The effect of oat (*Avena sativa* L.) genotype and plant population on wild oat (*Avena fatua* L.) competition

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Abstract

The inability to control wild oat (*Avena fatua* L.) in oat (*Avena sativa* L.) crops by chemical means limits growers to the use of cultural control methods. Delayed seeding is the most commonly used measure; however, both crop yield and quality may suffer as a result. The objectives of this research were to i) determine if western Canadian oat genotypes differ in competitive ability, ii) determine the effect of increased plant populations on oat – wild oat competition, iii) determine the effect of wild oat competition on oat quality, and iv) establish whether or not oat genotype and seed size affect germination characteristics under low temperature and moisture stress. These objectives were tested using field and laboratory experiments. Morphologically diverse oat genotypes differed in their ability to both tolerate wild oat competition and interfere with wild oat growth. Although low yielding under weed-free conditions, when subject to wild oat competition CDC Bell was able to maintain yield, reduce wild oat seed production and was the most competitive of the genotypes examined. Increased plant populations achieved through higher seeding rates provide an effective means by which to enhance the competitive ability of oat genotypes resulting in reduced yield loss and wild oat seed production. With the exception of the percentage of wild oat seed in harvested oat samples, wild oat competition had minimal effect on oat quality. Differences in germination characteristics were observed among the genotypes examined. Conclusions that emerge from this research are that i) oat genotypes differ in their ability to tolerate and interfere with wild oat competition, ii) increased plant populations may provide a long-term control measure that may reduce weed seed contribution to the soil seedbank as well as enhance the competitive ability of oat, iii) wild oat competition has minimal effect on milling oat quality with the exception of percentage of wild oat seed in harvested samples and iv) that median germination time varies among oat genotypes.

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List of Abbreviations

CA – Competitive ability

CPS – Canadian prairie spring

G – Genotype

HRS – Hard red spring

HRWW – Hard red winter wheat

KWT – 1000-kernel weight

LAI – Leaf area index

MGT – Median germination time

OMS – Osmotic stress

PAR – Photosynthetically active radiation

PWO – Percentage wild oat (in harvested oat samples)

S – Seed size

SR – Seeding rate

TPP – Target plant population

TWO – Target wild oat density

1.0 Introduction

Oat (*Avena sativa* L.) is grown in western Canada for both feed and milling purposes. As milling oat commands a premium over feed oat, growers focus their efforts on the production of oats suitable for the milling market. Strict quality measures must be met for oat to be sold into the milling market. Among these is a 1% limit on wild oat (*Avena fatua* L.) seed in milling oat samples. As chemical control of wild oat in tame oat is not possible, cultural control measures are the primary means by which growers can reduce the impact of wild oat on tame oat product.

Prior to the development of herbicides, weed control was highly dependent on crop competition. Along with cultural control measures, crop competition was used as a means of reducing yield and quality losses due to weeds (Reigner and Janke, 1990). Measures commonly used by oat growers in controlling wild oat include delayed seeding and tillage. By delaying seeding, growers are able to control early emerging weeds via mechanical or chemical control measures. Unfortunately, under weed-free conditions, this practice may result in reduced yields and test weight (Frey, 1959; Humphreys *et al*., 1994).

Differences in competitive ability have been observed among both crop species (Pavlychenko and Harrington, 1934) and genotypes (Appleby *et al*., 1976; Lemerle *et al*., 1996). Highly competitive genotypes often exhibit early vigorous growth, high

tillering capacity, increased height and the ability to intercept a large portion of available light (Froud-Williams, 1997). Furthermore, the competitive ability of a crop can be enhanced through agronomic practices such as increased seeding rates (Evans *et al*., 1991; Champion *et al*., 1998). The use of highly competitive oat genotypes or agronomic practices that enhance the competitive ability of the crop may be means by which the effect of wild oat on oat yield and quality can be reduced.

The focus of this research was the study of oat – wild oat competition and its effect on oat yield and quality. The primary hypothesis of this research was that oat genotypes possessing diverse morphological characteristics would differ in competitive ability versus wild oat and that increased seeding rates could be used to enhance crop competitive ability. The following key questions were addressed:

(1) Do western Canadian oat genotypes differ in their ability to tolerate and interfere with wild oat growth?

(2) Can increased seeding rates be used to enhance the competitive ability of oat genotypes?

(3) Does wild oat competition affect oat quality?

(4) How do increased oat seeding rates affect oat quality?

(5) Are differences in competitive ability in oat related to differences in their ability to germinate under low temperature and moisture stress?

Answers to these questions will provide information to growers as well as oat breeders that may assist in the development and use of competitive control measures in oat production.

2.0 Literature Review

2.1 The Role of Competition in Agroecosystems

Chemical control of wild oat (*Avena fatua* L.) in tame oat (*Avena sativa* L.) is not possible. Cultural control measures are therefore the primary means by which growers can reduce the impact of wild oat on oat production. Prior to the development of herbicides, weed control was highly dependent on crop competition. Along with other cultural control measures, crop competition was used as a means of reducing yield and quality losses due to weeds (Reigner and Janke, 1990). Measures commonly used by oat growers in controlling wild oat include delayed seeding and tillage. By delaying seeding, growers are able to control early emerging weeds using mechanical or chemical control measures. Unfortunately, under lower weed densities, this may result in reduced yields and test weight (Frey, 1959; Humphreys *et al.*, 1994). The concept of utilizing highly competitive genotypes as part of a weed management system has long been recognized (Pavlychenko and Harrington, 1934; Mann and Barnes, 1947). The identification and development of competitive genotypes may allow greater utilization of such genotypes.

Competition can be defined as the removal of resources by one plant that affects the growth of another (Loomis and Connor, 1996). Plants are able to usurp resources such as light, water and nutrients from their neighbors, thereby reducing their growth.

Successful competitors are able to appropriate resources from their neighbors, or make the most efficient use of them under low concentrations (Donald, 1963; Radosovich *et al*., 1997). The outcome of competitive interactions between two plants will be determined by the ability of a particular species or genotype to exploit resources to the greatest extent (Pavlychenko and Harrington, 1934). Crop and weed species are both classified as competitive ruderals, thus, they occupy similar ecological niches (Harper, 1977). As the extent of niche overlap increases, competition intensifies.

Crop competitive ability (CA) can be assessed in terms of the ability to interfere with, or tolerate weed growth (Jordan, 1993). Crop interference can be defined as the ability of the crop to suppress weed growth. Interference accounts for the ability of an individual plant to affect its neighbor through modifications to the immediate environment. These modifications may include the appropriation of resources or the release of allelochemicals (Harper, 1977). Crop tolerance to weeds is exhibited through the ability of the crop to maintain yield under competition while not affecting the competing species fecundity (Jordan, 1993). Lemerle *et al*. (1995; 2001a) suggest that both are valid measures of competitive ability. Jordan (1993) contends that tolerance and interference should be discerned from one another because they are driven by different mechanisms. Furthermore, interference is argued to be the more important of the two processes as it has further reaching implications such as reducing weed seed production. Positive correlations have been found to exist between the ability of crop genotypes to interfere with weed growth as well as tolerate it (Challaiah *et al*., 1986), indicating that there is the potential to develop genotypes that can suppress weed growth, yet produce satisfactory yields.

2.2 Species Differences in Competitive Ability

Large differences exist in the CA of field crops. Pavlychenko and Harrington (1934) were among the first to examine the competitive interactions between weeds and crops grown in western Canada. In examining the CA of crops with a broad range of weed species, barley (*Hordeum vulgare* L.) and rye (*Secale cereale* L.) were identified as being better competitors than wheat (*Triticum aestivum* L.) or oat. Of the crops examined, flax (*Linum usitatissimum* L.) was the least competitive. Differences in the competitive ability of weed species were also identified. Wild mustard (*Brassica kaber* (DC.) L.C. Wheeler) and wild oat were the most competitive weed species studied. Differences in CA among plant species can be accounted for by differences in life cycle, morphology and canopy development (Pavlychenko and Harrington, 1934; Van Hemmst, 1985).

Environmental conditions can affect the ranking of competing species. Work conducted by Seavers and Wright (1999) differs from the findings of others (Pavlychenko and Harrington, 1934; Bell and Nalewaja, 1968a; Lanning et al., 1997). Whereas barley was identified as being the most competitive crop species with numerous weeds under the semi-arid conditions of the western plains, Seavers and Wright (1999) identified oat as being more competitive than barley with cleavers (*Galium aparine* L.) under European climatic conditions. In addition, Lemerle *et al*. (1995) found wheat to be more competitive with annual ryegrass (*Lolium rigidum* Gaudin.) than barley under arid conditions in Australia. This result may be due to the ability of wheat to tolerate low moisture conditions better than barley (Loomis and

Connor, 1996). These findings indicate that environment can strongly influence the CA of species.

2.3 Genotypic Differences in Competitive Ability

Both broadleaf (Staniforth, 1962; Callaway, 1992) and cereal crop genotypes (Jensen and Federer, 1964; Appleby *et* al., 1976; Moss, 1985; Wicks *et al*., 1986; Kirkland and Hunter, 1991; Garrity *et al*., 1992; Grundy *et al*., 1993; Huel and Hucl, 1996; Lemerle *et al.*1996; Lemerle *et al.*, 2001b) differ in CA. Highly competitive genotypes are likely to possess the following characteristics: large seed size, early vigorous growth, tillering capacity, greater height, lax leaf canopy architecture and the ability to intercept a large portion of available light (Froud-Williams, 1997). Nevertheless, specific crop traits assumed to be linked to CA may vary in their effect on competition among crop species (Callaway and Forcella, 1992)

Associating specific traits with CA has been difficult as numerous traits are linked to CA; however, strong relationships between plant traits and CA have been identified (Gaudet and Keddy, 1988). Plant biomass is associated with upwards of 60% of the variation in CA. The remaining variation in CA is correlated with plant height, canopy diameter, canopy area and leaf shape.

