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EFFECTS OF SEEDING RATES AND SEEDING DATES ON AGRONOMIC CHARACTERISTICS OF SPRING WHEAT (*Triticum aestivum* L) GENOTYPES

BY

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled EFFECTS OF SEEDING RATES AND SEEDING DATES ON AGRONOMIC CHARACTERISTICS OF SPRING WHEAT (Triticum aestivum L) GENOTYPES submitted by Attinaw Aytenfisu in partial fulfilment of the requirements for the degree of Master of Science in Plant Breeding and Agronomy.

Supervisor

J. A. Robertson

Date February 25/77

ABSTRACT

The effects of seeding rate and seeding date on agronomic characteristics of seven common spring wheat (Triticum aestivum L.) genotypes were studied at three locations in Alberta in 1975. In a split plot design, seeding dates of May 8, 16, and 26 at Edmonton and Ellerslie and May 15 and 22 at Olds were used as main-plot treatments. Sub-plots consisted of 42 treatment combinations of genotype x seeding rate (30,60, 90,120,150, and 180 kg/ha). Data were collected on plant stand, plant height, days to heading and maturity, grain yield per plot, test weight, grain protein content, grain yield components (ears per plant, kernels per ear, kernel weight), ear length, extrusion length, flag leaf lamina and sheath areas. Grain yield per plant, grain yield per tiller, and protein yield per plot were computed.

Significant complex interactions between seeding dates and treatment combinations were the norm rather than the exceptions for most plant characteristics in this study. Therefore, averages across these interactions alone can be misleading.

Averaged over all seeding rates and seeding dates, Pitic 62 was the highest grain yielder and Park was among the lowest grain yielders at all locations. Pitic 62 was later in maturity than Park by about 16 days at Edmonton, 15 days at Ellerslie, and 6 days at Olds. 70M110001, one of the second highest grain yielders, outyielded Park by about 35% at Edmonton, and by 19% at Ellerslie and was later in maturity than Park by only 2 days at Edmonton and by 4 days at Ellerslie.

At all locations, increasing seeding rate increased grain yield and decreased the number of days to maturity of most genotypes. The 90 kg/ha seeding rate for Pitic 62 and the 180 kg/ha seeding rate for

Park at both Edmonton and Ellerslie and the 150 kg/ha seeding rate for each at Olds appeared optimum for achieving relatively higher grain yield and a fewer number of days to maturity. Early seeding at Edmonton and Ellerslie increased both grain yield per plot and the number of days to maturity of most treatment combinations.

Both higher seeding rate and later seedings suppressed the expression of all three grain yield components in most cases. Between genotype comparisons showed that higher grain yielding genotypes had relatively higher number of kernels per ear.

For a few genotypes, ear length and flag leaf lamina area decreased with increasing seeding rate while extrusion length showed an increase. Later seedings decreased ear length and extrusion length, and increased flag leaf sheath and lamina areas of most treatment combinations. It was not possible to attribute the higher grain yield, on a per plot, per plant, or a per tiller basis, of a genotype to anyone of the morphological characteristics above the flag leaf node.

At Edmonton and Ellerslie, both early seeding and higher seeding rates decreased grain protein percentage and increased protein yield per plot in most cases. The highest grain yielding genotype, Pitic 62, was also among the lowest in grain protein percentage but was among the highest in protein yield plot.

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INTRODUCTION

Since 1912, Marquis wheat has been the standard of good milling and bread making quality of wheat in Canada, (Dickinson) Since then the breeding objective has been to produce cultivars as good as or better than Marquis in both quality and grain yield. Recently a greater demand, outside Canada, for low priced wheat for both bread and feed purposes, with less regard to protein content and quality, has encouraged the Canadian market system to include new types of wheat with higher grain yield. New improvement in milling and baking technology, and higher grain yield potential of these wheat types are also among the factors which forced the creation of the new market class 'Utility Wheat' in the Canadian Grain Act, 1969. The creation of this new market class changed the objectives of some Canadian plant breeders who no longer have to breed exclusively for lines with Marquis type quality.

The possibility of using utility wheats within Canada has also been investigated. The grade quality of hard red spring wheat cultivars produced in Central and Northern Alberta is usually low despite the fact that high grain yields are common, especially compared to grain yields in the Palliser triangle. It has been suggested by Briggs (personal communication) that 20-30% yield gains could be made by breeding utility wheats adapted to the area. The higher grain yield of utility wheat and the problem of quality deterioration of hard red spring wheats from these areas has aroused an interest in producing utility wheats for feed purposes. In view of the variation in length of the growing season throughout the province, the need for plant breeders to select for types representing a wide range of maturity appeared to be necessary.

Wheat gives more energy per unit weight of grain for many livestock rations compared to barley or oats, (Canada Grains Council ,(a)). On this basis, wheat which equals both barley and oats in grain yield per unit area will actually produce more feed grain energy on that area than the other cereals.

Most of the new utility wheat types have very different genetic constitution from the commonly grown hard red spring wheats in the Province. Also within these new wheat types, there are radical differences with respect to grain yield and maturity.

The grain yield of a plant can be greatly influenced by environmental conditions regardless of its genetic constitution. Therefore, as a new cultivar or species is developed or introduced into a region, efficient cultural practices must be developed in order to obtain the maximum possible yield from it. Determination of the most suitable seeding date and seeding rate for optimum grain yield and earlier maturity should, therefore, be of primary importance for achieving high energy per unit area. It was with this objective in mind that seven different wheat genotypes were tested in this study of the effects of seeding rate and seeding date on important agronomic characteristics. This experiment, with two hard red spring and five utility wheats, is mainly concerned with the grain yield and maturity responses to different seeding rates and seeding dates at three locations in Alberta. The responses of grain yield components, and some morphological characteristics above the flag leaf node were also studied in order to obtain preliminary data concerning possible explanations of the grain yield and maturity responses.

LITERATURE REVIEW

GRAIN YIELD COMPONENTS IN CEREALS

Yield components

It was probably Engledow and Wadham, 1923, in England, who first divided cereal grain yield into components. They suggested that the number of ear bearing tillers per plant, the number of kernels per ear, the weight of single kernels, and the percentage of dry matter in the kernel could be "components" or "governing factors" of yield per plant in cereals. Later, many other investigators, among them Johnson *et al*., 1966, on winter wheat (*Triticum aestivum* L.), Walton, 1971, on spring wheat (*Triticum aestivum* L.), and Kaltsikes, 1973, on rye (*Secale cereale* L.) showed that the number of ears per plant, the number of kernels per ear, and the individual kernel weight were the main components of cereal grain yield. Cereal grain yield was determined on a per plant basis by Walton, 1971, on a per unit area basis by Johnson, 1966, and on both per plant and per unit area basis by Kaltsikes, 1973.

Association of grain yield and the components and their inheritance.

Singh *et al*., 1970, in India, reported significant simple correlation coefficients of 0.62 and 0.45 between grain yield per plant and number of kernels per ear and grain yield per plant and kernel weight, respectively in common wheat. The number of ears per plant, number of kernels per plant, and kernel weight made important contributions to wheat grain yield per plant as indicated by highly significant standardized regression coefficients of 0.69, 0.71 and 0.41, respectively, in a stepwise multiple regression analysis conducted by Walton, 1971. In rye (*Secale cereale* L.), Kaltsikes, 1973, in Manitoba, reported significant simple correlation coefficients of 0.58, 0.19 and 0.30 between grain yield per plant and ears per plant, kernels per ear, and kernel weight, respectively. In a stepwise multiple regression analysis, these classical grain yield components accounted for 97% of the total variability observed in grain yield per plot. Only the yield components were entered into the regression equation. The number of ears per plant and kernel weight, also had significant correlations with grain yield per plot. Kaltsikes, 1973, also obtained a high, significant, positive correlation (0.83) between grain yield per plant and grain yield per plot.

Using the progeny - parent regression method for heritability estimation, Lofgren et al., 1968, in Kansas, reported that kernel weight and kernels per 30 ml (kernel size) were highly heritable in common wheat. They suggested that it would be easy to select for these two characters in common wheat. Singh and Anand, 1971, in India, showed the number of kernels per ear in common wheat was under the control of genes with simple additive effects, but that dominance effects may become important under certain environmental conditions. They suggested that selection for number of kernels per ear could be very effective in attempting to make gains in improving grain yield per plant in segregating generations of wheat. This character had a high narrow sense heritability estimate.

In barley (Hordeum vulgare L.), Rasmusson and Cannell, 1970, in Minnesota, indicated that the number of ears per plant and kernel weight were better criteria than number of kernels per ear in making selection for grain yield per plot. When selection was practised for kernels per ear in one population of F_4 families, grain yield per plot in the F_5 bulk actually decreased. In durum wheat (Triticum turgidum L. var. durum), Lee and Kaltsikes, 1972, in Manitoba, reported narrow sense heritability estimates of 0.70, 0.30, 0.65, and 0.19 for number of ears per plant, number of spikelets per ear, number of kernels per spikelet, and kernel weight, respectively. The above four characters showed predominantly additive genetic effects with some degree of dominance and a general lack of epistasis.

General response of grain yield components to seeding rate and seeding date.

From a seeding rate experiment, Guitard et al., 1961, in Alberta, observed locational variation and varietal differences in response of grain yield components to different seeding rates. However, location averages for two common wheat cultivars indicated that an increase in seeding rate increased the number of plants per unit area and decreased the number of ears per plant. Number of kernels per ear and kernel weight were not as greatly influenced by increased seeding rates as were number of plants per unit area and number of ears per plant. Puckridge and Donald, 1967, in Australia, however, reported extreme and significant depression of number of ears per plant and number of kernels per ear with increased seeding rate for the wheat cultivar Insignia. Kernel weight also showed a decreasing trend with increased seeding rates. Both Guitard et al., 1961, and Puckridge and Donald, 1967, reported that grain yield per unit area increased with increasing seeding rate. They also indicated that the higher grain yields per unit area were obtained through the high plant population per unit area, since the grain yield components had lower values at higher seeding rates. The effect of seeding rate on ears per unit area and kernel weight was found negligible for the common wheat cultivar Hindu 62 in Gezira, Sudan (Khalifa, 1970). However, kernels per ear decreased with the highest seeding rate, 179 kg/ha, and this accounted for the reduced grain yield per unit area obtained at the highest seeding rate. All three grain yield components showed a trend of decrease with decreased within-row spacings in both hybrids and varieties of barley (Hordeum vulgare L.) in Minnesota, (Severson and Rasmusson, 1968). 2.5, 7.5, 15.0 and 22.5 cm were the within - row spacings used in their study.

Late seeding of Hindu 62 wheat cultivar in Gezira, Sudan, resulted in decreased grain weight per ear, decreased number of kernels per ear, lower kernel weight, and then lower grain yield per unit area (Khalifa, 1970). The higher grain yield from seeding one month earlier was attributed to higher grain weight per ear, a consequence of heavier and more numerous kernels per ear. Date of seeding for 34 wheat cultivars in the Ord River Valley, Australia, had very little effect on the fertile tiller population as measured by number of ears per plant (Beech and Norman, 1971). However, grain weight per ear was higher for early (April 20) seeding than with later (June 29) seeding and this effect was magnified for late maturing cultivars.

EFFECTS OF SEEDING RATE AND SEEDING DATE ON:

Plant stand per unit area

Plant stand generally increases with increased seeding rates in wheat (Guitard *et al.*, 1961, Puckridge and Donald, 1967, Pelton, 1969, Willey and Holliday, 1971, and Stoskopf *et al.*, 1974). However, Puckridge and Donald, 1967, in Australia, and Willey and Holliday, 1971, in England reported increased plant mortality at relatively higher seeding rates. Inadequate light, water, and nutrients due to high competition were suggested as causes for the higher plant mortality rate at the higher seeding rates.

Higher plant stand has often been associated with higher grain yield per unit area in wheat (Guitard *et al.*, 1961, and Puckridge and Donald, 1968). McKenzie and Grant, 1964, reported a decline of stem cutting by sawfly (*Cephus cinctus* Nort.) with increased seeding rates for Thatcher, Chinook, and Rescue spring wheat cultivars in Alberta. It was suggested that this response appeared to be due to the slender stem diameter of plants at the heavier seeding rates such that sawfly larvae could not tunnel in them and survive.

Willey and Holliday, 1971, and Puckridge and Donald, 1967, recorded problem of lodging associated with higher plant density while McKenzie and Grant, 1964, did not mention a problem of lodging in their report.

Plant height

Puckridge and Donald, 1967, obse[illegible]n increase in plant height of common wheat with increased s[illegible]d[illegible] rates while Pelton, 1969, noted the reverse on plants grown on st[illegible] and. On the other hand, Finlay et al., 1971, on barley (H. vulgare L. and H. distichum L.) in Ontario and Briggs, 1975, on common wheat in Alberta observed no significant plant height differences due to variation in seeding rate.

Taller plants generally appeared to have less tillers per plant, less kernels per plant, lower kernel weight, and lower grain weight per plant as compared to shorter plants in Saskatchewan (Simpson, 1968). He pointed out that short plants were more productive on a per plant basis and this was attributed principally to their increased tillering capacity. Donald, 1968, in Australia, has also indicated short plant height as being one of the criteria which characterize his wheat ideotype for higher grain yield per plant.

Days to heading

A trend of decreasing number of days to heading was observed with increased seeding rates on Manitou, Selkirk, and Cypress common wheats and Stewart 63 durum wheat for both fall and spring seeding in Saskatchewan (Austenson, 1972). Willey and Holliday, 1971, in England, reported faster plant development, including days to heading, due to increased seeding rates in common wheats. Finlay et al., 1971, in Ontario, observed a decrease in number of days to heading both with increased seeding rates and narrower row spacings in barley (H. vulgare L. and H. distichum L.).

Higher grain yield per ear was obtained from late heading cultivars compared to early heading cultivars in Australia (Rawson, 1970). In his study, Rawson, 1970, divided wheat development into three stages - sowing to floral initiation (double ridge, stage 1), double ridge to terminal spikelet production (stage 2), and terminal spikelet production to ear emergence (stage 3). All late heading cultivars took more time in stage 2 and higher grain yield per ear was obtained from these types because of higher spikelet number per ear compared to that from early heading types.

In a seeding date experiment in New South Wales, Australia, on 5 wheat cultivars (different maturity range), grain yield per unit area declined at rates between 9 - 14% for each week that flowering was delayed after October 10 (Doyle and Marcellos, 1974). In their study, greater moisture stress, higher temperature, and reductions in the duration of grain filling were mentioned as causes for the reduction in grain yield associated with flowering later than the first week in October.

Days to maturity

Both lower seeding rates and wider row spacings delayed maturity of spring wheats in a study conducted in Alberta (Briggs, 1975). McFadden, 1970, also reported that the number of days to maturity was reduced by 1-2 days by using heavier seeding rates for both Conquest and Olli barley cultivars in Lacombe, Alberta. The seeding rates used in this study were 40, 67, and 94 kg/ha. Higher seeding rates, up to 202 kg/ha rate, decreased the number of days to maturity of Yecora, Neepawa and Norquay wheat cultivars at Beaverlodge, Alberta by up to 6 days (Faris et al. 1976). This reduction in number of days to maturity was primarily attributed to reduction of tillering at higher seeding rates.

Number of days to maturity was reduced when seeding date was delayed for both late and early maturing wheat types in Ord

River Valley, Australia (Beech and Norman, 1971). A similar result was obtained by Doyle and Marcellos, 1974. In the Atlantic Region of Canada too, every delay in seeding in spring significantly reduced the number of days to maturity of Opal wheat (Nass et al., 1975).

Rawson, 1970, in Australia, reported that late maturing cultivars had a higher grain yield per ear than early maturing types. Late maturing cultivars were also reported to have more ears per plant, (Pinthus, 1969, in Israel, and Singh et al., 1970, in India) than early maturing cultivars, thus showing a possibility of expecting higher grain yield per plant, provided the other two grain yield components are held constant. By contrast, Beech and Norman, 1971, in Ord River Valley, Australia, reported that grain yield per unit area was higher for early maturing cultivars compared to mid-late and late maturing cultivars when seeded late. In their seeding date study, Beech and Norman, 1971, used 34 cultivars, with different maturity groups, and 3 seeding dates (April 20, May 25, and June 29). For the May 25 and June 29 seedings, most early maturing cultivars flowered earlier (before the mean monthly temperature rose up, before September) than mid-late and late maturing cultivars. The rising mean monthly temperature (above 23^{o}C after August) before and during flowering of mid-late and late maturing cultivars might have decreased fertilization rate. This led to lower grain weight per fertile tiller and then lower grain yield of mid-late and late maturing cultivars compared to early ones for late seedings.

Morphological characteristics above the flag leaf node.

Later seeding showed a trend of increasing flag leaf area of Rothwell-Sprite and Kloka wheat cultivars at Boxworth, England (Jessop and Invins, 1970).

Asana and Mani, 1950, in India, observed that about 50, 22 and 28% of the weight of grain of wheat came from assimilation in the leaves, ear, and stem, respectively. ^{14}C labelled assimilate movement from the flag leaf of spring wheat was reported to be predominantly towards the ears (Quinlan and Sagar, 1962, in India, and Stoy, 1963, in Sweden), peduncles (extrusion), and kernels (Stoy, 1963). Later, Thorne, 1965, in England, observed that about 83% of the carbohydrates entering the ear in spring wheat was from photosynthesis in the flag leaf (including the lamina, sheath, and extruded peduncle).

Thorne, 1965, also reported that about 17% of the carbohydrates entering the ear in spring wheat was from photosynthesis in the ear itself. ^{14}C labelled assimilates that entered the ear were observed to be distributed fairly uniformly throughout the length of the ear (Rawson and Evans, 1970). They also reported that of the ^{14}C present at maturity, only 12-14% was present in the ear structure, the remainder being in the grain. However, varietal differences in the amount of carbohydrate contribution to the grain by ear photosynthesis was noticed by Evans and Rawson, 1970, in Australia. They found that for the whole period of grain development, the estimated contribution to total grain yield by ear photosynthesis was 33, 28 and 20% in Sonora 64, Pitic 62 and Gabo wheat cultivars, respectively. Longer ears could therefore mean more chance for accumulation of assimilates in the wheat grain.

Voldeng and Simpson, 1967, in Saskatchewan, obtained significant positive simple correlation coefficients (0.54 to 0.90) between grain yield per main tiller and photosynthetic areas (photosynthetic areas included flag leaf and peduncle area, ear area, and flag leaf and ear areas) in both high and low grain yielding lines. In this leaf shading experiment, grain dry weight per tiller increased significantly more when ear and flag leaf areas together were unshaded compared to results from keeping any other plant part or parts unshaded. From a study on 120 wheat varieties in Saskatchewan, Simpson, 1968, reported significant simple correlation coefficients of 0.84, 0.91 and 0.93 between weight of grain per plant and flag leaf lamina area, flag leaf sheath area, and total photosynthetic area above the flag leaf node per plant respectively. Both on a per plant and on a per tiller basis, grain dry weight and components of photosynthetic area above the flag leaf node had high, significant, and positive simple correlation coefficients. This indicates that the photosynthetic areas above the flag leaf node could be important contributors of dry matter for the wheat grain. Simpson, 1968, also reported a very high, significant, and positive simple correlation coefficient between the area of the flag leaf sheath and total photosynthetic area above the flag leaf node both on a per plant and on a per tiller basis.

In spring rye (Secale cereale L.), Kaltsikes, 1973, in Manitoba, Canada, reported that there were no significant simple correlations between grain yield per plant or grain yield per plot with ear length, flag leaf lamina length or width, or flag leaf sheath length. Extrusion length, however, had significant positive correlation (0.24) with grain yield per plot.

In a factor analysis with 14 different plant characteristics in spring wheat, flag leaf sheath length was one of the six plant characteristics included in the largest factor, which explained about 31% of the total variability in the data (Walton, 1971). The second largest factor was made up of extrusion length, flag leaf length, flag leaf breadth, and flag leaf area, and accounted for another 30% of the total variability in the data In rye, however, Kaltsikes, 1973, reported that the morphological characteristics above the flag leaf node accounted for only about 6% of the total variability in grain yield per plot when they were entered alone in a stepwise multiple regression equation. The positive associations between grain yield and some morphological characteristics above the flag leaf node could mean that increasing the magnitude of these characteristics may result in increases in grain yield per plant or per plot in wheat.

Grain yield per unit area

Some investigators (Woodward, 1956, Puckridge and Donald, 1967, Austenson, 1972, Stoskopf *et al.*, 1974, Briggs, 1975, Faris *et al.*, 1976) showed that grain yield per unit area in wheat increased with increasing seeding rates, while others (Khalifa, 1970, Larter *et al.*, 1971, Willey and Holliday, 1971) observed a decrease in wheat grain yield with increased seeding rates. Finlay *et al.*, 1971, on the other hand, found no significant differences in grain yield of barley (*H. vulgare* L. and *H. distichum* L.) due to different seeding rates, nor did Day *et al.*, 1976, with Maricopa wheat.

From a seeding rate experiment on Saunders and Thatcher spring wheat cultivars over 3 years at 3 locations in Alberta, Guitard et al., 1961, recommended about 100 kg/ha as the optimum seeding rate for optimum wheat grain yield in these areas. Faris et al., 1976, suggested the 90 - 134 kg/ha seeding rate for Yecora and Neepawa and 202 kg/ha for Norquay spring wheat cultivars for optimum grain yield and early maturity in the Peace River Region of Alberta. Manitou wheat gave the highest average grain yield at the two lowest seeding rates (25 and 50 kg/ha) and a significant grain yield reduction was observed by using seeding rates of 100 kg/ha and above in Manitoba (Larter et al., 1971). However, they suggested that the recommended wheat seeding rate in Western Canada 68 - 102 kg/ha be maintained to cope with adverse weather conditions.

Narrower row spacings also resulted in higher grain yield per unit area in wheat (Briggs, 1975, and Clark, 1976), in barley (Finlay, et al., 1971, and Clark, 1976), and in oats (Clark, 1976). An average grain yield reduction of 27 - 30% was observed for 35.6 cm and 53.3 cm row spacings for Selkirk wheat, Bonanza barley, and Garry oats compared to that of 17.8 cm row-spacing (Clark, 1976).

In Utah, Western U.S.A., early seeding (beginning of April) of Lemhi wheat gave grain yields of 4700 kg/ha while late seeding (beginning of June) resulted in 2300 kg/ha average grain yield per unit area over 3 years (Woodward, 1956). The average grain yield of Saunders wheat decreased by 43% in unfertilized plots and by 35% in fertilized plots due to delay in seeding from the first (May 12) to the ninth (June 13) dates of seeding in Beaverlodge, Alberta (Anderson and Hennig, 1964). Regressions of grain yield on dates of seeding were significant and negative for 5 out of 6 years for both fertilized and unfertilized plots. In a 34 cultivar test, the grain yield of wheat dropped by 450 kg/ha with each successive later seeding (seeding dates used were April 20, May 25, and June 29) in the Ord River Valley, Australia (Beech and Norman, 1971). Higher grain yield from early seeding was also observed, on Hindu 62 wheat in Gezira, Sudan (Khalifa, 1970), on Rothwell-Sprite and Kloka wheats in Sutton Bonington, England (Jessop and Ivins, 1970), on Manitou wheat and Rosner triticale in Manitoba (Larter _et al_., 1971), on five wheat cultivars in New South Wales, Australia (Doyle and Marcellos, 1974), on Pitic 62, Opal, and Selkirk wheats in Ontario (Stoskopf _et al_., 1974), and on Opal wheat in the Atlantic Region of Canada (Nass _et al_., 1975).

Cultivar differences were also observed for grain yield response to variation in seeding date and for grain yield stability in different environmental conditions. McFadden, 1970, in Lacombe, Alberta, reported that delayed seeding in the spring caused a marked drop in grain yield of Olli barley and little variation in Conquest barley over 3 years. Seeding dates used were May 8, May 22 and June 7. Mack, 1973, observed that Pitic 62 significantly outyielded Manitou wheat in both early (May) and late (June) seedings under cool (10°C) and medium (18°C) soil temperature but not under high [illegible] temperature (28°C) conditions in Ontario. Temperatures as [illegible] as [illegible]8°C (day) and 13°C (night) were reported to have vernalization effect on some late or mid-late maturing tropical cultivars like Pitic 62 (Wall and Cartwright, 1974). Reduction in spikelet number per ear and then yield and bringing earlier heading are the major effects of vernalization on those late or mid-late maturing tropical cultivars. On the other hand, north temperate cultivars, like Manitou, respond more to photoperiod than to vernalization. In this regard, the lower yield of Pitic 62 at higher soil temperature conditions (Mack, 1973) seems difficult to explain. Park and Pitic 62 wheat cultivars had low phenotypic stability for grain yield per unit area in different environmental conditions (Walton, 1968). Park, a rust susceptible cultivar, in most cases outyielded Manitou, a rust-resistant cultivar, in rust-free areas of Alberta. In areas where rust is prevalent, in some parts of Manitoba, however, Park had lower grain yield than Manitou. Pitic 62 also yielded very well under the more productive growing conditions, but where conditions were less favorable, it yielded only slightly more than Manitou. Regression of the grain yield of a cultivar on the mean of the trial in which the cultivar is tested was used to determine the phenotypic stability of a cultivar by Walton, 1968. In this method, if the regression coefficient is high for a cultivar, it indicates low phenotypic stability because the pattern of the grain yield response of the cultivar follows the pattern of the trial mean which is the measure of environmental conditions. Both Park and Pitic 62 had higher regression coefficients than the remaining cultivars.

EFFECTS OF SEEDING DATE AND SEEDING RATE ON THE CLASSICAL GRAIN YIELD COMPONENTS AND TEST WEIGHT.

Ears per plant

In studies conducted by Pinthus, 1969, in Israel, tillering increased markedly and significantly in wider within - row spacings (similar to lower seeding rates) for both late and early maturing wheat cultivars. A similar relationship was also observed for seeding rate decreases in two barley cultivars, Olli and Conquest, by McFadden, 1970, in Alberta.

An increase in grain yield per plant could be expected from any increase in ears per plant provided compensatory reductions in the other components were not obtained. Simpson, 1968, associated the higher grain yield per plant of shorter plants with their increased tillering capacity compared to taller plants. About 81% of the total grain yield in wheat was contributed from main shoot ears and 19% from first and second tillers (Ishag and Taha, 1974). Significant cultivar differences were observed for ears per plant both in spring wheat in Ontario (Stoskopf et al., 1974) and in winter wheat in England (Bingham, 1967). Differences in number of ears per plant were also shown by different wheat cultivars of different maturity groups (Singh et al., 1970). They reported that later maturing cultivars produced a higher number of ear bearing tillers per plant, whereas early maturing cultivars had a shorter vegetative phase and subsequently a lower number of ears per plant, especially under high temperature conditions.

Kernels per ear

In a study conducted in Ontario (with 67, 135, 202 and 270 kg/ha seeding rates), the number of kernels per ear decreased significantly due to seeding rate increases for Pitic 62, Opal and Selkirk wheat cultivars (Stoskopf et al., 1974). Lower seeding rates, (54 and 108 kg/ha), in barley (H. vulgare L. and H. distichum L.) resulted in an increased number of kernels per ear for three out of four cultivars in 1967 in Ontario (Finlay et al., 1971). Willey and Holliday, 1971, also observed increases in spikelet number per ear from lower seeding rates in the wheat cultivar Koga II in England. Lower seeding rates, (e.g. 29 kg/ha), also resulted in a higher number of kernels per ear than did the higher rates of seeding (58 and 87 kg/ha) for Maricopa wheat in Arizona (Day et al., 1976).

Number of kernels per ear showed significant increases with delayed seeding for Kloka and Rothwell-Sprite wheat cultivars over 3 years in England (Jessop and Ivins, 1970) while Stoskopf et al., 1974, in Ontario, Canada, reported significant decreases in number of kernels per ear due to delayed seeding for Pitic 62, Opal, and Selkirk wheat cultivars.

Bingham, 1967, in England, found that reduction in kernel number per ear resulted in reduced grain yield per ear and in increased single grain weight throughout the ear on a winter wheat hybrid (TB208/14). Later, Simpson, 1968, in Saskatchewan, reported a significant high positive correlation coefficient of 0.86 between weight of grains per ear and number of kernels per ear. Rawson, 1970, in Australia, also observed that an increase in spikelet number per ear was followed by an increase in kernel number per ear and this was accompanied by an increase in grain yield per ear of over 30% for the wheat cultivar Triple Dirk. Number of kernels per ear has been reported by a number of workers as being the most important of the three grain yield components in influencing grain yield per plant in wheat (Johnson et al., 1966, Rawson, 1970, and Stoskopf et al., 1974). Johnson, 1966, also indicated that number of kernels per ear is a character which is consistent over years and locations.

Difference in kernel number per ear has also been referred to as being the main cause of grain yield difference between cultivars (Dubetz and Bole, 1973, and Rawson, 1970). Pitic 62 outyielded both Manitou and Kenhi wheat cultivars because of its capacity to produce more fertile florets and more kernels per spike (Dubetz and Bole, 1973). Rawson, 1970, also found that all cultivars with more kernels per ear had more grain yield per ear compared to those wheat cultivars with a lower number of kernels per ear.

Kernel weight

Pelton, 1969, in Saskatchewan, reported that the kernel weight of Chinook wheat decreased with increased seeding rates in both fallow and stubble land. A similar relationship was observed for Manitou wheat and Rosner triticale in Manitoba (Larter et al., 1971), for Opal and Selkirk wheat cultivars in Ontario (Stoskopf et al., 1974). On the other hand, Finlay et al., 1971, on two barley cultivars in Ontario and Stoskopf et al., 1974, on Pitic 62 wheat in Ontario, McFadden, 1970, on two barley cultivars in Alberta, and Day et al., 1976, on Maricopa wheat in Arizona, observed

Wider row spacing also increased kernel weight in spring wheats (Briggs, 1975). (Row spacings used were 15, 23 and 30 cm).

Stoskopf et al., 1974, observed a trend of decreasing kernel weight due to later seedings. At the latest seeding date in spring, (May 30), all three cultivars (Pitic 62, Opal, and Selkirk wheats) had significantly lower kernel weight compared to results from the earlier seedings.

Late seeding of Hindu 62 wheat in Gezira, Sudan, also resulted in lower kernel weight compared to results from early seeding (Khalifa, 1970). Within seasons, Doyle and Marcellos, 1974, reported that there was a trend of reduction in kernel weight with delayed seeding of 5 spring wheat cultivars in a 5 year study in Australia. In another study in the Atlantic Region of Canada, Nass *et al.*, 1975, reported that there were no significant differences in kernel weight of Opal wheat due to variation in seeding date.

Increased kernel weight was associated with reduced grain yield per ear in the winter wheat hybrid, TB208/14, (Bingham, 1967). Lower kernel weight was also mentioned as one of the causes for the lower grain yield per unit area of spring wheats compared to barley or winter wheats (Stoskopf *et al.*, 1974).

Test weight (kg/hectoliter)

Lower seeding rate significantly reduced the test weight of Glenlea wheat while Neepawa and Pitic 62 wheat cultivars did not show significant responses in test weight due to variation in seeding rate at Ellerslie, Alberta (Briggs, 1975). Seeding rates used were 34, 67 and 101 kg/ha. He also reported that wider row spacings significantly increased test weight of some spring wheat cultivars.

Nass *et al.*, 1975, observed a marked trend of decrease in test weight of Opal wheat as seeding date was delayed in the Atlantic Region of Canada.

From a seven years study (1916, and 1919 to 1924), Mangels and Sanderson, 1925, in North Dakota, reported significant positive associations between test weight and flour yield of wheat for each year. Positive simple correlation coefficients of 0.67 to 0.82 were obtained from sample sizes which ranged between 174 in 1922 to 305 in 1924. For the years 1949 through 1954 on 287 tests, Sheuy, 1960, in Minnesota, also observed a positive correlation coefficient (0.74) between test weight and milling yield of wheat. Both Mangels and Sanderson, 1925, and Sheuy, 1960, did not indicate whether the samples used in their studies represented genotypes or they were just samples from different environments.

