plant, fertile tillers per plant, seeds per spike and selected plant yield in the first cycle (P=0.01), and with tillers per plant, fertile tillers per plant and selected plant yield in the second cycle (P=0.05).

Effect of two cycles of selection

The differences for plot yield and agronomic characters of the second over the first cycle of selection for the three advanced lines and two segregating populations are presented in Table 14.

There were no consistent trends in the plot yield of the second cycle over the first for different seed sizes among the three advanced lines. The agronomic characters which showed significant changes were seed emergence and plants per plot, which showed an increase at the second cycle in bulk seed of 70HN458 (P=0.01) and a decrease in medium seed of 70HN458 (P=0.01), while tillers per plant and fertile tillers per plant both decreased in bulk seed of ITYN-6 (P=0.05).

The segregating populations showed increases in plot yield for all sizes of both populations (with the exception of large sizes seeds of A which showed a small decrease), with a significant increase (P=0.05) for small seeds of B. Tillers per plant and fertile tillers per plant both showed a decrease (P=0.05) in large seeds of A. Spikelets per spike decreased in medium seed selections of A (P=0.05) and large seed

TABLE 14. Agronomic Characteristics in Hexaploid Triticale-Difference of Second Cycle over First Cycle of Selection-Advanced Lines: West Field

Line and Size	Plot Yield (g)	Plants/ Plot	Seed Emergence	Plant Height (cm)	Tillers/ Plant	Fertile Tillers/ Plant	Spikelets/ Spike	Seeds/ Spike	Selected Plant Yield (g)
1. ITYN-6									
Bulk	- 2.5	9.0	9.0	-3.75	-1.45*	-1.33*	-0.5	-2.5	-1.59
Small	- 99.3	-12.3	-12.3	-1.88	0.08	-0.23	-0.4	-0.6	-0.27
Medium	87.8	0.0	0.0	1.40	0.60	0.28	0.1	0.1	0.39
Large	91.0	8.0	8.0	1.18	-0.25	-0.35	-0.2	-2.4	-0.65
2. 70HN458									
Bulk	28.4	22.8**	22.8**	0.53	-0.15	0.13	-0.5	-1.5	-0.28
Small	- 28.3	1.0	1.0	-0.08	-0.18	-0.15	-0.1	-1.2	-0.18
Medium	- 18.3	-25.3**	-25.3**	-0.25	-0.20	-0.15	-0.4	-0.2	0.22
Large	- 60.5	- 2.5	- 2.5	-0.85	0.75	0.53	0.6	1.4	0.50
3. Rosner									
Bulk	29.3	14.0	14.0	0.25	-0.23	-0.28	0.2	0.4	-0.67
Small	91.0	15.3	15.3	2.50	0.10	0.23	0.4	1.6	1.01
Medium	- 6.5	2.0	2.0	3.40	0.58	0.55	-0.3	-1.2	0.43
Large	- 79.0	- 1.0	- 1.0	-1.98	1.05	0.68	0.2	-1.1	0.41
LSD (P=0.05)	130.9	15.8	15.9	5.75	1.20	1.28	1.1	5.4	1.65
LSD (P=0.01)	173.6	20.9	21.1	7.62	1.60	1.70	1.4	7.1	2.19

TABLE 14. (Continued) Agronomic Characteristics in Hexaploid Triticale-Difference of Second Cycle over First Cycle of Selection-Segregating Populations: West Field

Population and Size	Plot Yield (g)	Plants/ Plot	Seed Emergence	Plant Height (cm)	Tillers/ Spike	Fertile Tillers/ Spike	Spikelets/ Spike	Seeds/ Spike	Selected Plant Yield (g)
A. 6TA204 X MT28-1									
Bulk	11.0	8.5	8.5	2.58	-0.58	-0.78	0.2	3.2	-0.47
Small	29.0	4.8	4.8	-0.88	-1.25	0.30	-0.9	13.7**	1.27
Medium	69.3	7.8	7.8	2.15	0.40	0.18	-1.2*	2.4	0.80
Large	- 36.0	0.0	0.0	4.63	-1.55*	-1.50*	-0.1	2.7	0.54
B. 6A405 X 70HN470									
Bulk	61.0	- 8.5	- 8.5	3.68	-0.63	0.15	-0.1	1.2	0.11
Small	143.0*	3.5	3.5	4.98	-1.10	-0.33	0.2	9.8**	1.22
Medium	79.3	7.8	7.8	5.43	-0.60	-0.08	-0.5	3.8	0.96
Large	49.0	13.5	13.5	1.83	-0.78	-0.23	-1.6**	0.6	0.02
LSD (P=0.05)	130.9	15.8	15.9	5.75	1.20	1.28	1.1	5.4	1.65
LSD (P=0.01)	173.6	20.9	21.1	7.62	1.60	1.70	1.4	7.1	2.19

selections of B (P=0.01). The number of seeds per spike increased in small seed size selections of both A and B (P=0.01).

The effects of mass selection for seed density and size

Advanced lines at Point Field

All three lines demonstrated increases in bulk seed selections in high density seed over low density seed (Table 15) for plot yield. Small seed selections had an increase for low density seed in ITYN-6 (P=0.05), a decrease in 70HN458 (P=0.01), and no significant change in Rosner, while all three lines were lower (P=0.01) for high density seed. Medium seed sizes showed a decrease for high density seed as compared with bulk in 70HN458 (P=0.01) and an increase for low density seed in Rosner (P=0.01). Large size selections showed increases in ITYN-6 (P=0.01) and Rosner (P=0.01) for low density seed, while there were increases for ITYN-6 (P=0.05) and Rosner (P=0.01) and a decrease for 70HN458 (P=0.01) in high density seed.

The number of plants per plot in the bulks showed a substantial increase of high over low density seed in ITYN-6, but little change in the other two lines. Small seed selections were greater in ITYN-6 (P=0.01), but less in 70HN458 (P=0.01) and Rosner (P=0.05) in the low density seed, with a decrease in ITYN-6 (P=0.01) and an increase in 70HN458 (P=0.01) for high density seed. Medium seed selections were higher in ITYN-6 (P=0.01) and Rosner (P=0.01), but lower for 70HN458 (P=0.01) for low density seed, while there was a decrease for ITYN-6 (P=0.05) and an increase for Rosner (P=0.01) for high density seed. Large seed size selections showed differences in ITYN-6, with an increase (P=0.01) for low density seed and a decrease (P=0.05) for high density.

TABLE 15. Advanced Lines: The Effects of Selection for Seed Density on Agronomic Characteristics of Hexaploid Triticale- Point Field

Line and Size Comparison	Seed Density	Plot Yield (g)	Plants/ Plot	Seed Emergence	Plant Height (cm)	Tillers/ Plant	Fertile Tillers/ Plant	Spikelets/ Spike	Seeds/ Spike	Selected Plant Yield (g)
ITYN-6										
Bulk	L	588.8	86.3	98.0	71.75	6.70	6.23	18.4	42.9	9.40
	H	797.8	103.3	119.8	71.68	5.75	5.25	18.5	38.9	7.02
S - B	L	52.8*	9.3*	15.5**	-1.20	-1.18**	-1.28**	0.4*	-2.7*	-2.55**
	H	-107.8**	- 7.3**	- 9.3**	2.20**	0.10	0.18	-0.3	2.5*	0.49
M - B	L	34.5	14.3**	20.5**	1.70*	-0.78**	-0.88**	0.3*	-1.0	-1.43**
	H	- 39.5	- 7.5*	- 8.5**	5.33**	0.68*	0.28	0.3*	2.1	1.32**
L - B	L	139.5**	7.3**	7.8**	1.20	0.13	-0.05	-0.1	-1.2	-0.25
	H	50.5*	- 6.0*	- 1.8	3.60**	0.95**	0.75**	-0.2	4.0**	2.73**
70HN458										
Bulk	L	863.5	102.5	117.5	76.68	6.50	5.78	18.8	46.6	8.68
	H	1030.3	104.3	118.0	78.38	7.53	6.88	19.1	49.0	10.72
S - B	L	-174.3**	-16.0**	-18.8**	-2.20**	-0.40	-0.15	0.7**	-1.6	-0.58
	H	-170.0**	11.0**	15.8**	-0.95	-0.98**	-0.80**	-0.2	-1.2	-1.13**
M - B	L	- 14.0	- 7.0*	- 7.3**	-0.23	0.53	0.80**	0.0	3.0	1.95**
	H	- 93.0**	2.3	6.3*	-1.70*	-1.13**	-1.10**	-0.4*	-4.1	-2.40**
L - B	L	35.3	0.5	1.8	1.25	0.28	0.50*	-0.1	-1.9	0.25
	H	-103.0	- 0.5	0.0	0.78	-0.53	-0.55*	-0.2	-1.7	-1.00*
Rosner										
Bulk	L	896.3	102.0	117.0	79.00	7.08	6.48	19.9	54.0	9.62
	H	965.5	104.3	118.5	79.55	7.70	7.48	19.6	54.0	10.72
S - B	L	- 10.5	- 5.5*	- 6.5*	-0.40	-0.05	0.03	-0.4*	-4.0**	-0.34
	H	- 96.0**	- 0.3	- 1.3	-4.30**	-0.08	-0.23	0.1	-0.2	0.22
M - B	L	112.0**	6.0*	11.5**	1.40*	0.53	0.23	0.7**	0.7	-0.38
	H	9.3	10.5**	13.5**	0.43	-0.20	-0.45	0.4*	-0.7	-0.05
L - B	L	155.0**	3.3	3.0	1.73*	0.43	0.58*	-0.2	-1.8	0.92*
	H	71.0**	- 1.0	0.8	1.43*	-0.58*	-0.95**	0.3*	2.9**	-0.02
LSD (P=0.05)		43.4	5.1	5.4	1.39	0.55	0.48	0.3	2.2	0.83
LSD (P=0.01)		57.6	6.8	7.1	1.84	0.72	0.63	0.5	2.9	1.10

Seed emergence also showed a large increase in high over low density seed in bulk selections of ITYN-6. Small seeds had an increase for ITYN-6 (P=0.01) and decreases for 70HN458 (P=0.01) and Rosner (P=0.05) for low density seeds, with a decrease for ITYN-6 (P=0.01) and an increase for 70HN458 (P=0.01) with high density seed. Medium selections produced increases for ITYN-6 (P=0.01) and Rosner (P=0.01) and decreases for 70HN458 (P=0.01) with low density seeds, while there was a decrease in ITYN-6 (P=0.01) and an increase in 70HN458 (P=0.05) and Rosner (P=0.01) in the high density seed. Large seed only showed significant change for ITYN-6, with an increase (P=0.05) for low density seeds.