Donald and Hamblin (1976) hypothesized that competitive ideotypes would be taller than their neighbors, have more tillers as well as an extensive leaf display. These ideotypes would be low yielding in monoculture, but successful in mixtures. The non-competitive ideotype would yield well under monoculture, be of shorter stature and have a low degree of tillering and erect leaves with a high harvest index. Based on these hypothetical ideotypes it is evident that current plant breeding has taken us

towards the non-competitive ideotype while traditional genotypes may possess many of the traits characteristic of the competitive ideotype.

Lemerle *et al*. (1996) examined the competitive ability of 250 wheat genotypes, 135 of which were of Australian origin. The genotypes ranged from traditional, standard-height lines to hybrids. The remaining genotypes were selected from areas where herbicide use is minimal as it was postulated that these genotypes would possess morphological characteristics that enhance CA. Furthermore, the genotypes tested encompassed a broad range of morphological diversity. Modern genotypes were much less competitive than traditional genotypes. Traditional genotypes were able to suppress annual ryegrass growth to a much greater extent, with the exception of eight hybrids. Moreover, durum wheat (*Triticum durum* L.) was much less competitive than spring wheat. Of particular interest is that genotypes derived in particular geographies remained grouped together with regards to their ability to suppress annual ryegrass growth. Genotypes from South America and Eastern Europe were found to be more competitive than those from India, the Middle East and the Mediterranean; however, this may be a result of South American and Eastern European genotypes being better adapted to Australian agronomic practices and environmental conditions.

Research conducted by Cosser *et al*. (1997) in the UK demonstrated similar results. Maris Widgeon, a traditional wheat genotype, was in most cases more competitive than the others in an organic production system. This genotype was the tallest of the three examined, intercepted the most photosynthetically active radiation (PAR) and accumulated the most nitrogen and dry matter when seeded early. Grain

yields of the modern genotypes were higher than those of Maris Widgeon under low weed pressure, indicative of the greater yield potential of modern genotypes.

Differences in CA of Canadian prairie spring wheat (CPS) (Kirkland and Hunter, 1991), hard red spring wheat (HRS) (Huel and Hucl, 1996) and hard red winter wheat (HRWW) (Blackshaw, 1994) have been identified. Kirkland and Hunter (1996) examined the CA of two Canadian wheat classes with wild oat. Differences in CA were found to exist within as well as between classes. The HRS genotype examined was more competitive than the CPS genotypes. Although higher yielding under wild oat free conditions, the CPS genotypes HY320 and HY355 suffered greater yield lossthan the HRS genotype Neepawa. Within the CPS class, the genotype HY355 was more competitive than HY320. Furthermore, wild oat biomass and seed production were significantly higher in the CPS genotypes. These findings indicate that CPS genotypes were not able to interfere with or tolerate wild oat competition to the same extent as the HRS genotype. Under weedy conditions there is an increased demand on available moisture. HRS genotypes may be better suited to moisture limiting conditions then CPS genotypes and as a result are more competitive, even though they are lower yielding under weed-free conditions

There may be a negative correlation between CA and weed-free yield (Donald and Hamblin, 1976; Siddique *et al*. 1989; Baylan *et al*., 1991; De Lucas and Froud-Williams, 1994). This is because competitive genotypes often possess morphological characteristics such as greater height and broad, large leaves. These traits are often associated with low yield. If a strong negative correlation does exist between CA and weed-free yield it may be difficult to develop highly competitive genotypes that have

acceptable weed-free yield potential. Nevertheless, other researchers contend that it is possible to select and develop genotypes that are both highly competitive and high yielding (Christensen, 1995; Lemerle *et al*. 1996; Cousens and Mokhtari, 1998). Work from Australia in particular has shown a strong positive correlation to exist between weed-free grain yield and weedy yield (Cousens and Mokhtari, 1998; Lemerle *et al*., 2001a). It appears that genetic variability is sufficient to identify and develop genotypes that are both highly competitive and high yielding under weed-free conditions.

2.4 Basis of Differential Competitive Ability

2.4.1 Germination and Emergence

Early emerging plants are likely to be more competitive than later emerging cohorts due to the development of a size bias and resulting asymmetric competition (O'Donovan *et al*., 1985; Gonzalez-Ponce, 1987; Connolly and Wayne, 1996). The effect of wild oat on wheat and barley yields is greater when wild oat emerges prior to the crop. The greater the disparity in emergence time between wild oat and the crop, the greater the associated yield reduction (O'Donovan *et al*., 1985). Several other studies have shown that the ability of weeds to compete depends to a great degree on their time of emergence relative to the crop (Williams, 1964; Ross and Harper, 1972; Christensen, 1995). The pre-emption of resources by plants at the seedling stage is essential in developing a competitive advantage, resulting in increased fitness.

Several factors can affect the rate of germination and emergence. These include seed size (Burleigh *et al*., 1956; Kaufmann and Guitard, 1967; Boyd *et al*., 1971; Ries

and Everson, 1973) and genotype (Allan *et al*., 1962; Lafond and Baker, 1986a,b). Differences in growth characteristics between weed and crop species may, to some extent, be attributed to differences in seed size (Seibert and Pearce, 1993; Mohler, 1996). The CA of weeds may result from their high relative early season growth rate. Rapid, early crop growth is therefore essential in order to prevent the development of a size bias favoring weed species.

Variation in the rate of germination and emergence among genotypes and between seed sizes may be one manner by which the competitive ability of field crops can be enhanced. Large seeded crops in particular may have an initial competitive advantage over annual weeds, based solely on seed size. For example, corn (*Zea mays* L.) and soybean (*Glycine max* Merr.) produce their first 2.8 g of leaf matter by mobilizing seed reserves (Mohler, 1996). Lambsquarters (*Chenopodium album* L.*)* and redroot pigweed (*Amaranthus retroflexus* L.) however, rely on photosynthetic fixation of carbon to produce the same mass leaf material. As a result, larger seeded crop plants have an initial higher absolute growth rate than smaller seeded annual weeds. This initial size advantage can give the crop a potential competitive advantage that may be exploited.

Seed size affects percent germination (Mathur *et al*., 1982; Guberac *et al*., 1998), rate of germination (Lafond and Baker, 1986b), speed of emergence (Lafond and Baker, 1986a), seedling vigor (Kaufmann and Guitard, 1967; Ries and Everson, 1973), yield and competitive ability (Kaufmann and McFadden, 1960). Seed size in oat has been positively correlated with final percent germination, with larger seeds having higher percentage germination (Mathur *et al*., 1982; Guberac *et al*., 1998). Lafond and

Baker (1986b) however found that small wheat seeds had a higher rate of germination than larger seeds. Their study examined the germination characteristics of nine spring wheat genotypes under laboratory conditions. Seedlots were sized into three classes and germinated at temperatures of 5, 8, 12, 20 and 30°C. With the exclusion of the 5°C temperature regime, smaller seeds had a significantly shorter germination period. Under field conditions smaller seeds were also faster to emerge (Lafond and Baker, 1986a). These seedlings however accumulated less shoot biomass than plants grown from larger seeds. As the smaller seeds had a significantly shorter emergence time, it would have been expected that their development would be accelerated as compared to the large seeded cohorts; however, seedlings arising from large seeds developed at a faster rate than plants arising from small seeds. Genotype also influenced the rate of emergence as a 30 h difference was observed between genotypes Columbus and Potam.

Middle-eastern wheat genotypes have exhibited differential rates of germination under low temperatures and moisture stress (Ashraf and Abu-Shakra, 1978) indicating the potential to select for genotypes that can become established under sub-optimum conditions. Semi-dwarf wheat genotypes have been identified as having slower rates of seedling emergence (Allan et al., 1962). These reduced rates of seedling emergence in semi-dwarfs can be accounted for by slower coleoptile growth. Genotypic differences in rate of emergence have also been identified in western Canadian barley genotypes (Briggs and Dunn, 2000).

2.4.2 Light Interception and Traits Associated with Above Ground Competitive Ability

Leaf morphology, angle and vertical distribution and tillering capacity all contribute to plant architecture. Plant architecture affects how plants capture light (Warren Wilson, 1967) and therefore their ability to utilize resources prior to their neighbors. Consequently, vegetative growth habit has a strong influence on the degree of competition between plant species (Thomas and Weiner, 1989; Caldwell, 1997) particularly for unidirectional resources such as light. The quantity and quality of light intercepted by plants and penetrating the canopy is affected by growth habit. Genotypes differ in growth habit, and morphological characteristics unique to certain genotypes have been associated with competitive ability. Genotypes possessing morphological attributes such as long, lax leaves for example, tend to be more competitive than those with short erect leaves (Jennings and Aquino, 1968).

The ability of a crop to rapidly produce a full canopy is also associated with competitive ability (Froud-Williams, 1997). The extent of canopy coverage is a function of growth habit. Leaf size, length and angle all contribute to the degree of ground cover or canopy coverage that a genotype is able to achieve. Genes associated with dwarfing characteristics in barley manifest themselves through variations in juvenile growth habit. The presence of the erectoides (erect juvenile growth) or denso (semi-prostrate juvenille growth) dwarfing genes confer variations in juvenile growth habit. (Richards and Davies, 1991). Consequently, genotypes with the denso dwarfing gene are able to rapidly develop a canopy and attain early ground cover and as a result the effects of weed interference are reduced (Richards and Whytock, 1993). Similarly, research conducted by Dhaliwal and Froud-Williams (1993) indicated that genotypes

with the denso dwarfing gene were more competitive than others due to their juvenile vegetative growth habit. Conversely, juvenile growth habit was unrelated to the competitive ability of semi-dwarf wheat with wild oat (Koscelny *et al*., 1990).