Hlynka and Bushuk, 1959, also discussed the factors that affect test weight. They argued that higher test weight is a result of higher kernel density, and uniformity of kernel shape and size. Kernel size by itself does not have significant effect on test weight.

Grain protein percentage and Total yield of protein.

In a study by Pelton, 1969, in Saskatchewan, the percentage nitrogen in wheat grain was found to be more for higher seeding rates on fallow plots but there were no significant responses to seeding rate from plants grown on stubble land. By contrast, Larter et al., 1971, in Manitoba, reported that grain protein percentage was not significantly influenced by different seeding rates of 25, 50, 75, 100, 125, 175 and 200 kg/ha for Manitou wheat and Rosner triticale in a two year study on summer fallow land. The availability of nitrogen compounds might have been increased in the summer-fallow plots. As a result, the accumulation of nitrogenous compounds in the plants and their translocation to kernels was not limited even at higher seeding rates. Later seeding in spring of Opal wheat appeared to increase grain protein percentage in the Atlantic Region of Canada (Nass et al., 1975). However, it was not possible to determine a definite trend of relationship between seeding dates and total yield of protein for Opal wheat.

In a study of Red Bobs and Marquis wheat cultivars in Alberta, Mallock and Newton, 1934, indicated an inverse relationship between grain yield per unit area and grain protein percentage. Significant and negative simple correlation coefficients of -0.68 (1930) and -0.42(1931) were obtained between grain yield and grain protein percentage from 50 plots of each cultivar in the above study. McNeal <u>et al</u>., 1972, in Montana, U.S.A., also reported that grain yield per unit area was highest from low protein composites (F_4 populations) of eight spring wheat crosses, compared to high protein composites. This relationship was also found to be consistent with locations and among crosses. They also observed that high protein composites of spring wheat had significantly less number of kernels per ear, and lower kernel weights. They also suggested that the difference in grain protein percentage between the two composites could be due to the uniformly lower distribution of nitrogen in many kernels in the low protein composites compared to the fewer kernels receiving relatively more nitrogen in the high protein composites.

Cultivar differences were observed both for grain protein percentage and total protein yield of wheat. Mack, 1973, observed that grain protein percentage was significantly higher for Manitou than Pitic 62 grown at three differing soil temperature conditions (10^oC, 18^oC, 28^oC) in Ontario.Grain protein percentage of Manitou was also found to be 25 - 31% higher than that of Pitic 62 in Southern Alberta, but the total protein yield per unit area of the two cultivars differed only by 3% (Dubetz, 1972). Dubetz and Bole, 1973, also showed that both grain protein percentage and yield of protein per unit area were higher for Manitou, Kenhi, and Pitic 62 at the highest nitrogen fertilizer treatment (224 kg/ha N) level in Lethbridge, Alberta. (Nitrogen treatment levels were 0, 56, 112 and 224 kg/ha).

MATERIALS AND METHODS

Plant Materials

Seven genotypes of spring wheat (*Triticum aestivum* L. em Thell) were used in this study of the effects of seeding rate and seeding date variation on plant and seed characteristics. Seed and other agronomic characteristics of the genotypes used are presented in Table 1.

Study areas and experimental design

The experiment was conducted in three sites in Alberta, at (i) Edmonton Research Station, University of Alberta, (ii) Ellerslie Research Station, University of Alberta, and (iii) Olds Agricultural College, in the summer of 1975. The climatic and edaphic details of these sites are described in Appendices 1, 2, and 3.

There were six rates of seeding (30, 60, 90, 120, 150 and 180 kg/ha) and three seeding dates (May 8, 16, and 26 for Edmonton and Ellerslie, and May 15, 22, and 29 for the Olds site). Data for the May 29 planting at Olds are not reported in the thesis, since they were incomplete.

The Split Plot design, with four replicates, was used with seeding dates assigned to main plots and genotype x seeding rates, treatment combinations, making up the forty-two treatments within subplots.

Soil fertility status and fertilizer applied for each test site are shown in Table 2. Fertilizer applications were broadcast using a Gandy Free Flow Spreader, Model, 1012, at all sites.

TABLE 1. SEED AND PLANT CHARACTERISTICS OF SEVEN SPRING WHEAT GENOTYPES.

Genotypes	Class of pedigreed seed used	Canadian Market class	Relative days to maturity +	Plant height + (cm)	Test weight * (kg/hl)	1000 kernel weight * (gm)	Year licensed in Canada ++	Origin
Park	Foundation	Hard red spring	-1	101	84.9	34.3	1963	Alberta
Neepawa	Foundation	Hard red spring	= check	102	81.2	28.5	1969	Manitoba
Pitic 62	Foundation	Utility	+6	85	72.4	43.3	1969	Mexico
Glenlea	Reg. No. 2	Utility	+8	108	81.2	43.3	1972	Manitoba
Norquay	Foundation	Utility	+4	82	77.4	38.0	1975 (licensed) 1976 (delicensed)	Manitoba
70M110001 **	Breeder	Utility	+3	91	77.4	35.5	Not licensed	Mexico
70M009002 **	Breeder	Utility	+4	86	78.7	37.0	Not licensed	Mexico

\+ From Briggs, K.G. 1974. 1974 Alberta preliminary regional wheat test. University of Alberta, Plant Sci. Dept., Edmonton, Alberta, Canada.

* Values determined on the seed source used for the 1975 experiment.

++ From Dickinson, F.L. Prairie wheat (Three centuries of wheat varieties in Western Canada). Canada Grains Council, Winnipeg, Manitoba, Canada.

** The pedigree of these genotypes is as follows:

70M110001 = CIANO S x ((CIANO x SON-KL.Rend) 8156)

70M009002 = CIANO S x ((SON 64-Y50E5 x G10) INIA'S')

TABLE 2. SOIL TEST NITROGEN (N), PHOSPHORUS (P), POTASSIUM (K) AND AMOUNT APPLIED IN THE FORM OF FERTILIZER IN KG/HA.

	Edmonton			Ellerslie			Olds		
	N	P	K	N	P	K	N	P	K
Soil test, fall 1974	104	15	1215	103	6	818	24	2	270
Fertilizer application, spring 1975	13	15	0	17	17	0	40	24	0

Four row plots, with 23 cm row spacing, were used at all sites. Row length was 5.63 m at both Edmonton and Ellerslie and 6.09 m at Olds.

A four row power seeder (Canada Department of Agriculture design, Swift Current, Saskatchewan) was used for seeding and a mechanical seed divider used to split the seed into the four seed drills.

Granular avadex B.W. (10% granular) was applied at Ellerslie in October, 1974, (before ground freeze-up), using a broadcast application method for wild oat control. The rate of application was 12.3 kg/ha. Herbicides to control the common weeds (stinkweed and hemp nettle at both Edmonton and Ellerslie and wild buckwheat and stinkweed at Olds) were used at different plant growth stages. Rates and dates of herbicide application are given in Table 3. 67 to 89 liters of water per hectare were used in spraying.

The following plant characteristics (variables) were evaluated in this experiment.

TABLE 3. RATES AND DATES OF HERBICIDE APPLICATION AND PLANT GROWTH STAGES.

Herbicide	Test site	Seeding date	Crop stage (No. of leaves)	Date of application	Rate of active ingredient (gm/ha)
MCPA (general type)	Edmonton	May 8	3 - 4	May 21	840
MCPA (general type)	Edmonton	May 16	5 - 6	June 9	840
MCPA (general type)	Edmonton	May 26	2 - 3	June 9	840
MCPA (general type)	Ellerslie	May 8	3 - 4	May 21	840
MCPA (general type)	Ellerslie	May 16	5 - 6	June 10	840
MCPA (general type)	Ellerslie	May 26	2 - 3	June 10	840
Buctril M	Olds	May 15	2 - 4	June 12	560

Plant characteristics (variables)	Recorded at
1 Plant stand	Edmonton, Ellerslie, Olds
2 Number of days to heading	Edmonton, Ellerslie, Olds
3 Ears per plant	Edmonton
4 Ears length, cm	Edmonton
5 Extrusion length, cm	Edmonton
6 Flag leaf lamina area, cm^2	Edmonton
7 Flag leaf sheath area, cm^2	Edmonton
8 Plant height, cm	Edmonton, Ellerslie, Olds
9 Number of kernels per ear	Edmonton
10 Number of days to maturity	Edmonton, Ellerslie, Olds
11 Grain yield, gm/2.30 m^2	Edmonton, Ellerslie, Olds
12 1000 kernel weight, gm	Edmonton, Ellerslie, Olds
13 Test weight of grain, kg/hl	Edmonton, Ellerslie, Olds
14 Grain protein content, %	Edmonton, Ellerslie, Olds
15 Protein yield, gm/2.30 m^2	Edmonton, Ellerslie, Olds
16 Grain yield per plant, gm	Edmonton
17 Grain yield per tiller, gm	Edmonton

1. Plant stand

Three sample counts, each based on a length of row one meter long, were taken at the 2 - 3 leaf stage from the center two rows in a plot. The average of these counts multiplied by 11.26 m was assigned as a plot value.

2. Number of days to heading

Date of heading was recorded when about 5% of the spikes in a plot came out of the boot. Days were recorded as the number of days from date of seeding to date of heading. Observations were done almost every day at Edmonton, every 2 - 3 days at Ellerslie, and every 3 days at Olds.

3. Ears per plant

Ten to fifteen days after all heading days were recorded (for any one seeding date) ten plants were pulled from the two border rows, five from each border row. Soil was removed by beating the lower part of the plant on a piece of board and the number of ear bearing tillers per plant counted. The average value was then recorded for the plot.

4, 5. Ear length and Extrusion length

At about the same time as the tiller count, one primary tiller of each of ten plants per plot (5 from each border row), was cut a little below the uppermost node. Extrusion length (that part of the culm between the tip of the flag leaf sheath and the base of the ear) and ear length were measured in centimeters and the average values assigned to the plot. The flag leaf lamina and its sheath were immediately wrapped in labelled plastic bags and put in a deep freeze until area measurements were done.

6, 7. Flag leaf lamina area and Flag leaf sheath area

The area of the preserved flag leaf samples (ten per plot) were measured by a KBK Automatic Area Meter, Type AAM-5 (manufactured by Hayashi Denko Co. Ltd.) and the average values recorded in cm^2. The area meter measures as small an area as 0.01 cm^2.

This photo electronic apparatus measures the total area of test objects by detecting how much the test objects shade the scanning light beam.

Since it was found difficult to keep the flag leaf sheath flat during the area measurement process, the area of the whole sheath with culm (ten per plot) was measured and the average value multiplied by a factor to give the relative flag leaf sheath area in cm^2. The factor was obtained using the following formula:

$$F_j = \frac{\sum_{i=1}^{i=N} (Y_i/X_i)}{N}$$

F_j = factor for jth treatment (j = 1, ..., 42)
Y_i = area of flat (true) flag leaf sheath
X_i = area of flag leaf sheath, non-flat, measured with culm.
N = number of plants tested (measured), usually 10 plant samples tested per treatment combination.

8. Plant height

A two-meter stick was used to take two readings from the center two rows of a plot at maturity. Main shoots were measured, excluding awns, and the average value in cm recorded for the plot.

9. Number of kernels per ear

Ten ears per plot from primary tillers (five from each border row) were harvested prior to maturity. The dried ears were threshed and kernels counted using a Syntron Electronic Seed Counter, Type EB00, Style 2040. The average value per ear was recorded for each plot.

10. Number of days to maturity

Maturity was recorded by visual rating. A plot was recorded mature when about 75% of the ears lost all the green tinge from their outer glumes. Observations were done almost every day at Edmonton, every 2 - 3 days at Ellerslie, and every 3 - 6 days at Olds. Days were recorded as the number of days from date of seeding to date of maturity.

At Edmonton, measurement of moisture percentage in the grain using a Burrows Digital Moisture Computer, Model 700, was tried in the field to see if it could be used as a guide for determining the differences in relative maturity of genotypes. About one week before the actual maturity date of Park in replication one, date one, a handful of plants from guard rows of plots were harvested, threshed, and moisture percentage of grains was determined right away. At this time, plots of Park (the early maturing genotype) at the relatively higher seeding rates (120, 150, and 180 kg/ha) had about 50% of the ears which had lost their green tinge from the outer glumes. In this test, a genotype with higher grain moisture percentage is considered relatively later in maturity than a genotype with low grain moisture percentage. Sampling was done in date one only, on August 22 (replication I), August 25 (replication II), and August 26 (replication III). Each sample included 42 subplot treatment combinations. Only limited data were obtained from this test due to procedural problems which are reported in the results and discussion section.

11. Grain yield

Harvested plants from the center two rows were dried in grain drying compartments heated by a Direct Gas Fired Make-up Air Heater, Model BMA D-3 at 36°C for 36 - 48 hours. The average grain moisture percentage after drying was about 10%. Threshing was done by a stationary HEGE - 125 combine and grain yield measured in grams. Harvested plot size after plot ends were trimmed was 5.02 x 0.46 m (2.30 m^2) for all three study sites.

12. <u>1000 kernel weight in grams</u>

200 seeds from the harvested sample from each plot were counted by using a Syntron Electronic Seed Counter, Type EB00, Style 2040. Weight of the 200 seeds was multiplied by 5 to give 1000 kernel weight in grams.

13. <u>Test Weight (kg/hectoliter)</u>

Test weight reading from plot grain yield was taken in pounds per bushel (lb/bu) and later converted to kilograms per hectoliter (kg/hl).

14. <u>Grain protein content</u>

The Neotec protein determining machine was used for evaluating grain protein in percentage. This machine works by the method of "Infrared Reflectance Spectroscopy". Details of sample preparation, grinding, and reading are given in "TIS, Winter, 1976. Infraletter, Vol. 2, No. 1., Technicon Ind. Systems, Tarrytown, New York".

15. <u>Protein yield per plot</u>

These data were obtained by multiplying plot grain yield by grain protein to give protein yield per plot (gm/2.30 m^2).

16. Grain yield per plant

The data for this variable were calculated as follows:

$$GP_i = GY_i \div PS_i$$ (i = 1 - 504, total number of plots at Edmonton)

GP_i = grain yield per plant for any one plot

GY_i = grain yield per plot (2.30 m^2) for any one plot

PS_i = plant stand per plot (2.30 m^2) for any one plot

17. Grain yield per tiller

The data for this variable were calculated as follows:

$$GT_i = GP_i : TP_i$$ (i = 1 - 504, total number of plots at Edmonton)

GT_i = grain yield per tiller for any one plot

GP_i = grain yield per plant for any one plot

TP_i = number of ear-bearing tillers per plant for any one plot

Later, the data for both grain yield per plant and grain yield per tiller were analyzed in the same way as the other variables.

Statistical analysis

1. Analysis of variance

For each site separately, all the data for each variable were subjected to the Analysis of Variance for Split Plot Design (Steel and Torrie, 1960) using the following model.

$$X_{ijk} = U + R_i + M_j + S_k + (RM)_{ij} + (MS)_{jk} + E_{ijk}$$

X_{ijk} = a single observation (value for a plot)

U = general population mean

R_i = replication effect (i = 1, ..., r)

M_j = main plot treatment effect (j = 1, ..., m)

S_k = subplot treatment effect (k = 1, ..., s)

$(RM)_{ij}$ = replication x main-plot treatment interaction effect (main-plot error)

$(MS)_{jk}$ = Main-plot treatment x sub-plot treatment interaction effect

E_{ijk} = residual error (subplot error)

Both main plot and subplot treatment effects are fixed in this model.

Duncan's Multiple Range test (Steel and Torrie, 1960) was used to compare main plot treatment means, subplot treatment means, genotype means and seeding rate means. Seeding date x (seeding rate x genotype) interaction means (DR interaction means) were compared using the Least Significance Difference (LSD) method.

2. Simple Correlations

The correlations among plant characteristics were calculated using plot mean values for any one variable. In these analyses, each genotype had 72 plot mean values (3 seeding dates x 4 replications x 6 seeding rates) for any one variable (N = 72).

3. Stepwise Multiple Regression

In this method, quantitative dependency relationships among variables are determined. For those genotypes where multiple regression equations were computed, observation number was the same as in the simple correlations (n = 72).

$$Y' = A + B_1 X_1 + B_2 X_2 + \dots + B_k X_k$$

Y' = estimated value for Y (dependent variable)

A = Y intercept

B_i = regression coefficient (solved by least square method)

X_i = independent variable

k = number of independent variables in the regression equation

In this stepwise multiple regression method, at each step after all the forced independent variables have been entered, the next independent variable entered into the regression equation is that which explains the greatest amount of variance between it and the dependent variable. (i.e. the variable with the highest partial correlation with the dependent variable). Every new independent variable entered into the equation has a B_i value which stands for the expected change in Y' value with a change of one unit of the new variable when the independent variables already in the equation are held constant or otherwise controlled for. Termination of the analysis occurred when the newly introduced variable resulted in giving a sequential F test value of 0.0001 or less.

4. Chi-Square Test for goodness of fit

Chi-square tests were conducted on plant stand data from date two for all locations. Observed plant stand was compared with the expected to determine if there were significant differences between the two. The model used was as follows: (Steel and Torrie, 1960).

$$\chi^2 = \sum_{i=1}^{i=N} \frac{(\text{observed} - \text{expected})^2}{\text{expected}}$$

N = Number of pairs (observed and expected)

RESULTS AND DISCUSSION

Analysis of Variance

Varying seeding dates at edmonton had significant effects on all variables except 1000 kernel weight (Table 4). Plant height and grain yield per plot at both Ellerslie and Olds, protein yield at Ellerslie and test weight and 1000 kernel weight at Olds were not significantly influenced by variation in seeding date.

At all locations, significant differences were observed in all variables studied due to different subplot treatment combinations (genotype x seeding rate).

At Edmonton, seeding date x (treatment combination) interaction (DR) effects were found significant for all variables except number of kernels per ear (Table 4). At Ellerslie, plant stand and plant height were not significantly influenced by DR interaction effects. At Olds, there were no significant DR interaction effects for any variables, except for days to heading (Table 4).

Mainplot coefficient of variations ($CV_{(a)}$) were found to be high ($CV_{(a)} \geq 15\%$) for plant stand and grain yield at all sites, 1000 kernel weight at Olds, protein yield at Edmonton and Ellerslie and extrusion length, flag leaf area, and kernels per ear at Edmonton (Table 4). Subplot coefficient of variation ($CV_{(b)}$) was also high ($CV_{(b)} \geq 15\%$) for plant stand, grain yield and protein yield at all locations, and for ears per plant at Edmonton. The technique used in collecting data for ears per plant was observed to be unreliable since it was difficult to separate individual ear bearing tillers from the parent plant and this might have accounted for the high CV values (101.7 for $CV_{(a)}$ and 34.7 for $CV_{(b)}$). Insufficient number of measurements per plot (as was the case with 1000 kernel weight, protein yield,

TABLE 4. ANALYSIS OF VARIANCE FOR SOME PLANT CHARACTERISTICS STUDIED AT EDMONTON, ELLERSLIE, AND OLDS.

Source of variation	DF	Plant stand	Plant height	Days to heading	Days to maturity	Grain yield	Test weight	1000 kernel weight	Grain protein %	Protein yield	Ear length	Extrusion length	Flag leaf lamina area	Flag leaf sheath area	Ears per plant	Kernels per ear
		MEAN SQUARES														
MAIN-PLOTS																
Replications	3*	41500	384	5.7	143	202912*	16.7	41.4	20.3*	14707*						
	3	6951	204	10.3*	37	107691	1.0	42.6*	5.7*	1304	2.79	9.7	57.7	84.9**	17.3	124
	2	65621*	458	14.0	276	232720*	11.3	93.4	15.7**	3627*						
Seeding dates	3	1083872**	4370**	2353.1**	2332**	2357216**	517.0**	15.5	200.7**	36190**						
	2	301192**	40	3719.5**	102*	347904	133.5**	33.5*	5.2*	5734	17.84**	196.8**	550.7	42.1*	163.7**	554*
	1	211194**	11	2242.0**	1152*	131392	0.0	46.6	3.2*	2325*						
Error (a)	6	41125	119	2.3	33	159915	14.5	25.6	2.9	2305						
	6	17245	112	0.3	10	109867	1.8	4.7	1.0	2533	0.95	8.9	148.6	5.7	11.4	126
	3	4496	90	6.3	109	26619	2.3	35.5	0.1	224						
SUB-PLOTS																
Treatment combinations	41	275889**	1191**	85.0**	343**	308524**	18.8**	142.4**	24.2**	3890**						
	41	633655**	1440**	87.0**	360**	276274**	16.6**	124.0**	25.9**	4722**	22.72**	354.1**	163.6**	125.6**	3.2**	618**
	41	269176**	568**	41.9**	180**	79340**	5.4**	123.6**	15.8**	1444**						
Seeding date x Treatment combinations	82	22637**	33**	4.0**	27**	49533**	4.0**	11.9**	1.0**	1336**						
	82	7982	14	2.4**	16**	38010**	4.0**	7.7**	0.9**	849**	0.35**	8.2**	23.6**	6.1**	1.9*	42
	41	19424	29	1.7**	15	29974	1.5	5.5	1.0	315						
Error (b)	369	11208	13	0.6	10	29432	2.0	7.7	0.6	738						
	369	8151	13	0.5	7	23138	1.7	4.9	0.5	542	0.17	3.5	9.4	4.1	1.3	35
	246	8555	25	0.8	11	24697	1.5	5.5	0.9	376						
COEFFICIENT OF VARIATION (CV %)																
Main-plots		58.7	13.0	2.8	5.0	40.4	4.7	12.4	10.2	30.0						
		27.6	12.6	1.0	2.7	34.3	1.7	5.6	6.3	32.6	10.2	15.4	50.1	11.2	101.7	24.8
		17.8	12.1	4.9	9.3	18.7	1.9	17.0	2.6	13.5						
Sub-plots		30.6	4.3	1.5	2.7	17.3	1.7	6.8	4.6	17.0						
		19.0	4.2	1.3	2.2	15.7	1.6	5.8	4.3	15.1	4.4	9.7	12.6	9.5	34.7	13.5
		24.5	6.4	1.8	3.0	20.4	1.5	6.7	6.4	17.5						

• First rows are for Edmonton, second rows for Ellerslie, and third rows for Olds for each source of variation and each CV %.

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

and grain yield) could also have contributed to the unexplainable variation, leading to higher CV. Plant stand might have also been influenced by differential germination due to inherent plot variability thus leading to higher CV values. High CV values indicate larger error ($CV_{(a)}$ for error (a) and $CV_{(b)}$ for error (b)). High error values mean that the explainable variation will be relatively smaller thereby decreasing the chance of detecting significant treatment differences in both mainplots and subplots.

EFFECTS OF VARIATION IN SEEDING RATE AND SEEDING DATE ON

Grain yield per plot

At all locations, increases in seeding rate significantly increased grain yield per plot (Table 5). This relationship was also true for most of the genotypes at all locations and is in agreement with reports by Woodward, 1956, Puckridge and Donald, 1967, Austenson, 1972, Stoskopf et al., 1974, Briggs, 1975, and Faris et al., 1976. For most genotypes, this effect was more pronounced at the relatively lower seeding rates (30, 60 and 90 kg/ha) and increases in grain yield were found to be relatively smaller, and non-significant, for seeding rates above the 120 kg/ha rate. The increases in grain yield from increased seeding rates of most genotypes could possibly be attributed to the increased plant stand (Table 30) since all other grain yield components showed negative responses to increased seeding rates (Tables 12, 14, and 16). This effect was also indicated by Guitard et al., 1961, and Puckridge and Donald. 1967.

Averaged over all seeding rates and seeding dates, Pitic 62

TABLE 5. MEANS (AVERAGED OVER ALL SEEDING DATES AND OVER ALL REPLICATIONS) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEEDING RATE) FOR GRAIN YIELD IN GM/2.30 M^2.

Seeding Rate (kg/ha)	Genotypes: Park	Neepawa	Pitic 62	Glenlea	Norquay	70M110001	70M009002	Seeding Rate Means
Edmonton								
30	682 l +	768 kl	1094 b-f	777 kl	776 kl	849 hijk	754 kl	814 c'
60	772 kl	961 f-j	1261 a	967 f-j	958 f-j	978 d-h	1019 c-h	988 b'
90	810 ijkl	917 g-k	1302 a	892 g-k	945 f-j	1140 a-e	1001 c-h	1001 b'
120	783 kl	973 e-i	1295 a	997 d-h	1059 d-g	1198 ab	1024 c-g	1047 ab'
150	804 jkl	1004 e-h	1206 ab	1089 b-f	1013 c-h	1167 abc	898 g-k	1026 ab'
180	952 f-j	1005 c-h	1287 a	1031 c-g	1057 b-g	1147 abcd	997 d-h	1068 a'
Genotype Means	800 d"	938 c"	1241 a"	959 c"	968 c"	1080 b"	949 c"	
Ellerslie								
30	589 p	758 no	996 d-k	803 m	755 no	610 p	647 op	737 c'
60	825 lm	972 e-l	1155 abc	888 j-n	976 e-k	921 i-m	762 no	928 b'
90	900 j-n	966 f-l	1186 a	1026 b-j	1008 c-k	1121 a-e	891 j-n	1014 a'
120	870 klm	1039 a-j	1176 ab	1075 a-h	1106 a-g	1085 a-h	1024 c-j	1053 a'
150	865 klm	939 h-m	1067 a-i	1004 c-k	1071 a-i	1100 a-h	965 f-l	1001 a'
180	964 g-l	1059 a-i	1117 a-f	1080 a-h	1134 abcd	1148 abc	988 d-k	1070 a'
Genotype Means	835 c"	956 b"	1116 a"	979 b"	1008 b"	997 b"	880 c"	
Olds								
30	570 jk	611 ijk	756 b-k	654 g-k	696 f-k	564 k	640 hijk	642 c'
60	653 g-k	754 b-k	771 b-i	700 f-k	757 b-j	850 b-f	722 d-k	744 b'
90	745 c-k	740 c-k	907 a-e	783 b-i	824 b-h	721 d-k	700 f-k	774 ab'
120	826 b-h	751 b-k	838 b-g	682 f-k	911 abcd	804 b-i	745 c-k	794 ab'
150	812 b-i	698 f-k	1041 a	932 abc	806 b-h	737 d-k	823 b-h	836 a'
180	776 b-i	802 b-i	910 abcd	940 ab	715 e-k	789 b-i	827 b-h	823 ab'
Genotype Means	730 b"	726 b"	870 a"	782 b"	785 b"	744 b"	743 b"	

\+ Means followed by the same letters are not significantly different from each other at the 5% level of probability. When a mean is followed by more than four letters, only the beginning and the last letters are written.

',". Indicate separate comparisons of seeding rate means and genotype means, respectively.

was significantly the highest grain yielder at all three locations giving 1241 gms/2.30 m^2 (5396 kg/ha) at Edmonton, 1116 gm/2.30 m^2 (4852 kg/ha) at Ellerslie, and 870 gm/2.30 m^2 (3783 kg/ha) at Olds. Park at Edmonton and Park and 70M009002 at Ellerslie were the lowest yielders. At Olds, all genotypes, except Pitic 62, which was significantly higher yielding, had similar grain yields per plot.

As mentioned earlier, grain yield for most genotypes showed a trend of leveling-off or dropping at the relatively higher seeding rates (120, 150 and 180 kg/ha). For some, similar grain yields were obtained at the highest four, five or six seeding rates. For instance, 70M110001 or 70M009002 at Edmonton, Pitic 62 at Ellerslie and Olds, and Norquay at Olds showed a trend of decrease in grain yield due to increase in seeding rate in the higher seeding rate range (120, 150 and 180 kg/ha). There were no significant grain yield differences for the five highest seeding rates for Norquay or Pitic 62 at Edmonton, or for Neepawa or Pitic 62 at Ellerslie, or for Park or 70M110001 at Olds. At Olds, Neepawa and 70M009002 had similar grain yields for all six seeding rates. This leveling-off or dropping of grain yield at higher seeding rates is likely due to corresponding leveling-off of plant stand (Table 30) accompanied by decrea s in ears per plant (Table 12), kernels per ear (Table 14) and kernel weight (Table 16). There was no marked lodging problem recorded at any site, which could account for grain yield leveling-off or decreasing at higher seeding rates, except for Pitic 62 at the 150 and 180 kg/h rates which showed slight lodging at Olds.

The grain yield response of genotypes to variation in seeding rate varied from one location to another. Grain yields of Pitic 62, for instance, were similar for the five highest seeding rates at Edmonton or

Ellerslie. However, at Olds, a higher grain yield for Pitic 62 was obtained from the 90 kg/ha rate than from the 30, 60, and 120 kg/ha seeding rates. Park had significantly the highest grain yield at the 180 kg/ha seeding rate at both Edmonton and Olds and at the 150 and 180 kg/ha seeding rates at Ellerslie. The above results indicate that the optimum seeding rate for high grain yield may vary from one genotype to another, and from one location to another within genotypes.

At Edmonton, grain yield (averaged over all treatment combinations) was significantly lower from date three seeding than from either date one or date two seeding (Table 6). At Ellerslie and Olds, there were no significant grain yield differences due to variation in seeding date. However, most treatment combinations had significantly higher grain yields when seeding was earlier. This result of higher grain yields from early seeding is in agreement with similar reports by Woodward, 1956, Anderson and Hennig, 1964, Khalifa, 1970, Beech and Norman, 1971, Larter et al., 1971, Stoskopf et al., 1974, and Nass et al., 1975. At Edmonton, the late maturing genotypes, Pitic 62, Glenlea, Norquay, and one of the early maturing genotypes, 70M110001, at most seeding rates, benefited more from early seeding, compared to the other relatively early maturing genotypes, Park, Neepawa, or 70M009002. For instance, seedings at either or both of dates one and two gave significantly higher grain yields for Pitic 62, Norquay at all seeding rates, and for Glenlea at th 30, 60, 90, 120 and 180 kg/ha, and for 70M110001 at the 30, 60, 90 and 120 kg/ha seeding rates. On the other hand, it was only the 120 and 150 kg/ha seeding rates for Park, the 30 kg/ha seeding rate for Neepawa, and the 30, 60 and 150 kg/ha seeding rates of 70M009002 which had significantly higher grain yields from either or both of dates one

TABLE 6. MEANS (AVERAGED OVER ALL REPLICATIONS) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEEDING RATE) FOR GRAIN YIELD IN GM/2.30 M^2.