Average plant height decreased in small seed selections of 70HN458 (P=0.01) for low density seed and showed an increase for ITYN-6 (P=0.01) and a decrease for Rosner (P=0.01) in high density seed. Medium seed selections demonstrated increases in ITYN-6 (P=0.05) and Rosner (P=0.05) in low density seed, with an increase in ITYN-6 (P=0.01) and a decrease for 70HN458 (P=0.05) for high density seed. Large seed size selections were higher for both low and high density seed in Rosner (P=0.05), while ITYN-6 showed an increase (P=0.01) only for high density seed.

The number of tillers per plant in bulk seed was higher in high density seed than in low for 70HN458 and Rosner, but lower in ITYN-6. Small seed sizes were lower in low density seeds in ITYN-6 (P=0.01) and lower for high density seeds for 70HN458 (P=0.01). Medium seed size selections were lower in ITYN-6 (P=0.01) in low density seeds and higher for ITYN-6 (P=0.05) but lower for 70HN458 (P=0.01) in high density seed. Large seed selections showed an increase for ITYN-6 (P=0.01) and a decrease for Rosner (P=0.01) with high density seed.

The number of fertile tillers per plant were lower in high density seed than low density seed for bulk seed of ITYN-6, but higher in high density seed for the other two lines. Small seed selections were lower for ITYN-6 (P=0.01) in low density seed and for 70HN458 (P=0.01) in high density seed. Medium seed size selections were lower in ITYN-6 (P=0.01) and higher in 70HN458 (P=0.01) for low density seed and lower in 70HN458 (P=0.01) for high density seed. Large seed size selections were higher for 70HN458 (P=0.05) and Rosner (P=0.05) in low density seeds, higher for ITYN-6 (P=0.01) and lower for 70HN458 (P=0.05) and Rosner (P=0.01) in high density seeds.

Spikelets per spike in small seed selections were higher for ITYN-6 (P=0.05) and 70HN458 (P=0.05) and lower for Rosner (P=0.05) in low density seeds, and lower for ITYN-6 (P=0.05) in high density seeds. Medium seed selections were higher than bulk for ITYN-6 (P=0.05) and Rosner (P=0.01) in low density seed, higher for ITYN-6 and Rosner (P=0.05) and lower for 70HN458 (P=0.05) in high density seed. Large seed size selections only demonstrated a change for Rosner, with an increase (P=0.05) for high density seed.

Seeds per spike in small selections decreased in the low density seed selections of ITYN-6 (P=0.05) and Rosner (P=0.01) and increased in the high density seeds of ITYN-6 (P=0.05). Medium seed selections did not change significantly from bulk for any of the three lines at either density, while large seed size selections produced increases for ITYN-6 (P=0.01) and Rosner (P=0.01) for high density seeds.

Average plant yield was lower in the high density seed bulks of ITYN-6 and higher in the other two lines than for low density. Small seed selections produced decreases in ITYN-6 (P=0.01) in low density seed and in 70HN458 (P=0.01) for high density seed. Medium selections showed a decrease for ITYN-6 (P=0.01) and an increase for 70HN458 (P=0.01) in low density seed, with the reverse occurring in high density seeds. Large seed size selections demonstrated an increase for Rosner (P=0.05) in low density seed and an increase for ITYN-6 (P=0.01) and decrease for 70HN458 (P=0.05) in high density seed.

Segregating populations at Point Field

The results for the two segregating populations are presented in Table 16. Plot yields in bulk selections were higher for high density seeds in population A, but higher for low density seeds in population B. Small seed selections were lower in low density seed selections for A (P=0.05), and lower in high density seeds for both A (P=0.01) and B (P=0.05). Medium seed size selections only demonstrated significant change for A, with an increase (P=0.01) in low density seed. Large seed size selections showed increases for A (P=0.01) in low density seed and for B (P=0.05) in high density seed.

Plants per plot in small size seed selections were lower in low (P=0.05) and high (P=0.01) density seeds of population A. Medium seed sizes showed higher numbers in both low (P=0.05) and high (P=0.01) density seeds of A, and lower numbers (P=0.05) in low density seed of B. Large seed size selections demonstrated increases over bulk in high density seeds of A (P=0.05) and in both low (P=0.01) and high (P=0.01) density seeds of B.

Seed emergence of bulk selections was higher for high density seed in A. Seed emergence in small seed size selections was lower for

TABLE 16. Segregating Populations: The Effects of Selection for Seed Density on Agronomic Characteristics of Hexaploid Triticale-Point Field

Line and Size Comparison	Seed Density	Plot Yield (g)	Plants/ Plot	Seed Emergence	Plant Height (cm)	Tillers/ Plant	Fertile Tillers/ Plant	Spikelets/ Spike	Seeds/ Spike	Selected Plant Yield (g)
6TA204 X MT28-1 F3										
Bulk	L	384.8	94.3	104.3	70.38	7.53	5.93	22.0	31.6	6.58
	H	471.8	97.5	115.8	68.88	5.95	5.08	22.2	37.0	5.34
S - B	L	- 56.8*	- 5.3*	1.0	-1.83*	0.88**	0.60*	-0.3	3.8**	0.02
	H	-137.8**	-11.0**	-13.3**	-6.75**	-0.03	-0.98**	0.1	-5.5**	-0.64
M - B	L	112.0**	6.0*	11.5**	1.40*	0.53	0.23	-0.7**	0.7	-0.38
	H	6.8	11.8**	11.5**	4.63**	0.05	0.15	0.2	6.5**	1.81**
L - B	L	96.8**	- 0.3	7.3**	3.38**	-0.63*	-0.20	-0.7**	7.1**	-0.32
	H	- 36.8	6.0*	2.0	5.05**	0.45	0.30	0.2	0.9	1.12**
6A405 X 70HN470 F3										
Bulk	L	347.3	93.8	106.0	66.28	6.45	5.40	20.3	27.3	5.77
	H	306.8	88.3	102.3	65.80	6.03	4.88	19.9	26.6	4.36
S - B	L	- 13.3	3.3	8.8*	0.58	-0.23	0.03	0.1	3.3**	0.71
	H	- 51.8*	1.3	- 1.0	3.13**	0.08	0.25	-0.4*	0.6	0.39
M - B	L	- 25.8	- 7.8*	- 5.8	4.00**	0.15	-0.30	-0.7**	1.8	-0.35
	H	6.0	0.8	0.3	2.43**	1.65**	0.83**	0.6**	-2.1	1.90**
L - B	L	14.8	7.3**	11.0**	3.73**	3.15**	1.85**	0.5**	5.9**	2.39**
	H	56.3*	14.5**	14.5**	1.18	0.38	0.58	0.5**	1.8	1.05**
LSD (P=0.05)		43.4	5.1	5.4	1.39	0.55	0.48	0.3	2.2	0.83
LSD (P=0.01)		57.6	6.8	7.1	1.84	0.72	0.63	0.5	2.9	1.10

high density seeds in A (P=0.01) and higher in low density seeds of B (P=0.01). Medium seed size selections showed higher emergence in both seed densities of A (P=0.01) and lower values in low density seed of B (P=0.05). Large seed selections were higher in low density seed of A (P=0.01) and both densities of B (P=0.01).

Average plant height in small seed selections showed decreases for both low density (P=0.05) and high density seeds (P=0.01) of A and an increase in high density seeds of B (P=0.01). Medium size seeds were higher in both low (P=0.05) and high (P=0.01) density seeds of A, and also in both densities of B (P=0.01). Large sized seeds were higher in both densities of A (P=0.01) and in low density seeds of B (P=0.01).

The number of tillers per plant in bulk seed lots were lower in high density than low density seeds of A. Small seed size selections showed higher numbers in low density seeds of A (P=0.01). Medium seed sizes were higher for high density seeds of B (P=0.01). Large seeds showed a decrease for low density seeds of A (P=0.05) and an increase for low density seeds of B (P=0.01).

The number of fertile tillers per plant in bulk seed selections were lower for high density than for low density seed of both A and B. Small seed selections showed an increase for low density (P=0.05) and a decrease for high density (P=0.01) seeds of A. Medium seeds were higher in high density seeds of B (P=0.01). Large size seed selections were higher for both low (P=0.01) and high density (P=0.05) seeds of B.

Spikelets per spike in small seed selections were lower in low density seeds of A (P=0.05) and high density seeds of B (P=0.05). Medium seed size selections demonstrated lower numbers for low density seeds of both A and B (P=0.01) and an increase in high density seeds of B (P=0.01). Large seeds showed a decrease for low density seeds of A (P=0.01), and increases for both low and high density seeds of B (P=0.01).

Seeds per spike were higher in bulk seed selections of high density seeds than for low density seeds of A. Small seed selections showed higher values for low density seeds of both A and B (P=0.01), and a decrease for high density seeds of A (P=0.01). Medium seed size selections were higher in high density seeds of B (P=0.01). Large seed sizes demonstrated increases in low density seed for both A and B (P=0.01).

Average plant yield in bulk seed selections was lower in high density seed than for low density seed in both populations. Small seed selections were not significantly different from bulk in either population for either density. Medium seed size selections showed increases for high density seeds of both A and B (P=0.01). Large seed size selections demonstrated increases for high density seeds of A (P=0.01) and for both high and low density seed of B (P=0.01).

Correlation of plot yields with agronomic characters

The correlation of plot yields with agronomic characters for both high and low density seeds of the three advanced lines and two segregating populations grown at the Point Field are presented in Table 17.

There was no consistent trend for effect of density level among the three advanced lines. Plants per plant was positively correlated with plot yield in both low and high density seed selections of ITYN-6 (P=0.01) and in high density seed of Rosner (P=0.05). Seed emergence showed significant positive correlations with plot yield for high density seed of ITYN-6 (P=0.01) and Rosner (P=0.05). Plant height was positively correl-

TABLE 17. Correlation Coefficients (x 100) of Plot Yields with Agronomic Characteristics at Point Field for Low and High Density Seed- All Seed Sizes Combined

	Advanced Lines						Segregating Populations			
	ITYN-6		70HN458		Rosner		6TA204 X MT28-1 F3		6A405 X 70HN470 F3	
Seed Density	L	H	L	H	L	H	L	H	L	H
1. Plants/plot	63**	77**	40	8	42	51*	35	39	29	31
2. Seed Emergence	45	61**	40	- 3	37	51*	39	44	33	24
3. Plant Height (cm)	49*	69**	40	74**	57*	71**	77**	50*	30	40
4. Tillers/ Plant	2	54*	39	16	8	37	10	18	50*	59*
5. Fertile Tillers/ Plant	21	63**	37	25	17	37	44	44	61**	72**
6. Spikelets/ Primary Spike	-33	64**	-54*	9	36	22	-11	4	30	31
7. Seeds/ Primary Spike	28	37	20	28	-20	47	40	12	28	13
8. Selected Plant Yield (g)	18	58*	33	15	11	52*	49*	25	51*	43

* significant at 0.05 level

** significant at 0.01 level

L low density seed

H high density seed

ated with plot yield at significant levels for low density seeds of ITYN-6 and Rosner (P=0.05) and for high density seed of all three lines (P=0.01). The number of tillers per plant only showed a significant positive correlation with plot yield for high density seeds of ITYN-6 (P=0.05), as did the number of fertile tillers per plant (P=0.01). The number of spikelets per spike showed a significant positive correlation with plot yield in high density seed of ITYN-6 (P=0.01) and a significant negative correlation in low density seeds of 70HN458 (P=0.05). There was a significant positive correlation of average plant yield with plot yield in high density seeds of ITYN-6 (P=0.05).