Genotypic differences in light interception and leaf area index (LAI) have been identified in winter wheat (Blackshaw, 1994), spring wheat (Lemerle *et al*., 1996; Cosser *et al*., 1997; Lanning *et al*., 1997), barley (Lanning *et al*., 1997) and corn (Lindquist *et al*., 1998). Wheat yield loss and annual ryegrass dry matter production are negatively correlated with the ability to intercept PAR (Lemerle *et al*., 1996). Similarly, reductions in wild oat seed production and LAI were greater for the wheat genotype PBW343 as compared to HD2329. PBW343 possessed a larger LAI and intercepted a larger portion of PAR than HD2339 (Sodhi and Dhaliwal, 1998). A high degree of light interception (low amount of light penetrating the canopy) is positively correlated with plant height in wheat and barley as taller genotypes intercept a larger portion of the PAR (Lanning *et al*., 1997). Furthermore, the ability of wheat and barley genotypes to suppress wild oat growth was greater in genotypes with high light interception. Yield was not correlated with light interception. Nevertheless, Christensen (1995) suggested that varietal competitiveness in barley did not appear to be related to light interception.

Differences in biomass accumulation between wild oat and wheat are associated to a greater extent with morphological characteristics rather than photosynthetic characteristics (Beyschlag *et al*., 1990). Barnes *et al*. (1990) examined the role of canopy structure in light competition between wild oat and wheat grown in both monoculture and mixture. Measurements of LAI were taken in both mixtures and monocultures of wheat and wild oat. Early season measurements of LAI in

monoculture did not differ between wheat and wild oat. Nevertheless, as the season progressed, wild oat developed a greater LAI. In mixture, wheat constituted a larger portion of the LAI early in the season, but as time progressed wild oat LAI surpassed that of wheat. The proportion of LAI in the upper half of the canopy also changed through the growing season. Early in the season 59% of the total leaf area in the upper half of the mixed culture constituted wheat. As time progressed the proportion of wheat leaf area in the upper portion of the canopy declined to 43% (Barnes *et al*., 1990). Differences were also observed in leaf inclination. Mean leaf blade inclination ranged from 40 to 80° for both species and leaves also tended to be more horizontal at greater depths in the canopy. Wild oat leaves in the uppermost canopy levels possessed a more horizontal leaf inclination than wheat (Barnes *et al*., 1990). It would be expected that this horizontal orientation would allow for the interception of a greater portion of PAR, therefore conferring a competitive advantage on wild oat.

Total leaf area is not the sole factor behind light competition. Rather, those genotypes with their leaf area positioned in the canopy profile so as to prevent light from reaching their competitors tend to be most competitive (Donald, 1963). The capacity for a genotype or species to position its leaf area above its competitors, even though its total leaf area may be less, can provide a competitive advantage. In corn, vertical leaf distribution is highly correlated with yield and the ability to suppress velvetleaf (*Abutilon theophrasti* Medik.) growth (Lindquist *et al*., 1998). Under conditions where light is the primary limiting resource, light interception by wild oat significantly reduced semi-dwarf wheat yields. Although wild oat had a significantly lower leaf area than wheat at tillering and a nearly identical leaf area at anthesis it was

able to reduce the yield of wheat by positioning a greater proportion of its canopy above 60 cm (Cudney *et al*., 1991). LAI therefore may not provide a good measure of CA; rather, the position of leaf area in the canopy may provide a better measure.

Modeling canopy photosynthesis and the use of sensitivity analysis indicated that characteristics that promote competitive ability in mixed culture can reduce productivity in monoculture (Barnes *et al*., 1990). Increasing LAI or the reducing horizontal inclination of the foliage in upper canopy levels is beneficial for species competing in a mixture. In monoculture however, increased leaf inclination in wild oat appears to correlate with increased productivity. Results for wheat indicate that either an increase or decrease in leaf inclination resulted in less canopy productivity. These findings suggest that leaf inclination in wheat may already be optimized for maximum productivity in monoculture (Barnes *et al*., 1990).

Maintaining late season light interception appears to have the potential to increase yields as well as competitive ability. Light interception in winter wheat during the post-anthesis period is crucial in reducing the growth of weeds germinating during late May to mid June (Wicks *et al*., 1986). Prolonged maintenance of green leaf area has also been associated with increased wheat yields (Khalifa, 1973) and reduced yield loss in rice (*Oryza sativa* L.) due to the presence of barnyard grass (*Echinochloa crusgalli* (L.) Beauv.) (Smith Jr., 1974). Nevertheless, cases where early maturing genotypes are more competitive have been identified in wheat (Gonzalez Ponce, 1988) and corn (Staniforth, 1961)

It has been suggested that high tillering capacity and subsequent increases in light interception can reduce the effects of weeds on crop yield (Sim, 1993; Blackshaw,

1994; Lemerle *et al*., 1996; Froud-Williams, 1997; Sodhi and Dhaliwal, 1998). High tillering spring wheat lines have produced yields 9% greater than low tillering lines (Hucl and Baker, 1991). Furthermore, the capacity to produce a large number of tillers does allow for compensation in sparse plant stands, resulting in reduced weed growth (Wicks *et al*., 1986). Nevertheless, height and leaf area index have been strongly correlated with suppressing weed growth in rice, whereas tillering capacity has not (Garrity *et al*., 1992). Similarily, tillering capacity has been shown to be a poor predictor of CA in wheat (Wicks *et al*., 1986; Baylan *et* al., 1991; Champion *et al*., 1998) and barley (Moss, 1985).

2.4.3 Root Competition

Root competition has been studied less than shoot competition due to the difficult nature of study. In studying the root development of several western Canadian crop and weed species, Pavlychenko and Harrington (1934) suggested competition below ground for water and nutrients begins when the root systems of neighboring plants begin to occupy the same space. Hence, root competition may occur prior to shoot competition. Under severe moisture limitation competition for water may actually occur before the root systems of plants begin to occupy the same space. A germinating seed may make use of available moisture in its immediate rhizosphere, preventing neighboring seeds from germinating.

Root competition may be more important than shoot competition (Aspinall, 1960; Idris and Milthorpe, 1966; Barret and Campbell, 1973). In examining the competitive nature of root systems Pavlychenko (1937) found wild oat to be a poor

early competitor due to its small number of seminal roots. At later stages wild oat was a much stronger competitor than wheat due to its greater root area. Differences in rate of root growth, which affects competitive ability, have been identified among wheat genotypes (Hurd, 1968). Although differences exist in rooting characteristics among genotypes, the difficulty in assessing them makes it an impractical method of identifying competitive genotypes.

2.5 Weed Competition and Crop Quality

Both biochemical and physical quality attributes of grain crops may be affected by weed competition (Manthey *et al*., 1996; Ellis *et al*., 1998). Grain quality can be downgraded due to excessive amounts of extraneous material, often composed largely of weed seed. Protein content appears to be the characteristic most often affected by weed interference (Friesen *et al*., 1960). The presence of wild mustard is negatively correlated with protein content in wheat (Burrows and Olson, 1955). Furthermore, the removal of weeds from wheat, barley and oat resulted in significant increases in the protein content (Freisen *et al*., 1960).

The presence of weeds often results in large yield reductions; nevertheless, crop quality is not always affected (Bell and Nalewaja, 1968b; Alessi and Power, 1970; Torner *et al*., 1991). Manthey *et al*. (1996) examined the effect of season-long kochia (*Kochia scoparia* L. Schrad.) interference on oat quality over 5 years. Physical quality attributes including test weight, kernel weight and groat percentage were unaffected. Biochemical attributes including ash, starch and ß-glucan percentage in oat groats were also unaffected; however, in one year protein content was reduced while lipid

concentration increased. It is evident that the effect of weed interference on crop quality is inconsistent and that certain characteristics appear to be affected more than others. Reduction in protein content appears to be the trait most often affected by weed interference. This may be a result of increased demands on the soil nitrogen pool by competing species.

2.6 Effect of Plant Population on Crop-Weed Interactions

Reductions in grain yield resulting from the presence of weeds can be diminished by increased plant populations (Carlson and Hill, 1985; Martin *et al*., 1987; Torner *et al*., 1991; Sodhi and Dhaliwal, 1998;). Carlson and Hill (1985) examined the effect of wild oat and wheat density on wheat yield. Yield reductions resulting from wild oat competition were much greater at lower seeding rates. Wheat sown to achieve a plant density of 100 plants m^{-2} suffered a yield reduction of 20% from an infestation of 5.5 wild oat plants m^{-2}; however, with a wheat density of 700 plants m^{-2}, 38 wild oat plants m^{-2} would have to be present in order to cause similar yield loss. A proportionate relationship existed between wheat densities and yield loss caused by wild oat. If wheat densities were doubled, the wild oat population would also need to double to cause similar yield reductions.

Weed biomass (Pfeiffer and Holmes, 1961; Kolbe, 1980; Champion *et al*., 1998) and seed production (Koscelny *et al*., 1990; Evans *et al*., 1991) are reduced by increased crop seeding rates. By doubling standard seeding rates of 10 wheat genotypes, *L. rigidum* biomass was reduced on average by 25% (Lemerle *et al*., 1996). Reduced weed seed production may also play an important role in long-term weed management

strategies. By increasing the seeding rate of spring wheat from 67 to 134 kg ha^{-1} volunteer rye seed production was reduced by 21 and 25% in two experiments (Roberts *et al*., 2001).

Variations in environmental conditions from year to year, as well as variations in site characteristics affect the competitive ability of individual genotypes (Lemerle *et al*, 1995; Cousens and Mokhtari, 1998). Agronomic practices such as increased seeding rates may be useful ways to enhance or stabilize the competitive ability of genotypes under wide ranging conditions. Furthermore, the effect of increased seeding rates on competitive ability may be more apparent in less competitive species (Mohler, 1996). Ranking of CA of genotypes is unaffected by increased seeding rate (Lemerle *et al*., 1996). This indicates the potential to utilize increased plant populations as a means of increasing the CA of all genotypes.