Treatment combination: Genotype x Seeding rate		Seeding date: Edmonton One	Edmonton Two	Edmonton Three	Ellerslie One	Ellerslie Two	Ellerslie Three	Olds One	Olds Two
Park	30 kg/ha	787	715	543	666	672	430	534	606
Park	60 kg/ha	854	774	683	806	845	823	594	713
Park	90 kg/ha	861	721	847	897	900	903	703	787
Park	120 kg/ha	983	750	610	893	839	877	768	884
Park	150 kg/ha	958	890	565	834	857	843	803	822
Park	180 kg/ha	986	966	905	1032	918	941	677	875
Neepawa	30 kg/ha	1035	824	444	923	607	745	647	575
Neepawa	60 kg/ha	983	1071	830	960	1026	929	792	716
Neepawa	90 kg/ha	933	908	911	980	970	950	741	739
Neepawa	120 kg/ha	1064	949	907	1093	1015	1008	646	856
Neepawa	150 kg/ha	1012	1016	983	866	1010	942	749	647
Neepawa	180 kg/ha	989	1067	959	960	1178	1039	775	829
Pitic 62	30 kg/ha	1072	1356	854	1144	1066	777	651	861
Pitic 62	60 kg/ha	1309	1384	1092	1177	1127	1162	780	762
Pitic 62	90 kg/ha	1432	1395	1080	1269	1232	1057	903	911
Pitic 62	120 kg/ha	1394	1380	1113	1062	1367	1098	726	950
Pitic 62	150 kg/ha	1340	1338	940	1059	1099	1043	1078	1004
Pitic 62	180 kg/ha	1358	1520	985	1027	1221	1103	841	980
Glenlea	30 kg/ha	841	958	532	994	729	688	582	726
Glenlea	60 kg/ha	1082	1164	656	1014	903	747	526	875
Glenlea	90 kg/ha	1117	998	561	1064	1153	862	842	723
Glenlea	120 kg/ha	[illegible]	1049	797	1081	1113	1031	665	700
Glenlea	150 kg/ha	1177	1093	999	975	1097	941	970	895
Glenlea	180 kg/ha	1199	1212	682	1055	1150	1034	932	949
Norquay	30 kg/ha	838	947	542	836	657	773	782	609
Norquay	60 kg/ha	1059	992	822	1094	931	902	753	762
Norquay	90 kg/ha	1161	905	769	991	1123	910	955	693
Norquay	120 kg/ha	1204	1067	908	1256	1124	938	842	981
Norquay	150 kg/ha	1176	1136	727	1200	1088	924	842	771
Norquay	180 kg/ha	1177	897	1098	1197	966	1238	699	731
70M110001	30 kg/ha	902	959	685	635	504	689	528	600
70M110001	60 kg/ha	1079	1138	718	829	965	969	817	884
70M110001	90 kg/ha	1138	1357	926	1190	1203	970	685	757
70M110001	120 kg/ha	1268	1317	1010	1280	966	1008	761	847
70M110001	150 kg/ha	1119	1274	1108	1132	1061	1107	736	738
70M110001	180 kg/ha	1072	1283	1085	1026	1266	1153	794	785
70M009002	30 kg/ha	993	665	605	843	590	508	538	743
70M009002	60 kg/ha	1084	1155	819	851	798	638	736	708
70M009002	90 kg/ha	1084	1089	907	939	940	794	755	645
70M009002	120 kg/ha	1067	1056	948	1030	1018	1025	796	694
70M009002	150 kg/ha	890	1057	746	861	1036	998	745	901
70M009002	180 kg/ha	1118	992	831	[illegible]	1044	940	768	885
Seeding date Mean		1078 a*	1066 a	828 b	1001 a'	985 a'	916 a'	749 a"	788 a"
+ LSD (5%)		259			228			222	
++ LSD (5%)		240			213			220	

* Within location, means followed by the same letters are not significantly different from each other at the 5% level of probability.

\+ Least significant difference between means of same treatment combination in different seeding dates or between means of different treatment combinations in different seeding dates.

++ Least significant difference between means of different treatment combinations in the same seeding date.

', " Indicate separate comparisons of seeding date means for Ellerslie and Olds, respectively.

and two seedings than from date three seeding. A similar relationship was also observed at Ellerslie for most of the treatment combinations which showed significant grain yield responses to variation in seeding date. At Olds, grain yields of all treatment combinations did not show significant responses to variation in seeding date. The explanation for this could be that the seven days difference between the two seeding dates at Olds was insufficient to affect the relative length of the growing season. The decrease in grain yield due to delayed seeding of most treatment combinations at Edmonton and some at Ellerslie could possibly be due to the relative shortness of the growing season at both locations which did not allow the normal completion of the development of plants. For instance, the average number of days to maturity was 125 and 127 for Pitic 62, 109 and 112 for Park, and 114 and 116 for 70M110001 at Edmonton and Ellerslie, respectively (Table 8), while the frost free days (1975 season) were 130 for Edmonton and 105 for Ellerslie (Appendix 1). This means that delayed seeding could have forced the grain filling period of plants to fall into the relatively cooler part of the growing season, August-September, (Figure 1), thereby resulting in poor grain filling and then poor grain yield. Therefore, the need for early planting in spring for most treatment combinations, especially at Edmonton, cannot be over-emphasized. Another alternative to avoid this grain yield loss from late seeding, could b o develop or introduce genotypes which are early maturing but still are higher grain yielders than the commonly grown cultivars in the area. At Edmonton for instance 70M110001 can fall in this category since it outyielded both Park and Neepawa by 15 - 35% and yet was only about 3-5 days later in maturity (Table 8). At Olds, grain yield should be given more emphasis than early maturity in selecting a feedwheat genotype since the growing season there is relatively longer than that of Edmonton or Ellerslie (Alberta Agriculture, 1975).

The remarkably higher grain yield of Pitic 62 at all three locations, (averaged over all seeding rates and seeding dates within locations) compared to the other genotypes supports the reports by Dubetz, 1972, from a study at two sites in Alberta, and Mack, 1973, in Ontario. In the present study, Pitic 62 outyielded Park, one of the lowest grain yielding genotypes, by about 55% at Edmonton, 34% at Ellerslie, and 19% at Olds (Table 5). Even one of the second highest grain yielding genotypes, 70M110001, gave about 35% more grain yield than Park at Edmonton and 19% at Ellerslie.

Protein level of hard red spring wheats grown in most parts of Alberta was found to be low (Dunne and Anderson, 1976). The bread making quality of these wheats was also low. The prospect of obtaining higher grain yield and more feed energy per unit area from new genotypes y relaxing the grain quality standards in the breeding program were among the conditions which led to the creation of the new market class "Utility Wheat" by the Grains Act of Canada in 1969. The fact that energy levels per unit weight of grain are higher from wheat for most livestock rations than from other cereals like barley and oats (Table 7) also adds to the importance of researching the potential of utility wheats for feed purpose in Alberta. With feed energy per unit area being so important and in view of the very narrow range in energy per unit weight of different wheat cultivars, as reported by De La Roche and Fowler, 1976, selection for high grain yield becomes the most effective way to produce a good feedwheat. In this regard the higher

TABLE 7. ENERGY LEVELS OF CEREAL GRAINS FROM CANADIAN GRAINS NORMALLY USED FOR RATING RATIONS.+

Livestock class ration	Wheat	Barley	Corn	Oats
Beef cattle , % TDN	78	74	78	68
Beef cattle , Kcal DE/kg	3415	3260	3450	2980
Dairy cows , % TDN	80	78	80	72
Poultry , Kcal ME/kg	3080	2860	3300	2600
Pigs , Kcal ME/kg	3275	2876	3275	2670

+ From Canada Grains Council ____. Feed grains of Canada. Winnipeg, Manitoba, Canada.

grain yields of genotypes like Pitic 62 and 70M110001 (Table 5) should not be overlooked, although the relative number of days to maturity required by these genotypes must also be considered. It appears that specific varietal management recommendations may also be required to optimise the yield of new and genetically diverse feedwheat genotypes as they are licensed in the future.

Days to Maturity

At all locations, the number of days to maturity was significantly reduced by increased seeding rates (Table 8). Number of days to maturity was significantly greater for the 30 kg/ha seeding rate compared to the other seeding rates at each location.

Averaged over all seeding rates and seeding dates, Pitic 62 was significantly the latest maturing genotype in all three sites requiring 125, 127 and 116 days at Edmonton, Ellerslie and Olds, respectively. Glenlea was as late as Pitic 62 at Olds. Park with 109 days at Edmonton and Park and 70M009002 with 112 and 113 days, respectively, at Ellerslie were the earliest maturing genotypes. At Olds, Park, Norquay 70M110001 and 70M009002 were the earliest maturing genotypes taking 110, 110, 109 and 109 days for maturity, respectively.

The effect of seeding rate on number of days to maturity for any genotype varied from one location to another. At Edmonton for instance, the number of days to maturity for Pitic 62 was not significantly influenced by variation in seeding rate. At Ellerslie, and Olds however, the number of days to maturity for Pitic 62 decreased by about 4-6 days for the 120, 150 and 180 kg/ha rates compared to results from the 30 kg/ha rate. Similarly, for 70M110001 at the 120,

TABLE 8. MEANS (AVERAGED OVER ALL SEEDING DATES AND OVER ALL REPLICATIONS) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEEDING RATE) FOR NUMBER OF DAYS TO MATURITY.

Seeding Rate (kg/ha)	Genotypes							Seeding Rate Means
	Park	Neepawa	Pitic 62	Glenlea	Norquay	70M110001	70M009002	
Edmonton								
30	111 ijk+	115 fgh	124 ab	123 b	118 cde	120 c	116 efg	118 a'
60	110 jk	112 ijk	124 ab	119 cd	114 ghij	117 def	111 ijk	115 b'
90	109 kl	110 jk	124 ab	119 cd	113 hi	114 ghi	111 ijk	114 bc'
120	109 kl	110 jk	125 ab	116 efg	112 ijk	113 hij	111 ijk	114 bc'
150	109 kl	109 kl	125 ab	116 efg	113 hij	111 ijk	111 ijk	113 c'
180	107 l	110 jk	126 a	116 efg	112 ijk	111 ijk	110 jk	113 c'
Genotype Means	109 e"	111 d"	125 a"	118 b"	114 c"	114 c"	112 d"	
Ellerslie								
30	117 hij	119 gh	130 a	125 cd	121 fg	123 def	117 hij	122 a'
60	113 lmn	115 jkl	128 ab	122 ef	119 gh	118 hi	115 jkl	119 b'
90	111 no	114 klm	128 ab	119 gh	117 hij	116 ijk	113 lmn	117 c'
120	112 mno	113 lmn	126 bc	118 hi	116 ijk	113 lmn	111 no	116 cd'
150	111 no	112 mno	124 cde	117 hij	114 klm	112 mno	110 o	115 de'
180	110 o	112 mno	126 bc	118 hi	114 klm	112 mno	110 o	114 e'
Genotype Means	112 e"	114 d"	127 a"	120 b"	117 c"	116 c"	113 de"	
Olds								
30	118 bc	116 cde	120 ab	122 a	118 bc	115 cdef	116 cde	118 a'
60	112 fghi	114 defg	117 bcd	117 bcd	111 ghij	111 ghij	111 ghij	113 b'
90	111 ghij	112 fghi	117 bcd	116 cde	109 ijkl	109 ijkl	108 jklm	112 b'
120	107 klm	112 fghi	114 defg	112 fghi	110 hijk	106 lm	106 lm	110 c'
150	105 m	108 jklm	116 cde	116 cde	105 m	106 lm	106 lm	109 cd'
180	106 lm	108 jklm	114 defg	113 efgh	105 m	106 lm	105 m	108 d'
Genotype Means	110 c"	112 b"	116 a"	116 a"	110 c"	109 c"	109 c"	

\+ Means followed by the same letters are not significantly different from each other at the 5% level of probability. When a mean is followed by more than four letters, only the beginning and the last letters are written.

'," Indicate separate comparisons of seeding rate means and genotype means, respectively.

150, and 180 kg/ha rates, the number of days to maturity decreased by about 7-9 days at Edmonton, by 10-11 days at Ellerslie, and by 9 days at Olds compared to results from the 30 kg/ha rate. The 30 kg/ha rate also increased the number of days to maturity of Park at about 4-7 days at Ellerslie and by 6-13 days at Olds compared to results from the remaining seeding rates. The influence of higher seeding rates in decreasing the number of days to maturity was also reported in Alberta by McFadden, 1970, Briggs, 1975, and Faris <u>et al</u>., 1976. Higher competition for light, water, and nutrients at higher seeding rates as indicated by Leonard and Martin, 1967, and Bidwell, 1974, could have made plants grow faster and mature relatively earlier compared to those at lower seeding rates. More rapid growth of plants at higher seeding rates was also suggested by Willey and Holliday, 1971.

At Edmonton, late maturing genotypes like Pitic 62 and Glenlea each at all seeding rates, Norquay at the 30,60 and 90 kg/ha rates and one of the early maturing genotypes, 70M110001, at the 60, 90 and 120 kg/ha rates, had significantly larger number of days to maturity from date three seeding than from either or both of dates one and two seeding (Table 9). The increases in number of days to maturity due to delayed seeding could possibly be due to the fact that late seeding forced the ripening stage of the grain into the cooler part of the growing season, August-September, (Fig.1), thus slowing down the ripening process. However, seedings at either or both of dates two and three compared to date one decreased the number of days to maturity of Park (one of the early maturing genotypes) at most seeding rates for which number of days to maturity responded significantly to variation in seeding date. A similar relationship was also observed at Ellerslie. The most important

TABLE 9. MEANS (AVERAGED OVER ALL REPLICATIONS) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEEDING RATE) FOR NUMBER OF DAYS TO MATURITY.

Treatment combination [Genotype x Seeding rate]		Seeding date: Edmonton One	Edmonton Two	Edmonton Three	Ellerslie One	Ellerslie Two	Ellerslie Three	Olds One	Olds Two
Park	30 kg/ha	112	109	113	116	120	116	119	117
Park	60 kg/ha	112	106	113	115	112	111	113	112
Park	90 kg/ha	111	107	109	115	110	110	113	110
Park	120 kg/ha	112	106	109	115	110	110	108	106
Park	150 kg/ha	112	107	109	115	109	109	108	102
Park	180 kg/ha	111	106	104	114	109	108	107	106
Neepawa	30 kg/ha	112	113	121	117	122	118	120	113
Neepawa	60 kg/ha	112	110	116	115	115	115	116	112
Neepawa	90 kg/ha	112	106	114	115	114	114	113	110
Neepawa	120 kg/ha	111	108	112	115	114	113	112	113
Neepawa	150 kg/ha	111	106	109	115	110	111	110	106
Neepawa	180 kg/ha	111	106	112	115	111	112	110	107
Pitic 62	30 kg/ha	121	122	130	127	132	131	121	120
Pitic 62	60 kg/ha	122	121	130	128	128	127	118	116
Pitic 62	90 kg/ha	123	122	128	127	130	128	118	116
Pitic 62	120 kg/ha	120	122	132	124	126	127	115	114
Pitic 62	150 kg/ha	123	121	132	121	124	126	118	114
Pitic 62	180 kg/ha	121	122	134	126	126	126	115	113
Glenlea	30 kg/ha	122	120	127	128	127	122	123	120
Glenlea	60 kg/ha	115	115	126	124	122	121	119	116
Glenlea	90 kg/ha	114	113	128	117	122	119	118	113
Glenlea	120 kg/ha	114	113	122	117	121	117	114	110
Glenlea	150 kg/ha	114	114	120	117	115	117	119	113
Glenlea	180 kg/ha	115	111	122	118	119	116	116	111
Norquay	30 kg/ha	116	116	123	123	120	119	117	120
Norquay	60 kg/ha	114	111	116	120	116	120	116	107
Norquay	90 kg/ha	114	111	116	119	116	115	115	103
Norquay	120 kg/ha	113	110	113	116	116	117	112	109
Norquay	150 kg/ha	112	112	116	116	113	115	109	102
Norquay	180 kg/ha	114	111	112	116	115	112	10[illegible]	103
70M110001	30 kg/ha	119	118	122	120	127	122	117	113
70M110001	60 kg/ha	116	115	120	118	117	118	113	108
70M110001	90 kg/ha	112	111	118	115	116	118	112	107
70M110001	120 kg/ha	113	110	116	115	111	113	108	104
70M110001	150 kg/ha	112	109	113	115	111	112	108	105
70M110001	180 kg/ha	113	110	111	114	111	112	109	103
70M009002	30 kg/ha	115	115	117	117	117	117	119	112
70M009002	60 kg/ha	112	109	112	115	114	115	110	112
70M009002	90 kg/ha	112	108	113	115	110	114	110	106
70M009002	120 kg/ha	111	110	111	115	109	109	108	105
70M009002	150 kg/ha	114	108	111	114	109	108	109	103
70M009002	180 kg/ha	112	108	111	114	109	108	107	103
Seeding date Mean		114 b*	112 c	118 a	118 a'	117 b'	116 c'	113 a"	110 b"
+ LSD (5%)		4.5			3.7			5.7	
++ LSD (5%)		4.3			3.6			4.6	

* Within location, means followed by the same letters are not significantly different from each other at the 5% level of probability.

+,++ See Table 6 for explanation.

'," Indicate separate comparisons of seeding date means for Ellerslie and Olds, respectively.

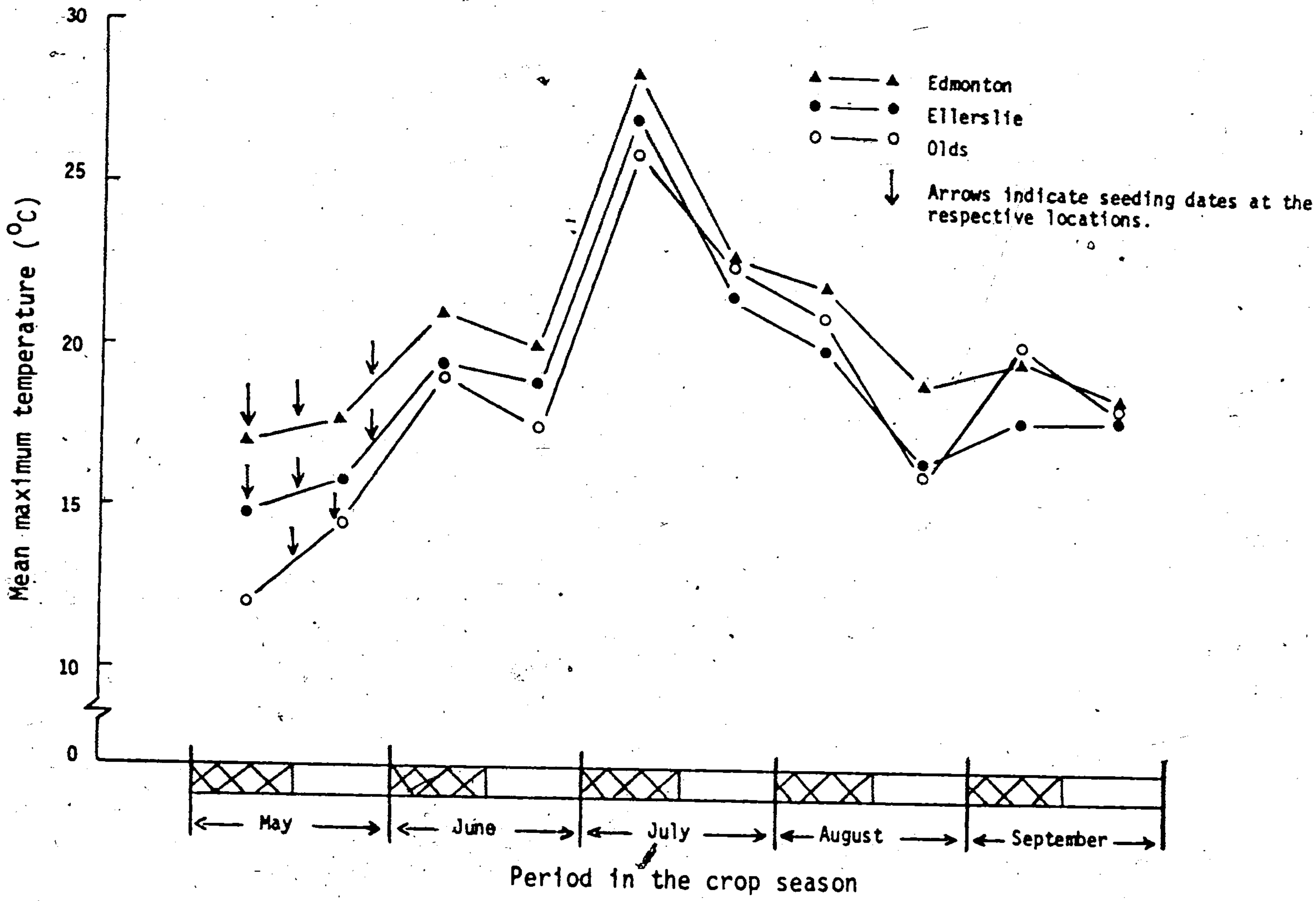

FIGURE 1. BIMONTHLY MEAN MAXIMUM TEMPERATURE (°C) FOR THE CROP SEASON (1975) FOR THE STUDY SITES, EDMONTON, ELLERSLIE, AND OLDS. (SEE APPENDIX 2 FOR SOURCES OF DATA).

part of this present study is probably the findings with respect to the effects of seeding date and seeding rate variation on the relationships of number of days to maturity and grain yield for different genotypes.

Grain yield per unit area and number of days to maturity

At all locations, increases in seeding rate increased grain yield and decreased the number of days to maturity of most genotypes (Fig. 2, 3). However, the magnitude of increases in grain yield and decreases in number of days to maturity varied from one genotype to another and from one location to another. At both Edmonton and Ellerslie for instance, increasing seeding rate did not greatly influence grain yield and number of days to maturity of Pitic 62 (Fig. 2). At Olds, however, grain yield of Pitic 62 increased markedly, though erratically, due to increased seeding rate. At Edmonton, increasing seeding rate did not influence grain yield of 70M009002 as greatly as it did at Ellerslie (Fig. 3).

At Edmonton, all genotypes had higher grain yield and fewer number of days to maturity from early seedings (date one or two)(Fig.4). At Ellerslie, only Pitic 62, Norquay, Glenlea, and 70M009002 had higher grain yield from early seedings. The number of days to maturity of most genotypes was not markedly influenced due to fferent seeding dates. At Olds, most genotypes had increased grain yields and a fewer number of days to maturity from date two seeding. Norquay, however, had higher grain yield and decreased number of days to maturity from date one seeding.

The mean length of frost-free period is normally between 100-120 days at both Edmonton and Ellerslie and is about 110 days at

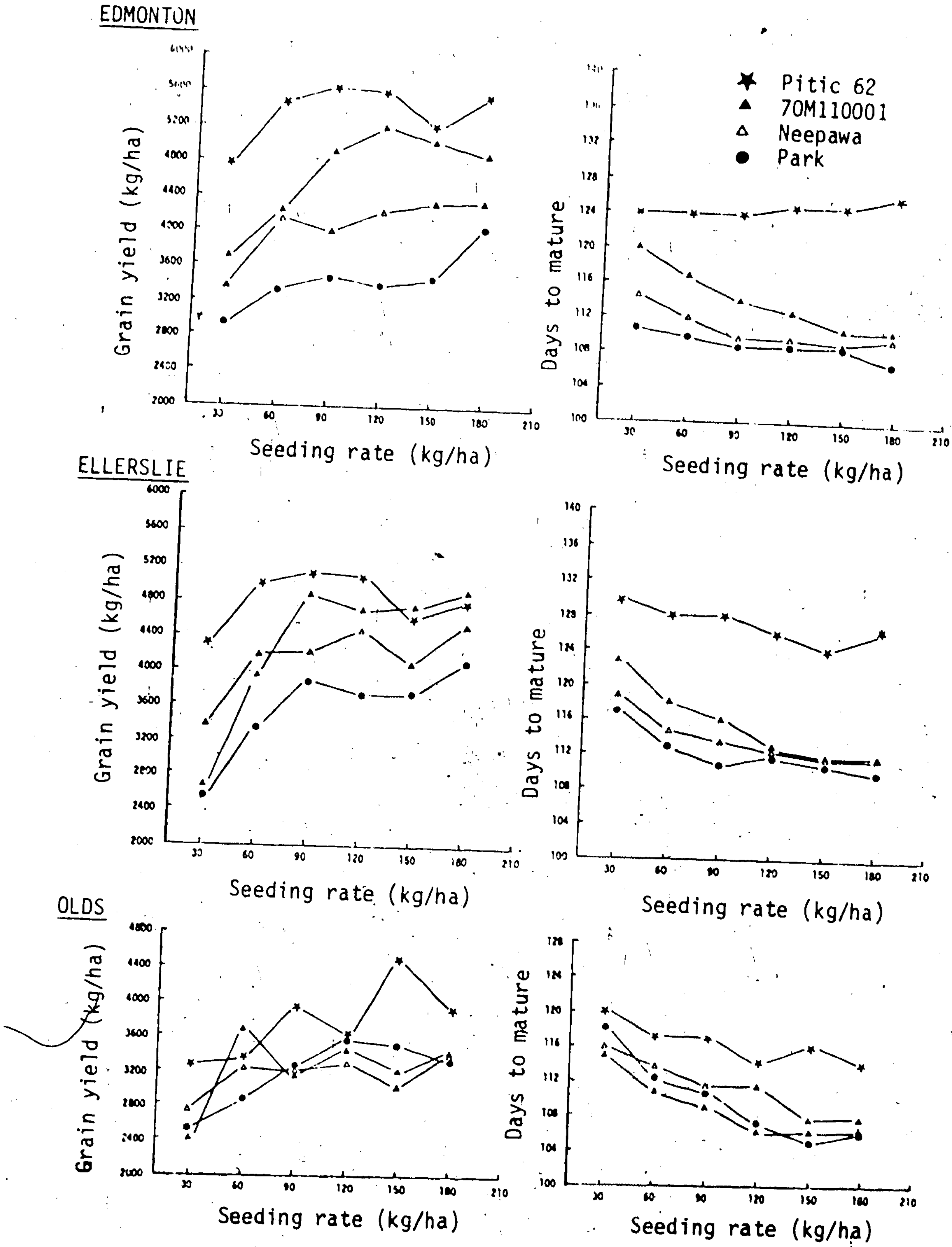

FIGURE 2. THE EFFECT OF SEEDING RATE ON GRAIN YIELD AND NUMBER OF DAYS TO MATURITY FOR SOME WHEAT GENOTYPES. (MEANS AVERAGED OVER ALL SEEDING DATES WERE USED FOR EACH GENOTYPE).

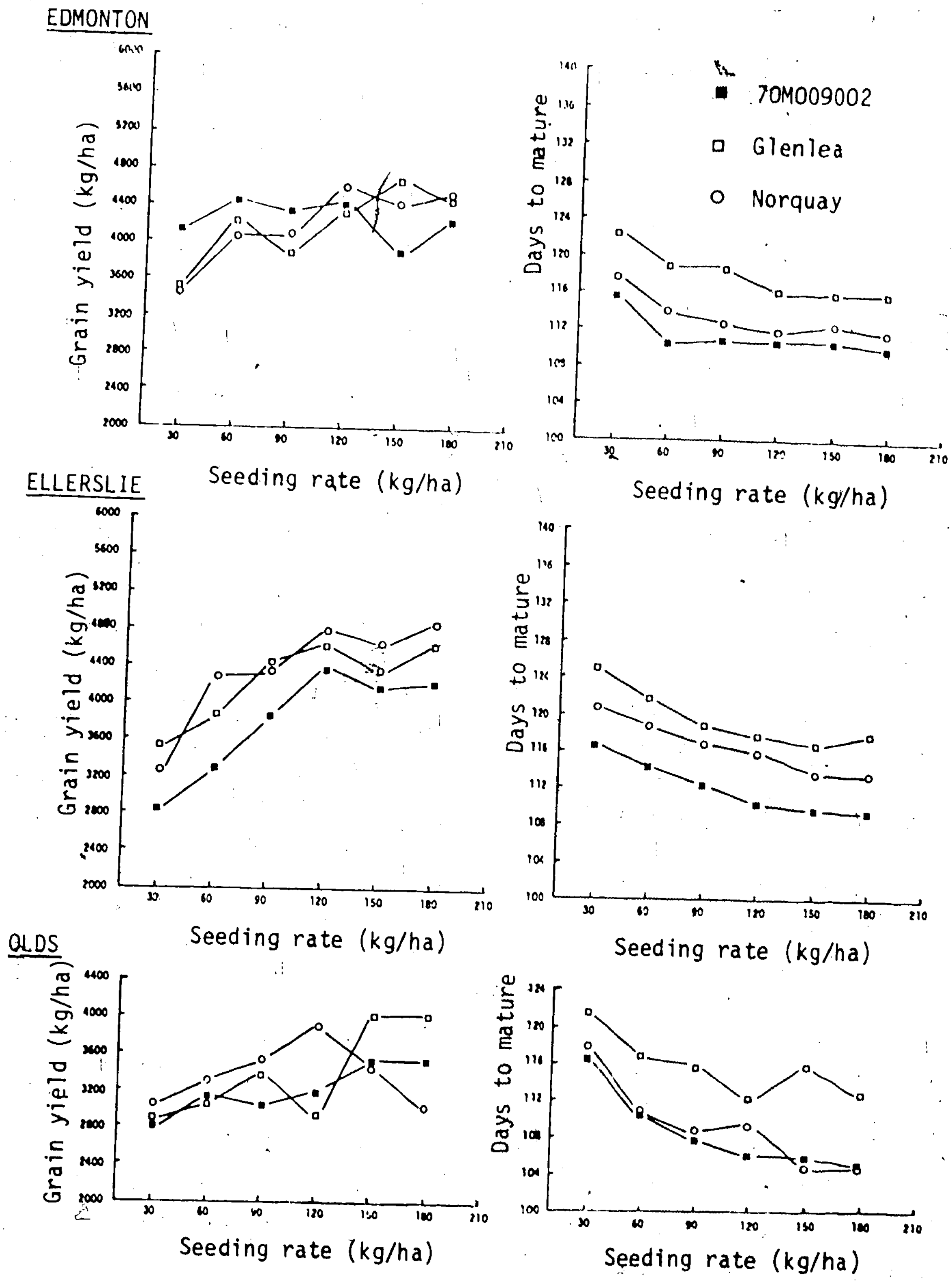

FIGURE 3. THE EFFECT OF SEEDING RATE ON GRAIN YIELD AND NUMBER OF DAYS TO MATURITY FOR SOME WHEAT GENOTYPES. (MEANS AVERAGED OVER ALL SEEDING DATES WERE USED FOR EACH GENOTYPE).

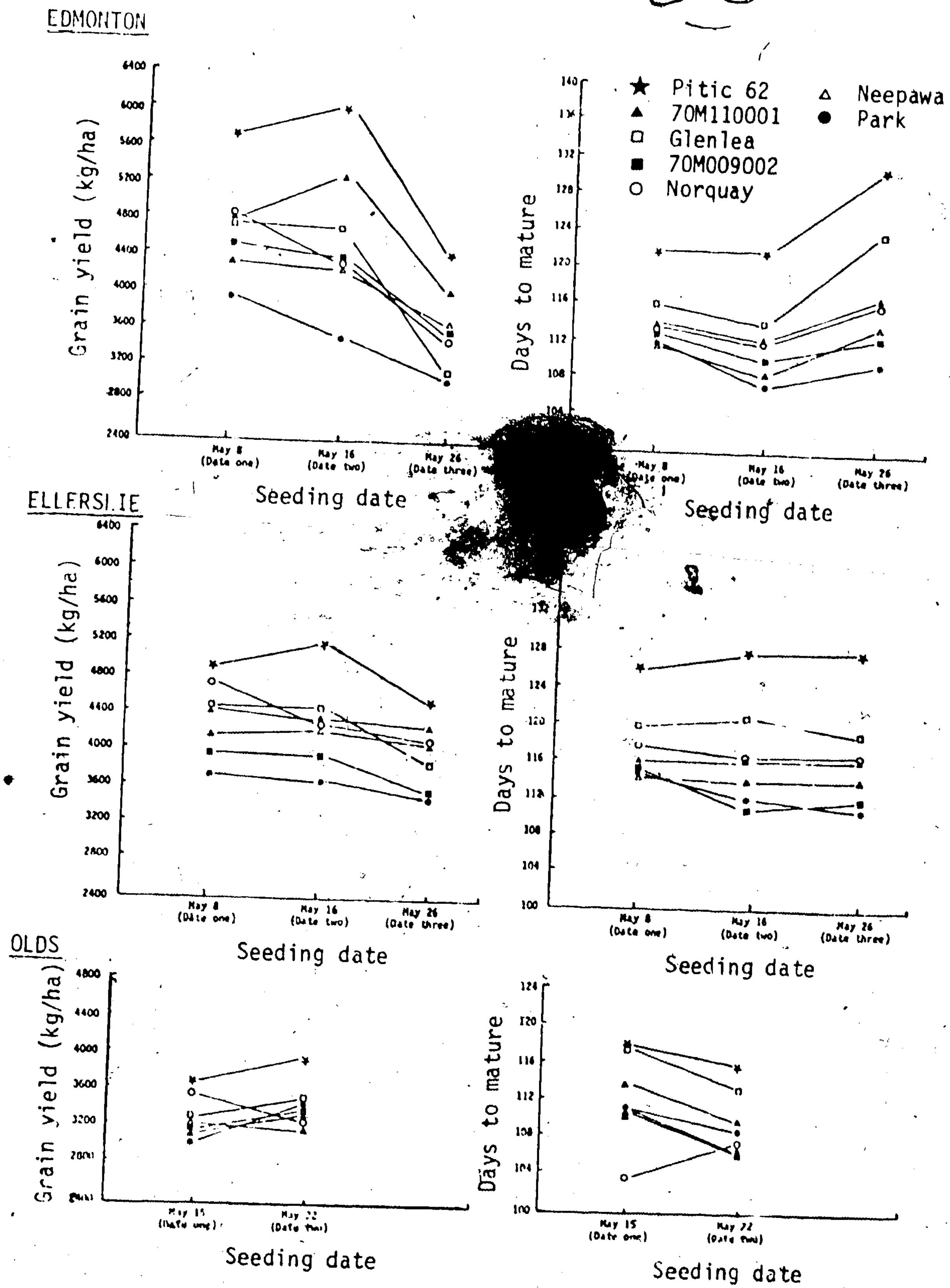

FIGURE 4. THE EFFECT OF SEEDING DATE ON GRAIN YIELD AND NUMBER OF DAYS TO MATURITY FOR SOME WHEAT GENOTYPES. (MEANS AVERAGED OVER ALL SEEDING RATES WERE USED FOR EACH GENOTYPE).