There were contrasting trends in the two segregating populations. Population A showed significant positive correlations between plot yield and plant height in both low (P=0.01) and high (P=0.05) density seeds. In population B there were significant positive correlations between plot yield and the number of tillers per plant in both low and high density seed (P=0.05) and also for plot yield with the number of fertile tillers for both low and high density seed (P=0.01). Individual plant yield showed a significant positive correlation with plot yield in the low density seeds of B (P=0.05).

Effect of high over low seed density

The differences between and high and low seed density selections for all seed sizes of the three advanced lines and two segregating populations grown at the Point Field are presented in Table 18.

In the three advanced lines, high density seeds produced higher plot yields for all seed sizes for both ITYN-6 and 70HN458 and lower yields for all sizes of Rosner. However, none of these differences were

TABLE 18. The Effect of Seed Density Selection on Several Agronomic Characteristics in Hexaploid Triticale- Advanced Lines: Point Field Difference of High over Low Density Seed

Line and Size	Plot Yield (g)	Plants/ Plot	Seed Emergence	Plant Height (cm)	Tillers/ Plant	Fertile Tillers/ Plant	Spikelets/ Spike	Seeds/ Spike	Selected Plant Yield (g)
1. ITYN-6									
Bulk	209.0	17.0	21.8	-0.08	-0.95	-0.98	0.2	-4.1	-2.37
Small	48.5	0.5	- 3.0	3.33	0.33	0.48	-0.6	1.2	0.67
Medium	135.0	- 4.8	- 7.3	3.55	0.50	0.20	0.2	-0.9	0.38
Large	63.0	3.8	12.3	2.33	-0.13	-0.28	0.1	1.1	0.61
2. 70HN458									
Bulk	166.8	1.8	0.5	1.70	1.03	1.10	0.3	2.3	2.04
Small	171.0	28.8**	35.0**	2.95	0.45	0.45	-0.6	2.7	1.49
Medium	87.8	11.0	14.0	0.23	-0.63	-0.80	-0.2	-4.8	-2.30
Large	28.5	0.8	- 1.3	1.23	0.23	0.05	0.1	2.6	0.80
3. Rosner									
Bulk	- 69.3	2.3	1.5	0.55	0.63	1.00	-0.3	0.0	1.11
Small	- 16.0	7.5	6.8	-3.35	0.65	0.75	0.2	3.8	1.67
Medium	- 62.8	3.8	6.5	0.75	-0.10	-0.35	0.4	-2.8	-0.60
Large	- 14.8	- 3.0	14.0	0.25	-0.38	-0.53	0.2	4.7	0.17
LSD (P=0.05)	279.4	19.7	20.5	7.04	1.82	1.73	1.3	7.3	3.08
LSD (P=0.01)	370.5	26.2	27.3	9.34	2.42	2.29	1.7	9.7	4.09

TABLE 18. (Continued) The Effect of Seed Density Selection on Several Agronomic Characteristics in Hexaploid Triticale- Difference of High Over Low Density Seed- Segregating Populations: Point Field

Population and Size	Plot Yield (g)	Plants/ Plot	Seed Emergence	Plant Height (cm)	Tillers/ Plant	Fertile Tillers/ Plant	Spikelets/ Spike	Seeds/ Spike	Selected Plant Yield (g)
A. 6TA204 X MT28-1									
Bulk	87.0	3.3	11.5	1.50	-1.58	-0.85	0.2	5.5	-1.25
Small	6.0	- 2.5	- 2.8	-6.43	-2.48**	-2.43**	0.5	- 3.8	-1.91
Medium	- 18.3	9.0	11.5	1.73	-2.05	-0.93	0.4	11.3**	0.94
Large	- 46.5	9.5	6.3	0.18	-0.50	-0.35	0.3	- 0.7	0.19
B. 6A405 X 70HN470									
Bulk	- 40.5	- 5.5	- 3.8	-0.48	-0.43	-0.53	-0.4	- 0.7	-1.41
Small	- 70.0	-10.0	-13.5	2.08	-0.13	-0.30	-0.8	- 3.4	-1.73
Medium	- 8.8	3.0	0.3	-2.05	1.08	0.60	0.9	4.6	0.85
Large	1.0	1.8	- 0.3	3.03	-3.20**	-1.80	0.5	- 4.8	-2.75
LSD (P=0.05)	279.4	19.7	20.5	7.04	1.82	1.73	1.3	7.3	3.08
LSD (P=0.01)	370.5	27.3	27.3	9.34	2.42	2.29	1.7	9.7	4.09

significant. Seed emergence showed significant increases for high over low density seeds in bulk selections of ITYN-6 (P=0.05) and small seed selections of 70HN458 (P=0.01). Plants per plot were also significantly higher in high density seeds for small seed selections of 70HN458 (P=0.01).

The segregating populations showed no consistent trend for plot yield over the different seed sizes, with only small differences between high and low density seeds, none of them significant. No trend was apparent in the various agronomic characteristics. The number of tillers per plant demonstrated decreases in high density seeds for small sizes of A (P=0.01) and large sizes of B (P=0.01). Significant decreases for the number of fertile tillers per plant were also shown for high density seeds in the small seed class of A (P=0.01) and the large seed class of B (P=0.05). A significant increase in the number of seeds per spike was present in high density seeds of medium seed size selections in A (P=0.01).

Advanced lines at West Field

Plot yields of high density seed bulks were lower than those from low density seed in 70HN458 and Rosner (Table 19). Small seed selections were lower in low density seed for ITYN-6 (P=0.01) and 70HN458 (P=0.01), and in high density seed of 70HN458 (P=0.01) as compared with bulks. Medium seed size selections showed a lower yield in 70HN458 (P=0.01) and higher yield in Rosner (P=0.01) for low density seed, and an increase in high density seeds of ITYN-6 and Rosner (P=0.01). Large seed selections were higher for all three lines at both densities (P=0.01), increases being larger for low densities for all three.

Plants per plot and seed emergence were lower for bulk seed in

TABLE 19. Advanced Lines: The Effects of Selection for Seed Density on Agronomic Characteristics of Hexaploid Triticale- West Field

Line and Size Comparison	Seed Density	Plot Yield (g)	Plants/ Plot	Seed Emergence	Plant Height (cm)	Tillers/ Plant	Fertile Tillers/ Plant	Spikelets/ Spike	Seeds/ Spike	Selected Plant Yield (g)
ITYN-6										
Bulk	L	528.3	86.8	96.8	67.58	6.78	5.93	16.8	32.2	5.95
	H	524.5	90.3	100.3	65.48	7.70	6.60	16.4	30.2	5.99
S - B	L	- 75.3**	- 5.5*	- 5.5*	-0.33	0.75**	0.98**	0.1	-0.4	1.06**
	H	- 52.5	0.5	0.5	0.08	-0.88**	-0.78**	0.7	-1.2	-0.62**
M - B	L	- 3.3	0.5	0.5	-2.05**	0.20	0.23	0.3	0.4	0.40
	H	37.3**	13.0**	13.0**	0.83	-0.80	-0.23	0.7**	1.9**	0.16
L - B	L	132.0**	20.0**	20.0**	-0.75	0.23	0.15	0.6**	-0.2	0.11
	H	77.8**	9.3**	9.3**	2.05**	-0.55*	-0.53*	0.7**	3.2**	0.72**
70HN458										
Bulk	L	631.8	103.8	113.8	65.85	7.23	5.93	17.8	34.7	6.43
	H	548.8	90.0	100.0	66.28	7.25	6.00	17.8	37.3	6.75
S - B	L	-178.5**	-22.0**	-22.0**	-1.60**	-0.20	0.40	-0.5**	0.9	0.25
	H	- 97.3**	6.5**	6.5**	-1.98**	-0.30	-0.53**	-0.2	-3.4**	-0.94**
M - B	L	-116.5	-16.8**	-16.8**	-0.93	-0.53*	0.25	-0.2	3.1**	0.56*
	H	5.3	4.5*	4.5*	-2.83**	-0.55*	-0.38	-0.3	-1.4*	-0.94**
L - B	L	120.5**	3.0	3.0	-2.28**	-0.18	-0.25	-0.2	-3.9**	0.49*
	H	84.8**	17.0**	17.0**	-0.53	-1.40**	-0.95**	-0.5**	-2.7**	-1.39**
Rosner										
Bulk	L	600.3	93.0	103.0	79.83	7.98	7.75	19.6	41.6	8.24
	H	542.5	87.5	97.5	77.35	8.50	8.40	18.9	39.6	8.32
S - B	L	- 21.8	- 5.5	- 5.5	-0.43	0.30	0.38	-0.2	0.9	0.07
	H	15.3	11.0**	11.0**	-2.45**	-1.45**	-1.55**	0.2	-0.2	-1.50**
M - B	L	57.5**	1.3	1.3	0.80	1.50**	1.48**	-0.1	-0.9	0.64**
	H	131.0**	21.0**	21.0**	-0.25	-0.33	-0.43*	0.6**	1.1	-0.83**
L - B	L	120.5**	3.0	3.0	-2.28**	-0.18	-0.25	-0.2	-3.9**	0.49*
	H	61.3**	16.5**	16.5**	0.53	-0.65**	-0.68**	0.6**	-1.1	-1.03**
LSD (P=0.05)		26.6	4.4	4.4	0.96	0.42	0.41	0.4	1.4	0.46
LSD (P=0.01)		35.3	5.9	5.9	1.27	0.56	0.54	0.5	1.8	0.60

high than form low density seed in 70HN458, with little difference in the other two lines. Small seed selections demonstrated decreases in low density seed of ITYN-6 (P=0.05), 70HN458 (P=0.01) and Rosner (P=0.05), while there were increases in high density seeds of 70HN458 (P=0.05) and Rosner (P=0.01). Medium seed selections produced a decrease in low density seeds of 70HN458 (P=0.01) and increases in high density seeds of ITYN-6 (P=0.01), 70HN458 (P=0.05) and Rosner (P=0.01). Large seed size selections were higher in low density seed for ITYN-6 (P=0.01), and in high density seed for all three lines (P=0.01).