3.0 Effect of oat (*Avena sativa* L.) genotype and plant population on oat – wild oat competition

3.1 Introduction

2.4 million hectares of oats were planted in Canada in 2002 (Statistics Canada, 2002). Production is primarily located in the eastern prairies, encompassing eastern Saskatchewan and Manitoba. Most oat are grown with the intention of being sold at a premium, into the milling market. The milling market tolerates 1% wild oat seed in oat samples (Canadian Grain Commission, 2002). The presence of wild oat is however widespread with 67% of Saskatchewan cropland and 47% of oat fields infested with wild oat (Thomas *et al*., 1996); however, these values may not adequately indicate the number of oat fields infested with wild oat due to the difficulties encountered in discerning oat from wild oat. Growers may therefore not be able to plant oat for milling purposes due to the pervasive nature of wild oat.

As chemical control of wild oat in oat is not possible, cultural control measures are the primary means by which growers can reduce the economic damage caused by wild oat. Cultural control measures include delayed seeding, in which wild oat seeds are allowed to germinate and are subsequently controlled by tillage or the use of a non-selective herbicide prior to oat seeding. Delayed seeding may however result in reduced grain yield and test weight (Frey, 1959; Schmidt, 1960). Besides reducing quality, wild oat can reduce oat yield. Yield loss associated with the presence of wild oat can be extensive, ranging from 4 to 75% in wheat, barley and flax

(Sexsmith and Russell, 1963; Bowden and Friesen, 1967; Bell and Nalewaja, 1968a; Bell and Nalewaja, 1986b; Morshita and Thill, 1988). The use of highly competitive cultivars and increased seeding rates may reduce the impact of wild oat on oat quality and yield.

CA can be considered in terms of the ability of the crop to interfere with, and tolerate weed growth (Jordan, 1993). Crop interference is the ability of an individual plant to affect its neighbor through modifications of the immediate environment, thereby reducing weed growth. Crop tolerance differs from interference and implies that yield loss due to the presence of weeds will be minimal. Crop interference with weed growth may be more important than crop tolerance as interference may reduce weed seed return whereas tolerance has little effect on weed seed production (Jordan, 1993). Through interference or tolerance, crop competition can play an integral part in reducing weed growth and associated yield loss.

Differences in competitive ability with wild oat have been identified among crop species. Barley and rye are considerably more competitive with wild oat than wheat or flax under western Canadian conditions (Pavlychenko and Harrington, 1934; O'Donovan *et al*., 1985). Further research has identified differences in competitive ability among western Canadian wheat classes (Kirkland and Hunter, 1991). Hard red spring wheat genotypes suffer less yield loss due to the presence of wild oat than Canadian Prairie Spring wheat genotypes (Kirkland and Hunter, 1991). Although CA is most often examined with one or two model weeds, competitive ability appears not to be weed specific (Huel and Hucl, 1996). This suggests that genotypes competitive with one weed species are very likely to be competitive with a range of species.

Increased seeding rates may provide a means by which to enhance the competitive ability of a particular genotype (Cousens and Mokhtari, 1998). Yield loss associated with the presence of weeds may be reduced with increased seeding rates (Carlson and Hill, 1985; Martin *et al*., 1987; Torner *et al*., 1991; Lemerle *et al*., 1996; Sodhi and Dhaliwal, 1998). Weed biomass (Pfeiffer and Holmes, 1961; Kolbe, 1980; Champion *et al*., 1998) and seed production (Koscelny *et al*., 1990; Evans *et al*., 1991) can also be reduced by increasing seeding rate. Research in Australia has found that by doubling standard seeding rates of wheat, annual ryegrass biomass can be reduced by 25% (Lemerle *et al*., 1996). Reducing weed seed production can also play an important role in long-term weed management strategies. Increasing wheat seeding rate from 67 to 134 kg ha^{-1} reduced volunteer rye (*Secale cereale* L.) seed production by 21 to 25% (Roberts *et al*., 2001). Nevertheless, at very high seeding rates, lodging may become a concern in oat and consequently yield may be reduced (Ciha, 1983).

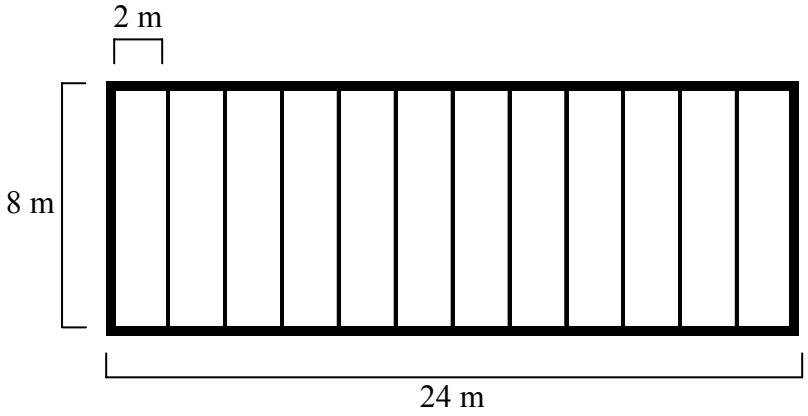
Weed competition may also have detrimental effects on crop quality, affecting both physical and chemical attributes (Manthey *et al*., 1996; Ellis *et al*., 1998). Extraneous material, which is often largely composed of weed seeds, may be present in sufficient amounts such that the quality of the product is downgraded. In some instances the presence of weeds has negatively affected wheat protein (Burrows and Olson, 1955; Friesen *et al*., 1960). The presence of weeds however does not always have detrimental effects on grain quality (Bell and Nalewaja, 1968a; Alessi and Power, 1970; Torner *et al*., 1991; Manthey *et al*., 1996). The effects of weed interference on crop quality are inconsistent; however, protein content seems to be affected more often than other attributes.

Increased seeding rate and the use of competitive genotypes may provide oat growers with means to reduce the effect of wild oat on crop yield and quality. There is no published information examining the CA of oat genotypes with wild oat. The objective of this study was to determine if western Canadian oat genotypes differ in CA with wild oat and whether increased seeding rate can enhance the competitive ability of oat. The effects of wild oat and increased seeding rate on oat quality were also examined.

3.2 Materials and Methods

Field experiments were conducted at the Kernen Crop Research Farm (52° 9' Latitude, 106° 33' Longitude), Saskatoon, Saskatchewan on a clay loam soil in 1999, 2000 and 2001. The study was abandoned at the Kernen Crop Research Farm in 2001 due to drought. Experiments were also conducted at Esk (51° 48' Latitude, 104° 51' Longitude), Saskatchewan on a clay loam soil in 2000 and 2001. The experiments were organized as a split-plot factorial design within a randomized complete block with four replications. Main plots were 8 by 24 m; sub-plots were 8 by 2 m (Figure 3.1). Each replication consisted of four main plots.

Figure 3.1 Main and sub-plot layout and dimensions.



All experiments were seeded into tilled land that had been cropped the previous year. A pre-seed application of glyphosate was applied at Esk in 2000 and 2001 at a rate of 0.9 kg ha^{-1}. Main plots of wild oat were seeded perpendicular to sub-plots at a depth of approximately 7-cm in 23-cm rows while sub-plots were seeded immediately thereafter. Nitrogen and phosphorous fertilizers were applied at the time of seeding at each location based on soil tests taken in the spring of each year. Fertilizer was applied at the time of seeding between seed rows. Sub-plots of oat were seeded approximately 5-cm deep in 23-cm rows. Broadleaf weed species were controlled in-crop with a 1:1

commercial mixture of bromoxynil (3,5-dibromo-4-hydroxybenzonitrile) and MCPA [(4-chloro-2-methylphenoxy) acetic acid] ester at 0.56 kg ha^{-1} in early to mid June. Herbicides were applied in 100 L of water ha^{-1}.

Main plot treatments consisted of target wild oat densities (TWO) of 0, 10, 40 and 120 plants m^{-2} in 1999. TWO were changed to 0, 15, 60 and 180 plants m^{-2} in 2000 and 2001. Wild oat seed was received from a common study at the Agriculture and Agri-Food Research Station at Scott, Saskatchewan. Wild oat seeding rates were adjusted based on germination and an assumed seedling mortality of 10%. At Kernen 1999, wild oat seedlings were counted in two 0.25 m^{-2} quadrats positioned approximately one meter from the front and back of the plot. Wild oat were counted in two sub-plots within each main plot. Actual densities of wild oat in 1999 were 0, 6, 36 and 71 plants m^{-2}. In 2000, wild oat density was measured by counting wild oat seedlings in every plot in the manner previously described. In 2001, plots sown only to wild oat were left at the end of each main plot and wild oat populations were determined by counting the wild oat in two 1-m^{-2} quadrants. Actual wild oat densities at Kernen in 2000 were 0, 7, 26 and 79 plants m^{-2}, while at Esk in 2000, actual densities were 0, 8, 31 and 92 plants m^{-2}. Actual densities at Esk in 2001 were 0, 7, 28 and 83 plants m^{-2}. Wild oat seedling density was determined at the 1 to 2-leaf stage of wild oat. Oat seedlings were counted in each sub-plot within the weed-free main-plots. Oat seedlings were counted in two 0.25 m^{-2} quadrats positioned approximately 1 meter from the front and back of each sub-plot. Actual densities at Kernen in 1999 were 130 and 234 plants m^{-2}, while at Kernen in 2000 actual densities were 187 and 274 plants m^{-2}.

Densities at Esk in 2000 were 191 and 263 plants m^{-2} while densities at Esk in 2001 were 170 and 257 plants m^{-2}.

Sub-plot treatments consisted of a factorial arrangement of genotype and seeding rate. Six oat genotypes were chosen to represent varying plant height and growth habit. Genotypes examined were AC Mustang, CDC Bell, CDC Pacer, OT 288, Riel and Triple Crown. Morphologically, CDC Bell and OT 288 were the most divergent of the genotypes examined. CDC Bell is a tall, leafy forage genotype with broad, lax leaves. Unlike the other genotypes, CDC Bell was developed for forage rather than grain production (Saskatchewan Seed Guide, 2003). OT 288 is a semi-dwarf genotype with relatively erect leaves. These two morphologically divergent genotypes were selected as it was postulated that CDC Bell would be highly competitive while OT 288 would not. The remaining four genotypes, referred to as standard genotypes are all suitable for milling and do not possess any distinct morphological or end use characteristics; however, within the standard group of genotypes it was hypothesized that AC Mustang would be the most competitive while Triple Crown would be the least competitive. Oat seeding rates targeted populations of 250 and 500 plants m^{-2}. Seeding rates for each genotype were adjusted based on 1000-kernel weight, germination and an assumed seedling mortality of 5%. Seeding dates were May 22 and 18 at Kernen in 1999 and 2000, respectively, and May 16 and 18 at Esk in 2000 and 2001, respectively.