Olds (Longley, 1967). Also, on the average, the first fall frost occurs after September 15 at Edmonton, and between September 1 to 15 at Ellerslie and Olds. In view of the short growing seasons at all three locations, higher grain yield combined with early maturity should be given major importance in selecting a feed-wheat genotype for Central and Northern Alberta.

Briggs and Faris, 1973, argued for early spring seeding to achieve higher grain yield and earlier maturity in Alberta. However, the last spring frost, May 16-31 at Edmonton and Ellerslie and before May 24 at Olds, on the average, (Longley, 1967), influences how early in spring seeding can be done. In this study, both grain yield and number of days to maturity responses to variation in seeding date varied from one treatment combination to another. At Edmonton, for instance, grain yields were similar from all three seeding dates for each of the 30, 60, 90, or 180 kg/ha rates of Park (Table 6). However, the number of days to maturity were significantly smaller for the 60 or 180 kg/ha rates in date two seeding than from either or both of dates one and three seedings (Table 9). At Ellerslie, Park for each of the five highest seeding rates had no significant grain yield differences due to variation in seeding date. However, each of the above treatment combinations had significantly reduced number of days to maturity when seeding was done on either date two and three, than on date one. At all locations, it appeared that variation in seeding date had very little effect on grain yield of early maturing genotypes like Park and 70M009002 at most seeding rates (Table 6). However, the number of days to maturity significantly decreased or showed a decreasing trend due to late seedings for most of the seeding rates of Park and 70M009002, compared to early seeding (Table 9). On the other hand, at Edmonton, late maturing genotypes like Pitic 62 and Glenlea at all seeding rates, and one of the early maturing genotypes, 70M110001 at the 60, 90 and 120 kg/ha seeding rates had significantly increased number of days to maturity from date three seeding than from either or both of dates one and two (Table 9). These increases in number of days to maturity were also accompanied by significantly decreased grain yields for most of the above treatment combinations (Table 6). Late seeding might have forced the grain filling and ripening stages of plants into the cooler part of the growing season, August-September, (Fig.1), thus slowing down these processes. This, in turn, resulted in reduced grain yield, possibly as a result of poor grain filling, for late and some early maturing genotypes at some seeding rates.

Determining the optimum seeding rate and the optimum seeding date with the objective of higher grain yield and early maturity is the most important point to be considered in growing a feed-wheat cultivar in Central and Northern Alberta. At Edmonton, there were 124 frost free days available for plant growth when date one seeding was used (Fig. 5). At this seeding date, for instance, Park, Pitic 62, and 70M110001, at all seeding rates, matured before the first fall frost date (Table 9). Also seeding rate increases for all the three genotypes mentioned above resulted in decreasing the number of days to maturity (Table 9) accompanied by increased grain yield (Table 6). Similar results were obtained for both Park and 70M110001 at all or most seeding rates, in date two. However, for Pitic 62 (at all seeding rates), dates of maturity were recorded 4-7 days later than the first fall frost date and significant differences in grain yield and in number

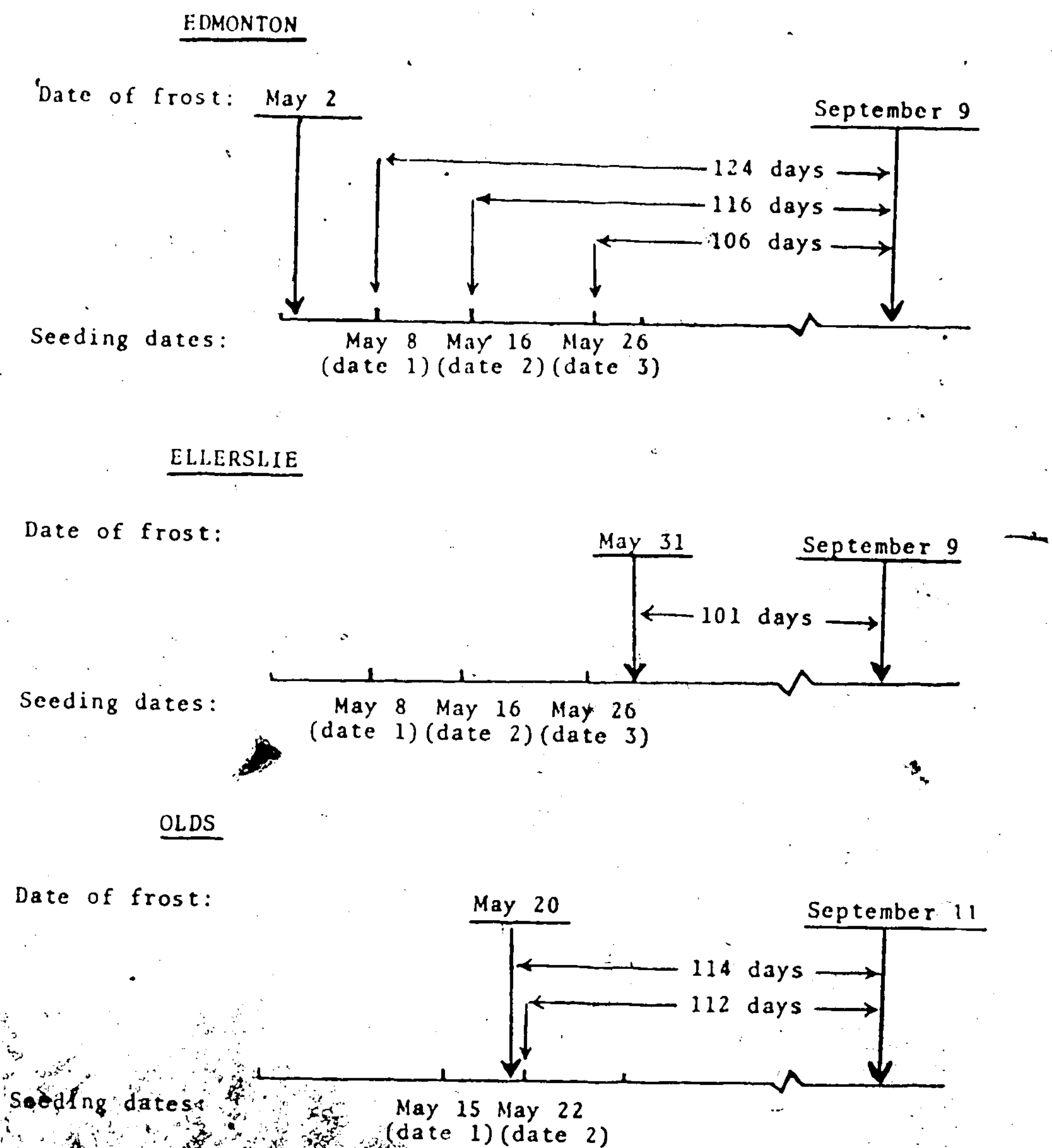

FIGURE 5. THE NUMBER OF FROST-FREE DAYS AVAILABLE FOR EACH SEEDING DATE FOR EDMONTON, ELLERSLIE, AND OLDS IN THE 1975 CROP SEASON.

of days to maturity were not observed due to variation in seeding rate (Tables 6, 9). In date three the number of frost free days available were 106 (Fig. 5) which did not satisfy the number of days required for maturity by Park, Pitic 62, or 70M110001 at all seeding rates, except Park at the 180 kg/ha rate. Increasing seeding rate for each of the above genotypes, in date three, significnatly reduced the number of days to maturity (Table 9) and also increased grain yields (Table 6). In this seeding date, however, since the grain filling and ripening stages of plants extended longer after the first fall frost and grains were filled poorly, grain yields of Park, Pitic 62, and 70M110001 (each at all seeding rates) were lower than or at best equal to results from either or both of dates one and two (Table 6). At Ellerslie, only both grain yield and number of days to maturity of a few treatment combinations responded to variation in seeding date compared to that of Edmonton and date three seeding gave generally lower grain yields than either or both of dates one and two seedings.

It appears that early spring seeding enabled the plants to make use of all the favorable days for optimum development in the summer. This could have led plants to mature before the fall frost. However, how early in spring a seeding can be carried out depends on how late the last spring frost occurs. The ideal choice for a feed-wheat could be to develop or introduce a genotype with high grain yield and early maturity for all areas of production. This combination would probably be difficult to achieve. The other alternative would be to impose different agronomic practices like high seeding rates and early seeding in spring which could have significant influences in bringing high grain yield and decreasing the number of days to maturity as evidenced by some genotypes in this study (Fig. 2, 3, and 4).

At Edmonton, genotype comparisons indicated that Pitic 62 was the latest in maturity and was also the highest in grain yield (Table 10) while Park, the earliest maturing genotype, was also the lowest in grain yield. This relationship supports the report by Rawson, 1970, in Australia who observed higher grain yield from later maturing genotypes than from early maturing ones. However, the combination of higher grain yield and relatively early maturity by 70M110001 in this test appears to support the report by Beech and Norman, 1971, who observed that the grain yield of early maturing cultivars was significantly higher than that of mid-late and late maturing cultivars. This indicates that the generally accepted genetic association between late maturity and high grain yield can be broken by appropriate breeding and selection.

Assessment of grain moisture content on wet grain samples harvested prior to maturity was done at Edmonton to see how well the differences in the relative maturity of genotypes can be determined. In this test, high grain moisture content indicates relative lateness in maturity. The latest maturing genotype, Pitic 62, was, as expected, also one of the highest in grain moist percentage and Park, the earliest maturing genotype, had significantly the lowest grain moisture percentage (Table 10). There was not a perfect agreement between this method of assessment of maturity and the visual method. However, a trend of decreasing grain moisture percentage was observed with increasing seeding rate for most genotypes. The non-significant differences in grain moisture percentage due to variation in seeding rate for most genotypes (Table 11) could either be due to some technical problems in sampling or to inherent inaccuracies in the moisture meter itself,

TABLE 10. MEAN VALUES OF SOME PLANT CHARACTERISTICS FOR SEVEN WHEAT GENOTYPES AT EDMONTON.

Plant characteristics (variables)		Genotypes						
		Pitic 62	70M110001	Norquay	Glenlea	70M009002	Neepawa	Park
Grain yield (gm/2.30 m^2)	*	1241 a[+]	1080 b	968 c	959 c	949 c	938 c	800 d
Days to heading	*	59 a	54 [illegible]	53 d	56 b	51 e	53 d	50 f
Days to maturity	*	125 a	114 c	114 c	118 b	112 d	111 d	109 e
Grain moisture %	**	54.6 a	43.6 c	48.2 b	56.5 a	39[illegible] d	39.3 d	33.0 e

* Mean values averaged over 3 seeding dates, 6 seeding rates, and 4 replications.

** Mean values averaged over 6 seeding rates and 3 replications from date one only.

\+ Means for one variable followed by the same letters are not significantly different from each other at the 5% level of probability.

TABLE 11. MEANS (AVERAGED OVER 3 REPLICATIONS (ALL IN DATE ONE)) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEEDING RATE) FOR GRAIN MOISTURE PERCENTAGE AT EDMONTON.

Seeding rate (kg/ha)	Genotypes							Seeding Rate Means
	Pitic 62	70M110001	Norquay	Glenlea	70M009002	Neepawa	Park	
30	58.7 a+	51.6 a	46.3 a	60.3 a	45.3 a	45.3 a	41.5 a	49.9 a'
60	51.4 a	48.7 a	51.1 a	59.5 a	40.2 a	42.9 a	35.4 a	47.0 ab'
90	55.6 a	39.6 a	48.9 a	61.6 a	37.7 a	43.4 a	32.3 a	45.6 b'
120	47.5 a	41.0 a	49.7 a	53.6 a	36.6 a	35.5 b	29.8 a	42.0 b'
150	54.7 a	40.6 a	45.1 a	55.1 a	40.7 a	32.3 b	30.9 a	42.8 b'
180	59.8 a	39.8 a	48.3 a	49.1 a	38.2 a	36.1 b	28.0 a	42.8 b'
Genotype means	54.6 a"	43.6 c"	48.2 b"	56.5 a"	39.8 cd"	39.3 d"	33.0 e"	

\+ Means for one genotype followed by the same letters are not significantly different from each other at the 5% level of probability.

'," Indicate separate comparisons of seeding rate means and genotype means, respectively.

particularly at higher moisture levels. This was evidenced by the great irregularity in grain moisture percentage recorded for some treatment combination in different replications. The irregularity in grain moisture percentages was also clearly exhibited by 70M110001 which had more chaff than other genotypes when threshed. Pitic 62 and Norquay were both hard to thresh due to wetness and presence of awns and had very irregular grain moisture percentage readings from one replication to another. More chaff, wetness, and presence of awns appeared to prevent proper compaction of grains in the moisture meter, thereby resulting in less accurate grain moisture percentage readings. It therefore appears advisable that this type of test should be investigated further before using it as a guide for determination of date of maturity.

Ears per plant, Kernels per ear, Kernel weight and test weight

Number of ears per plant

The data for ears per plant should be regarded with some reservation, since the technique used in determining ear number was not found dependable. It was difficult to separate individual ear bearing tillers from the main shoots and identify them as individual plants or tillers. Increasing seeding rate significantly reduced the number of ears per plant (Table 12). A similar influence of seeding rate on number of ears per plant was observed only for the genotypes Park, Neepawa, and Pitic 62 when analyzed separately. The decrease in ears per plant due to increasing seeding rate could possible be the result of higher competition by the already established tillers for

TABLE 12. MEANS (AVERAGED OVER ALL SEEDING DATES AND OVER ALL REPLICATIONS) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEEDING RATE) FOR NUMBER OF EARS PER PLANT AT EDMONTON.

Seeding Rate (kg/ha)	Genotypes							Seeding Rate Means
	Park	Neepawa	Pitic 62	Glenlea	Norquay	70M110001	70M009002	
30	4.4 ab +	4.3 abc	4.9 ab	3.6 b-f	3.6 b-f	3.6 b-f	3.6 b-f	4.0 a'
60	3.1 def	3.5 b-f	4.3 abc	3.5 b-f	3.3 b-f	3.4 b-f	3.3 b-f	3.5 b'
90	3.5 b-f	3.7 bcde	3.6 b-f	2.8 def	2.9 def	3.0 def	3.4 b-f	3.3 bc'
120	3.0 def	3.2 cdef	3.3 b-f	2.5 f	2.6 ef	3.2 cdef	3.0 def	3.0 c'
150	3.2 cdef	3.7 bcde	3.8 bcd	2.9 def	2.9 def	2.5 f	2.8 def	3.1 c'
180	3.8 bcd	3.1 def	2.9 def	2.6 ef	3.0 def	3.2 cdef	3.0 def	3.1 c'
Genotype Means	3.5 ab"	3.6 a"	3.8 a"	3.0 c"	3.0 c"	3.2 bc"	3.2 bc"	

+ Means followed by the same letters are not significantly different from each other at the 5% level of probability. When a mean is followed by more than four letters, only the beginning and the last letters are written.

'," Indicate separate comparisons of seeding rate means and genotype means, respectively.

nutrients, water, and light causing death of the later formed tillers. Pinthus, 1969, previously indicated that initiation of tiller primordia and the appearance of new tillers ceases shortly after spike-initiation of older tillers. It therefore seems that at higher seeding rates, main shoots (tillers) had developed faster (Willey and Holliday, 1971) and that spike initiation took place earlier, thus suppressing new tiller formation.

DR interaction means in Table 13 show that Park at all seeding rates, except the 60 kg/ha rate, had a significantly higher number of ears per plant from date one seeding than from either or both of dates two and three. A similar result was obtained for Neepawa at the 30, 90, and 150 kg/ha rates, for all seeding rates of Pitic 62 except the 120 kg/ha rate, for the 30 and 60 kg/ha rates of Glenlea, for the 90 and 180 kg/ha rates of Norquay, and for the 30, 90, 120 kg/ha rates of 70M009002. Ishag and Taha, 1974, reported that delayed seeding resulted in making newly formed tillers unproductive. In the present study, the vegetative development phase of newly formed tillers from late seedings might have been forced into the relatively cooler part of the growing season, August-September, (Fig. 1), thus suppressing their development and making them unproductive of ears.

Number of kernels per ear

Seeding rate means, Table 14, showed that lower seeding rates gave significantly more kernels per ear with the highest value of 46 for the 30 kg/ha seeding rate and the smallest values of 41 and 42 for the 150 and 180 kg/ha seeding rates, respectively. Among genotypes, kernels per ear for Park and 70M009002 were not influenced significantly by variation in seeding rate. The remaining genotypes showed decrease

TABLE 13. MEANS (AVERAGED OVER ALL REPLICATIONS) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEEDING RATE) FOR NUMBER OF EARS PER PLANT AT EDMONTON.

Treatment combination [Genotype x Seeding rate]		Seeding date		
		One	Two	Three
Park	30 kg/ha	6.2	3.5	3.4
Park	60 kg/ha	4.2	2.5	2.6
Park	90 kg/ha	5.7	2.5	2.2
Park	120 kg/ha	4.2	2.7	2.0
Park	150 kg/ha	5.0	2.5	2.0
Park	180 kg/ha	6.5	2.5	2.4
Neepawa	30 kg/ha	5.2	4.2	3.3
Neepawa	60 kg/ha	4.0	3.0	3.3
Neepawa	90 kg/ha	5.7	2.7	2.5
Neepawa	120 kg/ha	3.7	3.2	2.6
Neepawa	150 kg/ha	5.2	3.0	2.7
Neepawa	180 kg/ha	3.2	3.2	2.7
Pitic 62	30 kg/ha	8.5	3.7	2.5
Pitic 62	60 kg/ha	6.7	3.5	2.6
Pitic 62	90 kg/ha	4.7	3.5	2.6
Pitic 62	120 kg/ha	3.7	3.5	2.5
Pitic 62	150 kg/ha	5.5	3.0	2.9
Pitic 62	180 kg/ha	4.0	2.7	1.9
Glenlea	30 kg/ha	4.7	3.2	2.6
Glenlea	60 kg/ha	4.5	3.2	2.6
Glenlea	90 kg/ha	3.2	2.7	2.5
Glenlea	120 kg/ha	2.7	2.5	2.3
Glenlea	150 kg/ha	4.0	2.5	2.2
Glenlea	180 kg/ha	3.2	2.2	2.1
Norquay	30 kg/ha	4.7	3.0	2.9
Norquay	60 kg/ha	4.0	3.2	2.5
Norquay	90 kg/ha	4.2	2.2	2.3
Norquay	120 kg/ha	3.5	2.2	2.1
Norquay	150 kg/ha	3.2	3.0	2.5
Norquay	180 kg/ha	4.0	2.7	2.1
70M110001	30 kg/ha	4.0	4.0	2.7
70M110001	60 kg/ha	4.5	2.7	3.0
70M110001	90 kg/ha	4.0	2.5	2.4
70M110001	120 kg/ha	3.7	3.0	2.9
70M110001	150 kg/ha	2.7	2.2	2.5
70M110001	180 kg/ha	4.2	2.5	2.7
70M009002	30 kg/ha	5.5	2.5	2.8
70M009002	60 kg/ha	3.7	2.7	3.3
70M009002	90 kg/ha	4.5	2.2	3.4
70M009002	120 kg/ha	4.2	2.2	2.6
70M009002	150 kg/ha	3.7	2.0	2.7
70M009002	180 kg/ha	3.2	2.7	2.8
Seeding date Mean		4.5 a	2.9 b	2.6 b
+ LSD (5%)			1.8	
++ LSD (5%)			1.6	

* Means followed by the same letters are not significantly different from each other at the 5% level of probability.

+,++ See Table 6 for explanation.

TABLE 14. MEANS (AVERAGED OVER ALL SEEDING DATES AND OVER ALL REPLICATIONS) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEDING RATE) FOR NUMBER OF KERNELS PER EAR AT EDMONTON.

Seeding Rate (kg/ha)	Genotypes							Seeding Rate Means
	Park	Neepawa	Pitic 62	Glenlea	Norquay	70M110001	70M009002	
30	36 n-r +	40 k-p	61 a	50 cde	46 e-i	49 defg	43 h-l	46 a'
60	35 opqr	38 l-q	57 ab	48 efgh	43 h-l	49 defg	42 i-n	45 a'
90	35 opqr	39 k-p	57 ab	45 e-j	44 g-l	48 efgh	44 g-l	45 a'
120	37 m-r	36 n-r	58 ab	45 e-j	41 i-n	43 h-l	42 i-n	43 b'
150	33 q-r	32 r	54 bcd	44 g-l	40 k-p	44 g-l	40 k-p	41 c'
180	35 opqr	34 pqr	55 bc	44 g-l	41 i-n	46 e-i	40 k-p	42 bc'
Genotype Means	35 d"	36 d"	57 a"	46 b"	43 c"	47 b"	42 c"	

\+ Means followed by the same letters are not significantly different from each other at the 5% level of probability. When a mean is followed by more than four letters, only the beginning and the last letters are written.

'," Indicate separate comparisons of seeding rate means and genotype means, respectively.

in number of kernels per ear due to increasing seeding rates. The trend of decreasing number of kernels per ear resulting from increased seeding rate is in agreement with reports by Finlay et al., 1971, Willey and Holliday, 1971, Stoskopf et al., 1974, and Day et al., 1976. Higher competition by more numerous plants per unit area at higher seeding rates could have possibly limited the photosynthate production per plant. As a result, spikelet formation might have been suppressed. Even if spikelets were formed, there might have not been enough photosynthate to fill their kernels and this could result in a reduced number of kernels per ear. The failure of some florets to form kernels due to competition for a limited supply of assimilate has been previously suggested by Langer, 1972.

Averaged over all seeding rates, Pitic 62 had significantly the highest and Park and Neepawa the smallest number of kernels per ear. Higher numbers of kernels per ear from Pitic 62 have also been reported by Rawson, 1970, and by Dubetz and Bole, 1973.

Number of kernels per ear showed a decreasing trend due to delayed seeding for most treatment combinations (Table 15). Rawson, 1970, observed that plants which took more days to heading had a greater time available to lay down spikelet primordia and had a higher number of kernels per ear. In this study, however, delayed seedings might have forced the stage for the laying down of the spikelet primordia of the plants to move quickly into the warmer part of the growing season during July, (Fig. 1), thus completing the heading process faster (Table 36) and resulting in a lower number of kernels per ear. Faster heading processes at higher temperatures have been previously suggested by Willey and Holliday, 1971.

TABLE 15. MEANS (AVERAGED OVER ALL REPLICATIONS) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEEDING RATE) FOR NUMBER OF KERNELS PER EAR AT EDMONTON.

Treatment combination [Genotype x Seeding rate]		Seeding date One	Seeding date Two	Seeding date Three
Park	30 kg/ha	39.0	38.0	31.0
Park	60 kg/ha	39.0	29.7	35.0
Park	90 kg/ha	35.7	30.5	37.2
Park	120 kg/ha	37.5	31.0	41.7
Park	150 kg/ha	36.5	32.7	29.2
Park	180 kg/ha	34.0	34.7	35.2
Neepawa	30 kg/ha	40.7	40.7	37.0
Neepawa	60 kg/ha	42.2	39.5	33.2
Neepawa	90 kg/ha	37.7	34.2	45.2
Neepawa	120 kg/ha	36.2	36.0	34.2
Neepawa	150 kg/ha	32.5	31.5	31.5
Neepawa	180 kg/ha	33.2	30.2	39.0
Pitic 62	30 kg/ha	67.0	58.2	56.5
Pitic 62	60 kg/ha	62.7	56.2	50.7
Pitic 62	90 kg/ha	59.0	56.7	55.7
Pitic 62	120 kg/ha	61.5	59.5	51.5
Pitic 62	150 kg/ha	56.5	54.7	51.0
Pitic 62	180 kg/ha	59.7	51.2	52.7
Glenlea	30 kg/ha	54.0	49.0	46.0
Glenlea	60 kg/ha	48.2	48.0	48.5
Glenlea	90 kg/ha	48.0	43.2	45.0
Glenlea	120 kg/ha	47.7	46.7	39.7
Glenlea	150 kg/ha	47.0	43.7	39.7
Glenlea	180 kg/ha	44.7	45.5	40.5
Norquay	30 kg/ha	49.0	42.7	47.2
Norquay	60 kg/ha	49.2	38.2	41.5
Norquay	90 kg/ha	47.0	42.5	42.2
Norquay	120 kg/ha	44.7	36.2	43.0
Norquay	150 kg/ha	47.2	35.2	36.2
Norquay	180 kg/ha	44.5	41.2	38.2
70M110001	30 kg/ha	56.2	48.5	42.2
70M110001	60 kg/ha	50.5	50.7	46.7
70M110001	90 kg/ha	48.7	47.7	48.0
70M110001	120 kg/ha	41.2	47.0	42.0
70M110001	150 kg/ha	44.7	46.2	41.2
70M110001	180 kg/ha	49.5	45.0	43.2
70M009002	30 kg/ha	50.7	41.0	37.5
70M009002	60 kg/ha	41.7	42.0	40.7
70M009002	90 kg/ha	44.2	46.7	40.0
70M009002	120 kg/ha	45.0	39.0	41.2
70M009002	150 kg/ha	42.2	36.2	40.0
70M009002	180 kg/ha	41.0	38.2	40.7
Seeding date Mean		46.1 a*	42.5 b	41.9 b
+ LSD (5%)			8.6	
++ LSD (5%)			8.2	

* Means followed by the same letters are not significantly different from each other at the 5% level of probability.

+,++ See Table 6 for explanation.

Individual Kernel Weight (1000 kernel weight)

At all locations, increasing seeding rate significantly decreased 1000 kernel weight (Table 16). Similarly, decreases in 1000 kernel weight due to increased seeding rates were observed only for Park, Pitic 62, and Glenlea at Edmonton, for Neepawa, 70M110001, and 70M009002 at Ellerslie, and for all genotypes at Olds. The decrease in 1000 kernel weight due to increased seeding rate of most genotypes could possibly be due to the relatively small amount of assimilates per tiller available to the more numberous tillers per unit area (Table 30) and to their kernels. A decrease in 1000 kernel weight due to increased seeding rate was also reported previously by Pinthus, 196? Larter, et al., 1971, and Stoskopf et al., 1974.

Averaged over all seeding rates and seeding dates, Glenlea had significantly the highest kernel weight at all three locations. Park and Neepawa at Edmonton and Olds and Park at Ellerslie gave significantly the lowest kernel weight.

Kernel weights of only very few treatment combinations showed significant responses to variation in seeding date at Edmonton and Ellerslie (Table 17). Also it was not possible to determine any seeding date which favored 1000 kernel weight in general. However, at both Edmonton and Ellrslie, there was a very strong indication that higher kernel weights for late maturing genotypes like Pitic 62 or Glenlea (each at most seeding rates), were obtained from earlier seeding. Higher kernel weights from early seedings for some wheat cultivars were also reported previously by Khalifa, 1970, and by Doyle and Marcellos, 1974. In this study, early seeding could have allowed plants to make use of the favorable days in the season in producing

TABLE 16. MEANS (AVERAGED OVER ALL SEEDING DATES AND OVER ALL REPLICATIONS) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEEDING RATE) FOR 1000 KERNEL WEIGHT IN GM.

Seeding Rate (kg/ha)	Genotypes: Park	Neepawa	Pitic 62	Glenlea	Norquay	70M110001	70M009002	Seeding Rate Mean
Edmonton								
30	38.0 hij [+]	36.8 ijk	39.4 ghi	49.0 a	42.4 def	43.3 de	41.8 def	41.4 ab'
60	37.0 ijk	38.0 hij	40.6 efg	46.9 ab	40.6 efg	41.9 def	42.0 def	41.1 a'
90	36.8 ijk	36.8 ijk	40.1 fgh	45.8 bc	43.6 de	43.8 de	44.4 cd	41.4 ab'
120	37.7 hij	35.9 jk	41.1 efg	46.[illegible] ab	40.8 efg	41.3 efg	41.8 def	40.9 ab'
150	37.6 hij	35.8 jk	38.8 ghi	46.7 ab	40.8 efg	41.4 efg	42.2 def	40.6 bc'
180	35.0 k	36.3 jk	38.3 hij	46.3 bc	40.5 efg	41.2 efg	42.0 def	39.9 c'
Genotype Means	37.2 d"	36.7 d"	39.7 c"	47.0 a"	41.5 b"	41.8 b"	42.3 b"	
Ellerslie								
30	35.6 efg	36.6 def	37.3 def	45.1 a	41.1 b	40.3 bc	38.4 cde	39.1 a'
60	35.0 fg	35.7 efg	38.4 cde	45.5 a	40.8 bc	39.6 bc	39.9 bcd	39.1 a'
90	34.8 [illegible]	36.8 def	35.9 efg	44.9 a	39.5 bc	38.7 bcd	39.8 bcd	38.7 ab'
120	33.8 [illegible]	35.9 efg	36.8 def	44.2 a	39.1 bcd	37.8 cde	37.2 def	37.9 b'
150	34.2 g	34.3 g	36.4 efg	44.1 a	39.0 bcd	38.0 cde	37.7 cde	37.6 c'
180	35.1 fg	34.3 g	36.3 efg	45.0 a	38.5 bcd	37.3 def	39.9 bc	38.0 b'
Genotype Means	34.8 f"	35.7 e"	36.7"	44.8 a"	39.7 b"	38.7 c"	38.5 c"	
Olds								
30	34.4 ghi	34.9 ghi	36.4 fg	44.1 a	39.8 cd	39.3 de	39.0 de	38.0 a'
60	31.5 ijk	33.1 hij	33.6 ghi	44.5 a	38.5 de	36.0 fg	36.6 ef	36.4 b'
90	32.4 ijk	30.6 jkl	34.6 fgh	42.5 ab	35.6 fg	37.0 ef	35.3 fgh	35.6 b'
120	30.8 jkl	32.4 ijk	33.4 hij	39.5 cd	36.3 fg	31.9 ijk	32.9 hij	33.9 c'
150	29.0 l	29.6 kl	33.9 ghi	41.6 abc	35.9 fg	32.1 ijk	31.8 ijk	33.6 c'
180	31.1 jkl	29.3 l	32.6 hij	40.9 bcd	32.8 hij	33.3 hij	32.3 ijk	33.2 c'
Genotype Means	31.5 d"	31.5 d"	34.2 c"	42.3 a"	36.7 b"	34.8 c"	34.7 c"	

\+ Means followed by the same letters are not significantly different from each other at the 5% level of probability. When a mean is followed by more than four letters, only the beginning and the last letters are written.