Average plant height for bulk seed selections was lower for high density than for low density seed in ITYN-6 and Rosner. Small seed selections were lower for both low and high density seed in 70HN458 (P=0.01) and for high density seed in Rosner (P=0.01) than for bulks. Medium sized seed showed decreases for low density seed of ITYN-6 (P=0.01) and high density seed of 70HN458 (P=0.01). Large seed selections demonstrated decreases in low density seed of 70HN458 (P=0.01) and Rosner (P=0.01) and an increase in high density seed of ITYN-6 (P=0.01).

The number of tillers per plant in bulk seed selections were higher in high density seed than in low density seed for ITYN-6. Small seed selections demonstrated increases in low density seed of ITYN-6 (P=0.01) and decreases in high density seed of ITYN-6 (P=0.01) and Rosner (P=0.01). Medium seed size selections were higher in low density seeds of Rosner (P=0.01) and lower in high density seeds of 70HN458 (P=0.05). Large seed sizes showed lower numbers in high density seed for ITYN-6 (P=0.05), 70HN458 (P=0.01) and Rosner (P=0.01).

The number of fertile tillers per plant in small seed selections was higher in ITYN-6 (P=0.01) for low density seed, and lower for high density seed in ITYN-6 (P=0.01), 70HN458 (P=0.01) and Rosner (P=0.01). Medium seed sizes were lower in high density seed of Rosner (P=0.05) and higher in low density seeds of Rosner (P=0.01). Large seed sizes showed lower numbers in high density seed of all three lines (P=0.01).

Spikelets per spike were lower in low density seeds of 70HN458 (P=0.01) for small seed selections. Medium seed sizes were higher than bulks in high density seeds of ITYN-6 (P=0.01) and Rosner (P=0.01). Large seeds showed an increase in low density seeds of ITYN-6 (P=0.01), with increases for high density seeds of ITYN-6 (P=0.01) and Rosner (P=0.01), and a decrease in 70HN458 (P=0.01).

Seeds per spike in bulk selections were lower in high density seeds for ITYN-6 and Rosner than for low density seeds, while low density seeds were lower in 70HN458. Small seed selections produced a decrease for high density selections of 70HN458 (P=0.01). Medium size seeds were higher in ITYN-6 (P=0.01) and lower in 70HN458 (P=0.05) for high density seeds, while low density seeds showed an increase for 70HN458 (P=0.01). Large seed selections showed lower numbers in low density seeds of 70HN458 (P=0.01) and Rosner (P=0.01), with an increase in ITYN-6 (P=0.01) and a decrease in 70HN458 (P=0.01) for high density seed.

Average plant yield in small seed selections showed an increase for ITYN-6 (P=0.01) in low density seed and decreases for all three lines (P=0.01) for high density seed. Medium seed sizes were higher for 70HN458 (P=0.05) and Rosner (P=0.01) in low density seed and lower for these two lines (P=0.01) in high density seed. Large seed selections demonstrated increased yields for 70HN458 (P=0.05) and Rosner (P=0.05) in low density seed, with an increase in ITYN-6 (P=0.01) and decreases in 70HN458 (P=0.01) and Rosner (P=0.01) for high density seed.

Segregating populations at West Field

Plot yields in bulk selections (Table 20) of population A was lower in high density seeds than for low density seeds, while there was little change for B. Small seed selections demonstrated no significant change for either population at either density. Medium seed selections were lower (P=0.05) for low density and higher (P=0.05) for high density seeds in A, with no significant change in B. Large seed selections produced a decrease for A (P=0.05) in low density seed and an increase for B (P=0.05) in high density seed.

Plants per plot and seed emergence in small seed sizes were lower for B with low density seed. Medium seed sizes produced increases for both seed densities in A (P=0.01) over bulk, but in B a decrease in low density seed (P=0.01) and an increase in high density seed (P=0.05). Large seed sizes were higher (P=0.01) in low density seeds of A and in high density seeds of B (P=0.01).

Average plant height in small seed selections was low for both populations in both seed densities (P=0.01). Medium seed sizes showed an increase over bulks for low density seeds of A (P=0.01) and decreases for high density seeds of A (P=0.01) and low density seeds of B (P=0.01). Large seed selections were lower for both seed densities of A (P=0.01) and for low (P=0.01) and high (P=0.05) density seeds of B.

The number of tillers per plant in bulk seed lots was higher for high density seed selections of A and low density selections of B. In small seed size selections the number was higher than bulks in both low

TABLE 20. Segregating Populations: The Effects of Selection for Seed Density on Agronomic Characteristics of Hexaploid Triticale-West Field

Line and Size Comparison	Seed Density	Plot Yield (g)	Plants/ Plot	Seed Emergence	Plant Height (cm)	Tillers/ Plant	Fertile Tillers/ Plant	Spikelets/ Spike	Seeds/ Spike	Selected Plant Yield (g)
6TA204 X MT28-1 F3										
Bulk	L	328.3	89.0	99.0	70.08	7.20	5.75	21.5	30.0	5.00
	H	271.8	86.8	96.8	71.08	8.08	6.55	22.0	29.5	5.28
S - B	L	- 7.3	- 3.0	- 3.0	-1.88**	0.13	0.35	0.3	1.3	0.41
	H	- 7.3	- 4.0	- 4.0	-3.25**	0.05	-0.63**	-0.9	-4.3**	-0.73**
M - B	L	-32.0*	6.0**	6.0**	2.50**	1.40**	1.25**	0.6**	-3.1**	0.98**
	H	39.0*	8.0**	8.0**	-2.80**	-0.20	-0.13	0.3	-0.9	0.30
L - B	L	-26.5*	6.3**	6.3**	-1.83**	0.55*	0.38	0.7**	-4.3**	-0.39
	H	17.8	4.0	4.0	-2.40**	-0.93**	-0.80**	-0.8**	-6.5**	-0.58
6A405 X 70HN470 F3										
Bulk	L	258.8	95.0	105.0	67.50	8.20	6.95	19.7	24.6	5.02
	H	255.8	92.3	102.5	66.93	7.55	6.18	19.0	19.2	4.44
S - B	L	-24.0	-13.8**	-13.8**	-1.30	0.73**	-0.03	-0.2	-4.9**	-0.42
	H	- 3.0	2.3	2.3	-2.93**	0.73	0.05	-0.1	-0.9	-0.26
M - B	L	-10.0	- 5.8**	- 5.8**	-2.05**	0.28	-0.33	-0.7**	-4.2**	0.12
	H	- 3.8	4.8	4.8	0.15	0.63**	1.00**	-0.5**	3.9**	0.83**
L - B	L	1.8	- 1.0	- 1.0	-2.33**	0.48*	-0.05	-0.8**	-4.4**	-0.78**
	H	32.3*	15.0**	15.0**	-1.25*	0.25	0.35	-0.1	1.5*	-0.24
LSD (P=0.05)		26.5	4.4	4.4	0.95	0.42	0.40	0.4	1.4	0.46
LSD (P=0.01)		35.1	5.8	5.8	1.28	0.55	0.53	0.5	1.8	0.60

and high seed densities of B (P=0.01). Medium size seeds showed increases in low density seeds of A (P=0.01) and high density seeds of B (P=0.01). Large seed sizes were higher in low density seeds of both populations (P=0.05), and lower in high density seeds of A (P=0.01).

The number of fertile tillers per plant in bulk seed lots was higher for high density seeds in population A and low density seeds in population B. Small seed selections showed no significant difference from bulks in either population at either density. Medium seed sizes were higher in low density seeds of A (P=0.01) and high density seeds of B (P=0.01). Large seed sizes showed a decrease in high density seed of A (P=0.01).

The number of spikelets per spike was higher in high density seeds for population A and in low density seeds for population B in bulk seed lots. Small seed size selections were not significantly different from bulks for either population at either density. Medium seed sizes produced increases in A (P=0.01) and decreases in B (P=0.01) for low density seeds and a decrease for high density seeds in B (P=0.01). Large seed size selections were higher in A (P=0.01) and lower in B (P=0.01) for low density seed and lower in A (P=0.01) for high density seed.

The number of seeds per spike was lower in high density seeds than in low density seeds for bulk seed lots of population B. Small seed selections showed a decrease from bulks in low density seeds of B (P=0.01) and high density seeds of A (P=0.01). Medium seed size selections were lower in low density seeds of A (P=0.01) and B (P=0.01), and higher in high density seeds of B (P=0.01). Large seed size selections showed decreases in low density seeds of A (P=0.01) and B (P=0.01), an increase in high density seeds of B (P=0.05) and a decrease in high density seeds of A (P=0.01).

Average selected plant yield was lower in high density than low density seed of bulk lots of population B. Small seed size selections were lower than bulks in high density seeds of A (P=0.01). Medium seed selections demonstrated increases in low density seed of A (P=0.01) and high density seed of B (P=0.01). Large seed size selections showed decreases in high density seed of A (P=0.05) and low density seed of B (P=0.01).

Correlation of plot yields with agronomic characters

Correlation of plot yields with agronomic characters for both the advanced lines and the segregating populations of high and low density seed grown at the West Field are presented in Table 21.

The three advanced lines showed different trends, with ITYN-6 and Rosner showing similar correlations for most characters, while 70HN458 reacted differently. Plants per plot and seed emergence showed positive correlations with plot yield for both high and low density seed in ITYN-6 (P=0.01) and Rosner (P=0.05) and in low density seed of 70HN458 (P=0.01). Plant height was significantly correlated with plot yield in high density seed of ITYN-6 (P=0.05) and Rosner (P=0.01) and for both high and low density seed in 70HN459 (P=0.01). Seeds per spike showed significant positive correlations in high density seeds of ITYN-6 (P=0.01), while individual plant yield was significant in high density seeds of ITYN-6 (P=0.01) and Rosner (P=0.01).

The two segregating populations showed different trends. Plants per plot and seed emergence only showed significant positive correlations

TABLE 21. Correlation Coefficients (x 100) of Plot Yields with Agronomic Characteristics at West Field for Low and High Density Seed- All Seed Sizes Combined

	Advanced Lines						Segregating Populations			
	ITYN-6		70HN458		Rosner		6TA204 X MT28-1 F3		6A405 X 70HN470 F3	
Seed Density	L	H	L	H	L	H	L	H	L	H
1. Plants/plot	86**	60**	88**	34	49*	49*	52*	66**	30	38
2. Seed Emergence	86**	60**	88**	34	49*	49*	52*	66**	30	38
3. Plant Height (cm)	8	54*	70**	70**	34	64**	-15	14	65**	41
4. Tillers/ Plant	0	35	26	- 7	19	46	49*	12	- 7	1
5. Fertile Tillers/ Plant	- 4	42	5	19	22	46	40	56*	- 2	31
6. Spikelets/ Primary Spike	25	20	62*	18	25	38	- 2	4	59*	1
7. Seeds/ Primary Spike	-11	63**	3	17	5	23	19	17	38	18
8. Selected Plant Yield (g)	-10	72**	31	33	31	68**	56*	48*	37	3

* significant at 0.05 level

** significant at 0.01 level

L low density seed

H high density seed

with plot yield for low (P=0.05) and high (P=0.01) density seed of A. Plant height showed a significant positive correlation with plot yield in low density seeds of B (P=0.01). The number of tillers per plant showed significant positive correlations with plot yield in low density seeds of A (P=0.05), as did the number of fertile tillers per plant in high density seeds of A (P=0.05). The number of spikelets per spike was positively correlated with plot yield in low density seeds of B (P=0.05). Selected individual plant yield was positively correlated with plot yield in both low and high density seeds of population A (P=0.05).