Wild oat shoot biomass was determined by randomly harvesting 5 plants in each sub-plot in late July to early August, prior to wild oat seed shed. Wild oat florets were also counted on each of the harvested plants and used to estimate total seed production.

Plant height of oat and wild oat were determined concurrently and three individuals of each species were measured. Biomass samples were collected and dried at 40°C for 72 hours prior to weighing. These values were then used to determine biomass and seed production on an area basis. Wild oat seed production (seeds m^{-2}) was determined by multiplying the average number of seeds produced per plant by the average wild oat density for each wild oat density treatment at individual locations. Wild oat biomass (grams m^{-2}) was determined in the same manner, using the average dry weight of the plants harvested.

Prior to grain harvest, plots were reduced in length to 6 meters to reduce edge effects. Plots were direct combined in late August. Harvested grain samples were placed in a drying room for 3 to 5 days before they were weighed. Considerable rainfall was received at Esk in 2001 during late July and early August, resulting in secondary plant growth. All plots were therefore desiccated with 1.8 kg ha^{-1} of glyphosate to terminate this growth and accelerate ripening.

Percentage wild oat (PWO) in the harvested grain samples was determined by removing all wild oat seed from a 500-gram sample. The wild oats removed from the sample were then weighed and the percentage of the sample that consisted of wild oat seed was determined. Final yields were then calculated, accounting for the wild oat seed present in the harvested sample. Percent yield loss was determined by subtracting the weedy yield (Y_W) from the weed-free yield (Y_{WF}) for each matching sub-plot treatment pair within each replication.

$$[(Y_{WF} - Y_W) / Y_{WF}] \text{ X } 100 \qquad [1]$$

Test weight and 1000-kernel weight were determined at the same time. 1000-kernel weight was based on two 200-seed samples. Groat fat and protein content were estimated using a cleaned 50-gram sample of oat with a Foss Model 6500 Near Infrared Spectrometer (Foss Incorporated, 11 Edvac Drive, Unit 10, Brampton, Ontario, Canada, L6S SW5). Additional 50-gram samples were used to determine percentage of plump and thin kernels. Plump kernels consisted of those retained on a 2.15- by 8.33-mm slotted sieve and thin kernels were those that passed through a 1.95- by 8.33-mm slotted sieve (Canada Seed Equipment Limited, 322 Packham Avenue, Saskatoon, Saskatchewan, Canada, S7N 2T1). The weight of the respective plump and thin fractions of seed were determined and used to establish the percentage of the sample of each fraction. Groat percentage was determined by using 50-gram samples of cleaned oat. Groats were separated from hulls using a laboratory impact huller (Codema Inc., Minneapolis, Minnesota, USA). All samples were dehulled for a period of 60 seconds at an air pressure of 100 psi. The blast gate apeture was set at 18.75 mm while the air adjustment sleeve was opened to 12.50 mm. All groat samples were then weighed. This value was used to determine the percentage of the sample that consisted of groat.

Data were analyzed using the MIXED procedure of SAS (SAS, 1990). Replication effects were considered random while all other treatments were fixed. Site-years were analyzed individually due to heteroscedascity and differences in target wild oat densities in 1999 compared to 2000 and 2001. Means were separated with a protected least significant difference at the $P < 0.05$ level by Tukey's statistic. Apriori orthogonal contrasts were used to compare differences between divergent and standard oat genotypes. The group of standard genotypes consisted of AC Mustang, CDC Pacer,

Riel and Triple Crown. Linear and quadratic trend comparisons were used to examine the relationship between wild oat density and dependent variables. As wild oat density was unequally spaced, mutually orthogonal contrasts were calculated as described by Gomez and Gomez (1984).

3.3 Environmental Conditions

Monthly average temperature and accumulated precipitation from May 1st to August 31st are provided in Table 3.1 for the three years of the study for Saskatoon and Esk. Conditions at Kernen 1999 were ideal with below-normal temperatures and above-normal precipitation in May, June and July. Although precipitation was well below average at Kernen and Esk in May, 2000, moisture conditions improved through the year and yields were satisfactory. In 2001, the Kernen site was abandoned due to drought while temperatures were above normal and precipitation was well below average at Esk, adversely affecting crop growth.

Table 3.1 Growing season monthly mean temperatures (°C) and total precipitation (mm) for Saskatoon and Esk, Saskatchewan in 1999, 2000 and 2001. Numbers in parentheses are long-term averages for the Environment Canada weather station located closest to the experimental site and within the same soil climatic zone.

Year	Location	May		June		July		August	
				Average Temperature (°C)					
1999	Kernen	10.0	(11.8)	14.2	(15.9)	16.1	(18.3)	17.4	(17.6)
2000	Kernen	10.2	(11.8)	13.3	(15.9)	18.2	(18.3)	17.1	(17.6)
	Esk	9.9	(11.0)	13.2	(15.5)	18.2	(17.7)	16.4	(16.9)
2001	Esk	12.0	(11.0)	15.0	(15.5)	18.9	(17.7)	18.8	(16.9)
				Total Precipitation (mm)					
1999	Kernen	53	(44)	66	(60)	94	(57)	24	(36)
2000	Kernen	18	(44)	49	(60)	78	(57)	37	(36)
	Esk	28	(49)	92	(75)	29	(66)	31	(51)
2001	Esk	31	(49)	9.0	(75)	66	(66)	15.5	(51)

3.4 Results and Discussion

3.4.1 Effect of Genotype on Oat – Wild Oat Competition

OT 288 was consistently the least tolerant of wild oat competition of the oat genotypes examined, with yield loss in excess of 10% in all site-years (Table 3.2). OT 288 yield loss range from 10.65% at Esk 2000 to a high of 15.60% at Kernen 1999. Overall the yield loss of standard genotypes did not differ in most years (Table 3.2). CDC Bell was highly tolerant to wild oat competition in 2000 at both locations, having a yield loss of –0.03 and 0.16% as compared to an average yield loss of 5.02 and 7.16% in the standard genotypes at Esk 2000 and Kernen 2000, respectively ($P< 0.05$) (Table 3.2). Furthermore, yield loss at the highest target wild oat density was significantly lower in CDC Bell than in the standard genotypes. When averaged over all wild oat densities, percentage yield loss was not always the lowest for CDC Bell; however, at high target wild oat density CDC Bell had the smallest yield loss of the genotypes examined, although this was only significant at Kernen 2000 (Table 3.3). Increasing wild oat density consistently reduced yield among genotypes (Table 3.3). The exception to this was the occurrence of a genotype by wild oat density interaction ($P<0.05$) at Kernen 2000. At this location CDC Bell showed greater tolerance to wild oat competition as its oat yield was reduced less than other genotypes ($P< 0.05$) with increasing wild oat density (Figure 3.2). Consistent genotype by wild oat density interactions would be indicative of differential competitive ability among genotypes (Huel and Hucl, 1996).

Table 3.2 The mean effect of oat genotype (G), target wild oat density (TWO) (plants m^{-2}) and oat target plant population (TPP) (plants m^{-2}), on percentage grain yield loss for each site-year. Probability of main effect or interaction in parenthesis.

		Yield Loss (%)			
		Kernen 1999[a]	Kernen 2000	Esk 2000	Esk 2001
G	AC Mustang	5.11	8.12	12.67	2.07
	CDC Bell	10.32	-0.03	0.16	4.10
	CDC Pacer	11.12	7.45	6.52	-6.14
	OT 288	15.60	10.94	10.65	12.52
	Riel	6.46	1.38	0.08	6.43
	Triple Crown	9.40	3.14	9.40	-6.59
	P [b]	(<0.0001)	(<0.0001)	(<0.0001)	(<0.0001)
	LSD (0.05)	5.90	4.70	5.10	12.10
	OT288 vs. Std.[c]	(0.3979)	(0.4057)	(0.4093)	(<0.0001)
	CDC Bell vs. Std.[c]	(0.6147)	(0.0026)	(0.0002)	(0.2000)
	OT 288 vs. CDC Bell	(0.7854)	(0.0026)	(0.0153)	(0.1700)
TWO	15	-0.13	-3.35	0.32	-12.06
	60	8.24	2.83	3.71	-5.81
	180	20.89	16.02	15.71	22.00
	P [b]	(0.0044)	(0.0049)	(<0.0001)	(0.0499)
	LSD (0.05)	9.40	9.00	5.80	NS
	Linear	(<0.0001)	(<0.0001)	(<0.0001)	(0.0200)
	Quadratic	(0.4704)	(0.7922)	(0.7454)	(0.7735)
TPP	250	11.57	9.25	10.16	1.41
	500	7.77	1.08	3.00	1.34
	P [b]	(0.0093)	(0.0020)	(0.0055)	(0.9892)
	LSD (0.05)	2.80	4.30	4.70	NS
G * TWO	P [b]	(0.1640)	(0.3532)	(0.8866)	(0.7123)
G * TPP	P [b]	(0.0927)	(0.0713)	(0.4195)	(0.0057)
TWO * TPP	P [b]	(0.0014)	(0.5761)	(0.3416)	(0.8723)
G * TWO * TPP	P [b]	(0.5685)	(0.7638)	(0.0943)	(0.0401)

[a] Target wild oat densities in Kernen 1999 were 0, 10, 40 and 120 plants m^{-2}.

[b] Probability for main effect or interaction.

[c] Standard genotypes - AC Mustang, CDC Pacer, Riel and Triple Crown.