'," Indicate separate comparisons of seeding rate means and genotype means, respectively.

TABLE 17. MEANS (AVERAGED OVER ALL REPLICATIONS) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEEDING RATE) FOR 1000 KERNEL WEIGHT IN GM.

Treatment combination [Genotype x Seeding rate]		Seeding date							
		Edmonton			Ellerslie			Olds	
		One	Two	Three	One	Two	Three	One	Two
Park	30 kg/ha	37.3	38.5	38.3	35.3	35.0	35.8	32.5	36.3
Park	60 kg/ha	37.8	35.3	38.0	34.3	34.8	36.0	31.5	31.5
Park	90 kg/ha	36.5	37.3	36.5	35.5	34.0	35.0	32.8	32.0
Park	120 kg/ha	37.0	38.3	37.8	33.3	34.0	34.0	29.5	32.0
Park	150 kg/ha	36.5	34.5	41.8	34.8	33.5	34.3	29.8	28.3
Park	180 kg/ha	35.3	34.8	35.0	34.8	37.0	33.5	29.0	31.3
Neepawa	30 kg/ha	37.3	36.5	36.8	35.0	37.8	37.0	33.8	34.0
Neepawa	60 kg/ha	36.0	38.0	40.0	35.0	35.3	36.8	33.3	33.3
Neepawa	90 kg/ha	36.5	36.3	37.8	34.8	39.0	36.8	30.5	30.8
Neepawa	120 kg/ha	35.0	35.5	37.3	34.3	37.3	36.3	32.0	32.8
Neepawa	150 kg/ha	35.3	35.5	36.8	34.3	33.3	35.5	29.8	29.5
Neepawa	180 kg/ha	35.8	35.0	38.0	33.8	34.3	34.8	29.3	29.3
Pitic 62	30 kg/ha	40.0	41.6	36.8	38.8	39.3	33.8	35.5	37.3
Pitic 62	60 kg/ha	41.5	41.0	39.3	39.0	38.5	37.8	33.8	33.5
Pitic 62	90 kg/ha	40.3	41.0	39.0	36.3	37.5	34.0	35.3	34.0
Pitic 62	120 kg/ha	40.8	43.0	39.5	37.0	37.3	36.0	33.0	33.8
Pitic 62	150 kg/ha	39.0	39.8	37.8	35.3	36.3	37.8	34.0	33.8
Pitic 62	180 kg/ha	38.8	39.8	36.3	36.3	37.3	35.5	31.2	34.0
Glenlea	30 kg/ha	51.0	49.8	46.3	45.3	46.0	44.0	44.0	44.3
Glenlea	60 kg/ha	47.3	48.3	45.3	44.8	47.3	44.5	43.5	41.5
Glenlea	90 kg/ha	47.8	46.5	43.3	43.8	46.0	45.0	42.3	42.8
Glenlea	120 kg/ha	47.8	46.8	46.3	44.0	46.0	42.5	39.5	39.5
Glenlea	150 kg/ha	45.8	46.3	48.0	45.0	42.3	45.0	41.8	41.5
Glenlea	180 kg/ha	47.0	45.5	46.3	43.8	46.8	44.5	40.5	41.3
Norquay	30 kg/ha	43.3	43.0	41.0	41.5	41.3	40.5	39.0	40.5
Norquay	60 kg/ha	40.8	39.3	41.8	39.8	40.5	39.0	39.0	38.0
Norquay	90 kg/ha	43.0	43.8	41.0	39.3	38.8	40.5	36.3	35.0
Norquay	120 kg/ha	40.8	41.3	40.3	38.8	39.0	39.5	34.8	37.8
Norquay	150 kg/ha	41.3	39.3	42.0	38.5	39.8	38.8	34.5	37.3
Norquay	180 kg/ha	39.8	42.0	39.8	38.0	40.0	37.5	32.5	33.0
70M110001	30 kg/ha	44.0	42.5	43.3	38.5	42.0	40.5	39.5	39.0
70M110001	60 kg/ha	39.5	42.8	43.5	38.3	40.0	40.5	35.8	36.3
70M110001	90 kg/ha	40.5	41.5	46.3	36.3	39.0	40.8	38.3	35.8
70M110001	120 kg/ha	39.0	40.8	44.0	36.3	38.5	38.5	30.8	33.0
70M110001	150 kg/ha	41.0	40.0	43.3	36.5	36.8	40.8	31.8	32.5
70M110001	180 kg/ha	39.5	42.0	42.0	35.5	37.3	39.3	31.8	34.8
70M009002	30 kg/ha	40.8	41.5	43.3	38.3	38.8	38.3	38.8	39.3
70M009002	60 kg/ha	40.8	41.3	44.0	38.3	37.8	40.8	34.0	39.3
70M009002	90 kg/ha	41.5	49.3	42.5	38.8	37.0	40.8	33.8	36.8
70M009002	120 kg/ha	42.3	39.8	43.5	37.0	36.0	38.5	32.8	33.0
70M009002	150 kg/ha	40.0	42.3	44.3	37.8	37.5	37.8	32.0	31.5
70M009002	180 kg/ha	40.8	42.8	42.5	39.0	37.8	43.0	32.3	32.3
Seeding date Mean		40.5 a*	40.9 a	41.1 a	37.9 b'	38.7 a'	38.6 a'	34.6 a"	35.4 a"
+ LSD (5%)			4.1			3.1		3.8	
++ LSD (5%)			3.9			3.1		3.3	

* Within location, means followed by the same letters are not significantly different from each other at the 5% level of probability.

+,++ See Table 6 for explanation.

'," Indicate separate comparisons of seeding date means for Ellerslie and Olds, respectively.

assimilates and accumulating them in grains thus resulting in heavier kernels. On the other hand, 1000 kernel weight of relatively early maturing genotypes like Park, 70M110001, and 70M009002, each at most seeding rates, showed a trend to increase due to delayed (date three) seeding.

General relationships between grain yield and its components (ears per plant, kernels per ear, 1000 kernel weight)

For most genotypes in this test, increases in seeding rate suppressed the expression of all three grain yield components at all locations where they were determined (Tables 12, 14, and 16). This effect was also reported by Guitard et al., 1961, and Puckridge and Donald, 1967. However, the increase in plant stand at higher seeding rates (Table 30) compensated for the lower values of grain yield components and resulted in higher grain yield per plot (Table 5).

This compensatory effect of higher plant stand for lower values of grain yield components, and resulting in high grain yield, was also reported previously by Guitard et al., 1961, and by Puckridge and Donald, 1967.

Late seeding for most treatment combinations resulted in decreased values for two of the grain yield components (ears per plant and kernels per ear) at Edmonton, and in certain cases for kernel weight at Edmonton and Ellerslie (Tables 13, 15, and 17). Also, since these decreases were accompanied by decreased plant stand (Table 32), most treatment combinations ended up in having significantly lower grain yields in date three (Table 6).

Each of the grain yield components has been referred to as being the most important contributor to grain yield per plant by one or more investigators. Comparisons for the relationships between grain yield per plant and its components showed that genotypes differ in the use of the components which account for most of their grain yield per plant (Table 18). Pitic 62, the highest grain yielding genotype per plant, was also the highest in kernels per ear, one of the highest in ears per plant and among the lowest in kernel weight (1000 kernel weight) (Table 18). Pitic 62 was also the highest grain yielding genotype on a per plot basis. On the other hand, one of the lowest grain yielders per plant, Park, was among the highest in ears per plant, and one of the lowest in kernels per ear and 1000 kernel weight. Park was one of the lowest grain yielding genotypes per plot. 70M110001, the second highest grain yielding genotype per plot, was among the highest in grain yield per plant. It was also among the lowest in ears per plant, but it had a significantly higher number of kernels per ear and a higher 1000 kernel weight than Park, one of the lowest yielding genotypes. From the above relationships it is possible to suggest that Pitic 62 obtained its highest yield per plant through its exceptionally high number of kernels per ear and, to a certain extent, through its high number of ears per plant. For 70M110001, both 1000 kernel weight and number of kernels per ear appeared to have contributed more to its high grain yield per plant than did ears per plant.

High values of plant stand and ears per plant for Park (similar to those of Pitic 62) did not compensate for Park's lower values of kernels per ear and 1000 kernel weight to give it grain yield per plot similar to Pitic 62. This lack of compensation by high plant densities for low values of grain yield components being able to bring about high grain yield was reported previously by Donald, 1967. Early maturing

TABLE 18. MEAN VALUES (AVERAGED OVER 3 SEEDING DATES, 6 SEEDING RATES, AND 4 REPLICATIONS) OF SOME PLANT CHARACTERISTICS FOR SEVEN WHEAT GENOTYPES AT EDMONTON.

Plant characteristics (variables)	Genotypes						
	Pitic 62	70M110001	Norquay	Glenlea	70M009002	Neepawa	Park
Grain yield (gm/2.30 m^2)	1241 a[+]	1080 b	968 c	959 c	949 c	938 c	800 d
Grain yield per plant (gm/plant)*	5.48 a	4.54 b	4.33 b	4.78 b	4.35 b	3.18 c	2.99 c
Ears per plant	3.80 a	3.15 c	3.04 c	2.97 c	3.18 bc	3.56 a	3.49 a
Kernels per ear	57 a	47 b	43 c	46 b	42 c	36 d	35 d
1000 Kwt (gm)	39.66 c	41.83 b	41.50 b	47.00 a	42.33 b	36.66 d	37.16 d
Plant stand per 2.59 m^2	329 bc	332 bc	309 c	311 c	309 c	437 a	393 ab
Test weight (kg/hl)	79.8 d	83.0 b	81.8 c	81.7 c	84.0 a	81.8 c	81.7 c
Plant height (cm)	82 c	74 d	74 d	99 a	73 d	93 b	92 b
Days to heading	59 a	54 c	53 d	56 b	51 e	53 d	50 f

+ Means for one variable followed by the same letters are not significantly different from each other at the 5% level of probability.

* Calculated data (method of calculation described in materials and methods).

cultivars, as reported by Pinthus, 1969, and Singh et al., 1970, tend to have a shorter vegetative phase which leads to fewer tillers per plant. However, this was not the case with two of the relatively early maturing genotypes in this present study, Park and Neepawa. Park and Neepawa had ear number per plant similar to Pitic 62, the latest maturing genotype (Table 18).

The number of kernels per ear could possibly be the most important of the grain yield components, since all genotypes (except 70M009002) showed a consecutive decrease in kernels per ear when arranged in the order of decreasing grain yields per plant (Table 18). Number of kernels per ear has also been previously suggested by a number of workers as the most important of the grain yield components in influencing grain yield per plant for wheat (Johnson et al., 1966, Simpson, 1968, Rawson, 1970, Dubetz and Bole, 1973, and Stoskopf et al., 1974). Johnson, 1966, also indicated that any gain in a single grain yield component offset by a decrease in one or both of the other components would produce no change in total grain yield per plant. This effect is clearly evidenced by the genotypes Park and Neepawa (Table 18) which were among the highest in ears per plant, but the lowest in kernels per ear, 1000 kernel weight and grain yield per plant. However, any increase in one component with the others remaining constant could produce an equal increase in total grain yield per plant.

To summarize, the contribution of each grain yield component to grain yield varied with genotypes, locations, and different agronomic practices (seeding date and seeding rate). Manipulation of genotype, location and management practices all changed the values of individual grain yield components, and these changes were usually accompanied by compensatory changes in the other grain yield components. Complex interactions appear to be the norm.

Test Weight

Test weight appeared to increase significantly due to increases in seeding rate only Edmonton and Ellerslie, as shown by seeding rate means (Table 19). However, only a few genotypes, Glenlea, 70M110001, and 70M009002 in Edmonton, Neepawa, Pitic 62 and Glenlea at Ellerslie, and Park at Olds, showed significant increases in test weight due to increased seeding rates. At higher seeding rates, there is faster plant development (Willey and Holliday, 1971). This faster development of plants which includes faster grain filling, could also have resulted in more uniform distribution of assimilate to kernels thereby giving more uniformly sized kernels. Uniformity in kernel size was indicated as one of the important factors for higher test weight (Zeleny, 1964). Another possibly explanation is that the higher competition of plants at higher seeding rates could have resulted in reduced kernel number per ear (Table 14). This may have led to a relatively increased amount of assimilate movement into the fewer kernels per ear thereby making them more plump, and uniform in shape, subsequently resulting in higher test weight. This effect of increasing test weights from increased seeding rate was previously reported by Briggs, 1975, for the wheat cultivar Neepawa.

Averaged over all seeding rates and seeding dates, the genotypes with the highest test weight were 70M009002 at Edmonton, and Park, Neepawa, Glenlea and 70M009002 at Ellerslie. At Olds, Pitic 62 had significantly lower test weight than most genotypes. Relatively low test weights were given by Pitic 62 at all locations.

TABLE 19. MEANS (AVERAGED OVER ALL SEEDING DATES AND OVER ALL REPLICATIONS) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEEDING RATE) FOR TEST WEIGHT IN KG/HL.

Seeding Rate (kg/ha)	Genotypes							Seeding Rate Means
	Park	Neepawa	Pitic 62	Glenlea	Norquay	70H110001	70H009002	
Edmonton								
30	81.3 de+	81.8 de	78.8 f	81.3 de	80.6 ef	82.8 bc	83.9 ab	81.4 b'
60	82.3 cd	81.9 de	80.3 ef	81.1 de	81.8 de	81.9 de	84.0 ab	81.9 ab'
90	82.4 cd	82.2 de	80.0 ef	81.4 de	81.6 de	83.6 ab	83.6 ab	82.0 a'
120	81.8 de	81.7 de	80.3 ef	82.3 cd	81.9 de	82.6 bc	84.0 ab	82.1 a'
150	81.3 de	81.8 de	79.8 ef	82.8 bc	81.8 de	83.3 bc	82.9 bc	82.0 a'
180	82.2 de	82.4 cd	79.6 ef	82.3 cd	82.0 de	83.5 ab	84.5 a	82.4 a'
Genotype Means	81.7 c"	81.8 c"	79.8 d"	81.7 c"	81.8 c"	83.0 b"	84.0 a"	
Ellerslie								
30	81.2 bc	80.3 cd	78.[illegible] e	80.0 cd	79.9 cd	79.7 de	80.6 bc	79.9 c'
60	81.9 ab	81.0 bc	79.5 de	81.6 ab	80.3 cd	80.6 bc	80.6 bc	81.0 b'
90	82.3 ab	81.7 ab	78.5 de	81.8 ab	81.0 bc	81.3 bc	82.2 ab	81.3 ab'
120	82.2 ab	81.8 ab	79.6 de	81.8 ab	80.2 cd	81.7 ab	81.6 ab	81.4 ab'
150	81.8 ab	81.8 ab	78.8 de	81.2 bc	81.3 bc	81.9 ab	81.8 ab	81.3 ab'
180	82.[illegible] ab	81.9 ab	79.0 de	82.3 ab	81[illegible]	81.7 ab	83.8 a	81.7 a'
Genotype Means	81.8 a"	81.5 a"	79.2 c"	81.5 a"	80.7 b"	81.2 bc"	81[illegible]	
Olds								
30	82.1 bc	82.5 ab	81.4 cd	82.3 bc	82.3 bc	81.6 bc	82.8 ab	82.1 a'
60	82.3 bc	83.0 ab	80.4 d	82.5 ab	82.0 bc	82.5 ab	83.0 ab	82.3 a'
90	82.4 bc	82.3 bc	81.1 cd	82.3 bc	81.6 bc	82.9 ab	82.5 ab	82.1 a'
120	82.3 bc	81.8 bc	81.8 bc	82.9 ab	82.5 ab	81.5 bc	81.5 bc	82.3 a'
150	82.5 ab	81.9 bc	81.4 cd	83.9 a	81.0 cd	81.8 bc	82.3 bc	82.0 a'
180	83.5 a	82.1 bc	81.5 bc	83.1 ab	79.8 d	81.8 bc	82.1 bc	82.5 a'
Genotype Means	82.5 ab"	82.2 ab"	81.0 c"	82.8 a"	81.7 bc	82.3 ab	82.5 ab	

\+ Means followed by the same letters are not significantly different from each other at the 5% level of probability. When a mean is followed by more than four letters, only the beginning and the last letters are written.

',″ Indicate separate comparisons of seeding rate means and genotype means, respectively.

At Edmonton and Ellerslie, delayed seeding resulted in decreased test weights for most treatment combinations (Table 20). At Edmonton for instance, Pitic 62 and 70M110001 at all seeding rates had significantly higher test weights from either or both of dates one and two seeding than from seeding on date three. Test weights of Park, on the other hand, at all seeding rates did not change significantly due to variation in seeding date either at Edmonton or Ellerslie. At Ellerslie, Pitic 62 at all seeding rates, and 70M110001 at the 30 and 60 kg/ha rates also had significantly higher test weights from either or both of dates one and two seedings than from date three seeding. Decreasing test weights from delayed seeding of some treatment com[illegible] in this study supports a similar report by Nass *et al.*, 1975, [illegible]tic Region of Canada. Delayed seeding might have forced th[illegible]ain filling stage of the plants into the cooler part of the growing season, in August to September, (Fig. 1) which could slow the grain filling process by limiting the movement of assimilates to the grains. As a result, shrunken kernels and kernels with lower density would be produced which would lead to lower test weight. Test weight is regularly measured as a factor of wheat quality, because of its known significance in affecting milling quality.

MORPHOLOGICAL CHARACTERS ABOVE THE FLAG LEAF NODE

(Ear length, Extrusion length, flag leaf area, and flag leaf sheath area)

Ear Length

Ear length was significantly decreased by increases in seeding

TABLE 20. MEANS (AVERAGED OVER ALL REPLICATIONS) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEEDING RATE) FOR TEST WEIGHT IN KG/HL.

Treatment combination (Genotype x Seeding rate)		Seeding date: Edmonton One	Edmonton Two	Edmonton Three	Ellerslie One	Ellerslie Two	Ellerslie Three	Olds One	Olds Two
Park	30 kg/ha	82.0	81.8	80.3	81.3	81.3	81.0	82.0	82.3
Park	60 kg/ha	83.0	82.0	82.0	81.8	82.3	81.8	81.3	83.3
Park	90 kg/ha	83.3	81.8	82.3	81.8	82.8	82.3	82.5	82.3
Park	120 kg/ha	82.3	82.0	81.3	82.5	82.3	81.8	82.3	82.3
Park	150 kg/ha	82.0	82.0	79.8	82.3	81.8	81.5	82.5	82.5
Park	180 kg/ha	83.3	81.5	81.8	82.5	82.3	81.5	83.8	83.3
Neepawa	30 kg/ha	83.0	81.5	78.0	80.5	81.3	79.0	82.8	82.3
Neepawa	60 kg/ha	83.3	82.3	80.3	82.3	81.0	79.8	83.5	82.5
Neepawa	90 kg/ha	83.5	82.3	80.8	81.5	82.0	81.5	82.3	82.3
Neepawa	120 kg/ha	82.5	81.8	80.8	82.0	81.3	82.3	80.8	82.8
Neepawa	150 kg/ha	83.0	81.5	81.0	81.3	82.3	81.8	80.5	81.3
Neepawa	180 kg/ha	83.3	82.3	81.8	81.5	81.8	82.5	82.3	82.0
Pitic 62	30 kg/ha	80.5	81.0	75.0	81.0	78.8	74.5	81.5	81.3
Pitic 62	60 kg/ha	80.8	81.8	78.3	80.8	79.3	78.5	80.8	80.0
Pitic 62	90 kg/ha	81.3	81.8	77.0	79.0	79.8	76.8	80.8	81.5
Pitic 62	120 kg/ha	82.0	82.0	77.0	81.3	79.8	77.8	82.3	81.3
Pitic 62	150 kg/ha	81.3	81.8	76.3	79.5	79.3	77.5	81.3	81.5
Pitic 62	180 kg/ha	81.0	82.0	75.8	80.0	79.0	78.0	79.8	81.3
Glenlea	30 kg/ha	82.8	82.3	79.0	82.0	80.0	78.0	82.3	82.3
Glenlea	60 kg/ha	82.5	82.3	78.5	82.0	82.8	80.0	82.8	82.3
Glenlea	90 kg/ha	83.0	83.3	78.0	81.8	84.0	79.8	82.3	82.3
Glenlea	120 kg/ha	84.8	82.5	79.5	[illegible]	82.8	80.8	83.0	82.8
Glenlea	150 kg/ha	84.0	83.3	81.0	[illegible]	82.0	80.3	84.0	83.8
Glenlea	180 kg/ha	84.0	82.5	80.3	[illegible]	82.8	81.8	83.5	82.8
Norquay	30 kg/ha	82.8	81.8	77.3	[illegible]	[illegible]	76.5	82.5	82.0
Norquay	60 kg/ha	83.8	81.5	80.0	[illegible]	[illegible]	77.5	82.0	82.0
Norquay	90 kg/ha	82.5	81.5	80.8	[illegible]	[illegible]	79.3	82.3	81.0
Norquay	120 kg/ha	83.3	82.3	80.3	81.5	79.8	79.3	82.3	82.8
Norquay	150 kg/ha	84.0	82.0	79.5	82.0	[illegible]	80.0	81.3	80.0
Norquay	180 kg/ha	82.8	82.5	80.8	81.8	81.8	81.3	79.5	80.0
70N110001	30 kg/ha	84.5	83.0	81.0	80.5	77.8	77.8	82.3	81.0
70N110001	60 kg/ha	83.8	83.8	79.0	81.3	82.0	78.5	82.5	82.5
70N110001	90 kg/ha	84.3	82.8	80.8	81.8	81.8	80.5	83.0	82.8
70N110001	120 kg/ha	84.5	82.5	80.8	82.3	82.3	80.5	80.5	82.5
70N110001	150 kg/ha	85.3	82.8	81.8	82.0	81.5	82.3	82.3	81.3
70N110001	180 kg/ha	85.0	83.3	82.3	81.8	82.0	81.3	81.8	81.8
70N009002	30 kg/ha	85.8	84.0	82.0	82.0	81.0	78.8	82.3	83.3
70N009002	60 kg/ha	85.5	84.3	82.3	82.8	80.8	76.3	82.8	83.3
70N009002	90 kg/ha	85.8	84.0	81.0	82.0	82.3	82.3	82.3	82.8
70N009002	120 kg/ha	86.0	83.3	82.8	82.3	81.0	81.5	81.5	81.5
70N009002	150 kg/ha	84.5	84.8	79.5	82.0	82.0	81.3	81.5	83.0
70N009002	180 kg/ha	86.3	84.8	82.5	83.0	83.0	82.3	81.8	82.5
Seeding date Mean*		83.4 a	82.4 a	80.0 b	81.6 a'	81.4 a'	80.0 b'	82.0 a"	82.0 a"
+ LSD (5%)			2.2			1.8		1.7	
++ LSD (5%)			2.0			1.8		1.7	

* Within location, means followed by the same letters are not significantly different from each other at the 5% level of probability.

+,++ See Table 6 for explanation.

',\" Indicate separate comparisons of seeding date means for Ellerslie and Olds, respectively.

rates (Table 21). This relationship was true for all genotypes studied, except for 70M110001 which did not respond significantly to variation in seeding rate. This decrease in ear length of most genotypes due to increased seeding rates could possibly be due to less spikelet formation caused by limited amount of assimilate per tiller. This was also evidenced by a lower number of kernels per ear at higher seeding rates (Table 14).

Averaged over all seeding rates and seeding dates, Glenlea and Pitic 62 had significantly longer and Neepawa the shortest ear lengths. Glenlea and Pitic 62 also had relatively higher number of kernels per ear compared to most of the other genotypes (Table 18).

Ear length responses of genotypes to variation in seeding date varied with maturity groups. For instance, early maturing genotypes like Park and 70M009002, each at most seeding rates, had significantly longer ears from seeding in either or both of dates one and three than from seeding on date two (Table 22). The low ear length values from date two seeding were difficult to explain. On the other hand, late maturing genotypes like Pitic 62 and Glenlea, each at most seeding rates, had significantly longer ears from date one seeding compared to seedings on either or both of dates two and three.

Extrusion Length

Increasing seeding rate showed a trend of increasing extrusion length (Table 23). Among genotypes, Pitic 62 and 70M110001 were the only two for which extrusion length showed significant responses to variation in seeding rate Pitic 62 at the 120 kg/ha seeding rate had significantly longer extrusion length than from seeding at the 30 and

TABLE 21. MEANS (AVERAGED OVER ALL SEEDING DATES AND OVER ALL REPLICATIONS) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEEDING RATE) FOR EAR LENGTH IN CM AT EDMONTON.

Seeding Rate (kg/ha)	Genotypes							Seeding Rate Means
	Park	Neepawa	Pitic 62	Glenlea	Norquay	70M110001	70M009002	
30	9.1 ghi[+]	8.3 no	10.9 d	12.5 ab	9.2 ghi	8.9 ijkl	9.7 f	9.8 a'
60	8.7 klmn	8.3 no	10.7 de	12.6 a	9.1 ghi	8.6 lmno	9.6 f	9.6 b'
90	8.7 klmn	7.9 p	10.5 e	12.2 bc	8.9 ijkl	8.6 lmno	9.4 fg	9.5 bc'
120	8.4 no	7.8 p	10.4 e	12.2 bc	8.9 ijkl	8.7 klmn	9.6 f	9.4 cd'
150	8.5 mno	7.8 p	10.5 e	12.2 bc	8.7 klmn	8.7 klmn	9.2 ghi	9.4 cd'
180	8.5 mno	7.9 p	10.5 e	11.9 c	8.8 jklm	8.9 ijkl	9.4 fg	9.4 cd'
Genotype Means	8.6 e"	8.0 f"	10.6 b"	12.3 a"	8.9 d"	8.7 e"	9.5 c"	

\+ Means followed by the same letters are not significantly different from each other at the 5% level of probability. When a mean is followed by more than four letters, only the beginning and the last letters are written.

'," Indicate separate comparisons of seeding rate means and genotype means, respectively.

TABLE 22. MEANS (AVERAGED OVER ALL REPLICATIONS) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEEDING RATE) FOR EAR LENGTH IN CM AT EDMONTON.

Treatment combination [Genotype x Seeding rate]		Seeding date One	Seeding date Two	Seeding date Three
Park	30 kg/ha	9.3	8.9	8.9
Park	60 kg/ha	8.8	8.1	8.9
Park	90 kg/ha	8.8	8.3	8.8
Park	120 kg/ha	9.0	7.5	8.5
Park	150 kg/ha	8.6	8.1	8.5
Park	180 kg/ha	8.7	7.9	8.6
Neepawa	30 kg/ha	8.5	8.6	7.9
Neepawa	60 kg/ha	8.1	8.5	8.2
Neepawa	90 kg/ha	7.8	7.8	8.1
Neepawa	120 kg/ha	7.9	7.6	7.7
Neepawa	150 kg/ha	7.6	7.6	7.9
Neepawa	180 kg/ha	7.8	7.9	8.0
Pitic 62	30 kg/ha	11.2	10.8	10.4
Pitic 62	60 kg/ha	11.4	10.3	10.2
Pitic 62	90 kg/ha	11.2	10.1	10.2
Pitic 62	120 kg/ha	10.9	9.9	10.3
Pitic 62	150 kg/ha	10.7	10.8	10.5
Pitic 62	180 kg/ha	10.6	10.4	10.4
Glenlea	30 kg/ha	13.5	12.1	11.7
Glenlea	60 kg/ha	13.1	12.4	12.1
Glenlea	90 kg/ha	12.1	12.3	11.9
Glenlea	120 kg/ha	12.6	11.8	11.9
Glenlea	150 kg/ha	12.7	12.1	11.8
Glenlea	180 kg/ha	12.5	11.2	11.[illegible]
Norquay	30 kg/ha	9.5	8.9	9.2
Norquay	60 kg/ha	9.1	8.8	9.1
Norquay	90 kg/ha	9.0	8.4	9.3
Norquay	120 kg/ha	8.9	8.6	9.0
Norquay	150 kg/ha	8.5	8.4	8.9
Norquay	180 kg/ha	9.0	8.2	9.1
70N110001	30 kg/ha	9.1	8.6	8.8
70N110001	60 kg/ha	8.6	8.2	8.7
70N110001	90 kg/ha	9.3	7.9	8.5
70N110001	120 kg/ha	8.9	8.4	8.7
70N110001	150 kg/ha	9.1	8.4	8.6
70N110001	180 kg/ha	9.3	8.2	8.9
70N009002	30 kg/ha	10.3	9.3	9.3
70N009002	60 kg/ha	9.8	9.1	9.7
70N009002	90 kg/ha	9.8	8.8	9.4
70N009002	120 kg/ha	10.0	9.1	9.7
70N009002	150 kg/ha	9.5	8.5	9.4
70N009002	180 kg/ha	9.9	8.7	9.5
Seeding date Mean		9.8 a*	9.2 c	9.5 b
+ LSD (5%)			0.6	
++ LSD (5%)			0.6	

* Means followed by the same letters are not significantly different from each other at the 5% level of probability.

+,++ See Table 6 for explanation.

TABLE 23: MEANS (AVERAGED OVER ALL SEEDING DATES AND OVER ALL REPLICATIONS) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEEDING RATE) FOR EXTRUSION LENGTH IN CM AT EDMONTON.

Seeding Rate (kg/ha)	Genotypes							Seeding Rate Means
	Park	Neepawa	Pitic 62	Glenlea	Norquay	70M110001	70M009002	
30	29.0 a+	22.6 bc	13.2 klm	21.4 bc	15.3 ghij	12.1 m	16.8 defg	18.6 b'
60	29.8 a	22.4 bc	13.8 jklm	21.3 c	16.0 efgh	14.8 hijk	17.3 def	19.3 a'
90	30.5 a	22.2 bc	14.2 ijkl	21.8 bc	16.0 efgh	13.6 jklm	17.0 defg	19.3 a'
120	29.8 a	22.5 bc	15.6 fghi	21.1 c	16.4 d-h	13.7 jklm	18.0 d	19.6 a'
150	30.0 a	22.9 bc	14.9 hijk	21.9 bc	16.2 efgh	12.7 lm	17.6 de	19.5 a
180	30.0 a	23.2 b	14.8 hijk	21.6 bc	16.8 defg	13.4 klm	17.6 de	19.6 a'
Genotype Means	30.0 a"	22.6 b"	14.3 f"	21.4 c"	16.1 e"	13.3 g"	17.3 d"	

+ Means followed by the same letters are not significantly different from each other at the 5% level of probability. When a mean is followed by more than four letters, only the beginning and the last letters are written.

'," Indicate separate comparisons of seeding rate means and genotype means, respectively.

60 kg/ha rates. 70M110001 at the 60 kg/ha seeding rate also had significantly longer extrusion length than from seeding at the 30 and 150 kg/ha rates. The increase in extrusion length due to increased seeding rates could possibly be due to higher competition for light or shade avoidance.

Most treatment combinations had significantly decreased extrusion lengths when seeded in date three (Table 24). However, very marked differences were observed among genotypes in extrusion length responses to variation in seeding date. For instance, two of the early maturing genotypes, Park and Neepawa, each at most seeding rates, had significantly longer extrusion lengths from either or both of dates one and two seedings than from date three seeding. By contrast, extrusion length of 70M00900[illegible] (another early maturing genotype), at all seeding rates, did not [illegible] any significant response to variation in seeding date. However, for the late maturing genotypes like Pitic 62 and Glenlea, each at most seeding rates, extrusion length did not show significant responses to variation in seeding date. The decreases in extru[illegible] of most treatment combinations due to late seeding could [illegible] due to the relative shortness of the growing season which did not enable plants to develop normally to reach closer to their genetic potnetial in extrusion length.