Effect of high over low seed density

The differences between high and low density seed slections for the three advanced lines and two segregating populations grown at the West Field are presented in Table 22.

The three advanced lines showed no consistent trend for differences between high and low density seed in the different seed classes, with few significant differences present. A significant decrease for plot yield was present in high density seeds of the large seed size class in Rosner (P=0.05). Average plant height showed a decrease (P=0.05) for high density seed in the small seed class for Rosner.

Differences between high and low density seeds in the two segregating F3 populations were generally small, showing no consistent trend, with little significance. Average plant height demonstrated a significant decrease in high density seed of the medium seed size class for A (P=0.05). The number of seeds per spike showed a significant decrease in high density seeds of the small seed class in population A (P=0.05).

TABLE 22. The Effect of Seed Density Selection on Several Agronomic Characteristics in Hexaploid Triticale- Advanced Lines: West Field Difference of High over Low Density Seed

Line and Size	Plot Yield (g)	Plants/ Plot	Seed Emergence	Plant Height (cm)	Tillers/ Plant	Fertile Tillers/ Plant	Spikelets/ Spike	Seeds/ Spike	Selected Plant Yield (g)
1. ITYN-6									
Bulk	- 3.8	- 3.5	- 3.5	-2.10	0.93	0.68	-0.4	-2.0	0.05
Small	19.0	9.5	9.5	-1.70	0.70	-1.08	0.2	-2.8	-1.63
Medium	36.8	16.0	16.0	0.78	-0.08	0.23	0.0	-0.5	-0.20
Large	- 58.0	- 7.3	- 7.3	0.70	0.18	-0.05	-0.3	1.4	0.66
2. 70HN458									
Bulk	- 83.0	-13.8	-13.8	0.43	0.03	0.08	0.0	2.6	0.32
Small	1.8	14.8	14.8	0.05	-0.08	-0.85	0.4	-1.7	-0.87
Medium	38.8	7.5	7.5	-1.48	0.0	-0.55	-0.1	-1.8	-1.18
Large	9.8	9.0	9.0	0.45	-0.83	-0.88	0.4	-1.6	-1.24
3. Rosner									
Bulk	- 57.8	- 5.5	- 5.5	2.48	0.53	0.65	-0.7	-2.0	0.08
Small	- 64.3	11.0	11.0	-4.50*	-1.23	-1.28	-0.4	-3.1	-1.50
Medium	16.3	14.3	14.3	-3.53	-1.30	-1.25	-0.1	-0.1	-1.40
Large	-117.0*	8.0	8.0	0.38	0.05	0.23	0.1	0.7	-0.47
LSD (P=0.05)	113.0	17.3	17.3	4.28	1.36	1.39	1.3	4.9	1.64
LSD	149.8	23.0	23.0	5.68	1.80	1.84	1.7	6.4	2.17

TABLE 22. (Continued) The Effect of Seed Density Selection on Several Agronomic Characteristics in Hexaploid Triticale- Difference of High Over Low Density Seed- Segregating Populations: West Field

Population and Size	Plot Yield (g)	Plants/ Plot	Seed Emergence	Plant Height (cm)	Tillers/ Plant	Fertile Tillers/ Plant	Spikelets/ Spike	Seeds/ Spike	Selected Plant Yield (g)
A. 6TA204 X MT28-1									
Bulk	- 56.5	- 2.3	- 2.3	1.00	0.88	0.80	0.5	-0.5	0.28
Small	- 56.5	- 3.3	- 3.3	-0.38	0.80	-0.18	-0.7	-6.1*	-0.85
Medium	14.5	0.3	0.3	-4.30*	-0.73	-0.58	0.1	1.6	-0.41
Large	- 12.3	- 4.5	- 4.5	0.43	-0.60	-0.38	-1.0	-2.8	0.08
B. 6A405 X 70HN470									
Bulk	- 3.0	- 2.8	- 2.8	-0.58	-0.65	-0.78	-0.8	-5.5	-0.58
Small	18.0	14.3	14.3	-2.20	-0.65	-0.70	-0.6	-1.5	-0.42
Medium	3.3	7.8	7.8	1.63	-0.30	0.55	0.5	2.6	0.13
Large	27.5	13.3	13.3	0.50	-0.88	-0.38	0.1	0.4	-0.04
LSD (P=0.05)	113.0	17.3	17.3	4.28	1.36	1.39	1.3	4.9	1.64
LSD (P=0.01)	149.8	23.0	23.0	5.68	1.80	1.84	1.7	6.4	2.17

Embryo and mature plant relationship

Culture of embryos from different sizes seeds

The relationship between embryo dimensions and mature plant part weights showed different responses among the three advanced lines and the two segregating F3 populations, and also in some cases between different seed sizes within a group. Relationships between seed dimensions and that of embryos excised from them showed differences between seed size classes within a given group.

Correlation of embryo dimensions with seed dimensions and mature plant part weights for all three seed sizes together for each advanced line and segregating population are presented in Table 23. In all of the three lines and two segregating populations, the embryo lengths and widths were positively correlated with seed length and width (P=0.01). The correlations of embryo dimensions with the weight of mature plant parts differed among the various lines and populations. In ITYN-6 there were significant positive correlations between the actual embryo length and the weight of the mature plant head (P=0.01) and stem (P=0.05). Embryo width, however, showed a negative correlation (P=0.05) with mature dry root weight. In 70HN458 there was no significant correlation of embryo length with any mature plant part, while there was a significant correlation between embryo width and both head weight (P=0.01) and leaf weight (P=0.05). Rosner showed no significant correlation between embryo dimensions and any mature plant part weights.

Correlations were found between embryo length and head weight (P=0.05), leaf weight (P=0.05), and stem weight (P=0.01) in the segregating population A (6TA204 X MT28-1:F3), as well as between embryo width and head weight

TABLE 23. Correlation Coefficients (x 100) of Embryo Dimensions with Seed Dimensions and Mature Plant Part Weights- All Seed Sizes Combined

	Head Weight	Leaf Weight	Stem Weight	Root Weight	Seed Length	Seed Width
1. <u>ITYN-6</u>						
Embryo Length	55**	18	40*	3	66**	52**
Embryo Width	11	- 9	9	-36*	61**	56**
Scutellum Length	46**	5	29	-14	74	65
2. <u>70HN458</u>						
Embryo Length	25	25	21	8	53**	62**
Embryo Width	52**	37*	30	3	54**	73**
Scutellum Length	31	34	29	19	67**	62**
3. <u>Rosner</u>						
Embryo Length	7	15	6	2	46**	62**
Embryo Width	- 8	13	24	3	61**	70**
Scutellum Length	20	24	9	-11	46**	63**
4. <u>6TA204 X MT28-1 F3</u>						
Embryo Length	43*	46**	47**	16	70**	70**
Embryo Width	37*	22	33	11	46**	64**
Scutellum Length	26	50**	54**	19	69**	65**
5. <u>6A405 X 70HN470 F3</u>						
Embryo Length	5	-19	24	20	75**	61**
Embryo Width	-18	-11	13	12	57**	50**
Scutellum Length	- 5	-13	22	17	72**	60**

* significant at 0.05 level

** significant at 0.01 level

(P=0.05). The other segregating population, B (6A405 X 70HN470:F3), showed no correlation between embryo length and width with any of the mature plant part weights.

Each group was also analysed separately for each seed size category to ascertain if any significant correlations existed within a specific size selection (Tables 24 and 25). ITYN-6 showed positive correlations between embryo measurements and seed dimensions, but no significant correlation between embryo measurements and any mature plant part weights within the small seed size class. There was no significant correlation between embryo dimensions and either seed dimensions or mature plant part weights for either the medium or large seed classes.

Line 70HN458 showed a correlation of embryo length with seed length (P=0.05), but was not significant with seed width, while embryo width showed positive significant correlations with both seed length and seed width (P=0.05) in the small seed class. A negative correlation, (P=0.05) was shown between mature plant head weight and embryo width, with no significant correlations between embryo dimensions and any other mature plant part weights. The medium seed size class showed no significant correlations between embryo dimensions and seed dimensions, and a negative correlation (P=0.05) between embryo length and mature plant leaf, stem and root weight. The large seed size class showed a positive correlation of embryo length with seed length (P=0.01), and of embryo width with seed width (P=0.05), but no correlation between embryo dimensions and mature plant part weights.

In Rosner there was no significant correlation between embryo length and seed length for the small seed class, but a significant correlation (P=0.05) between embryo width and seed width. Positive

TABLE 24. Correlation Coefficients (x 100) of Embryo Dimensions with Seed Dimensions and Mature Plant Part Weights within Seed Size Groups in Three Advanced Lines of Hexaploid Triticale

Line and Seed Size	Head Weight	Leaf Weight	Stem Weight	Root Weight	Seed Length	Seed Width
1. ITYN-6						
Small Size Seed						
Embryo Length	39	-53	17	-49	94**	81**
Embryo Width	23	-34	18	-32	70*	74**
Scutellum Length	44	-56	11	-54	84**	68*
Medium Size Seed						
Embryo Length	-27	- 9	-13	27	- 5	-39
Embryo Width	17	6	18	-28	10	-25
Scutellum Length	-27	-21	-20	31	-26	- 9
Large Size Seed						
Embryo Length	57	41	40	54	55	- 6
Embryo Width	-54	-33	-41	-55	-33	17
Scutellum Length	40	-24	20	50	33	- 9
2. 70HN458						
Small Size Seed						
Embryo Length	-19	- 1	7	27	60*	54
Embryo Width	-63*	-30	-23	13	60*	69*
Scutellum Length	- 5	6	18	25	76**	37
Medium Size Seed						
Embryo Length	-50	-63*	-65*	-58*	-54	17
Embryo Width	11	-20	-12	-39	- 3	11
Scutellum Length	-47	-26	-50	- 2	- 6	- 7
Large Size Seed						
Embryo Length	-35	-36	-49	- 4	78**	10
Embryo Width	54	2	- 4	-30	7	70*
Scutellum Length	-30	-35	-41	- 4	73**	20
3. Rosner						
Small Size Seed						
Embryo Length	60*	70*	50	28	-10	24
Embryo Width	- 3	25	- 4	-25	19	71*
Scutellum Length	68*	71*	55	40	12	44
Medium Size Seed						
Embryo Length	-48	12	27	-38	57	51
Embryo Width	-67*	15	79**	2	9	44
Scutellum Length	-10	10	-17	-26	30	30
Large Size Seed						
Embryo Length	-27	-30	-33	-33	- 9	60*
Embryo Width	-17	- 4	-13	-17	56	35
Scutellum Length	-10	- 5	- 5	-56	18	77**