Table 3.3 The mean effect of oat genotype (G), target wild oat density (TWO) (plants m^{-2}) and oat target plant population (TPP) (plants m^{-2}), on oat yield (kg ha^{-1}) for each site year. Probability of main effect or interaction in parenthesis.

		Yield (kg ha^{-1})			
		Kernen 1999[a]	Kernen 2000	Esk 2000	Esk 2001
G	AC Mustang	4300	4020	3900	2080
	CDC Bell	3810	3200	3440	1650
	CDC Pacer	4750	4040	4120	2410
	OT 288	4860	3860	3830	2000
	Riel	4820	3950	3880	1880
	Triple Crown	5360	3930	3910	1280
	P [b]	(<0.0001)	(<0.0001)	(<0.0001)	(<0.0001)
	LSD (0.05)	272	143	170	219
	OT288 vs. Std.[c]	(0.5731)	(0.0372)	(0.0687)	(0.2978)
	CDC Bell vs. Std.[c]	(<0.0001)	(<0.0001)	(<0.0001)	(0.0029)
	OT 288 vs. CDC Bell	(<0.0001)	(<0.0001)	(<0.0001)	(0.0017)
TWO	15	5010	4000	4050	1920
	60	5030	4130	4030	2130
	180	4600	3870	3890	2020
	P [b]	3960	3340	3400	1480
	LSD (0.05)	(0.0003)	(0.0059)	(0.0176)	(0.1136)
	Linear	370	381	280	NS
	Quadratic	(<0.0001)	(0.0008)	(0.0002)	(0.0357)
		(0.1428)	(0.6024)	(0.6478)	(0.2951)
	250				
TPP	500	4470	3760	3720	1930
	P [b]	4820	3910	3970	1840
	LSD (0.05)	(<0.0001)	(0.0214)	(0.0079)	(0.2694)
		121	126	152	NS
G * TWO	P [b]	(0.1467)	(0.0294)	(0.2316)	(0.6619)
G * TPP	P [b]	(0.0148)	(0.0402)	(0.7423)	(0.2113)
TWO * TPP	P [b]	(0.0029)	(0.0952)	(0.1625)	(0.9984)
G * TWO * TPP	P[b]	(0.5643)	(0.6927)	(0.9592)	(0.0585)

[a] Target wild oat densities in Kernen 1999 were 0, 10, 40 and 120 plants m^{-2}.

[b] Probability for main effect or interaction.

[c] Standard genotypes - AC Mustang, CDC Pacer, Riel and Triple Crown.

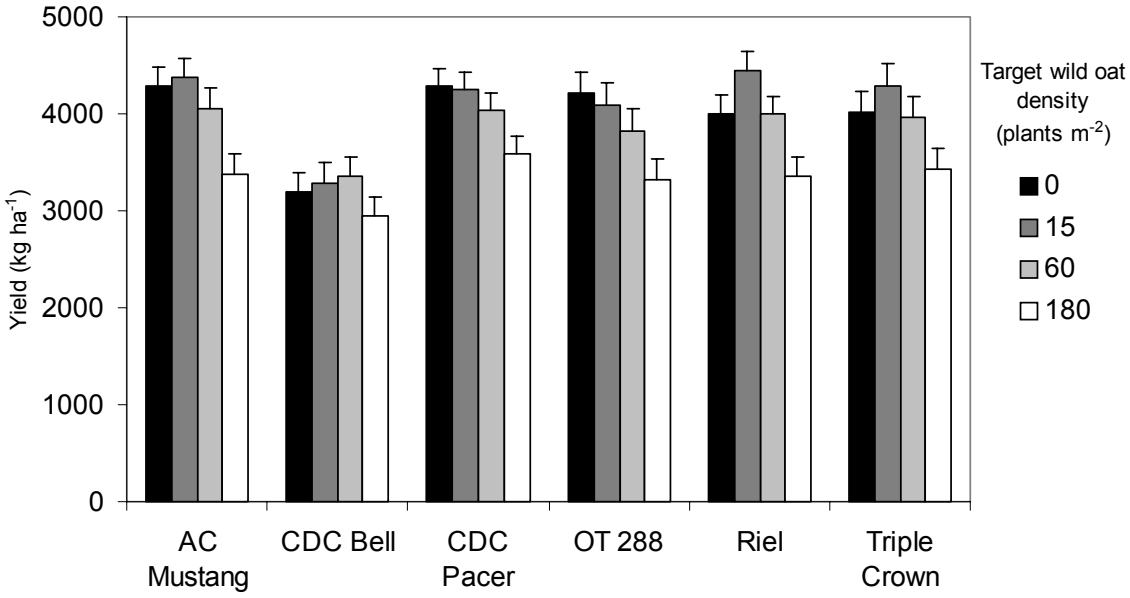


Figure 3.2 Effect of increasing wild oat density on grain yield (kg ha^{-1}) of six western Canadian oat genotypes averaged over two plant populations (250 and 500 plants m^{-2}) at Kernen 2000. Standard error bars represent standard errors of the means.

CDC Bell yield was considerably lower than the standard genotypes in all four site-years (Table 3.3). These results indicate that although CDC Bell has low yield potential, it may be able to tolerate weed competition better than the other genotypes. As CDC Bell was developed as a forage oat, grain yield potential is less than that of the other genotypes tested. Thus, CDC Bell may be able to maintain yield under weedy conditions, yet growers are unlikely to select this genotype as a means of stabilizing yield under weedy conditions. Other genotypes, although unable to tolerate weed competition to the same extent, are still higher yielding under weedy conditions than CDC Bell. This work and that of others (Donald and Hamblin, 1976; Siddique *et al*., 1989; Baylan *et al*., 1991; DeLucas and Froud-Williams, 1994), suggests that genotypes tolerant to weed competition lack high weed-free yield potential. The traits associated with competitive ability in these studies included increased height and tillering as well as the production of significant leaf area; however, these traits are

associated with reduced harvest indices which may be why genotypes tolerant to weed competition lack weed-free yield potential. If a strong negative correlation does exist between CA and weed-free yield, the development of genotypes that are tolerant to weed competition, yet high yielding may be difficult. Alternatively, others suggest that the genetic variability present among crop genotypes is sufficient to develop highly competitive genotypes that are also high yielding (Christensen, 1995; Lemerle *et al*., 1996; Cousens and Mokhtari, 1998).

Differences in the ability of CDC Bell and OT 288 to tolerate weed competition may in part be due to differences in height. CDC Bell was the tallest or among the tallest genotype in two of four years, while OT 288 was the shortest or among the shortest in all experiments ($P<0.01$) (Table 3.4). Tall genotypes have been found to be more competitive than shorter genotypes (Cosser *et al*., 1997) as they are able to intercept a larger portion of incoming PAR (Lanning *et al*., 1997). The ability to intercept PAR is especially important in agroecosystems, as competition for light is commonplace (Loomis and Connor, 1996). As CDC Bell is tall, it should be able to position a greater portion of its canopy at or above that of wild oat. As a result, CDC Bell should have been able to intercept more PAR and therefore be affected to a lesser extent by the presence of wild oat

Large yield loss in OT 288 may also be associated with wild oat biomass production (Table 3.5). Wild oat biomass differed ($P<0.05$) among genotypes in all site-years with the exception of Kernen 2000 (Table 3.5). Wild oat biomass was the greatest, although not statistically different from the other genotypes, in those plots sown to OT 288 in all site-years except Esk 2001 (Table 3.5). Furthermore, biomass

Table 3.4 The mean effect of oat genotype (G), target wild oat denisty (TWO) (plants m^{-2}) and oat target plant population (TPP) (plants m^{-2}), on oat height (cm) for each site year. Probability of main effect or interaction in parenthesis.

		Oat height (cm)			
		Kernen 1999[a]	Kernen 2000	Esk 2000	Esk 2001
G	AC Mustang	103	111	106	54
	CDC Bell	109	104	107	58
	CDC Pacer	97	95	105	51
	OT 288	74	71	82	47
	Riel	98	98	109	54
	Triple Crown	102	95	101	49
	P[b]	(<0.0001)	(<0.0001)	(<0.0001)	(0.0006)
	LSD (0.05)	1	15	3	5
	OT288 vs. Std.[c]	(<0.0001)	(<0.0001)	(<0.0001)	(0.0173)
	CDC Bell vs. Std.[c]	(<0.0001)	(0.4411)	(0.1708)	(0.0032)
	OT 288 vs. CDC Bell	(<0.0001)	(<0.0001)	(<0.0001)	(<0.0001)
TWO	0	97	92	102	51
	15	98	97	102	55
	60	97	103	102	54
	180	96	92	99	48
	P[b]	(0.3356)	(0.2824)	(0.8235)	(0.2234)
	LSD (0.05)	NS	NS	NS	NS
	Linear	(0.1646)	(0.6696)	(0.4106)	(0.1376)
	Quadratic	(0.6792)	(0.0676)	(0.7152)	(0.2247)
TPP	250	99	101	104	55
	500	95	90	99	49
	P[b]	(<0.0001)	(0.0102)	(<0.0001)	(0.0023)
	LSD (0.05)	2	9	2	3
G * TWO	P[b]	(0.9885)	(0.3852)	(0.9851)	(0.9432)
G * TPP	P[b]	(<0.0001)	(0.2246)	(0.0240)	(0.4530)
TWO * TPP	P[b]	(0.6170)	(0.3926)	(0.8306)	(0.5527)
G * TWO * TPP	P[b]	(0.3271)	(0.6546)	(0.2828)	(0.7284)

[a] Target wild oat densities in Kernen 1999 were 0, 10, 40 and 120 plants m^{-2}.

[b] Probability for main effect or interaction.

[c] Standard genotypes - AC Mustang, CDC Pacer, Riel and Triple Crown.

Table 3.5 The mean effect of oat genotype (G), target wild oat density (TWO) (plants m^{-2}) and oat target plant population (TPP) (plants m^{-2}), on wild oat biomass (g m^{-2}) for each site year. Probability of main effect or interaction in parenthesis.