<u>Flag leaf sheath area and flag leaf area</u>

Overall, there were no significant changes in flag leaf sheath area due to changes in seeding rate (Table 25). However, genotypes like Park, Neepawa, and Norquay showed significant decreases in flag leaf sheath area due to increased seeding rates. For Pitic 62 and 70M110001, flag leaf sheath areas were significantly larger for the

TABLE 24. MEANS (AVERAGED OVER ALL REPLICATIONS) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEEDING RATE) FOR EXTRUSION LENGTH IN CM AT EDMONTON.

Treatment combination [Genotype x Seeding rate]		Seeding date One	Seeding date Two	Seeding date Three
Park	30 kg/ha	31.6	31.2	24.0
Park	60 kg/ha	31.6	30.6	27.0
Park	90 kg/ha	31.6	31.0	28.8
Park	120 kg/ha	31.7	30.6	27.0
Park	150 kg/ha	31.2	30.3	28.2
Park	180 kg/ha	30.6	30.4	28.5
Neepawa	30 kg/ha	23.9	22.5	21.1
Neepawa	60 kg/ha	24.2	22.9	19.9
Neepawa	90 kg/ha	23.7	23.9	18.9
Neepawa	120 kg/ha	24.4	21.3	21.6
Neepawa	150 kg/ha	24.5	23.4	20.6
Neepawa	180 kg/ha	23.3	24.6	21.6
Pitic 62	30 kg/ha	11.9	12.7	15.0
Pitic 62	60 kg/ha	13.1	13.1	15.0
Pitic 62	90 kg/ha	13.3	13.7	15.3
Pitic 62	120 kg/ha	13.6	16.8	16.1
Pitic 62	150 kg/ha	13.9	14.4	16.2
Pitic 62	180 kg/ha	14.2	14.1	15.9
Glenlea	30 kg/ha	21.9	21.0	21.0
Glenlea	60 kg/ha	22.4	20.8	20.4
Glenlea	90 kg/ha	23.3	20.6	21.3
Glenlea	120 kg/ha	21.3	22.3	19.5
Glenlea	150 kg/ha	22.7	20.7	22.3
Glenlea	180 kg/ha	23.5	19.9	21.3
Norquay	30 kg/ha	16.4	15.0	14.5
Norquay	60 kg/ha	17.6	15.5	14.7
Norquay	90 kg/ha	18.1	15.5	14.2
Norquay	120 kg/ha	18.5	16.2	14.3
Norquay	150 kg/ha	18.2	16.3	14.1
Norquay	180 kg/ha	17.7	14.7	18.4
70M110001	30 kg/ha	12.7	11.8	11.7
70M110001	60 kg/ha	18.8	12.7	12.9
70M110001	90 kg/ha	14.9	12.4	13.2
70M110001	120 kg/ha	14.7	13.3	12.9
70M110001	150 kg/ha	14.5	12.9	10.6
70M110001	180 kg/ha	15.3	14.0	10.6
70M009002	30 kg/ha	17.1	17.0	16.2
70M009002	60 kg/ha	18.3	17.6	15.8
70M009002	90 kg/ha	18.2	16.9	15.6
70M009002	120 kg/ha	19.3	16.8	17.8
70M009002	150 kg/ha	19.0	16.6	17.0
70M009002	180 kg/ha	19.0	17.1	16.3
Seeding date Mean		20.4 a*	19.2 b	18.3 c
+ LSD (5%)			2.7	
++ LSD (5%)			2.6	

* Means followed by the same letters are not significantly different from each other at the 5% level of probability.

+,++ See Table 6 for explanation.

TABLE 25. MEANS (AVERAGED OVER ALL SEEDING DATES AND OVER ALL REPLICATIONS) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEEDING RATE) FOR FLAG LEAF SHEATH AREA IN CM^2 AT EDMONTON.

Seeding Rate (kg/ha)	Genotypes							Seeding Rate Means
	Park	Neepawa	Pitic 62	Glenlea	Norquay	70M110001	70M009002	
30	20.2 klmn+	23.5 efgh	19.5 lmno	24.5 cdef	26.2 abc	20.4 klm	18.1 pq	21.8 a'
60	17.3 qr	24.9 bcde	23.4 efgh	27.4 a	22.6 fghi	21.0 ijkl	23.9 efg	22.9 a'
90	15.9 rs	19.3 lmno	26.4 ab	25.9 abcd	21.5 hijk	24.2 defg	18.8 mnop	21.7 a'
120	16.4 rs	15.1 s	24.0 efg	21.0 ijkl	20.7 jklm	20.4 klm	22.9 fgh	20.1 a'
150	15.6 rs	20.4 klm	23.3 efgh	26.4 ab	22.7 fghi	20.9 ijkl	19.4 lmno	21.2 a'
180	15.6 rs	18.4 nop	19.2 lmno	24.2 defg	22.5 ghij	20.4 klm	20.9 ijkl	20.2 a'
Genotype Means	16.8 c"	20.3 b"	22.6 ab"	24.9 a"	22.7 ab"	21.2 b"	20.7 b"	

+ Means followed by the same letters are not significantly different from each other at the 5% level of probability. When a mean is followed by more than four letters, only the beginning and the last letters are written.

'," Indicate separate comparisons of seeding rate means and genotype means, respectively.

90 kg/ha rate than from the other seeding rates. Glenlea and 70M009002 did not show a specific trend of increasing or decreasing flag leaf sheath area due to increased seeding rates.

In general, flag leaf area decreased significantly due to increased seeding rates (Table 26). A similar relationship was observed for individual genotypes, except 70M110001 and 70M009002. At higher seeding rates, there would be more plants per unit area to compete for raw materials of photosynthesis resulting in less photosynthate production per tiller. As a result of inadequate photysynthate produced, the growth of flag leaf and its sheath would be suppressed leading to smaller areas of these plant parts at higher seeding rates.

Averaged over all seeding rates and seeding dates, Glenlea had both the largest flag leaf sheath and flag leaf lamina areas and Park was among the lowest in both (Tables 25, 26). Pitic 62 was among the highest in flag leaf sheath area and intermediate in flag leaf lamina area.

Flag leaf sheath areas of only a few treatment combinations showed any significant responses to variation in seeding date (Table 27). Seeding on date two gave significantly larger flag leaf sheath areas for the 30 kg/ha rate of Park and Pitic 62, for the 30 and 180 kg/ha rates of Neepawa, for the 90 and 180 kg/ha rates of Glenlea, for the 60 kg/ha rate of Norquay and for the 30 and 180 kg/ha rates of 70M110001 than from seeding at either or both of dates one and three. Park at the 90 kg/ha and 70M110001 at the 180 kg/ha rates also had significantly larger flag leaf sheath areas from date three seeding than from seeding at either or both of dates one and two. Flag leaf sheath areas of all the other treatment combinations, except for the 150 kg/ha rate of

TABLE 26. MEANS (AVERAGED OVER ALL SEEDING DATES AND OVER ALL REPLICATIONS) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEEDING RATE) FOR FLAG LEAF LAMINA AREA IN CM^2 AT EDMONTON.

Seeding Rate (kg/ha)	Genotypes							Seeding Rate Means
	Park	Neepawa	Pitic 62	Glenlea	Norquay	70M110001	70M009002	
30	23.1 i-q+	21.3 m-u	26.0 e-i	33.5 a	29.0 bcd	24.0 f-n	25.6 e-j	26.1 a'
60	20.5 p-u	22.6 j-r	25.2 e-k	33.1 a	27.3 cde	22.0 l-t	25.0 e-l	25.1 a'
90	20.4 p-u	22.8 j-q	22.7 j-r	29.1 bcd	26.8 d-q	21.2 n-u	24.3 f-m	23.9 b'
120	19.6 stu	18.6 u	22.4 k-s	30.3 b	26.4 d-h	23.9 j-n	23.4 i-p	23.5 b'
150	19.8 rstu	20.1 q-u	23.7 h-o	31.0 ab	25.2 e-k	23.0 i-q	22.7 j-r	23.6 b'
180	19.4 tu	20.7 o-u	23.4 i-p	29.8 bc	26.9 def	23.7 h-o	23.0 i-q	23.9 b'
Genotype Means	20.5 d"	21.0 d"	23.9 c"	31.1 a"	26.9 b"	23.0 c"	24.0 c"	

+ Means followed by the same letters are not significantly different from each other at the 5% level of probability. When a mean is followed by more than four letters, only the beginning and the last letters are written.

'," Indicate separate comparisons of seeding rate means and genotype means, respectively.

TABLE 27. MEANS (AVERAGED OVER ALL REPLICATIONS) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEEDING RATE) FOR FLAG LEAF SHEATH AREA IN CM^2 AT EDMONTON.

Treatment combination [Genotype x Seeding rate]		Seeding date One	Two	Three
Park	30 kg/ha	18.9	22.5	19.2
Park	60 kg/ha	17.2	17.2	17.5
Park	90 kg/ha	14.0	15.1	18.4
Park	120 kg/ha	15.8	15.9	17.3
Park	150 kg/ha	15.8	15.7	15.1
Park	180 kg/ha	15.1	15.7	16.1
Neepawa	30 kg/ha	23.5	25.1	21.9
Neepawa	60 kg/ha	23.4	26.2	24.8
Neepawa	90 kg/ha	18.2	19.7	19.7
Neepawa	120 kg/ha	14.5	15.0	15.8
Neepawa	150 kg/ha	23.5	18.6	19.1
Neepawa	180 kg/ha	16.3	19.8	18.9
Pitic 62	30 kg/ha	19.5	21.0	18.0
Pitic 62	60 kg/ha	23.2	23.6	23.3
Pitic 62	90 kg/ha	27.6	24.9	26.6
Pitic 62	120 kg/ha	22.6	24.9	24.2
Pitic 62	150 kg/ha	22.4	22.4	25.0
Pitic 62	180 kg/ha	18.6	19.1	19.8
Glenlea	30 kg/ha	26.1	24.0	23.2
Glenlea	60 kg/ha	27.7	28.4	26.1
Glenlea	90 kg/ha	24.5	28.1	24.9
Glenlea	120 kg/ha	20.8	20.4	21.4
Glenlea	150 kg/ha	25.3	26.5	27.1
Glenlea	180 kg/ha	22.3	25.7	24.6
Norquay	30 kg/ha	25.0	27.5	26.2
Norquay	60 kg/ha	22.7	24.0	21.0
Norquay	90 kg/ha	20.4	22.4	21.5
Norquay	120 kg/ha	19.9	20.4	21.8
Norquay	150 kg/ha	22.3	22.7	23.0
Norquay	180 kg/ha	22.4	21.4	23.7
70M110001	30 kg/ha	19.8	22.7	18.5
70M110001	60 kg/ha	21.8	21.6	19.5
70M110001	90 kg/ha	23.5	25.9	23.1
70M110001	120 kg/ha	19.4	21.2	20.6
70M110001	150 kg/ha	20.1	19.8	22.6
70M110001	180 kg/ha	18.9	20.3	21.8
70M009002	30 kg/ha	18.1	18.2	17.9
70M009002	60 kg/ha	23.3	24.9	23.3
70M009002	90 kg/ha	18.9	19.1	18.2
70M009002	120 kg/ha	21.9	23.0	23.6
70M009002	150 kg/ha	19.1	18.3	20.6
70M009002	180 kg/ha	19.6	20.7	22.2
Seeding date Mean		20.9 b*	21.7 a	21.4 ab
+ LSD (5%)			2.9	
++ LSD (5%)			2.8	

* Means followed by the same letters are not significantly different from each other at the 5% level of probability.

+,++ See Table 6 for explanation.

Neepawa which had larger flag leaf sheath area from date one seeding than from either date two or date three seeding, did not significantly respond to variation in seeding date.

Flag leaf areas were significantly larger from seeding at either or both of dates two and three than from seeding on date one for the 30 and 60 kg/ha rates of Park, for the 30, 60, 90, 150 and 180 kg/ha rates of Neepawa, for the 30 kg/ha rate of Pitic 62, for the 30, 90, 150 and 180 kg/ha rates of Glenlea, for the 30, 120 and 180 kg/ha rates of Norquay, for the 90, 120, 150 and 180 kg/ha rates of 70M110001, and for the 120, 150 and 180 kg/ha rates of 70M009002 (Table 28). Flag leaf areas of the remaining treatment combinations did not show significant responses to variation in seeding date. Delayed seeding (dates two and three) could have pushed the vegetative development phase of plants into the cooler part of the growing season during August and September, (Fig. 1), thereby not allowing the faster completion of the reproductive phase. This could have resulted in making plants more vegetative, with larger flag leaf sheath and flag leaf areas.

General relationships between grain yield and morphological characters above the flat leaf node

Several investigators, Thorne, 1965, Voldeng and Simpson, 1967, Simpson, 1968, and Walton, 1971, have indicated the important contribution to the dry matter of cereal grains by one or more of the morphological characters above the flag leaf node. Each character has been found as the most important contributor to grain yield per plant by one or more of the above workers.

In this test, one of the higher grain yielders per tiller,

TABLE 28. MEANS (AVERAGED OVER ALL REPLICATIONS) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEEDING RATE) FOR FLAG LEAF LAMINA AREA IN CM^2 AT EDMONTON.

Treatment combination [Genotype x Seeding rate]		Seeding date One	Seeding date Two	Seeding date Three
Park	30 kg/ha	19.9	26.0	23.1
Park	60 kg/ha	20.0	20.2	21.3
Park	90 kg/ha	17.2	20.5	23.5
Park	120 kg/ha	18.8	17.6	22.2
Park	150 kg/ha	19.7	18.9	20.8
Park	180 kg/ha	17.1	18.8	22.1
Neepawa	30 kg/ha	18.7	25.3	19.7
Neepawa	60 kg/ha	18.7	25.8	23.1
Neepawa	90 kg/ha	17.6	25.9	24.5
Neepawa	120 kg/ha	16.8	18.2	20.7
Neepawa	150 kg/ha	16.2	20.9	23.1
Neepawa	180 kg/ha	16.7	22.1	23.2
Pitic 62	30 kg/ha	26.3	30.1	21.5
Pitic 62	60 kg/ha	25.2	26.9	23.5
Pitic 62	90 kg/ha	23.3	23.8	20.9
Pitic 62	120 kg/ha	20.7	24.8	21.5
Pitic 62	150 kg/ha	23.7	24.1	23.0
Pitic 62	180 kg/ha	21.6	24.6	23.9
Glenlea	30 kg/ha	33.4	36.7	30.3
Glenlea	60 kg/ha	31.3	34.3	33.5
Glenlea	90 kg/ha	28.3	34.6	24.4
Glenlea	120 kg/ha	27.9	31.4	31.5
Glenlea	150 kg/ha	26.5	32.2	34.2
Glenlea	180 kg/ha	26.8	30.4	32.1
Norquay	30 kg/ha	25.7	31.1	30.3
Norquay	60 kg/ha	26.5	27.4	27.9
Norquay	90 kg/ha	24.9	28.2	27.3
Norquay	120 kg/ha	23.1	27.3	28.6
Norquay	150 kg/ha	23.1	28.1	24.3
Norquay	180 kg/ha	24.4	23.3	32.8
70M110001	30 kg/ha	22.8	26.6	22.6
70M110001	60 kg/ha	20.4	24.0	21.5
70M110001	90 kg/ha	17.7	24.2	21.7
70M110001	120 kg/ha	19.6	26.2	25.7
70M110001	150 kg/ha	18.1	22.6	28.1
70M110001	180 kg/ha	19.4	22.5	29.2
70M009002	30 kg/ha	25.0	23.8	27.7
70M009002	60 kg/ha	22.1	26.0	26.9
70M009002	90 kg/ha	21.9	25.4	25.4
70M009002	120 kg/ha	20.4	22.6	27.0
70M009002	150 kg/ha	19.4	20.9	27.5
70M009002	180 kg/ha	19.0	21.8	28.0
Seeding date Mean		22.1 b*	25.4 a	25.5 a
+ LSD (5%)			5.3	
++ LSD (5%)			4.3	

* Means followed by the same letters are not significantly different from each other at the 5% level of probability.

+,++ See Table 6 for explanation.

Pitic 62, was also among the highest in flag leaf sheath area, second highest in ear length, relatively low in flag leaf area, and among the lowest in extrusion length (Table 29). On the other hand, one of the lower grain yielders per tiller, Park, was also the highest in extrusion length and among the lowest in ear length, flag leaf sheath area, and flag leaf area. 70M110001, another genotype with higher grain yield per tiller, was among the lowest in ear length like Park (the lowest grain yielder per tiller), among the lowest in extrusion length like Pitic 62 (one of the highest grain yielders per tiller), and similar in flag leaf sheath and flag leaf areas to Pitic 62.

The above relationships suggest, to a certain extent, that larger extrusion length is possibly associated with genotypes which have lower grain yields per tiller. The association of lower grain yield per tiller and larger extrusion length was also observed by Walton, 1971. In the present study, it was not possible to clearly define general relationships between both flag leaf sheath area and flag leaf area with grain yield per tiller for comparing genotypes. For instance, both flag leaf sheath and flag leaf areas of Glenlea (24.89 cm^2 and 31.14 cm^2, respectively) were significantly larger than that of 70M009002 (20.65 cm^2 and 23.99 cm^2, respectively). However, there was no significant difference in either grain yield per tiller or in grain yield per plot between Glenlea and 70M009002.

Also ear length was not found to have a clearly exhibited relationship with either grain yield per tiller or grain yield per plot. Therefore, it may not be used to make genotype comparisons for grain yielding ability either on a per tiller or on a per plot basis.

Genotypes with higher grain yield per tiller or higher grain

TABLE 29. MEAN VALUES (AVERAGED OVER 3 SEEDING DATES, 6 SEEDING RATES, AND 4 REPLICATIONS) OF SOME PLANT CHARACTERISTICS FOR SEVEN WHEAT GENOTYPES AT EDMONTON.

Plant characteristics (variables)	Genotypes						
	Pitic 62	70M110001	Norquay	Glenlea	70M009002	Neepawa	Park
Grain yield (gm/2.30 m^2)	1241 a +	1080 b	968 c	959 c	949 c	938 c	800 d
Grain yield per plant (gm/plant) *	5.48 a	4.54 a	4.33 b	4.78 b	4.35 b	3.18 c	2.99 c
Grain yield per tiller (gm/tiller) *	1.67 a	1.66 a	1.58 a	1.71 a	1.48 a	0.96 b	0.96 b
Ear length (cm)	10.58 b	8.72 e	8.92 d	12.25 a	9.49 c	8.01 f	8.63 e
Extrusion length (cm)	14.33 f	13.33 g	16.10 e	21.43 c	17.33 d	22.58 b	29.77 a
Flag leaf sheath area (cm^2)	22.64 ab	21.21 b	22.71 ab	24.89 a	20.65 b	20.26 b	16.83 c
Flag leaf lamina area (cm^2)	23.90 c	22.98 c	26.93 b	31.14 a	23.99 c	21.00 d	20.47 d

\+ Means for one variable followed by the same letters are not significantly different from each other at the 5% level of probability.

* Calculated data (method of calculation described in materials and methods).

yield per plant were also among the higher grain yielders per plot (Table 29). Especially, grain yield per plant appeared to be a good indicator of grain yielding ability of a genotype on a per plot basis.

Some investigators, Voldeng and Simpson, 1967, Simpson, 1968, and Walton, 1971, indicated the existence of positive associations between grain yield per tiller and one or more of the morphological characters above the flag leaf node. In this study, however, it was not possible to attribute the grain yielding ability of a certain genotype to any one of the morphological characteristics above the flag leaf node.

Plant stand per unit area

At all locations, and averaged over all genotypes and seeding dates, there was a significant increase in plant stand due to increased seeding rates (Table 30). This relationship was also true for individual genotypes in the test, although every increase in seeding rate did not result in a significant increase in plant stand. A similar result of increased plant stand from increased seeding rates was previously reported by Guitard *et al.*, 1961, Puckridge and Donald, 1967, Pelton, 1969, Willey and Holliday, 1971, and Stoskopf *et al.*, 1974.

There was a trend of leveling-off of plant stand at the relatively high seeding rates for most genotypes. At Edmonton for instance, Pitic 62 or 70M110001, each at the 120, 150 and 180 kg/ha seeding rates had similar plant stands. At Ellerslie, every increase in seeding rate, up to the 150 kg/ha, for Pitic 62 or Park increased plant stand significantly. For 70M110001, every seeding rate increase gave a significant increase in plant stand at Ellerslie. At Olds, the

TABLE 30. MEANS (AVERAGED OVER ALL SEEDING DATES AND OVER ALL REPLICATIONS) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEEDING RATE) FOR PLANT STAND PER 2.59 M^2.

Seeding Rate (kg/ha)	Genotypes							Seeding Rate Means
	Park	Neepawa	Pitic 62	Glenlea	Norquay	70M110001	70M009002	
Edmonton								
30	161 pqr+	176 opqr	131 qr	116 r	131 qr	131 qr	123 r	138 d'
60	289 j-n	266 k-o	283 j-n	229 m-q	210 n-r	204 n-r	227 m-q	245 c'
90	329 g-m	349 f-l	266 k-o	251 l-p	286 klmn	319 h-m	300 i-n	300 c'
120	424 c-g	475 cd	450 c[illegible]	363 e-k	360 e-k	410 c-h	321 h-m	400 b'
150	398 c-i	665 b	408 c-h	428 c-g	420 c-h	456 cde	388 d-j	452 b'
180	758 a	694 ab	429 c-g	480 c-d	450 cdef	469 cd	495 c	539 a'
Genotype Means	393 ab"	437 a"	329 bc"	311 c"	309 c"	332 bc"	309 c"	
Ellerslie								
30	164 p	179 op	137 p	125 p	134 p	172 p	165 p	154 f'
60	237 jkl	379 j	274 lmn	254 mno	271 lmn	293 klmn	251 no	294 e'
90	498 i	525 hi	397 j	363 jk	334 jklm	401 j	347 jkl	409 d'
120	630 def	653 cde	537 ghi	487 i	486 i	537 ghi	520 i	551 c'
150	770 ab	789 a	655 cde	559 fghi	615 defg	632 def	604 efgh	661 b'
180	951 a	970 a	715 abc	693 bcd	734 abc	777 a	687 cde	790 a'
Genotype Means	558 a"	583 a"	453 bc"	412 c"	429 bc"	469 b"	429 bc"	
Olds								
30	140 nopq	154 nopq	115 opq	95 q	100 pq	125 opq	132 nopq	123 f'
60	238 lmn	288 klm	193 m-q	201 m-q	221 lmno	208 mnop	205 mnop	222 e'
90	385 g-k	433 fgh	325 ijkl	298 klm	318 jkl	283 klm	267 lm	330 d'
120	474 efgh	498 def	428 fghi	418 f-j	378 hijk	446 fgh	387 g-k	433 c'
150	564 cde	712 a	505 def	443 fgh	460 efgh	490 defg	471 efgh	521 b'
180	697 ab	730 a	652 abc	611 bc	591 cd	594 cd	563 cde	634 a'
Genotype Means	416 b"	470 a"	370 c"	344 c"	345 c"	358 c"	338 c"	

\+ Means followed by the same letters are not significantly different from each other at the 5% level of probability. When a mean is followed by more than four letters, only the beginning and the last letters are written.

'," Indicate separate comparisons of seeding rate means and genotype means, respectively.

120 and 150 kg/ha rates for Pitic 62 or Park gave similar plant stands while the 180 kg/ha rate produced the significantly highest plant stand for each genotype. This leveling-off of plant stands at relatively higher seeding rates could possibly be due to a higher mortality rate of plants due to failure in competition for light, water and nutrients as was also previously suggested by Puckridge and Donald, 1967, and Willey and Holliday, 1971.

At all locations and for every genotype, the Chi square test indicated that there were significant differences ($P \leq 0.05$) between observed and expected plant stands for date two data (Table 31). For most genotypes, at all locations, the differences between observed and expected plant stands were much more pronounced at the relatively higher (120, 150 and k80 kg/ha) seeding rates.

At Edmonton, there were no significant differences among genotypes for observed plant stands at the 30 or 90 kg/ha seeding rates (Table 31). At the 150 kg/ha seeding rate, Neepawa had significantly higher number of observed plant stands than did other genotypes at the same seeding rate. At the 180 kg/ha seeding rate, too, both Park and Neepawa had significantly higher number of observed plant stands than did the other genotypes at the same seeding rate.

At Ellerslie, there were no significant differences among genotypes for observed plant stands at the 30 or 120 kg/ha seeding rates (Table 31). At the 150 and 180 kg/ha seeding rates, Park and Neepawa also had significantly higher observed plant stands than did the other genotypes at the same seeding rates.

At Olds, at the 90 and 180 kg/ha seeding rates, Park had a significantly higher number of observed plants than did most other

TABLE 31. MEANS (AVERAGED OVER ALL REPLICATIONS) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEEDING RATE) FOR OBSERVED AND EXPECTED PLANT STAND PER 2.59 M^2. (ONLY DATE TWO DATA USED).**

Seeding Rate (kg/ha)	Genotypes						
	Park	Neepawa	Pitic 62	Glenlea	Norquay	70M110001	70M009002
Edmonton+							
30	186 a*	172 a	181 a	161 a	163 a	161 a	133 a
	246	296	195	195	222	237	228
60	378 a	347 ab	398 a	282 ab	257 ab	240 b	271 ab
	492	592	390	390	444	474	456
90	322 a	434 a	312 a	310 a	336 a	423 a	370 a
	738	888	585	585	666	711	684
120	561 a	516 ab	451 abc	412 bc	449 abc	522 ab	372 c
	984	1184	780	780	888	948	912
150	612 b	838 a	550 bc	465 c	643 b	595 bc	686 b
	1230	1480	975	975	1110	1185	1140
180	1024 a	925 a	547 bc	660 b	466 c	567 bc	612 b
	1476	1776	1170	1170	1332	1422	1368
Chi square values (χ^2)	899(5 df)	1449	789	826	1234	1256	1177
Ellerslie++							
30	155 a	149 a	113 a	82 a	135 a	119 a	122 a
	246	296	195	195	222	237	228
60	302 ab	336 a	246 ab	234 ab	234 ab	265 ab	203 b
	492	592	390	390	444	474	456
90	429 a	443 a	389 ab	350 ab	322 ab	319 ab	293 b
	738	888	585	585	666	711	684
120	516 a	547 a	494 a	415 a	483 a	539 a	457 a
	984	1184	780	780	888	948	912
150	742 ab	798 a	638 bcd	499 d	553 cd	558 cd	561 cd
	1230	1480	975	975	1110	1185	1140
180	883 a	855 ab	635 c	668 c	725 bc	713 c	716 bc
	1476	1776	1170	1170	1332	1422	1368
Chi square values (χ^2)	890(5 df)	1541	619	789	1052	1229	1245
Olds+++							
30	132 a	160 a	109 a	87 a	67 a	123 a	163 a
	246	296	195	195	222	237	228
60	228 a	236 a	166 a	202 a	197 a	205 a	166 a
	492	592	390	390	444	474	456
90	329 ab	436 a	281 bc	253 bc	293 bc	265 bc	191 c
	738	888	585	585	666	711	684
120	383 a	419 a	425 a	362 a	357 a	420 a	380 a
	984	1184	780	780	888	948	912
150	546 a	636 a	479 a	475 a	397 a	473 a	450 a
	1230	1480	975	975	1110	1185	1140
180	642 b	834 a	659 b	526 b	526 b	566 b	541 b
	1476	1776	1170	1170	1332	1422	1368
Chi square values (χ^2)	1638(5 df)	1982	962	1174	1718	1721	1786

\+ LSD (5%) between any two treatment combination means = 148

++ LSD (5%) between any two treatment combination means = 126

+++ LSD (5%) between any two treatment combination means = 129

* Within location and within seeding rate , means followed by the same letters are not significantly different from each other at the 5% level of probability.

** In each seeding rate, first rows are observed and second rows expected.

genotypes at the same seeding rates (Table 31). There were no significant genotype differences for observed plant stands at the 30, 60, 120 or 150 kg/ha seeding rates. Genotypes like Park or Neepawa had higher number of expected plants (Table 31) at each seeding rate than most other genotypes, due to their lower 1000 kernel weight (Table 1). However, at some seeding rates, observed plant stands for these two genotypes were found to be similar to results from those genotypes which had higher 1000 kernel weight than Park and Neepawa. This could possibly be due to Park and Neepawa having relatively lower percentage germination or higher mortality of seedlings compared to that of other genotypes.

At Edmonton, plant stand of only a few treatment combinations responded significantly to variation in seeding date (Table 32). Also this effect of seeding date variation in influencing plant stand appeared to be more common on the relatively higher seeding rates for most genotypes. In Edmonton, for instance, plant stand counts were significantly higher from seeding at either or both of dates one and two than from seeding on date three for the 150 and 180 kg.ha seeding rates of Park, Neepawa, Pitic 62, 70M110001 and 70M009002. At Edmonton, most of the treatment combinations for which plant stand showed significant responses to variation in seeding date, seeding early (either or both of dates one and two) gave significantly higher plant stands than seeding late (date three). This result of decreasing plant stand from later seeding is in agreement with similar reports by Jessop and Ivins, 1970, Khalifa, 1970, and Stoskopf et al., 1974. In this study, the relatively higher available soil moisture level normally present for the early seedings might have brought better germination and

TABLE 32. MEANS (AVERAGED OVER ALL REPLICATIONS) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEEDING RATE) FOR PLANT STAND PER 2.59 M^2.

Treatment combination [Genotype x Seeding rate]		Seeding date							
		Edmonton			Ellerslie			Olds	
		One	Two	Three	One	Two	Three	One	Two
Park	30 kg/ha	155	186	141	186	155	150	149	132
Park	60 kg/ha	237	378	251	375	302	333	248	228
Park	90 kg/ha	299	322	367	547	429	519	442	329
Park	120 kg/ha	367	567	338	742	516	632	565	383
Park	150 kg/ha	319	612	262	849	742	719	583	546
Park	180 kg/ha	567	1024	683	1038	883	934	752	642
Neepawa	30 kg/ha	192	172	164	223	149	166	149	160
Neepawa	60 kg/ha	285	347	167	449	336	353	341	[illegible]
Neepawa	90 kg/ha	299	434	313	609	443	522	430	436
Neepawa	120 kg/ha	536	516	373	756	547	671	577	419
Neepawa	150 kg/ha	612	838	544	674	798	894	788	636
Neepawa	180 kg/ha	685	925	471	1094	855	962	626	834
Pitic 62	30 kg/ha	119	181	93	172	113	127	121	109
Pitic 62	60 kg/ha	184	398	285	296	246	282	219	166
Pitic 62	90 kg/ha	277	302	220	429	389	373	368	281
Pitic 62	120 kg/ha	502	457	392	572	494	544	431	425
Pitic 62	150 kg/ha	358	550	316	705	638	623	532	479
Pitic 62	180 kg/ha	417	547	322	801	635	711	645	659
Glenlea	30 kg/ha	93	161	93	150	82	144	104	87
Glenlea	60 kg/ha	229	282	175	291	234	237	200	202
Glenlea	90 kg/ha	290	310	152	398	350	341	343	253
Glenlea	120 kg/ha	381	412	296	533	415	513	473	362
Glenlea	150 kg/ha	352	465	466	567	499	612	411	475
Glenlea	180 kg/ha	426	660	355	776	668	634	695	526
Norquay	30 kg/ha	130	163	99	158	135	110	132	67
Norquay	60 kg/ha	206	257	167	305	234	274	245	197
Norquay	90 kg/ha	330	336	192	353	322	327	343	293
Norquay	120 kg/ha	361	449	271	556	483	420	400	357
Norquay	150 kg/ha	403	643	214	651	553	640	524	397
Norquay	180 kg/ha	398	466	485	809	725	668	656	526
70M110001	30 kg/ha	130	161	102	164	119	233	126	123
70M110001	60 kg/ha	240	240	136	333	265	282	211	205
70M110001	90 kg/ha	276	423	257	443	319	443	302	265
70M110001	120 kg/ha	355	522	353	576	539	496	473	420
70M110001	150 kg/ha	369	595	404	688	558	651	507	473
70M110001	180 kg/ha	409	567	432	838	713	781	622	566
70M009002	30 kg/ha	141	133	96	[illegible]	[illegible]	147	101	163
70M009002	60 kg/ha	240	271	169	[illegible]	[illegible]	277	244	166
70M009002	90 kg/ha	268	370	262	[illegible]	[illegible]	395	343	191
70M009002	120 kg/ha	251	372	318	534	457	519	394	380
70M009002	150 kg/ha	277	686	203	581	561	669	492	450
70M009002	180 kg/ha	451	612	420	[illegible]	716	674	585	541
Seeding date Mean		319 b*	436 a	282 c	51[illegible]	434 c	476 b'	402 a"	352 b"
+ LSD (5%)		156			129			130	
++ LSD (5%)		148			126			129	

* Within location, means followed by the same letters are not significantly different from each other at the 5% level of probability.