* significant at 0.05 level

** significant at 0.01 level

TABLE 25. Correlation Coefficients (x 100) of Embryo Dimensions with Seed Dimensions and Mature Plant Part Weights within Seed Size Groups in Two Segregating Populations of Hexaploid Triticale

Population and Seed Size	Head Weight	Leaf Weight	Stem Weight	Root Weight	Seed Length	Seed Width
A. 6TA204 X MT28-1 F3						
Small Size Seed						
Embryo Length	57	6	35	32	84**	64*
Embryo Width	23	-21	- 7	4	57	79**
Scutellum Length	55	21	40	21	80**	45
Medium Size Seed						
Embryo Length	45	42	27	-19	5	76**
Embryo Width	25	11	17	- 8	-48	39
Scutellum Length	29	37	25	-19	42	49
Large Size Seed						
Embryo Length	51	53	37	55	9	30
Embryo Width	63*	55	65*	57	15	17
Scutellum Length	16	57	57	72	4	-19
B. 6A405 X 70HN470 F3						
Small Size Seed						
Embryo Length	48	-12	43	2	49	- 7
Embryo Width	-21	-15	- 9	-42	36	19
Scutellum Length	22	15	49	25	49	30
Medium Size Seed						
Embryo Length	15	0	-26	-45	23	48
Embryo Width	9	15	- 3	-21	-28	62*
Scutellum Length	- 1	- 4	-37	-48	37	53
Large Size Seed						
Embryo Length	-28	-36	-31	8	29	- 8
Embryo Width	-12	- 6	- 4	27	48	-17
Scutellum Length	-13	-41	-16	5	35	-21

* significant at 0.05 level

** significant at 0.01 level

correlations (P=0.05) were demonstrated between embryo length and mature plant head and leaf weight. Medium seed size showed no significant correlation between embryo dimensions and seed dimensions, but a negative correlation (P=0.05) between embryo width and mature head weight and a positive correlation between embryo width and mature stem weight (P=0.01). Large sized seeds showed a positive correlation between embryo length and seed width (P=0.05) and no significant correlations between embryo dimensions and any mature plant part weights.

The segregating population A (6TA204 X MT28-1:F3) showed positive correlations between embryo length and both seed length (P=0.01) and seed width (P=0.05), as well as between embryo width and seed width (P=0.01), but no significant correlation between embryo dimensions and mature plant part weights in the small seed size selections. Medium sized seed showed only a positive correlation between embryo length and seed length (P=0.05), with no significant correlation between embryo measurements and mature plant part weights. Within the large seed size selections, there was no significant correlation between embryo and seed measurements, but there were positive correlations between embryo width and mature plant head and stem weights (P=0.05).

The other segregating population B (6A405 X 70HN470:F3) showed no significant correlations between embryo and seed dimensions or between embryo dimensions and mature plant part weights for small seed classes. In the medium seed selections there was a positive correlation between embryo width and seed width (P=0.05), but none between embryo dimensions and mature plant part weights. The large size seeds showed no significant correlations between embryo dimensions and seed dimensions or between embryo dimensions and mature plant part weights.

DISCUSSION

Visual selection for seed size in F2 populations

The small number of paired F2 progeny rows available for analysis reduced the precision of this series of experiments. Few degrees of freedom were available so that a large difference would have to be present in order to show statistical significance.

The fact that in all crosses, except 6531 X 6A405, all measured agronomic characteristics were higher in plants from selected large F2 seeds would indicate that initial selection for large seed should be made in the bulk F2 seed from single F1 plants. Each seed on a F1 plant is a distinctive F2 individual; as identification of superior genotypes at the earliest possible segregating generation increases the probability of their selection, effective selection at such an early generation should greatly increase the efficiency of a breeding programme.

Because individual F1 plants were grown in four inch pots in the greenhouse, the number of tillers produced by a single plant (5-6) was reduced, resulting in a yield of approximately 200-250 seeds per plant. Visual selection for the 10 largest and 10 smallest plump seed resulted in a selection intensity of 4-5%, a fairly high level. The total number of seeds available for the F2 of any one cross was probably below the level for selection of the theoretically optimum genotypes (Shebeski, 1967) if the number of genes controlling seed size is at all large.

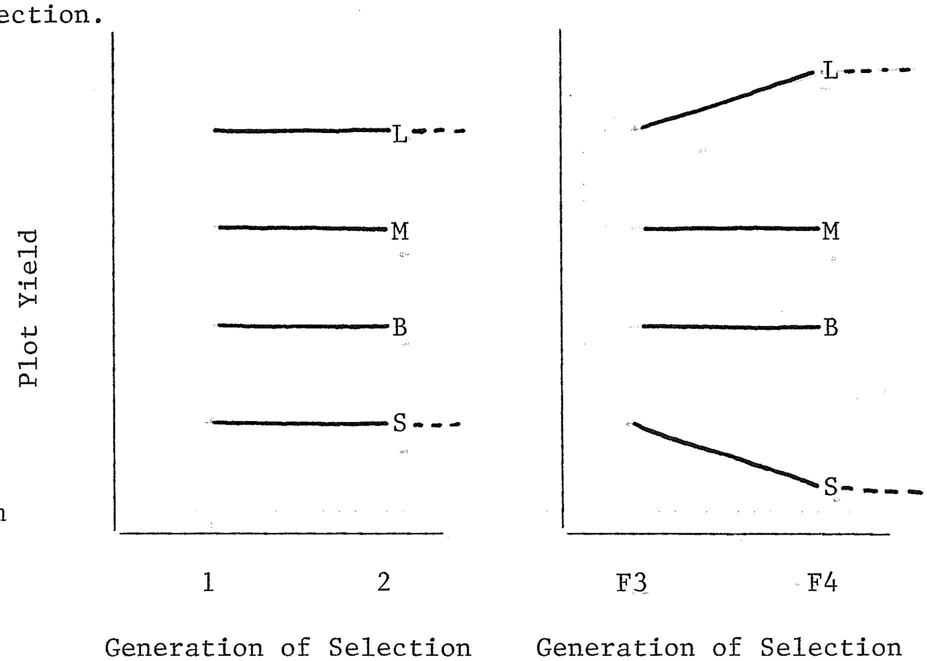
The comparison of plants originating from large and small seeds, tracing to different plants of line 6531 showed little difference between the two groups (none significant). As expected, selection for non-genetic differences in seed size had little effect on the performance of paired rows of widely spaced plants. In the segregating generations, however, rows originating from large seeds consistently showed superiority in some or all of the measured agronomic characteristics. Selection, therefore, for plant yield and other agronomic characters could be accomplished by selecting for large size in F2 seeds of segregating populations of hexaploid triticale.

The average number of spikelets per spike and seeds per spike indicated a higher fertility in four of the five crosses for selected large seeds, although in all cases even the higher fertility plants from the large F2 seed had a much lower fertility than the advanced line 6531. However, the increased yield from large seeded F2 selections did not result in an increased shift in the size of F3 seed. It was due to an increased number of seeds per plot due to higher plant survival and a higher number of fertile tillers per plant and seeds per spike. It is likely that further selection at the F3, and later generations, of such plants, under unprotected field conditions, would result in the same effects as those observed in the mass seed-size selections in replicated three-row plots. There would be interpollination which would result in further uncontrolled hybridization and a possible shift in the direction of the mean phenotype of the dominant pollen source. Any improvement of selection in early segregating generations of triticale must take into account the breeding system of the species. Programmes which have proven to be effective in wheat will not necessarily be applicable without modification.

Larger numbers of F1 plants from each cross, larger numbers of F2 seed from each F1 plant, and a higher intensity of selection would be needed to confirm the indications that selection for large size in F2 seed is an effective method for increasing single plant yield in segregating populations of hexaploid triticale. Even if this is demonstrated in populations of adequate size, it is difficult to extrapolate from the performance of widely spaced single plants to that of plants of the same genotype growing under the more crowded conditions of the optimum commercial seeding rate for cereal crops. Donald (1968) theorized that the cereal genotypes with the highest yield potential under the closed canopy conditions of commercial production would have the lowest performance under widely spaced plantings, due to low competitive ability. On the other hand, plants selected for high production and a strong competitive ability at wide spacings would lead to yield depression under close spacing due to mutual competition. Selection of individual spaced plants on the basis of performance has usually not been successful due to greater environmental than genotypic variation. Chebib, Helgason and Kaltsikes (1973) reported that environmental variation was greater than genotypic variation in segregating wheat plants at narrower plant spacings than those used in this section of experiments. However, the proper design and the use of suitable controls may permit identification of superior genotypes from spaced plants. Fasoulas (1973), with the use of the "honeycomb" design in which widely spaced F2 plants were compared with equally spaced neighbouring plants, was able to make effective selection for yield and quality in F2 plants and the resulting F3 families with the use of a suitable control variety. As much of the initial individual selections in cereal programmes are still being made on spaced plants, it would be important if the indications of a positive effect from the selection of large F2 seeds could be conclusively confirmed or denied.

Genetic selection in self-pollinating species

Selection for seed size in a theoretically homozygous line should be ineffective as there is only non-genetic variability. for any character. Such selection should not be affecting the genetic structure of the population, assuming that the line is completely homozygous, rather than a mixture of different homozygous lines. A second cycle of selection for the same seed size should not show any change in seed size or characters correlated with it when grown under the same environmental conditions as the first selection.



L - large

M - medium

B - bulk

S - small

Inbred Lines | Segregating Populations

Figure 5.

Figure 5. (Continued) Theoretical effect of selection for seed size on yield in inbred lines and segregating populations, assuming a positive correlation between seed size and yield.

Mass selection for seed size in a segregating population (if large seed size is positively correlated with increased grain yield) should theoretically cause a shift in plot yield over two generations (Figure 5). Large seeds may produce superior seed emergence or plant survival to maturity due to greater initial embryo size or greater available nutrient reserves in the seed. Other factors such as the greater number of fertile tillers or seeds per spike produced by plants emerging from large seeds may further contribute to higher yields. In such a case, fixation of genes for large seed size should result in increased yield for each generation of selection for large seed size until all favourable gene combinations for large seed size are fixed in the homozygous state, after which selection should have no further effect (Figure 5). Conversely, selection for small seed size should result in a continuous downward shift in plot yield, plant survival and any other factors which are positively correlated with large seed size, until all genes for small seed size are fixed in the homozygous state.