		Wild Oat Biomass (g m^{-2})			
		Kernen 1999[a]	Kernen 2000	Esk 2000	Esk 2001
G	AC Mustang	86	59	78	83
	CDC Bell	70	45	63	70
	CDC Pacer	100	46	70	105
	OT 288	156	65	92	76
	Riel	106	50	71	83
	Triple Crown	120	48	60	106
	P[b]	(<0.0001)	(0.0762)	(0.0024)	(0.0359)
	LSD (0.05)	24	NS	17	27
	OT288 vs. Std.[c]	(<0.0001)	(0.0253)	(0.0008)	(0.0959)
	CDC Bell vs. Std.[c]	(0.0008)	(0.3892)	(0.2612)	(0.1126)
	OT 288 vs. CDC Bell	(<0.0001)	(0.0153)	(0.0005)	(0.0112)
TWO	15	21	14	14	21
	60	116	44	55	83
	180	182	99	148	157
	P[b]	(<0.0001)	(<0.0001)	(<0.0001)	(<0.0001)
	LSD (0.05)	21	11	26	25
	Linear	(<0.0001)	(<0.0001)	(<0.0001)	(<0.0001)
	Quadratic	(0.0005)	(0.1592)	(0.6462)	(0.0313)
TPP	250	133	67	82	99
	500	80	38	62	75
	P[b]	(<0.0001)	(<0.0001)	(0.0055)	(0.0127)
	LSD (0.05)	14	8	13	18
G * TWO	P[b]	(0.0061)	(0.5194)	(0.5125)	(0.1511)
G * TPP	P[b]	(0.2810)	(0.0416)	(0.2686)	(0.0367)
TWO * TPP	P[b]	(0.0002)	(0.0004)	(0.0476)	(0.2043)
G * TWO * TPP	P[b]	(0.1616)	(0.0042)	(0.5960)	(0.1464)

[a] Target wild oat densities in Kernen 1999 were 0, 10, 40 and 120 plants m^{-2}.

[b] Probability for main effect or interaction.

[c] Standard genotypes - AC Mustang, CDC Pacer, Riel and Triple Crown.

production was the lowest in plots sown to CDC Bell in all years with the exclusion of Esk 2000 (Table 3.5). In all site-years with the exception of Kernen 1999, the effect of increasing wild oat density was consistent across genotypes. Nevertheless, the presence of a genotype by target wild oat density interaction at Kernen 1999 (Table 3.5) indicates a differential response among genotypes to increasing wild oat density (Figure 3.3). At a target wild oat density of 40 plants m^{-2} the increase in wild oat biomass for OT 288 is considerably greater than for any other genotype. These results suggest that OT 288 is less able to interfere with wild oat growth than the other genotypes examined.

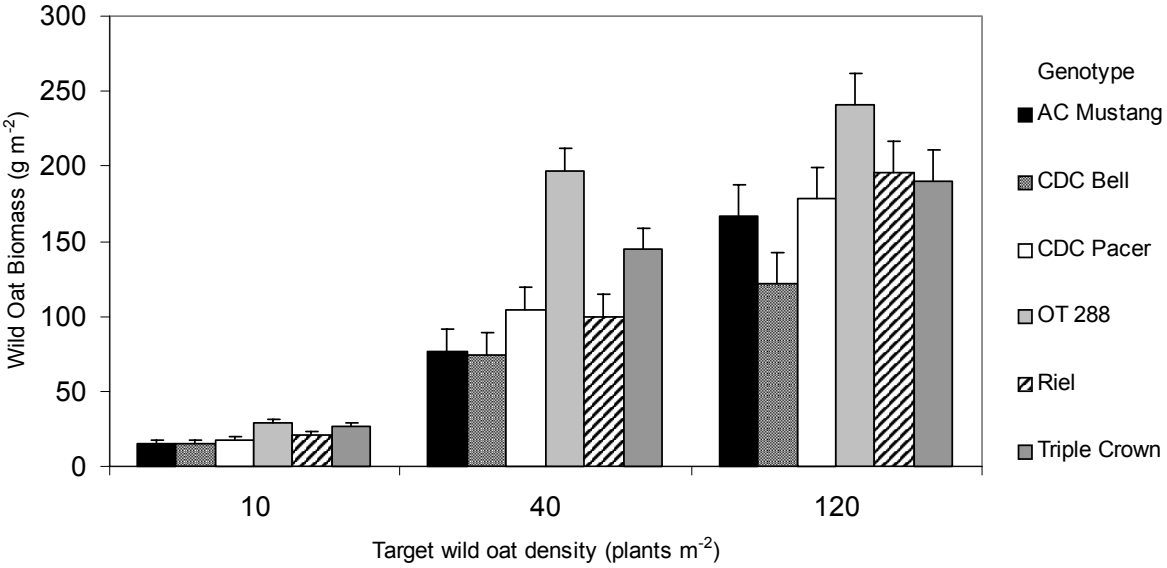


Figure 3.3 Wild oat biomass production (g m^{-2}) at Kernen 1999, at target wild oat densities of 10, 40 and 120 plants m^{-2} (actual densities of 6, 36 and 71 plants m^{-2}) on plots sown to six western Canadian oat genotypes (Means of plant populations of 250 and 500 plants m^{-2}). Standard error bars represent standard errors of the means.

As wild oat biomass production directly affects estimated seed production, results were similar for this variable. Wild oat seed return varied ($P<0.01$) among genotypes at Kernen 1999 and Esk 2000 (Table 3.6). With the exception of Kernen 2000, seed production was greater ($P<0.05$) in plots sown to OT 288 than to standard genotypes by 32, 19 and 21% at Kernen 1999, Esk 2000 and Esk 2001, respectively (Table 3.6). This confirms that OT 288, the semi-dwarf genotype is a consistently poor competitor and unable to either tolerate or interfere with wild oat growth. Excluding OT 288 at Kernen 1999, all genotypes responded the same to increasing target wild oat density. The occurrence of a genotype by target wild oat density interaction at Kernen 1999 (Figure 3.4) is similar to that observed for wild oat biomass. Wild oat seed production in OT 288 at a target wild oat density 40 plants m^{-2} is comparable to wild oat seed production in the standard genotypes at a target wild oat density of 120 plants m^{-2} (Figure 3.4).

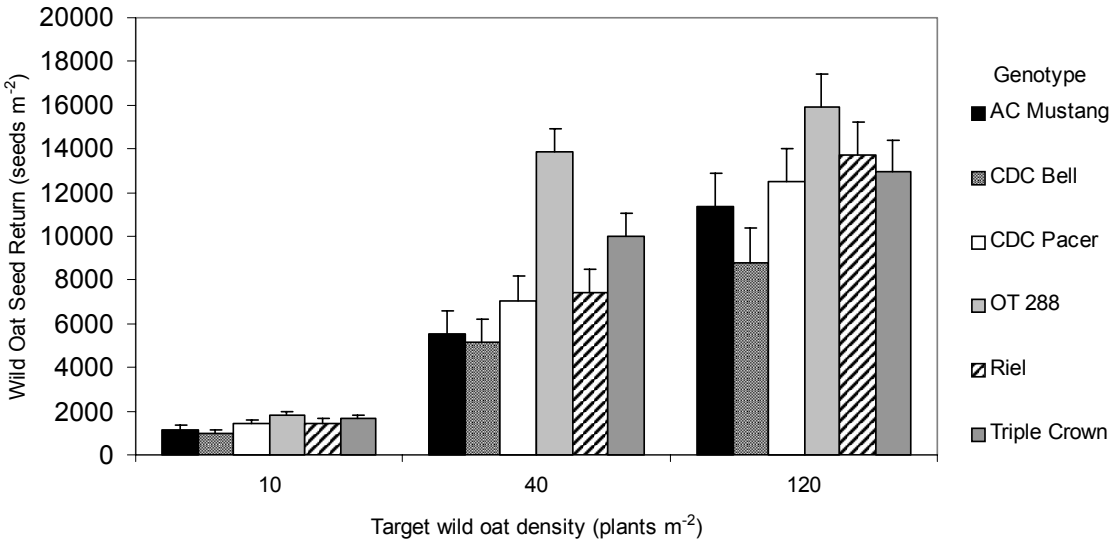


Figure 3.4 Wild oat seed production (seeds m^{-2}) at Kernen 1999, at target wild oat densities of 10, 40 and 120 plants m^{-2} (actual densities of 6, 36 and 71 plants m^{-2}) on plots sown to six western Canadian oat genotypes. Standard error bars represent standard errors of the means.

Table 3.6 The mean effect of oat genotype (G), target wild oat denisty (TWO) (plants m^{-2}) and oat target plant population (TPP) (plants m^{-2}), on wild oat seed production (seeds m^{-2}) for each site year. Probability of main effect or interaction in parenthesis.

		Wild Oat Seed Production (seeds m^{-2})			
		Kernen 1999[a]	Kernen 2000	Esk 2000	Esk 2001
G	AC Mustang	6010	2260	2250	1250
	CDC Bell	5030	2280	2000	1350
	CDC Pacer	6970	2460	2130	1310
	OT 288	10540	2880	2580	1690
	Riel	7530	2840	2180	1220
	Triple Crown	8180	2370	1900	1580
	P[b]	(<0.0001)	(0.5465)	(0.0079)	(0.0598)
	LSD (0.05)	1660	NS	365	368
	OT288 vs. Std.[c]	(<0.0001)	(0.2516)	(0.0017)	(0.0154)
	CDC Bell vs. Std.[c]	(0.0015)	(0.5645)	(0.4270)	(0.9020)
	OT 288 vs. CDC Bell	(<0.0001)	(0.1751)	(0.0020)	(0.0607)
TWO	15	1410	540	448	294
	60	8310	1710	1600	1190
	180	12590	5300	4470	2710
	P[b]	(<0.0001)	(<0.0001)	(<0.0001)	(<0.0001)
	LSD (0.05)	1630	798	283	329
	Linear	(<0.0001)	(<0.0001)	(<0.0001)	(<0.0001)
	Quadratic	(0.0010)	(0.7041)	(0.6634)	(0.1128)
TPP	250	9458	2300	2440	1560
	500	5420	2040	1910	1230
	P[b]	(<0.0001)	(0.0027)	(<0.0001)	(0.0104)
	LSD (0.05)	1670	570	231	236
G * TWO	P[b]	(0.0053)	(0.9090)	(0.5967)	(0.3755)
G * TPP	P[b]	(0.2744)	(0.1536)	(0.9146)	(0.0341)
TWO * TPP	P[b]	(0.0089)	(0.0655)	(0.0181)	(0.3866)
G * TWO * TPP	P[b]	(0.2625)	(0.0663)	(0.9470)	(0.1462)

[a] Target wild oat densities in Kernen 1999 were 0, 10, 40 and 120 plants m^{-2}.