+,++ See Table 6 for explanation.

'," Indicate separate comparisons of seeding date means for Ellerslie and Olds, respectively.

establishment of seedlings thereby resulting in higher plant stands.

For most treatment combinations, plant stand was in general very much lower at Olds than at Edmonton and Ellerslie (Table 32). The possible explanation for this occurrence is that the seed bed at Olds was not as even and well prepared as that at Edmonton or Ellerslie, and this might have lowered the percentage germination since seeds were not covered well. In fact some plots had uncovered seeds 3-4 weeks after seeding was done, due to lack of penetration of the seeding coulters through some of the undecayed pieces of sod on the seed bed. Also, there might have been very poor seed-soil contact since the soil was dry and loose.

Plant Height

At Edmonton and Ellerslie, increases in seeding rate appeared to increase plant height (Table 33). For most genotypes, taller plants were obtained from increased seeding rates at Edmonton and Ellerslie. At Olds, only Glenlea showed a significant increase in plant height due to increased seeding rates. Increased plant height of some genotypes due to increased seeding rate is in agreement with similar reports by Puckridge and Donald. 1967. However, on a test grown on stubble, Pelton, 1969, reported a decrease in plant height due to increased seeding rate. As Leonard and Martin, 1967, indicated, increase in plant height due to increased seeding rate could be a mechanism of shade avoidance or competition for light. This suggestion was also supported by Bidwell, 1974.

Averaged over all seeding rates and seeding dates, Glenlea was significantly the tallest genotype at all locations, although Park

TABLE 33. MEANS (AVERAGED OVER ALL SEEDING DATES AND OVER ALL REPLICATIONS) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEEDING RATE) FOR PLANT HEIGHT IN CM.

Seeding Rate (kg/ha)	Park	Neepawa	Pitic 62	Glenlea	Norquay	70M110001	70M009002	Seeding Rate Means
Edmonton								
30	89 h +	90 gh	81 i	96 cde	72 klm	74 jklm	71 m	82 c'
60	92 fgh	92 fgh	83 i	99 abc	74 jklm	73 jklm	73 jklm	84 ab'
90	91 fgh	92 fgh	83 i	97 bcd	74 jklm	74 jklm	72 klm	83 bc'
120	93 fg	94 def	82 i	100 ab	75 jkl	74 jklm	76 jk	85 a'
150	92 fgh	94 def	83 i	100 ab	74 jklm	74 jklm	74 jklm	84 ab'
180	94 def	94 def	83 i	101 a	74 jklm	76 jk	75 jkl	85 a'
Genotype Means	92 b"	93 b"	82 c"	99 a"	74 d"	74 d"	73 d"	
Ellerslie								
30	92 de	93 de	80 f	101 a	72 ghij	71 ij	71 ij	83 b'
60	92 de	95 cd	82 f	99 ab	73 ghij	73 ghij	71 ij	84 ab'
90	91 e	94 de	82 f	101 a	73 ghij	74 ghi	70 j	83 b'
120	93 de	95 cd	82 f	101 a	74 ghi	74 ghi	72 ghij	84 ab'
150	93 de	93 de	82 f	97 bc	74 ghi	73 ghij	72 ghij	83 b'
180	95 cd	94 de	81 f	100 ab	75 gh	75 gh	72 ghij	85 a'
Genotype Means	93 b"	94 b"	82 c"	100 a"	74 d"	73 d"	71 e"	
Olds								
30	89 bcd	86 d	72 efg	91 abcd	70 efg	69 g	71 efg	78 a'
60	90 abcd	88 bcd	71 efg	90 abcd	68 fg	68 fg	70 efg	78 a'
90	92 abc	86 d	74 ef	92 abc	69 fg	67 g	70 efg	78 a'
120	93 ab	90 abcd	71 efg	85 d	71 efg	66 g	69 fg	78 a'
150	93 ab	86 d	76 e	94 ab	69 fg	68 fg	69 fg	79 a'
180	93 ab	89 d	72 efg	96 a	69 fg	70 efg	69 fg	79 a'
Genotype Means	92 a"	87 b"	73 c"	91 a"	69 d"	68 d"	70 d"	

\+ Means followed by the same letters are not significantly different from each other at the 5% level of probability. When a mean is followed by more than four letters, only the beginning and the last letters are written.

'," Indicate separate comparisons of seeding rate means and genotype means, respectively.

equalled it in height at Olds. At all three locations, Norquay, 70M110001 and 70M009002 were among the significantly shortest genotypes while Pitic 62 had an intermediate plant height (Table 33).

At Edmonton, Park, Neepawa, and Glenlea, at all seeding rates, Pitic 62 at the 180 kg/ha seeding rate, Norquay and 70M110001 at the 60, 90, 120, 150 and 180 kg/ha seeding rates, and 70M009002 at the 30, 90, 120, 150, 180 kg/ha seeding rates had significantly taller plants from either or both of dates one and two seedings than from date three seeding (Table 34). Plant height for the remaining treatment combinations did not respond significantly to variation in seeding date. At Ellerslie and Olds, plant height of all treatment combinations did not show significant responses to variation in seeding date. The increased plant heights from earlier seedings of most treatment combinations at Edmonton could possibly be due to the relatively longer growing season available from early seeding. The longer growing season might have exposed plants to more favorable days in the summer which would lead to normal plant development and enable plants to attain heights closer to their genetic potential.

Within genotypes and within locations increased seeding rate resulted in increased plant height (Table 33) and also in higher grain yield per plot for most genotypes (Table 5). Among genotypes, however, relatively shorter genotypes gave higher grain yield per plot (Table 18). For instance, Pitic 62 and 70M110001, the relatively shorter genotypes were among the high grain yielders at all three locations (Table 5). Two of the taller genotypes, Park and Neepawa, were also among the lowest grain yielders per plot.

In the description of his high grain yielding wheat ideotype,

TABLE 34. MEANS (AVERAGED OVER ALL REPLICATIONS) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEEDING RATE) FOR PLANT HEIGHT IN CM.

Treatment combination [Genotype x Seeding rate]		Seeding date: Edmonton One	Edmonton Two	Edmonton Three	Ellerslie One	Ellerslie Two	Ellerslie Three	Olds One	Olds Two
Park	30 kg/ha	96	89	82	94	93	91	86	93
Park	60 kg/ha	99	92	84	91	94	92	91	90
Park	90 kg/ha	98	93	84	89	87	97	92	92
Park	120 kg/ha	102	92	85	94	91	95	91	95
Park	150 kg/ha	98	94	83	95	93	92	93	93
Park	180 kg/ha	100	98	85	94	95	96	91	95
Neepawa	30 kg/ha	99	90	82	92	95	93	88	85
Neepawa	60 kg/ha	99	92	86	97	93	95	90	87
Neepawa	90 kg/ha	97	94	85	95	92	94	88	84
Neepawa	120 kg/ha	101	92	88	95	94	96	86	94
Neepawa	150 kg/ha	102	94	87	93	94	92	86	87
Neepawa	180 kg/ha	102	95	86	96	95	93	85	86
Pitic 62	30 kg/ha	82	83	79	79	79	83	72	72
Pitic 62	60 kg/ha	86	82	81	78	84	86	71	71
Pitic 62	90 kg/ha	86	81	81	81	81	84	80	69
Pitic 62	120 kg/ha	82	83	81	79	81	85	70	72
Pitic 62	150 kg/ha	83	83	82	79	83	85	78	74
Pitic 62	180 kg/ha	85	85	79	80	82	81	73	71
Glenlea	30 kg/ha	98	101	90	100	100	102	91	91
Glenlea	60 kg/ha	106	102	89	98	100	98	85	95
Glenlea	90 kg/ha	102	99	90	99	103	101	94	91
Glenlea	120 kg/ha	108	99	93	99	102	101	84	87
Glenlea	150 kg/ha	107	102	93	94	98	100	97	92
Glenlea	180 kg/ha	109	100	94	98	102	99	97	95
Norquay	30 kg/ha	74	72	71	72	73	71	70	70
Norquay	60 kg/ha	80	74	69	73	74	72	71	66
Norquay	90 kg/ha	81	71	70	75	73	71	72	66
Norquay	120 kg/ha	81	73	71	76	75	72	71	72
Norquay	150 kg/ha	82	73	67	76	75	71	70	68
Norquay	100 kg/ha	81	71	71	75	76	76	69	70
70M110001	30 kg/ha	75	72	74	69	72	73	69	65
70M110001	60 kg/ha	78	74	68	73	73	73	69	67
70M110001	90 kg/ha	80	73	71	73	75	73	68	67
70M110001	120 kg/ha	81	72	71	75	74	74	67	66
70M110001	150 kg/ha	78	73	71	73	73	73	68	68
70M110001	180 kg/ha	80	74	74	74	76	75	70	69
70M009002	30 kg/ha	74	70	68	71	72	71	70	72
70M009002	60 kg/ha	76	72	71	69	73	72	69	71
70M009002	90 kg/ha	77	71	68	71	71	68	71	70
70M009002	120 kg/ha	78	79	71	72	72	72	71	68
70M009002	150 kg/ha	80	73	69	72	71	73	69	69
70M009002	180 kg/ha	80	73	71	72	72	73	68	70
Seeding date Mean		89 a*	84 b	79 c	83 a'	84 a'	84 a'	78 a"	78 a"
+ LSD (5%)		5.8			5.6			7.6	
++ LSD (5%)		5.1			4.8			7.1	

* Within location, means followed by the same letters are not significantly different from each other at the 5% level of probability.

+,++ See Table 6 for explanation.

'," Indicate separate comparisons of seeding date means for Ellerslie and Olds, respectively.

Donald, 1968, has associated short plants with higher grain yield per unit area. Simpson, 1968, indicated reduced lodging, more tillering, and smaller amount of photosynthate use by shorter stems as key factors which account for the higher grain yield of shorter genotypes. He argued that photosynthate that would have gone to the long stems in tall plants could go towards the production of more tillers and then more grain yield per plant from the shorter plants. In the present study, the high tillering capacity of Pitic 62 accompanied by higher grain yield compared to other genotypes (Table 18) supports Simpson's 1968 argument.

Simpson, 1968, also observed a general tendency of tall plants to have fewer number of tillers per plant, kernels per ear, and a lower kernel weight per plant compared to shorter ones. However, only some of the above relationships were found to hold true in this study as shown in Table 18. For instance, Pitic 62, which had significantly shorter plants than either Park or Glenlea, had a similar tiller number of Park but higher than that of Glenlea. The higher number of kernels per ear for Pitic 62, the highest yielding genotype and one of the shortest in height, was in agreement with Simpson's, 1968, report which showed an association of higher kernel number per ear with shorter plants. On the other hand, Pitic 62 had significantly smaller kernel weight than Glenlea, one of the taller genotypes.

Pitic 62 and 70M110001, two of the shorter genotypes in this test, were also among the highest grain yielders satisfying one of the criteria that Donald, 1968, has set for his high grain yielding wheat ideotype. However, some of the variables that he suggested as being associated with shorter plants in bringing higher grain yield did not have similar effects for the shorter genotypes in this study.

Days to heading

Only at Olds did increasing the seeding rate decrease the number of days to heading significantly (Table 35). Number of days to heading of most genotypes at Edmonton and Ellerslie (but only for Glenlea at Olds) significantly decreased due to increased seeding rates. However, the decreases in number of days to heading due to increased seeding rates were not appreciable for most genotypes. At Edmonton for instance, the 60 and 180 kg/ha seeding rates each made Pitic 62 significantly later in heading by one day compared to results from the remaining seeding rates. There were no significant differences in number of days to heading among the other seeding rates. Nor Neepawa and Glenlea, the 30 kg/ha seeding rate delayed heading by one day compared to the other seeding rates for which the number of days to heading did not have significant differences. At Ellerslie, the 30 and 90 kg/ha seeding rates for Pitic 62 and the 30 and 60 kg/ha seeding rates for 70M009002 also delayed heading by one day compared to the other seeding rates for each genotype. Such decreases in number of days to heading due to increased seeding rates were explained by Willey and Holliday, 1971, as being due to rapid development of plants due to higher competition. The response of dec[illegible]g number of days to heading due to increased seeding rates of [illegible]enotypes is in agreement with similar reports by Severson and Rasmuss[illegible] 968, Finlay et al., 1971, Willey and Holliday, 1971, and [illegible]usten[illegible]on[illegible] 972.

At all three locations, seeding on the [illegible] date, May 26, in Edmonton and Ellerslie and May 22 at Olds, significantly reduced [illegible]

TABLE 35. MEANS (AVERAGED OVER ALL SEEDING DATES AND OVER ALL REPLICATIONS) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEEDING RATE) FOR NUMBER OF DAYS TO HEADING.

Seeding Rate (kg/ha)	Genotypes							Seeding Rate Means
	Park	Neepawa	Pitic 62	Glenlea	Norquay	70M110001	70M009002	
Edmonton								
30	50 i +	54 e	58 b	57 c	53 f	54 e	52 g	54 a'
60	50 i	53 f	59 a	56 d	53 f	54 e	52 g	54 a'
90	50 i	53 f	58 b	56 d	53 f	54 e	51 h	54 a'
120	50 i	53 f	58 b	56 d	53 f	54 e	51 h	54 a'
150	50 i	53 f	58 b	56 d	53 f	54 e	51 h	54 a'
180	49 j	53 f	59 a	56 d	53 f	54 e	51 h	54 a'
Genotype Means	50 f"	53 d"	59 a"	56 b"	53 d"	54 c"	51 e"	
Ellerslie								
30	52 h	54 f	60 a	58 c	55 e	55 e	53 g	55 a'
60	52 h	55 e	59 b	58 c	55 e	55 e	53 g	55 a'
90	51 i	55 e	60 a	58 c	55 e	55 e	52 h	55 a'
120	51 i	55 e	59 b	58 c	54 f	55 e	52 h	55 a'
150	51 i	54 f	59 b	58 c	54 f	55 e	52 h	55 a'
180	50 j	55 e	59 b	57 d	54 f	55 e	52 h	55 a'
Genotype Means	51 e"	55 c"	59 a"	58 b"	55 c"	55 c"	52 d"	
Olds								
30	55 fg	58 cd	62 a	61 ab	57 de	58 cd	56 ef	58 a'
60	55 fg	58 cd	62 a	60 b	57 de	58 cd	56 ef	58 a'
90	55 fg	57 de	62 a	60 b	56 ef	58 cd	55 fg	58 a'
120	54 g	57 de	61 ab	59 c	57 de	57 de	56 ef	57 b'
150	54 g	57 de	62 a	60 b	56 ef	57 de	55 fg	57 b'
180	54 g	57 de	61 ab	59 c	56 ef	57 de	55 fg	57 b'
Genotype Means	55 f"	57 d"	62 a"	60 b"	57 d"	58 c"	56 e"	

+ Means followed by the same letters are not significantly different from each other at the 5% level of probability. When a mean is followed by more than four letters, only the beginning and the last letters are written.

'," Indicate separate comparisons of seeding rate means and genotype means, respectively.

number of days to heading of all treatment combinations, except for Pitic 62 at the 30 kg/ha seeding rate in Edmonton, compared to seeding on the first date (May 8) (Table 36). In fact, for most treatment combinations at Edmonton and Ellerslie, every delay in seeding significantly reduced the number of days to heading. The possible explanation for this occurrence is that later seeding could have exposed the plants to the relatively warmer part of the growing season (July) (Fig.1), relatively sooner than early planted ones. As a result, plants would develop faster and head in a fewer number of days compared to those planted earlier. However, for some treatment combinations, the earliness in heading from delayed seeding was not accompanied by earlier maturity (Table 9).

Another interesting result was that late seeding decreased the number of days to heading more for early heading genotypes than for late heading ones. In Edmonton, for instance, seeding on date three compared to seeding on date one reduced the number of days to heading of Park (one of the early heading genotypes) at all seeding rates by about 7-9 days compared to that of 4-6 days for all seeding rates of Pitic 62, the latest heading genotype (Table 36). At Olds, Park and Pitic 62, at all seeding rates, had 4-6 and 3-4 days reduction in number of days to heading, respectively, as a result of seeding on date two compared to seeding on date one. At Ellerslie, a similar relationship was observed for early and late maturing genotypes with regards to heading and late seeding. This difference between early and late heading genotypes in response of number of days to heading to variation in seeding date could be explained as follows. At later seedings, the warmer part of the growing season (July) may not

TABLE 36. MEANS (AVERAGED OVER ALL REPLICATIONS) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEEDING RATE) FOR NUMBER OF DAYS TO HEADING.

Treatment combination (Genotype x Seeding rate)		Seeding date: Edmonton One	Edmonton Two	Edmonton Three	Ellerslie One	Ellerslie Two	Ellerslie Three	Olds One	Olds Two
Park	30 kg/ha	54	51	46	57	53	47	57	52
Park	60 kg/ha	53	50	46	56	53	47	58	52
Park	90 kg/ha	53	51	45	56	52	47	58	53
Park	120 kg/ha	55	51	46	55	52	47	57	52
Park	150 kg/ha	54	51	46	56	52	46	56	51
Park	180 kg/ha	53	50	45	55	51	45	56	52
Neepawa	30 kg/ha	57	54	50	59	56	49	61	55
Neepawa	60 kg/ha	57	54	49	59	56	51	61	55
Neepawa	90 kg/ha	56	54	49	59	56	50	60	55
Neepawa	120 kg/ha	56	54	49	59	56	49	60	55
Neepawa	150 kg/ha	56	54	48	58	55	49	60	55
Neepawa	180 kg/ha	56	53	49	59	55	50	59	54
Pitic 62	30 kg/ha	59	58	58	64	59	58	64	60
Pitic 62	60 kg/ha	61	58	57	64	59	56	64	60
Pitic 62	90 kg/ha	61	58	55	63	59	57	63	60
Pitic 62	120 kg/ha	61	58	57	64	59	56	63	59
Pitic 62	150 kg/ha	61	58	57	62	59	55	63	60
Pitic 62	180 kg/ha	61	58	47	64	59	56	62	59
Glenlea	30 kg/ha	60	58	52	63	59	52	63	59
Glenlea	60 kg/ha	60	58	52	63	59	52	63	58
Glenlea	90 kg/ha	58	57	52	63	59	52	62	57
Glenlea	120 kg/ha	59	57	52	62	59	52	61	56
Glenlea	150 kg/ha	59	57	52	62	58	52	62	57
Glenlea	100 kg/ha	59	56	52	62	58	52	62	56
Norquay	30 kg/ha	57	55	49	59	55	49	60	55
Norquay	60 kg/ha	57	54	48	60	55	49	60	54
Norquay	90 kg/ha	57	54	49	60	56	49	60	53
Norquay	120 kg/ha	57	54	48	59	55	49	60	54
Norquay	150 kg/ha	57	54	48	59	55	49	59	53
Norquay	180 kg/ha	58	54	48	59	55	49	59	53
70M110001	30 kg/ha	59	55	50	60	56	50	61	55
70M110001	60 kg/ha	59	55	50	60	56	50	60	55
70M110001	90 kg/ha	58	56	50	60	56	50	61	55
70M110001	120 kg/ha	58	55	50	59	56	49	61	55
70M110001	150 kg/ha	58	55	50	60	56	50	60	54
70M110001	180 kg/ha	58	54	50	59	55	50	60	54
70M009002	30 kg/ha	56	53	47	58	54	47	60	53
70M009002	60 kg/ha	56	52	47	57	54	48	59	53
70M009002	90 kg/ha	55	52	47	57	54	47	58	53
70M009002	120 kg/ha	55	53	47	55	53	47	59	53
70M009002	150 kg/ha	56	51	46	56	56	47	58	53
70M009002	180 kg/ha	55	52	47	56	52	47	57	53
Seeding date Mean		57 a*	54 b	50 c	59 a'	56 b'	50 c'	60 a"	55 b"
+ LSD (5%)		1.2			1.0			1.5	
++ LSD (5%)		1.1			1.0			1.3	

* Within location, means followed by th ame letters are not significantly different from each otner at the 5% level of probability.

+,++ See Table 6 for explanation.

'," Indicate separate comparisons of seeding date means for Ellerslie and Olds, respectively.

have been long enough to extend fully through the time of the beginning of inflorescence initiation and its completion (at heading) for the late heading genotypes. Another explanation could be that genotypes from lower latitudes or those bred for relatively warmer areas, such as Pitic 62, may not be able to carry out their normal physiological processes at lower temperature, and may respond by exhibiting delayed heading (Rawson, 1971, and Evans *et al*., 1975).

Earlier seeding, although it delayed heading for most treatment combinations (Table 36) resulted in increased grain yield per plot, especially in Edmonton (Table 6). This kind of relationship has been explained by Rawson, 1970 in considerable detail. He indicated that later heading gives more time for spikelet primordia to be laid down and this could result in an increased number of kernels per ear which would lead to higher grain yield per plant. At Edmonton for instance, the higher number of kernels per ear and higher grain yield per plant of Pitic 62, the latest heading genotype, compared to Park, the early heading genotype (Table 18), exactly fits into Rawson's, 1970, explanation. However, later heading, especially if followed by later maturity, can result in special disadvantages in Alberta conditions where sudden and early termination of the growing season can frequently occur due to early fall frost.

Averaged, over all seeding rates and seeding dates, Pitic 62 was found to be significantly the latest and Park the earliest heading genotype at each location (Table 35).

Protein content in the grain, and protein yield

Protein content in the grain

At all locations, averaged over all genotypes and seeding dates, grain protein percentage decreased significantly with increased seeding rates, (Table 37). This relationship of seeding rate and grain protein was also true for most genotypes at all three locations. At Edmonton for instance, grain protein percentage for Neepawa and Glenlea was higher from the 30 kg/ha seeding rate than from the other seeding rates. Also, at the 30 kg/ha seeding rate, grain protein percentage was higher for Park, Neepawa, Norquay and 70M110001 at Ellerslie, and for Norquay at Olds than from the other seeding rates for each genotype. This response of decreasing grain protein percentage due to increased seeding rate is in disagreement with the report by Pelton, 1969, who observed increasing grain protein percentage in wheat at higher seeding rates from plants grown on fallow plots. In the present study, there were relatively more plants per unit area at higher seeding rates (Table 30) to use the same amount of nitrogen from the soil. This means that the distribution of nitrogen in the numerous kernels per unit area at higher seeding rates could be lower resulting in lower grain protein percentage. Since protein in the grain of wheat results from the translocation of nitrogenous compounds from the other parts of the plant, (Haunold _et al_., 1962), the fewer the number of plants per unit area, the higher will be the nitrogenous compounds per plant leading to higher grain protein provided nitrogen in the soil does not become limiting.

Averaged over all seeding dates and seeding rates, Park

TABLE 37. MEANS (AVERAGED OVER ALL SEEDING DATES AND OVER ALL REPLICATIONS) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEEDING RATE) FOR PERCENTAGE PROTEIN IN THE GRAIN.

Seeding Rate (kg/ha)	Genotypes							Seeding Rate Means
	Park	Neepawa	Pitic 62	Glenlea	Norquay	70M110001	70M009002	
Edmonton								
30	18.8 ab+	19.1 a	14.1 n	17.6 de	16.5 fghi	17.6 de	16.2 g-k	17.1 a'
60	18.4 bc	18.3 bcd	14.0 n	16.8 fg	16.0 h-m	17.0 ef	15.3 m	16.5 b'
90	18.3 bcd	17.8 cd	14.0 n	16.4 f-j	16.5 fghi	16.1 g-l	15.3 m	16.3 b'
120	18.2 bcd	17.9 cd	14.0 n	16.8 fg	16.1 g-l	16.0 h-m	15.4 lm	16.3 b'
150	18.2 bcd	17.9 cd	13.9 n	16.6 fghi	16.4 f-j	16.0 h-m	15.6 klm	16.4 b'
180	17.7 cd	17.6 de	14.3 n	16.7 fgh	16.0 h-m	15.9 i-m	15.7 jklm	16.3 b'
Genotype Means	18.3 a"	18.1 a"	14.0 e"	16.8 b"	16.3 c"	16.4 c"	15.6 d"	
Ellerslie								
30	18.6 ab	18.9 a	13.9 p	17.0 de	16.5 efgh	17.6 cd	16.2 ghij	17.0 a'
60	17.7 c	18.0 bc	13.6 p	16.8 ef	15.7 i-m	16.7 efg	15.8 ijkl	16.3 b'
90	17.7 c	17.9 bc	13.5 p	16.1 ghij	15.8 ijkl	15.8 ijkl	15.6 j-n	16.1 bc'
120	17.7 c	17.7 c	13.9 p	16.0 hijk	15.1 mno	15.6 j-n	14.9 o	15.8 c'
150	18.0 bc	17.8 c	13.5 p	16.3 fghi	15.0 no	15.4 k-o	15.2 lmno	15.9 c'
180	17.5 cd	17.6 cd	13.9 p	16.1 ghij	14.9 o	15.3 lmno	15.3 lmno	15.8 c'
Genotype Means	17.9 a"	18.0 a"	13.7 d"	16.4 b"	15.5 c"	16.1 b"	15.5 c"	
Olds								
30	17.0 a	16.7 ab	13.2 lmn	16.0 a-e	14.5 g-k	15.3 d-h	13.3 lmn	16.1 a'
60	16.0 a-e	16.3 abcd	13.6 klmn	16.6 abc	13.2 lmn	14.2 i-m	13.3 lmn	14.7 ab'
90	16.0 a-e	16.4 abcd	13.0 n	15.5 c-g	12.9 n	14.9 e-i	13.4 lmn	14.6 [illegible]
120	15.4 defg	16.4 abcd	13.4 lmn	16.1 a-e	12.9 n	14.8 f-j	13.8 j-n	14.7 ab'
150	15.5 c-g	16.6 abc	12.9 n	14.9 n	13.1 mn	13.8 j-n	13.2 lmn	14.3 b'
180	15.7 b-f	16.7 ab	12.9 n	15.3 d-h	13.4 lmn	14.3 h-l	13.0 n	14.5 b'
Genotype Means	15.9 b"	16.5 a"	13.2 d"	15.7 b"	13.3 d"	14.6 c"	13.3 d"	

\+ Means followed by the same letters are not significantly different from each other at the 5% level of probability. When a mean is followed by more than four letters, only the beginning and the last letters are written.

'," Indicate separate comparisons of seeding rate means and genotype means, respectively.

and Neepawa at both Edmonton and Ellerslie and Neepawa at Olds had significantly the highest grain protein percentages. Grain protein percentages were the lowest for Pitic 62 at both Edmonton and Ellerslie and for Pitic 62, Norquay and 70M009002 at Olds.

At Edmonton, Pitic 62 at the 60, 120, and 150 kg/ha and 70M110001 at the 30 kg/ha seeding rates were the only treatment combinations for which grain protein percentage did not show significant responses to variation in seeding date (Table 38). For all the other treatment combinations, except for Pitic 62 at the 180 kg/ha seeding rate, date three seeding gave significantly higher grain protein than did seeding at either or both of dates one and two. Pitic 62 at the 180 kg/ha rate had a higher grain protein percentage from date one seeding than from date two. At Ellerslie, grain protein contents were higher from seeding at either or both of dates two and three than from seeding at date one for Pitic 62 at the 30 and 180 kg/ha, for Norquay at the 60, 90, 120 and 150 kg/ha, for 70M110001 at the 90 and 150 kg/ha, and for 70M009002 at the 30 and 60 kg/ha seeding rates. Date two seeding gave significantly lower grain protein for the 150 kg/ha seeding rate of Glenlea and the 90 kg/ha seeding rate of 70M009002 compared to results from seeding at either or both of dates one and three. Grain protein percentages of the other treatment combinations did not show significant responses to variation in seeding date at Ellerslie.

Protein percentage in the grain represents the ratio of protein to non-protein material in the grain and any change in either component will affect the magnitude of the percentage value. Late seedings therefore might have forced plants to complete their life

TABLE 38. MEANS (AVERAGED OVER ALL REPLICATIONS) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEEDING RATE) FOR PERCENTAGE PROTEIN IN THE GRAIN.