Whether this will happen will be determined by the number of genes controlling seed size and the type of gene action. In these investigations, the two cycles of selection on segregating populations were made on F3 and F4 seed. If the number of genes controlling seed size is small, homozygosity for seed size may already have been attained by the F3 population in both crosses, leaving very low genetic variability by the second cycle of selection.

The genetic advance in a completely self-pollinated crop is given by Allard (1966) as $G_s = k\sigma_A H$ where: G_S = genetic advance

k = selection differential (in standard deviation units)

(k = 2.64 (1% selection) ------------------------ 1.16 (30% selection))

H = heritability coefficient $= \frac{\sigma^2_a}{\sigma^2_A}$ σ^2_a = genotypic variance

σ^2_A = phenotypic variance

σ_A = phenotypic standard deviation of the lines in the source population

Lack of genetic advance may be due to low selection intensity on the source population, a lack of phenotypic diversity in the population and/or a low heritability of the character under selection. The magnitude of environmental effects on the character and the interaction of genotypic and environmental effects will also affect genetic advance.

The type of gene action will also affect improvement, with other than additive action changing the value for genetic advance. The types of gene action for quantitative characters have been described by Fasoulas (1973). Certain heterotic effects may be produced by co-dominant alleles at a single locus and these effects will be impossible to fix as they will be lost on attaining homozygosity. Types of epistatic action may be caused by dominant or additive action and the latter may be fixed in the homozygous state on further inbreeding. Hypostatic action by differing dominant or recessive genes from either parent may produce effects in the F1 and later generations (dominant) or the F2 and later generations (recessive) which can be greater than that of either of the parental lines. The larger the number of genes controlling the expression of seed size, the greater the number of cycles over which selection would be effective in fixing all the positive genes in the homozygous state. Conversely, the fewer gene differences for seed size present between the two parents of each segregating population, the shorter the number of generations required for the population to attain a high degree of homozygosity for this factor.

Initial selection for seed size

In the initial selection for seed size, the selections grown from large seeds significantly outyielded controls in all three of the advanced lines and the two segregating populations under investigation. The number of plants per plot was correlated with plot yield (P=0.01) in all of the five groups except for line #1 (Table 6). None of the indicators or components of yield recorded from the 10 plants sampled from each plot had a significant level of correlation with plot yield and variations in the number of plants surviving to harvest was the only significant component of yield for the three advanced lines. (In the spaced F2 plants, the number of fertile tillers per plant was correlated with plot yield in four of the five crosses). In the two segregating populations, Population A showed a positive correlation (P=0.05) between the number of seeds per spike and plot yield while Population B demonstrated negative correlations between plot yield and both the number of spikelets per spike (P=0.05) and seeds per spike (P=0.05). Preliminary selection appeared to be largely effective in increasing the survival to maturity of plants grown from large seeds. Selection on an individual plant basis appeared to be completely ineffective, as the average plant yield from the 10 plants selected in each plot had no significant correlation with plot yield in any of the five different groups.

On reviewing the data on the number of seeds and of spikelets per spike in all five groups, there were increased problems of sterility in the two segregating populations. The ratio of seeds/spikelet approached 3:1 in the three advanced lines while it was only about 2.5:1 in the segregating population A and less than 2:1 in segregating population B (Tables 4 and 5). Negative effects of small selections as compared with unselected bulk controls were most apparent in the F3 of population B with highly significant reductions (P=0.01) for both plants per plot and plot yield. The high degree of sterility in the cross can possibly be explained by its pedigree (6A405 X 70HN470). Gustafson and Zillinsky (1973) determined that the hexaploid triticale line "Armadillo" 70HN458, a line of the same descent as the male parent of this cross, had a chromosome of wheat (2D) substituted for rye chromosome 2R, and possibly a segment of 5D for one of 5R. It is probable that the same condition is present in 70HN470, in which case there will be a number of problems in crossing with triticales which contain a complete rye genome. Early generations from such a cross would be expected to contain a high proportion of aneuploids, resulting in a certain amount of sterility. If male fertility was affected more than female fertility, considerable outcrossing could take place under field conditions. Selection in such a case would not be effective unless random outcrossing was prevented.

Comparison of first and second cycles grown in the same year

The actual percentage of each seed size in the source populations and in the seed resulting from the two cycles of selection in both locations are shown for the large size selections of the two segregating populations (Table 26). The selection differential would in each case be based on the percentage of large seeds which were retained for the subsequent generation. As the percentage of seed retained from population

TABLE 26. Effect of Selection for Large Seed Size over Two Generations on the Percentage of Seeds Belonging to the Three Seed Classes

Seed Size	Location					
	Point Field			West Field		
	Source	1st Cycle	2nd Cycle	Source	1st Cycle	2nd Cycle
A. 6TA204 X MT28-1						
Large	18.2	16.3	25.0	18.2	16.6	19.4
Medium	31.4	38.5	42.4	31.4	36.1	39.0
Small	50.4	45.2	32.6	50.4	47.3	41.6
B. 6A405 X 70HN470						
Large	34.8	23.9	26.6	34.8	27.4	23.0
Medium	33.2	36.8	39.0	33.2	39.2	39.2
Small	32.0	39.3	34.4	32.0	33.4	37.8

A is only about one half that from B, it would be expected that this more intense selection differential would be more effective in shifting the seed size for the succeeding generation. This was in fact the case for population A at the Point Field. However, even for population A, the selection intensity was very low, and this could be one major factor for the general lack of response.

Analysis of the two segregating populations indicated that mass selection for seed size over two generations had not been effective as a method of increasing yield. In both of the two locations, the medium seed selections of both populations were the highest yielding at the second cycle, showing significant increases over unselected bulks, while the large selections showed no significant difference or a slight decrease. Superiority of medium size selections for A was due to an increase in the number of seeds per spike at the Point Field and in the number of fertile tillers at the West Field. Medium selections of population B demonstrated higher plant survival at the Point Field and higher numbers of seeds per spike at the West Field.

Neither the selections made from the theoretically inbred advanced lines or those from the segregating F3 and F4 populations fitted theoretical expectations for a completely self-pollinated species. Derera and Bhatt (1972) improved plot yields by two cycles of selection for large seed size in segregating F2 populations of bread wheat crosses (F3 and F4). However, the breeding system of the commercial hexaploid wheats differs considerably from that in most hexaploid triticales. Aneuploidy has not been an important factor in commercially grown lines of hexaploid wheat but it is present in varying proportions in many triticale lines which have been under selection for a number of generations (Tsuchiya, 1973; Weimarck, 1975). Such problems would tend to reduce male fertility more than female fertility and increase the possibility of outcrossing. Yeung and Larter (1972) reported that Rosner (advanced line #3 in this investigation), at that time the most advanced line of hexaploid triticale in Canada, exhibited about five percent outcrossing. In the primary spike of the plants sampled in each plot, a high degree of sterility was noted, with most selections of population B producing only about 1-1.5 seeds per spikelet. With this high degree of sterility, it is probable that there was a high degree of intercrossing, as male fertility is more likely to be adversely affected by abnormalities than female fertility.

Yeung and Larter (1972) demonstrated a high degree of cross pollination at distances up to 40 ft (12.2 m) from the pollinator. As all five groups were planted randomly in closely spaced three-row plots, a certain amount of cross pollination probably occurred both within and between plots for all sizes and all groups. This would then largely negate the selection for a specific seed size which was exercised in each group. With the lower fertility in the two segregating populations, a large amount of cross pollination could be expected in their plots from pollen produced by the more fertile plants of the three advanced lines in the adjacent plots.

The effect of environment on the two generations of selection for seed size appeared to be minimal on population B. There was little difference in size shift between the two locations. There was a similar downward shift in the percentage of large seeds at both locations. For population A there was a greater shift towards medium and large sizes and away from small sizes at the more favourable Point location. This agrees with Fasoulas (1973) who found that selection for differences between agronomic performance of segregating genotypes is more effective at the most favourable environment.

The higher sterility of population B probably caused a higher degree of outcrossing in this population than in population A, causing the shift away from large seed size and towards a medium size corresponding to the mean of the pollen contributing parents.

Selection for high and low density in selected seed sizes

The main generalisation from the performance of the present material is that selection for high seed density did not appear to result in increased seed yield. No significant differences between high and low density seeds of a given size in a given group were found at either location, with the exception of line #3 at the West Field location, where significantly lower plot yields were obtained from high density seeds.

Bremner, Eckersall and Scott (1963), working with hexaploid wheat, concluded that plant size is governed by the amount of reserve material present in the seed. The specific gravity apparatus classified seeds into two categories: "high" and "low" density. If larger amounts of reserve material were present in the "high" as opposed to the "low" category, "high" seeds should have produced better seedlings leading to increased grain yield at maturity. Machine classification by density generally did not result in differential performance at maturity between high and low classes, indicating that the apparatus was unable to differentiate between seeds which contained a degree of differentiation in reserve material sufficient to affect harvest performance.

The seed density from harvested plots of both high and low density seeds from large selections of the two segregating populations at both locations (Table 27) indicates that mechanical separation was totally ineffective. Population A showed no differences between F4 seed orginating from F3 seed selected for high or low density. The effect of the two environments did show differing effects, with much greater percentages of high density seed resulting from plots grown at the West Field location. Low density seed plots from population B demonstrated a similar trend, while a reverse trend was shown for high density seed plots. The percentages of seed harvested in the F4 generation showed no relation to the density of the parental material in both populations.

Several factors could account for the complete lack of progress in mass selection for seed density. In the first case, selection intensity was at a very low level, as the source population had previously been selected on the basis of the top 50% of the population as "high density" and the bottom 50% as "low density." Unless there was a high heritability quotient and a high population genetic variance, little, if any, genetic advance could be made with such a low intensity of selection. The difference in performance of individuals selected for the same phenotypic character at the two different environments could indicate that the character selected (seed density) might have a low degree of heritability. It would appear that seed density is highly affected by environment, with a much higher intensity of expression under the conditions of the West Field (high density). The actual performance of the specific gravity machine could also affect the process of selection. As the populations separated were generally in small lots of less than

TABLE 27. Effect of Selection for High and Low Density F3 Seed in Large Seed Size Selections of Two Segregating Hexaploid Triticale Populations: Percentages of High and Low Density Seed and Size Classes in the F4 Progeny

		Location							
		Point Field				West Field			
		Total	Large	Medium	Small	Total	Large	Medium	Small
A. 6TA204 X MT28-1									
Low Density Selection	Low	56.05	8.10	25.05	22.90	37.75	3.25	13.80	20.70
	High	43.95	7.05	19.15	17.75	62.25	4.65	22.00	35.60
High Density Selection	Low	59.25	8.90	26.75	22.70	37.00	3.10	14.00	19.90
	High	40.75	5.95	18.40	16.40	63.00	5.70	23.90	33.40
B. 6A405 X 70HN470									
Low Density Selection	Low	51.70	9.30	23.75	18.65	35.75	5.30	14.85	15.60
	High	48.30	14.35	17.05	16.90	64.25	10.95	28.45	24.85
High Density Selection	Low	42.60	7.65	22.25	12.70	50.40	8.70	21.70	20.00
	High	57.40	11.40	22.15	23.85	49.60	6.70	19.80	23.10

1 kg (below the optimum size for accurate machine operation) and of varying shape and size within a single size class, the accuracy of the machine would be considerably less than when handling large volumes of more uniformly shaped and sized seeds.

Embryo and mature plant relationship

The effect of embryo dimensions on mature plant characters was different among different lines and populations and within a line or population, among different seed sizes. Bremner, Eckersall and Scott (1963), working with different embryo sizes and amounts of reserve material in the wheat "Cappelle," concluded that up to 30 days, differences in seedling growth between seedlings with differing amounts of nutrient reserves and differing embryo sizes, were determined by the amount of nutrient reserve and that initial embry size did not make a significant contribution to growth during this period.

When all seed sizes within a line or population were taken together, there were significant effects of embryo dimensions on mature plant characteristics in lines #1 and #2 and also on population A, but no significant effects in line #3 and population B.

The effect of embryo dimensions on mature head weight for all seed sizes together differed among the three advanced lines, with embryo length being positively correlated with head weight (P=0.01) in #1, embryo width positvely correlated with head weight (P=0.01) in #2 and neither significantly correlated with head weight or any other mature plant part weight in #3. These varietal differences would appear to explain the conflicting results of Bremner, Eckersall and Scott (1963), who reported no signific- differences in the number of leaf primordia between large and small embryos of Cappelle wheat, and a negligible effect of embryo size on seedling growth with that of Fasoulas (1964) who worked with four different wheat varieties (Generoso, T-58383, T-46025 and T-38290). Fasoulas (1964) concluded that, within varieties, larger embryos have higher numbers and an increased degree of development of root and shoot primordia, which give rise to a greater size and number of seminal roots, leaves, tillers and spikelets per spike. Increased embryo size appeared to give increased early growth which was maintained to maturity, to give increased yield in some genotypes but not in others.

The two segregating populations showed contrasting relationships over the complete range of seed sizes. The F3 embryos of population A (6TA204 X MT28-1) had a positive correlation (P=0.05) of both length and width with mature head weight, while those of B (6A405 X 70HN470) showed no significant correlation with any mature plant part. Higher yields from large seeds in population B would appear to be caused only by higher amounts of nutrient reserve material.

Selection for large seed size should in any case be synonymous with selection for a large embryo size over the the complete range of seed size in the population. Such selection should automatically increase single plant yield in populations such as A, where embryo size did appear to increase single plant yields. Varieties with large embryos have a greater competitive ability in mixtures but not necessarily a greater yielding ability (Fasoulas, 1964). Roy (1973) reported that large wheat seeds in pure stands, at closely spaced plantings, actually produced lower yields than small seeds of the same variety. The reverse was true in a varietal mixture. This would indicate that a minimum of competition is desired within a variety. Donald (1968) stated that minimum competition is desired and presented a wheat ideotype which would have a large spike capable of producing many grains and a uniculm habit of growth. Head weight appeared to be positively correlated with embryo size in population A, so selection for large seed and embryo theoretically could form one method of screening for yield.

In conclusion, it must be stated that experiments undertaken on individual plants in pots may not give a true indication of the performance of such genotypes under optimum field seeding rates. These experiments do tend to support previous investigations with different wheat varieties. There are great differences between different triticale lines and populations. In some genotypes there appears to be a direct relationship between the size of an embryo excised from a seed and the mature weight of the head and other plant parts of the plant which develops from the embryo. In other populations there is no such relationship between embryo size and mature plant part weights of plants grown under uniform environments, indicating that any advantages from larger seeds under field conditions are due to greater nutrient reserves in the larger seeds. Under the complete range of seed sizes in any line or population, there appears to be a highly significant correlation of embryo size with seed size, but this did not necessarily apply within the range of any one size as used in these size selection experiments.

GENERAL DISCUSSION

Mass selection for large seed size in the two segregating populations of hexaploid triticale in the F3 and F4 generations did not appear to be as effective in improving seed yield as was similar selection in hexaploid wheat populations (Derera and Bhatt, 1972, 1973). Some indications of advancement were obtained from seed size selection at the F2 level, but there was little evidence of seed size shift between large and small F2 seed size selections.

The problems of selection for a quantitative character, such as seed yield, are much more complex in an artificially synthesized new species than for a polyploid species which has evolved under natural and artificial selection for many hundreds of generations. Many of the present hexaploid triticale populations show considerable sterility in the early segregating generations. Even relatively advanced lines still show a much higher level of outcrossing than is generally associated with the established self-pollinated species. The association of the chromosomes of the tetraploid *Triticum* species, which are all adapted to self-pollination, with those of cultivated rye (*Secale cereale* L.), which has evolved as a cross-pollinated species, presents many problems for the evolution of a stable inbreeding hexaploid species. The fact that a number of the most widely used lines of hexaploid triticale for some breeding programmes are in fact substitution lines, with one or more rye chromosomes substituted by wheat D chromosomes (Gustafson and Zillinsky, 1973), further complicates the selection process in crosses of varieties with different chromosome complements. Early generations of crosses between such parent lines will produce many plants containing homoeologous rather than homologous chromosomes for one or more chromosome pairs, leading to various cytological and fertility problems.

In view of the problems associated with a new species in the early stages of evolution and the general lack of response with the selection intensity practised in these investigations, it would seem advisable that much larger populations and a higher selection intensity be used if any effective improvement is to be made in increasing seed size in segregating material of crosses of the presently available triticale lines. Much larger numbers of crosses between each given set of parents are required to ensure a sufficient number of F1 plants of each cross desired. Possibly the number of F2 seed could be increased several times over that used in these experiments by growing F1 seed under irrigated field conditions which would produce maximum tillering or possibly by subdividing tillers of young F1 plants and repotting to produce more plants for greenhouse or growth chamber production of F2 seed. This increased production of F2 seed would enable a much greater selection intensity for seed size to be made with the resulting increased possibility of improvement.

The second major factor which would negate any selection for seed size is the possibility of uncontrolled outcrossing. Here it would seem that bagging the heads of F1 and F2 or later generations before anthesis and the retention of only those heads which show a high degree of self-fertility for selection on the basis of seed size should largely prevent uncontrolled outcrossing.

In view of these problems, the main conclusion of this investigation are that breeding programmes which have produced satisfactory improvement with the traditional self-pollinated cereals will not necessarily be successful for the improvement of triticale without modifications. However, if the specific difficulties in breeding a new species are recognized, successful modifications in techniques should achieve the desired objectives.

SUMMARY

Visual selection for large seed size, in F2 seeds of individual F1 plants in five crosses of hexaploid triticale, resulted in significantly improved plant yields in four of the five crosses. Significantly higher scores for various other agronomic characters in favour of large seed selections for all five crosses were also observed. No significant differences were present between large and small seed selections in the progeny of a control advanced line.

Two cycles of mechanical mass selection, for large, medium and small seeds (as compared with unselected bulks) in F3 and F4 seeds of two segregating populations and three advanced lines failed to demonstrate significant advances in yield for large seed size, in replicated three rwo plots or randomly selected individual plants.

Separation of the unselected bulk and the three seed size selections into high and low density fractions, on a specific gravity separating machine, failed to show significant yield advantages for the high density fraction.

Actual embryo size measurements were found to be significantly positively correlated with mature plant weights (for single potted plants) in two of the three advanced lines and in one of the F3 crosses, but not in the third line or the second F3 population.

The breeding system of present lines of hexaploid triticale is considered, and it is concluded that systems of mass selection which are effective in the improvement of hexaploid wheat will not be effective for hexaploid triticale unless specific modifications are made.

RESUMÉ

En seleccion visuel pour graines de grande taille en semence F2 des plantes individuelles F1 en cinq hybrides de triticale hexaploide, on a produit rendements ameliorés avec quatre hybrides. On a produit les resultats plus hauts avec quelques caracteres agronomiques pour tous les hybrides. Il n'était pas des differences significatifs entre les seleccīones des grandes et petites semence dans les descendants d'une lignée avancée.

En deux generations de seleccion en masse pour graines de tailles grandes, moyennes et petites (avec graines sans seleccion) de semence F3 et F4 en deux hybrides et en trois lignées avancées, el n'était pas amelioration de rendement significatif pour les selecciones de grande semence en parcelles de trois files ou en plantes seleccionees au hasar.

La separation de semence sans seleccion pour taille y les trois tailles selecccionees avec une machine de gravité specifique n'a pas produit rendements plus hauts significatifs pour la fraction de gravité lourde.

On a trouvé les tailles actuelles des embryos con correlationes significatives positives avec les parties des plantes mûres (en plantes seules) en deux de trois lignées avancées et un hybride F3, mais pas en la troisième lignée avancée et le deuxième hybride.

Le systeme de reproduction en les lignées de triticales hexaploides usées en les programmes d'amelioration d'aujourd'hui est consideré et on a fait la conclusion que les systemes de seleccion en masse effectifs en le blé hexaploide ne seront pas en les triticales sans modifications specifiques.

SUMARIO

En seleccionar por semillas de gran tamaño en semillas F2 de cinco cruzas de triticales hexaploides, hubo rendimientos mejoradas en cuatro cruzas. Hubo valores más altos por carácteres agronomicos varios en todas cruzas con selecciones de semillas grandes. No hubo diferencias entre selecciones de semillas grandes y pequeñas en una linea avanzada.

En dos ciclos de selección masal por semillas de tamaño grande, medio y pequeña en generación F3 y F4 (con semillas no seleccionadas tambien) en dos cruzas y tres lineas avanzadas, no hubo mejoramiento de rendimiento significativo por las plantas de origen de semillas grandes en parcelas replicadas de tres hileras y plantas unicas escogidas al azar.

En la separacion de semillas no seleccionadas y los tres tamaños seleccionados, en fracciones pesadas y ligeras, con una maquina de peso especifico, no hubo mejoramiento significativo de rendimiento con la fracción pesada.

Se halló el tamaño actual del embrion con correlación positiva con el peso de porciones maduras (con plantas solas en macetas) en dos lineas y una población F3 pero no en la linea tercera y la población F3 segunda.

Se consideró el sistema de reproducción en los tipos de triticales hexaploides en los programas de mejoramiento usados ahora a se ha hecho la conclusión que no se puede usar los métodos de selección masal usados en el mejoramiento de trigo hexaploide para el triticale sin modificarlos.

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