Treatment combination [Genotype x Seeding rate]		Seeding date							
		Edmonton			Ellerslie			Olds	
		One	Two	Three	One	Two	Three	One	Two
Park	30 kg/ha	17.4	19.2	19.7	18.3	19.0	18.5	16.7	17.4
Park	60 kg/ha	17.5	18.4	19.3	17.3	17.8	18.1	16.0	16.0
Park	90 kg/ha	17.4	18.4	19.1	17.7	17.7	17.7	16.1	16.0
Park	120 kg/ha	17.7	18.0	19.0	17.6	17.8	17.7	15.6	15.2
Park	150 kg/ha	17.3	17.7	19.5	18.2	17.8	17.9	15.4	15.6
Park	180 kg/ha	17.1	17.4	18.5	17.2	17.9	17.5	16.5	14.9
Neepawa	30 kg/ha	17.3	19.4	20.6	18.7	18.9	19.1	16.6	16.8
Neepawa	60 kg/ha	17.3	17.7	19.9	18.1	17.9	18.1	16.0	16.6
Neepawa	90 kg/ha	17.1	17.0	19.3	18.2	17.5	18.1	16.2	16.6
Neepawa	120 kg/ha	17.1	17.5	19.2	17.8	17.2	18.0	15.1	15.8
Neepawa	150 kg/ha	17.1	17.7	18.8	17.8	17.6	18.1	16.7	16.5
Neepawa	180 kg/ha	17.1	16.8	18.9	17.8	17.5	17.4	16.7	16.8
Pitic 62	30 kg/ha	13.6	13.9	14.8	13.4	14.5	13.7	13.3	13.1
Pitic 62	60 kg/ha	13.4	14.3	14.5	14.0	13.8	13.2	13.3	13.8
Pitic 62	90 kg/ha	13.2	14.2	14.6	13.2	13.8	13.6	12.6	13.4
Pitic 62	120 kg/ha	13.3	14.2	14.4	14.4	13.9	13.5	13.3	13.5
Pitic 62	150 kg/ha	13.6	13.6	14.6	13.8	13.6	13.3	12.8	13.0
Pitic 62	180 kg/ha	14.9	13.6	14.6	13.4	14.7	13.5	12.8	13.0
Glenlea	30 kg/ha	17.0	17.1	18.7	16.7	17.5	16.8	16.2	15.9
Glenlea	60 kg/ha	15.8	15.9	18.7	16.4	16.8	17.3	17.7	15.5
Glenlea	90 kg/ha	16.2	16.0	17.2	15.9	16.0	16.3	15.5	15.5
Glenlea	120 kg/ha	15.9	16.3	18.4	15.7	15.9	16.4	16.7	15.6
Glenlea	150 kg/ha	15.7	16.0	18.2	16.9	15.3	16.7	14.0	15.7
Glenlea	180 kg/ha	15.5	16.3	18.3	16.1	16.1	16.1	15.2	15.5
Norquay	30 kg/ha	14.9	16.8	18.0	16.3	16.9	16.4	14.4	14.7
Norquay	60 kg/ha	14.8	15.8	17.2	14.9	15.5	16.7	13.1	13.2
Norquay	90 kg/ha	14.2	17.3	17.5	15.5	15.4	16.6	12.8	13.1
Norquay	120 kg/ha	14.1	16.4	17.8	14.3	15.3	15.7	13.2	12.5
Norquay	150 kg/ha	14.6	16.9	17.7	14.0	15.5	15.6	13.0	13.3
Norquay	180 kg/ha	14.7	16.5	16.9	14.8	15.4	14.6	14.2	12.6
70M110001	30 kg/ha	17.3	17.3	18.1	17.2	18.0	17.4	15.2	15.5
70M110001	60 kg/ha	15.3	17.4	18.3	16.2	17.2	16.7	14.1	14.3
70M110001	90 kg/ha	14.8	15.9	17.7	15.2	15.7	16.7	14.7	15.1
70M110001	120 kg/ha	14.6	15.8	17.7	15.0	15.9	15.9	14.8	14.8
70M110001	150 kg/ha	15.0	15.7	17.3	15.0	14.9	16.4	13.5	14.2
70M110001	180 kg/ha	14.7	15.8	17.1	15.1	15.0	15.7	14.4	14.2
70M009002	30 kg/ha	14.6	16.3	17.7	15.4	15.9	17.2	13.9	12.6
70M009002	60 kg/ha	14.2	14.9	16.8	15.3	15.7	16.4	13.2	13.4
70M009002	90 kg/ha	14.1	15.3	16.5	16.0	14.9	15.9	13.6	13.2
70M009002	120 kg/ha	14.0	15.7	16.4	14.9	14.7	15.1	13.8	13.7
70M009002	150 kg/ha	14.6	15.3	16.8	15.0	15.1	15.3	13.2	13.2
70M009002	180 kg/ha	14.2	16.1	16.7	15.3	15.5	15.0	13.5	12.5
Seeding date Mean*		15.5 c	16.4 b	17.6 a	15.9 b'	16.2 a'	16.3 a'	14.7 a"	14.6 a"
+ LSD (5%)			1.1			1.0		1.3	
++ LSD (5%)			1.1			1.0		1.3	

* Within location, means followed by the same letters are not significantly different from each other at the 5% level of probability.

+,++ See Table 6 for explanation.

'," Indicate separate comparisons of seeding date means for Ellerslie and Olds, respectively.

cycles in a relatively shorter season which did not allow for enough accumulation of carbohydrates, thereby resulting in a relative increase in grain protein percentage. A decrease in grain protein percentage due to delayed seeding was previously reported by Nass et al., 1975 in the Atlantic Region of Canada.

Protein Yield per plot

At all locations, increasing seeding rate increased protein yield significantly (Table 39). This relationship was also true for most of the individual genotypes when analyzed separately. Even Pitic 62 which did not show any significant change in grain protein percentage due to changes in seeding rate at all locations (Table 37), showed significant increases in protein yield due to increased seeding rates (Table 39). Norquay and 70M009002 at Olds were the only two genotypes for which variation in seeding rate did not bring about significant changes in protein yield in this study. A significant compensatory effect from grain yield per plot might have enabled genotypes like Pitic 62 and 70M110001, which were low in grain protein (Table 37) to have higher protein yield per plot. This occurred even though their grain protein percentages were significantly lower than that of Park, one of the genotypes with the highest grain protein percentages (Table 37).

At all locations, protein yield of only very few treatment combinations responded significantly to variation in seeding date (Table 40). At Edmonton for instance, seeding at either or both of dates one and two gave significantly higher protein yield for Park at the 120 and 150 kg/ha, for Neepawa at the 30 kg/ha, for Pitic 62

TABLE 39. MEANS (AVERAGED OVER ALL SEEDING DATES AND OVER ALL REPLICATIONS) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEEDING RATE) FOR PROTEIN YIELD IN GM/2.30 M^2.

Seeding Rate (kg/ha)	Genotypes							Seeding Rate Means
	Park	Neepawa	Pitic 62	Glenlea	Norquay	70M110001	70M009002	
Edmonton								
30	127 mno+	143 i-o	153 f-n	135 lmno	126 no	148 h-n	118 o	136 c'
60	141 j-n	174 a-h	177 a-g	159 b-l	151 g-n	164 a-k	154 d-l	160 b'
90	148 h-n	163 b-k	181 abcd	144 i-o	153 f-n	182 abc	150 g-n	160 b
120	141 j-o	174 a-h	180 a-e	165 a-k	167 a-j	190 a	155 c-l	165 ab'
150	144 i-o	179 a-f	166 a-j	180 a-e	163 b-k	185 a-b	138 k-o	167 ab'
180	168 a-j	176 a-g	184 ab	169 a-i	167 a-j	182 abc	154 d-l	171 a'
Genotype Means	145 d"	168 ab"	174 a"	159 bc"	155 c"	175 a"	145 d"	
Ellerslie								
30	110 n	142 ijkl	138 jklm	136 klm	124 lmn	106 n	103 n	123 d'
60	146 g-k	175 abcd	157 c-k	149 f-k	152 d-k	153 c-k	119 m	150 c'
90	158 c-k	173 a-e	160 b-j	165 a-i	159 c-j	176 abc	138 j-m	161 ab'
120	153 c-k	183 ab	163 a-i	171 a-f	166 a-h	169 a-g	152 d-k	165 ab'
150	155 c-k	167 a-h	145 h-l	163 a-i	160 b-j	169 a-g	146 g-k	158 bc'
180	169 a-g	186 a	156 c-k	174 a-e	169 a-g	175 abcd	150 e-k	168 a'
Genotype Means	149 c"	171 a"	153 bc"	160 b"	155 bc"	158 bc"	135 d"	
Olds								
30	97 fghi	102 e-i	99 e-i	105 d-i	100 e-i	86 i	84 i	96 b'
60	104 d-i	123 a-e	104 d-i	113 b-h	99 e-i	120 b-f	95 ghi	108 a'
90	119 b-f	121 a-e	117 b-h	120 b-f	106 d-i	106 d-i	93 hi	112 a'
120	127 abcd	122 a-e	110 c-h	108 d-i	117 b-h	118 b-g	101 e-i	115 a'
150	126 abcd	115 b-h	134 abc	137 ab	104 d-i	100 e-i	108 d-i	118 a'
180	120 b-f	133 abc	115 b-h	144 a	95 ghi	112 c-h	106 d-i	113 a'
Genotype Means	116 ab"	119 a"	113 abc"	121 a"	104 cd"	107 bcd"	98 d"	

+ Means followed by the same letters are not significantly different from each other at the 5% level of probability. When a mean is followed by more than four letters, only the beginning and the last letters are written.

'," Indicate separate comparisons of seeding rate means and genotype means, respectively.

TABLE 40. MEANS (AVERAGED OVER ALL REPLICATIONS) OF SUBPLOT TREATMENT COMBINATIONS (GENOTYPE x SEEDING RATE) FOR PROTEIN YIELD IN $GM/2.30\ M^2$.

Treatment combination [Genotype x Seeding rate]		Seeding date							
		Edmonton			Ellerslie			Olds	
		One	Two	Three	One	Two	Three	One	Two
Park	30 kg/ha	137	137	107	122	127	80	89	105
Park	60 kg/ha	149	142	132	139	150	149	94	114
Park	90 kg/ha	150	132	162	158	158	159	113	126
Park	120 kg/ha	175	134	115	156	149	155	119	134
Park	150 kg/ha	165	157	109	163	152	151	123	128
Park	180 kg/ha	168	168	167	177	164	164	109	130
Neepawa	30 kg/ha	179	159	91	171	113	142	107	96
Neepawa	60 kg/ha	170	188	165	173	184	168	126	119
Neepawa	90 kg/ha	159	154	175	178	170	171	120	123
Neepawa	120 kg/ha	182	165	173	194	174	181	109	135
Neepawa	150 kg/ha	173	179	184	154	178	171	125	106
Neepawa	180 kg/ha	169	179	180	171	206	181	129	138
Pitic 62	30 kg/ha	144	188	125	153	154	105	87	112
Pitic 62	60 kg/ha	175	198	158	164	155	153	103	104
Pitic 62	90 kg/ha	183	196	158	167	170	143	113	120
Pitic 62	120 kg/ha	185	196	160	152	190	147	92	128
Pitic 62	150 kg/ha	181	181	137	146	150	138	138	130
Pitic 62	180 kg/ha	204	207	142	138	182	147	107	123
Glenlea	30 kg/ha	142	163	100	166	127	115	94	116
Glenlea	60 kg/ha	170	184	122	167	152	129	92	135
Glenlea	90 kg/ha	181	155	96	169	184	141	130	111
Glenlea	120 kg/ha	181	168	146	169	175	169	109	107
Glenlea	150 kg/ha	182	175	181	164	167	157	136	137
Glenlea	180 kg/ha	186	198	124	169	185	166	141	146
Norquay	30 kg/ha	124	158	96	134	110	127	112	88
Norquay	60 kg/ha	157	157	139	162	144	149	99	99
Norquay	90 kg/ha	170	166	134	153	173	151	122	90
Norquay	120 kg/ha	170	174	159	179	171	147	111	122
Norquay	150 kg/ha	171	169	128	168	168	144	109	99
Norquay	180 kg/ha	172	146	182	177	149	180	99	91
70M110001	30 kg/ha	155	165	123	109	90	120	80	93
70M110001	60 kg/ha	165	197	131	132	166	162	115	125
70M110001	90 kg/ha	168	215	162	180	187	162	99	112
70M110001	120 kg/ha	185	208	178	192	154	161	112	124
70M110001	150 kg/ha	167	199	190	169	158	179	96	104
70M110001	180 kg/ha	157	202	185	155	190	180	113	111
70M009002	30 kg/ha	145	105	106	128	95	87	75	94
70M009002	60 kg/ha	153	172	136	129	125	103	96	93
70M009002	90 kg/ha	141	164	145	151	139	125	103	84
70M009002	120 kg/ha	150	161	154	153	150	154	108	94
70M009002	150 kg/ha	130	161	123	129	157	153	97	118
70M009002	180 kg/ha	158	160	145	150	161	140	103	110
Seeding date Mean		165 a*	171 a	144 b	158 a'	157 a'	148 a'	108 b"	114 a"
+ LSD (5%)		39.6			34.8			27.3	
++ LSD (5%)		38.0			32.6			27.1	

* Within location, means followed by the same letters are not significantly different from each other at the 5% level of probability.

+,++ See Table 6 for explanation.

'," Indicate separate comparisons of seeding date means for Ellerslie and Olds, respectively.

at the 30, 60, 150 and 180 kg.ha, for Glenlea or 70M009002 at the 30, 60, 90 and 180 kg/ha, and for Norquay at the 30 and 150 kg/ha seeding rates than from seeding on date three. At Ellerslie, seeding at either or both of dates one and two also gave significantly higher protein yield compared to date three for those treatment combinations for which protein yield responded significantly to variation in seeding date. At Olds, Pitic 62 at 120 kg/ha and Glenlea at the 60 kg/ha seeding rates had significantly higher protein yield per plot from date two seeding compared to date one. But Norquay at the 90 kg/ha seeding rate had significantly hgiher protein yield from seeding on date one than from seeding on date two. Protein yield of the other treatment combinations did not respond significantly to variation in seeding date.

Averaged over all seeding rates and seeding dates, Neepawa, Pitic 62, and 70M110001 in Edmonton, Neepawa at Ellerslie, and Park, Neepawa, Pitic 62 and Glenlea at Olds were among the highest protein yielders per plot (Table 39). Park and 70M009002 at Edmonton, 70M009002 at Ellerslie, and Norquay, 70M110001 and 70M009002 at Olds were among the lowest protein yielders per plot.

Relationships between grain yield per plot, grain protein, content, and protein yield per plot

The significantly higher protein yield from genotypes Pitic 62, Neepawa, and 70M110001 at most locations (Table 39) has considerable significance in feed wheat production in Alberta. Wheat has higher grain protein percentage than barley, yellow corn, or oats (Table 41). This indicates that more protein yield per unit area would be obtained from wheat even if grain yields per unit area are similar for all the above mentioned cereals. Plant breeders have constantly improved wheat

TABLE 41. AVERAGE AMINO ACID AND PROTEIN LEVELS OF CANADIAN CEREAL GRAINS.+

	Wheat	Barley	Yellow corn	Oats
Grain protein %	13.5	11.8	9.0	11.5
Lysine (% as fed basis)	0.40	0.40	0.20	0.40

+ From Canada Grains Council ____. Canadian grains for pigs. Winnipeg, Manitoba, Canada.

grain yield per unit area in different parts of the world, but mostly at the expense of grain protein percentage (Lofgren, et al., 1968). A similar relationship was exhibited by two of the highest yielders in the present study at Edmonton, namely Pitic 62 and 70M110001 (Table 42). However, the big difference in grain protein percentage among genotypes seemed to disappear for protein yield per plot. For instance, Pitic 62 and 70M110001 were among the lowest in grain protein percentage but gave similar or better protein yields than Neepawa or Park, which had the highest grain protein percentage (Table 42). This phenomena of genotypes, with significantly different grain protein percentage, to even out in protein yield was also reported by Dubetz, 1972.

The inverse relationship between grain yield per plot and grain protein percentage as reported by Mallock and Newton, 1934, and McNeal et al., 1972, also holds true on a cultivar basis (Mack, 1973). Similar relationships were observed in this test as shown in Table 42. The inverse relationship between grain yield per plot and grain protein percentage could be more clearly understood by the following explanation. Grain yield per plot could be increased by an increase in any one of the grain yield components or plant density provided the remaining ones are held constant. However, any increase in any one of the grain yield components or plant density means relatively less allocation of nitrogen to the other grain yield components. This then could result in a lower grain protein percentage with higher grain yield per plot. Therefore, it appears that the difference in grain protein percentage is possibly due to a difference in the relative distribution of nitrogenous compounds to the grains. The above explanation has been strongly

TABLE 42. MEAN VALUES (AVERAGED OVER 3 SEEDING DATES, 6 SEEDING RATES, AND 4 REPLICATIONS) OF SOME PLANT CHARACTERISTICS FOR SEVEN WHEAT GENOTYPES AT EDMONTON.

Plant characteristics (variables)	Genotypes						
	Pitic 62	70M110001	Norquay	Glenlea	70M009002	Neepawa	Park
Grain yield (gm/2.30 m^2)	1241 a[+]	1080 b	968 c	959 c	949 c	938 c	800 d
Grain protein %	14.0 e	16.4 c	16.3 c	16.8 b	15.6 d	18.1 a	18.3 a
Protein yield (gm/2.30 m^2)	174 a	175 a	155 b	159 b	145 c	168 a	145 c

\+ Means for one variable followed by the same letters are not significantly different from each other at the 5% level of probability.

supported by McNeal et al., 1972.

It appears that genotypes such as Pitic 62 and 70M110001 could take an important place in Alberta's feed wheat production. A genotype such as 70M110001, because of its relative earliness in maturity, may be suitable for the short growing season in the central and northern part of the province, by giving a good grain yield and a good protein yield per unit area.

Associations between grain yield per plot and other variables

a. Simple correlations

For all genotypes, grain yield per plot appeared to have positive associations with plant stand, days to heading, test weight, and protein yield per plot, as shown by the simple correlation coefficients in Table 43. Plant height too had significant positive associations with grain yield per plot for all genotypes, except for 70M110001. Days to maturity and grain protein had significant negative associations with grain yield per plot for all genotypes.

Associations between grain yield per plot and the remaining variables varied depending on the genotype. For instance Pitic 62, the highest grain yielder showed significant negative correlation between grain yield per plot and days to maturity, while this correlation was non-significant for Park (Table 43).

The three grain yield components, ears per plant, kernels per ear, and 1000 kernel weight, had no significant correlations with grain yield per plot for most genotypes. Also, most genotypes did not show significant associations between grain yield per plot and most of the morphological characters above the flag leaf node (ear length, flag leaf

TABLE 43. SIMPLE CORRELATION COEFFICIENTS BETWEEN GRAIN YIELD PER PLOT AND OTHER PLANT CHARACTERISTICS FOR SEVEN WHEAT GENOTYPES AT EDMONTON (N=72 FOR EACH GENOTYPE (3 SEEDING DATES x 6 SEEDING RATES x 4 REPLICATIONS)).

Plant characteristics (variables)	Genotypes						
	Pitic 62	70M110001	Norquay	Glenlea	70M009002	Neepawa	Park
Plant stand	0.39 **	0.62 **	0.57 **	0.60 **	0.43 **	0.42 **	0.44 **
Test weight	0.71 **	0.41 **	0.60 **	0.61 **	0.48 **	0.51 **	0.35 **
Protein yield per plot	0.95 **	0.94 **	0.95 **	0.96 **	0.95 **	0.95 **	0.98 **
Days to heading	0.34 **	0.30 *	0.43 **	0.51 **	0.27 *	0.34 **	0.38 **
Plant height	0.45 **		0.68 **	0.73 **	0.54 **	0.57 **	0.61 **
Extrusion length			0.48 **	0.24 *	0.40 **	0.26 *	0.39 **
Ears per plant							0.25 *
1000 Kwt	0.32 **	-0.39 **					
Grain protein %	-0.37 **	-0.61 **	-0.68 **	-0.70 **	-0.68 **	-0.65 **	- 0.64 **
Days to maturity	-0.55 **	-0.72 **	-0.64 **	-0.82 **	-0.56 **	-0.61 **	
Grain yield per plant		-0.24 *		-0.28 *			
Grain yield per tiller				-0.41 **			
Flag leaf sheath area			-0.30 **				
Flag leaf lamina area					-0.31 **		
Kernels per ear							
Ear length							

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

sheath area and flag leaf area).

b. Stepwise multiple regressions

For this analysis, only Pitic 62 (the highest grain yielder) and Park (one of the lowest grain yielders) were used to see if they differ in variables that predict their respective grain yields. Regressing grain yield (per plot) of Pitic 62 on all variables, except protein yield, grain yield per plant, and grain yield per tiller, demonstrated that test weight, plant height, and ears per plant were the most important predictors of grain yield per plot for this genotype (Table 44). These three characters accounted for about 61% of the total variance in grain yield per plot of Pitic 62 while the introduction of all the remaining variables into the equation explained only an additional 6%. An estimate of grain yield per plot of Pitic 62 (Y') could be obtained as follows:

$$Y' = -5439.73 + 62.82X_1 + 21.35X_2 - 23.44X_3$$

where X_1, X_2 and X_3 are test weight in kg/hl, plant height in cm, and ears per plant, respectively. This equation suggests that any change in the values of any one of the above independent variables could lead to changes in grain yield per plot. These significant associations of test weight and plant height with grain yield per plot were also indicated by the simple correlation test results in Table 43.

Likewise for Park, grain protein and plant stand appeared to have significant influences on grain yield per plot and accounted for about 46% of the total variability in grain yield per plot (Table 44). Introducing the other variables into the equation explain only an

TABLE 44. PARTIAL REGRESSION COEFFICIENTS OF GRAIN YIELD PER PLOT ON SOME VARIABLES FOR PITIC 62 AND PARK WHEAT GENOTYPES AT EDMONTON (FOR EACH GENOTYPE, N=72; 3 SEEDING DATES x 6 SEEDING RATES x 4 REPLICATIONS).

PITIC 62					PARK				
			Standardized regression coefficients					Standardaized regression coefficients	
Plant characteristics (variables)	Step 3	Step 13	Step 3	Step 13	Plant characteristics (variables)	Step 2	Step 13	Step 2	Step 13
Test weight	62.82 **	57.94 **	0.68	0.63	Grain protein %	-106.44 **	-55.85	-0.55	-0.29
Plant height	21.35 **	14.87 *	0.29	0.21	Plant stand	0.19 *	0.36 **	0.23	0.44
Ears per plant	-23.44 *	-22.62 *	-0.20	-0.19	Plant height		7.42		0.30
Plant stand		0.25		0.16	Ear length		57.24		0.17
Ear length		72.80		0.18	Kernels per ear		3.39		0.10
Extrusion length		24.34		0.18	Extrusion length		9.11		0.13
Days to heading		10.60		0.08	Days to heading		-5.53		-0.10
Flag leaf area		3.69		0.05	Test weight		16.81		0.11
Flag leaf sheath area		-3.63		-0.05	Flag leaf sheath area		4.62		0.06
1000 Kwt		3.27		0.04	1000 Kwt		2.84		0.05
Grain protein %		-8.34		-0.03	Days to maturity		3.87		0.07
Kernels per ear		-0.50		-0.02	Flag leaf area		4.76		0.08
Days to maturity		-1.04		-0.02	Ears per plant		-5.06		-0.05
Intercept	-5439.73	-6201.29			Intercept	2668.39	-1671.22		
R^2	0.61	0.67			R^2	0.46	0.59		

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

additional 13% of the variation in grain yield per plot. Variables which predict grain yield per plot varied among genotypes as shown above and in Table 44.

GENERAL DISCUSSION AND CONCLUSION

Since the bread making quality of hard red spring wheats produced in central and northern Alberta has been found to be inferior, the interest for producing wheats suitable for feed purposes was initiated. The higher grain yield from some introduced and developed new wheat types compared to standard hard spring wheats grown in the province was also among the factors that forced the Canadian Grains Act to include these different wheat types under the new market class "Utility Wheat". In this study, some of the agronomic management requirements for some utility wheats and some hard red spring wheats were investigated at three sites in Alberta. At Edmonton, the 1975 crop season was long (130 frost-free days) and very atypical, compared to the long term average (109). The unusually long crop season has enabled the late maturing genotypes to reach maturity even in the late seedings. This long season was an advantage in that the collection of data in this experiment was complete. However, it may also have been a disadvantage because results from this study cannot be directly used in making recommendations which will be valid for seasons of more normal frost-free duration. At all locations, increases in seeding rate had a general influence of increasing grain yield and decreasing the number of days to maturity for most genotypes. However, the influence of late seeding on grain yield and number of days to maturity varied among genotypes. The effect of high seeding rates for increasing grain yi d was relatively less for the latest maturing genotype, Pitic 62, than for the remaining ones.

Park and 70M110001 showed a more pronounced response of increased grain yield due to increased seeding rates compared to the other genotypes at most locations.

In this study, interaction between treatment combinations and seeding dates were the norm rather than the exception. Therefore, it is advisable that new genotypes be subjected to tests of different agronomic management practices under different environmental conditions so that the optimum manner for farmers to grow the new genotypes can be determined.

Increasing seeding rate also decreased the number of days to maturity for most genotypes. Increasing seeding rate decreased the number of days to maturity more for early maturing genotypes like Park, Neepawa, and 70M110001 than it did for the late maturing genotype, Pitic 62.

At Edmonton, grain yield was higher from early seedings (May 8 and 16) than from date three (May 26) for all genotypes. The number of days to maturity was also smaller from early seedings (May 8 and 16) than from late seeding (date three) (May 26). However, there was a very clear indication that late seeding (May 26) increased the number of days to maturity more for late maturing genotypes like Pitic 62 and Glenlea than it did for early maturing ones like 70M110001, Park and Neepawa. At Ellerslie, however, only Pitic 62, Norquay, Glenlea and 70M009002 had increased grain yield from early seedings (May 8 and 16). For most genotypes, the influence of early seedings on the number of days to maturity was not as marked as it was at Edmonton. At Olds, most genotypes had increased grain yields and a smaller number of days to maturity from date two (May 22) seeding than from date one (May 15).

The results from this study suggest that the effects of increasing seeding rate in increasing grain yield and decreasing the number of days to maturity were more for early maturing wheat genotypes than for late maturing types. The effect of early seedings on grain yield and number of days to maturity varied from one location to another. However, early seeding (May 8 and 16) is a good practice for achieving high grain yield and early maturity for all genotypes at Edmonton and for some at Ellerslie.

Genotypes like 70M110001, which combine earliness with high grain yield per unit area, indicate that the generally accepted genetic association between late maturity and high grain yield can be broken by appropriate breeding and selection.

For most genotypes, increasing seeding rate decreased the values of all the three grain yield components (ears per plant, kernels per ear, and 1000 kernel weight) and thus grain yield per plant. However, most genotypes ended up having high grain yield per unit area through compensation by high plant stand at the relatively higher seeding rates. Early seedings gave higher values for grain yield components than late seedings for those treatment combinations for which grain yield components showed significant responses to variation in seeding date.

Genotype comparison for the grain yield components indicated that genotypes with fewer number of kernels per ear had relatively lower grain yields per unit area. Also, genotypes with relatively higher grain yields per plant were among the higher grain yielders per unit area. It therefore appeared that the number of kernels per ear was possibly the most important of all the grain yield components.

Consequently selection of genotypes based on number of kernels per ear could possibly result in higher grain yield per unit area. However, simple correlation tests indicated that t .e were no significant associations between grain yield per plot and any one of the grain yield components for most genotypes. Individual genotypes were quite distinct from each other in the manner in which their yield was constituted by the various yield components.

The effect of seeding rate and seeding date on the morphological characteristics above the flag leaf node varied in a very irregular fashion. Ear length and flag leaf area decreased with increasing seeding rate while extrusion length showed an increase. Flag leaf sheath area did not show a specific trend of increase or decrease with increasing seeding rate for most genotypes. Early seeding increased ear length, extrusion length, and flag leaf sheath area and decreased flag leaf area for most genotypes. For most genotypes, ear length, flag leaf sheath area, and flag leaf area did not have significant associations with grain yield per plot. However, genotypes like Park and Neepawa with larger extrusion length were also among the lowest grain yielders either on a per tiller or on a per plot basis. Genotypes with longer extrusion may lodge due to high velocity wind or due to some other causes and then lower grain yield per plot could result. Results of stepwise multiple regression analysis for Park and Pitic 62 using grain yield per plot as a dependent variable did not include any of the morphological characteristics above the flag leaf node as significantly important predictors. From this present study, it was found difficult to clearly define any relationships between morphological characteristics above the flag leaf node and grain yield per plot or grain yield per tiller.

Both increasing seeding rate and early seeding appeared to have the influence of decreasing grain protein percentages. Protein yield per unit area, however, increased both with increasing seeding rate and early seeding for most genotypes. Simple correlation tests indicated that for most genotypes, grain protein percentages had significant negative association with grain yield per plot. However, protein yield per plot and grain yield per plot were significantly and positively correlated for most genotypes. Significant genotype differences in grain protein percentages appeared to disappear for protein yield per unit area. A significant compensatory effect from grain yield per plot could possibly have been the factor which enabled genotypes with lower grain protein to even out in protein yield with genotypes having high grain protein percentages.

From the result in this study, it appears that early seeding in spring gave relatively higher grain yield per unit area for most genotypes at most seeding rates. For some genotypes, early seeding also brought significant reduction in the number of days to maturity. Higher seeding rates, especially if seeding has to be done late in spring, seemed to give higher grain yield and to bring early maturity than did lower seeding rates for most genotypes. The existence of genotypes which combine early maturity and high grain yield per plot also gives an indication to plant breeders that there is an opportunity to work in this direction.

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APPENDIX 1. METEOROLOGICAL RECORDS FOR THE 1975 SPRING CROP SEASON FOR THE STUDY SITES, EDMONTON[1], ELLERSLIE[2], AND OLDS[3].

Month	Location	Temperature (°C) Maximum	Minimum	Mean Maximum	Mean Minimum	Precipitation (mm)	Frost date**	Frost-free days *
MAY	Edmonton	24	-1	17.4	3.4	35	May 2	
	Ellerslie	21	-5	15.4	1.6	42	May 31	
	Olds	21	-5	13.4	1.8	61	May 20	
JUNE	Edmonton	28	1	20.6	6.3	108		
	Ellerslie	27	-1	19.2	4.5	89		EDMONTON
	Olds	24	3	18.5	6.5	54	June 7 & 8	
JULY	Edmonton	34	4	25.7	12.0	32		130, 1975 Season
	Ellerslie	31	3	24.4	9.9	44		109, long term[a]
	Olds	34	7	24.4	10.9	24		ELLERSLIE
AUGUST	Edmonton	27	0	20.4	6.7	87		
	Ellerslie	26	-1	18.7	5.2	73		100, 1975 Season
	Olds	29	2	18.7	6.5	38	August 16	109, long term[b]
SEPTEMBER	Edmonton	27	-3	19.2	3.1	3	September 9	OLDS
	Ellerslie	26	-6	18.1	2.2	3	September 9	
	Olds	28	-1	19.4	3.7	26	September 11	113, 1975 Season
								110, long term[c]

1 and 2 From The University of Alberta. 1975. Meteorological records. Plant Sci. Dept. (Field lab), Edmonton, Alberta, Canada.

3 From Olds College. 1975. 1975 Climatological station report. Olds, Alberta, Canada.

** Temperature of -1°C or less.

* Temperature greater or equal to 0°C.

a Averaged over 3 years (1973-1975).
b Averaged over 5 years (1971-1975)
c Averaged over at least 9 years (1951-1964), Longley, 1967.

APPENDIX 2. BIMONTHLY TEMPERATURE (^{o}C) RECORDS FOR THE 1975 SPRING CROP SEASON FOR THE STUDY SITES, EDMONTON[1], ELLERSLIE[2], AND OLDS[3].

	Period in crop season									
	MAY		JUNE		JULY		AUGUST		SEPTEMBER	
	1 — 15	16 — 31	1 — 15	16 — 30	1 — 15	16 — 31	1 — 15	16 — 31	1 — 15	16 — 30
EDMONTON										
Mean Maximum	17.1	17.8	21.2	20.0	28.6	22.8	22.0	18.9	19.7	18.6
Mean Minimum	3.2	3.6	5.8	6.8	13.1	11.0	6.8	6.5	3.1	3.1
ELLERSLIE										
Mean Maximum	14.8	15.9	19.5	18.9	27.0	21.8	20.7	16.7	18.1	18.1
Mean Minimum	1.8	1.3	4.0	5.0	12.0	7.9	4.9	5.5	2.3	2.1
OLDS										
Mean Maximum	12.2	14.6	19.1	17.6	26.0	22.8	21.2	16.1	20.4	18.3
Mean Minimum	1.3	2.3	6.0	7.0	12.1	9.8	6.5	6.4	3.5	3.9

1 and 2 From The University of Alberta. 1975. 1975 meteorological recods. Plant Sci. Dept. (Field lab), Edmonton, Alberta, Canada.

3 From Olds College. 1975. 1975 climatological station report. Olds, Alberta, Canada.

APPENDIX. 3. SOIL TYPES OF THE STUDY SITES, EDMONTON[1], ELLERSLIE[2], AND OLDS[3].

Location	Soil		
	Order	Great Group	Series and texture
Edmonton	Chernozemic	Black	Silty clay loam (predominantly)
Ellerslie	Chernozemic	Black	Malmo Silty clay loam (predominantly)
Olds	Chernozemic	Black	1. Antler loam 2. Didsbury loam (predominantly)

1 From Alberta Agriculture, Soil Survey Division (personal communication).

2 From Soil Survey of the Edmonton Sheet, Province of Alberta. Soil Research Institute, Research Branch, Canada Department of Agriculture, Ottawa, Canada. 1962.

3 From Soil Survey of Rocky Mountain House Sheet, Province of Alberta. Experimental Farm Services, Canada Department of Agriculture, Ottawa, Canada. 1957.