[b] Probability for main effect or interaction.

[c] Standard genotypes - AC Mustang, CDC Pacer, Riel and Triple Crown.

Wild oat seed production was the lowest in plots sown to CDC Bell at Kernen 1999 and the second lowest in 2000 at both locations, yet only differed ($P<0.01$) from the standard genotypes at Kernen 1999 (Table 3.6). Nevertheless, CDC Bell was the most consistent in suppressing wild oat seed production (Table 3.6). Wild oat can be a difficult and costly weed to control and therefore cultural control measures that can reduce future weed infestations are invaluable. The erratic duration of dormancy in wild oat (Naylor and Jana, 1976; Naylor, 1983) makes the management of this weed difficult; consequently, reducing seed return through the use of genotypes that are able to interfere with seed production can play a role in integrated weed management systems by reducing additions to the wild oat seed bank.

Percent wild oat in harvested samples (PWO) differed among genotypes ($P<0.01$) in all site-years (Table 3.7). Furthermore, with the exception of Esk 2001, genotype by target wild oat density interactions were present in all site-years (Table 3.7). OT 288 exhibited a large increase in PWO when wild oat density was increased from the lowest to the highest density (Figure 3.5). PWO in OT 288 was higher ($P<0.01$) than the standard genotypes in all site-years, exceeding 2% when averaged over all densities and plant populations (Table 3.7). These results provide further indication that OT 288 is a poor competitor. Conversely, PWO in CDC Bell differed ($P<0.01$) from the standard genotypes when averaged over all wild oat densities and plant populations, at both sites in 2000 (Table 3.7); however, in site-years where above (Kernen 1999) and below (Esk 2001) normal growing season precipitation were received, differences were not observed.

Table 3.7 The mean effect of oat genotype (G), target wild oat density (TWO) (plants m^{-2}) and oat target plant population (TPP) (plants m^{-2}), on percentage wild oat (PWO) in 500 gram samples of harvested oat seed for each site year. Probability of main effect or interaction in parenthesis.

		PWO			
		Kernen 1999[a]	Kernen 2000	Esk 2000	Esk 2001
G	AC Mustang	1.13	1.29	2.18	1.28
	CDC Bell	0.74	0.50	1.07	1.13
	CDC Pacer	0.98	0.83	1.37	0.84
	OT 288	2.40	2.17	2.63	2.25
	Riel	1.13	0.74	1.23	1.35
	Triple Crown	1	0.80	1.53	1.75
	P[b]	(0.0001)	(0.0001)	(<0.0001)	(<0.0001)
	LSD (0.05)	0.5	0.2	0.3	0.4
	OT288 vs. Std.[c]	(0.0001)	(0.0001)	(0.0001)	(0.0001)
	CDC Bell vs. Std.[c]	(0.1075)	(0.0001)	(0.0004)	(0.2983)
	OT 288 vs. CDC Bell	(0.0001)	(0.0001)	(<0.0001)	(<0.0001)
TWO	15	0.21	0.29	0.99	0.51
	60	1.06	0.93	1.04	1.26
	180	2.38	1.95	2.98	2.53
	P[b]	(<0.0001)	(<0.0001)	(0.0085)	(<0.0001)
	LSD (0.05)	0.3	0.2	1.2	0.6
	Linear	(0.0001)	(0.0001)	(<0.0001)	(0.0001)
	Quadratic	(0.0001)	(0.0470)	(0.3500)	(0.3966)
TPP	250	1.49	1.46	2.22	1.84
	500	0.94	0.65	1.11	1.02
	P[b]	(<0.0001)	(<0.0001)	(0.0013)	(0.0000)
	LSD (0.05)	0.3	0.2	0.5	0.2
G * TWO	P[b]	(0.0076)	(<0.0001)	(0.0003)	(0.2828)
G * TPP	P[b]	(0.6755)	(<0.0001)	(0.5316)	(0.3539)
TWO * TPP	P[b]	(<0.0001)	(<0.0001)	(0.0493)	(<0.0001)
G * TWO * TPP	P[b]	(0.2756)	(0.0289)	(0.2526)	(0.3564)

[a] Target wild oat densities in Kernen 1999 were 0, 10, 40 and 120 plants m^{-2}.

[b] Probability for main effect or interaction.

[c] Standard genotypes - AC Mustang, CDC Pacer, Riel and Triple Crown.

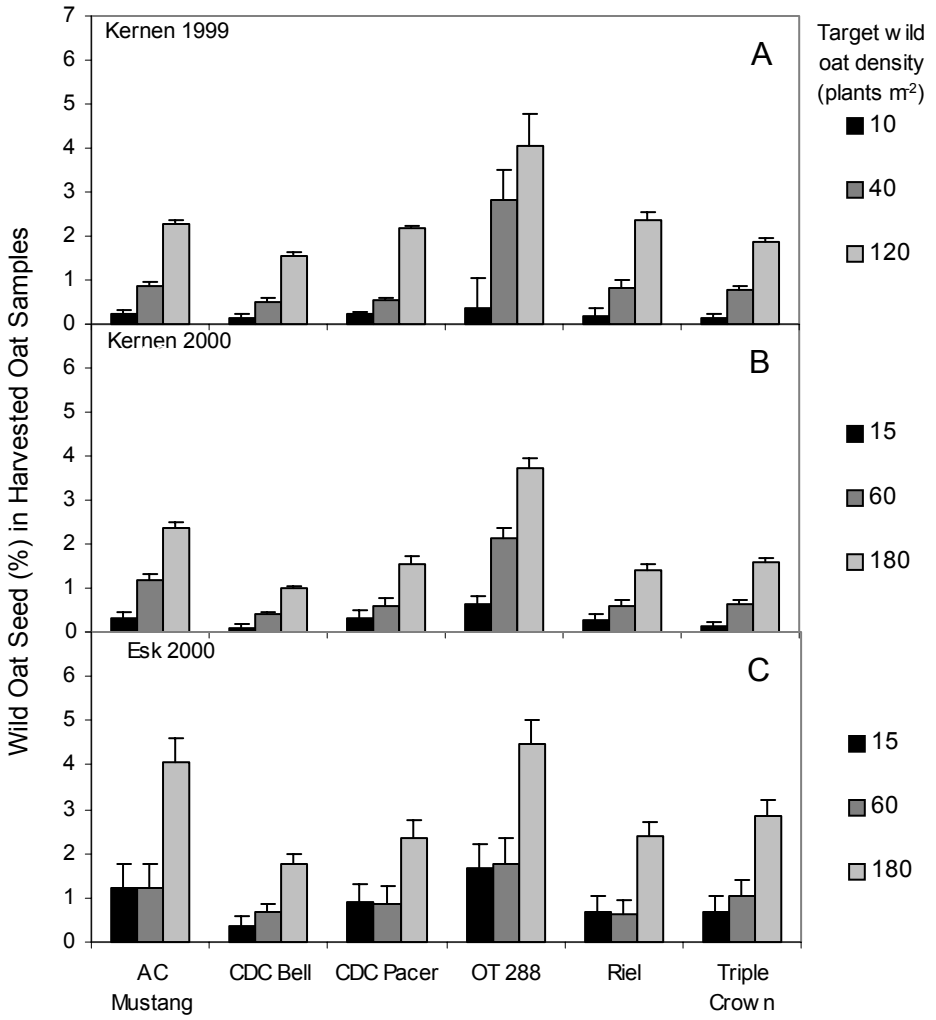


Figure 3.5 Effect of increasing wild oat density on percent wild oat in harvested grain samples of six western Canadian oat genotypes over three site-years (Kernen 1999 (A), Kernen 2000 (B) and Esk 2000 (C)). Standard error bars represent standard errors of the means.

3.4.2 Effect of Wild Oat Competition on Oat Yield and Quality

In all site-years increasing wild oat density causes a significant ($P<0.05$) linear decrease in yield (Table 3.3); consequently, a linear increase ($P<0.05$) in yield loss was observed (Table 3.2). Yield loss would be expected to exhibit an asymptotic response to increasing wild oat density (Cousens, 1985); however, the relatively low wild oat

density achieved in this experiment restricted yield loss to the linear phase of the hyperbolic function. Yield loss at the highest wild oat density ranged from 16% at Esk 2000 at an actual density of 92 plants m^{-2} to 22% at Esk 2001 at an actual density of 83 plants m^{-2} (Table 3.2). Similarly, at a wild oat density of 86 plants m^{-2}, Bell and Nalewaja (1968a) observed yield loss of 22% and 7% in wheat and barley respectively. Furthermore, O'Donovan *et al*. (1985) suggest that if wild oat is present at a density of 50 plants m^{-2} and emerges the same time as barley, crop yield loss will approach 10%; however, if wild oat emerges four days prior to the crop, yield loss of up to 20% may be observed. Additional work by O'Donovan *et al*. (2000) identified yield loss among barley genotypes that ranged from 3% to 14% at a wild oat density of 56 plants m^{-2}. With wild oat densities comparable between these studies, it appears that oat would be intermediate in competitive ability with wild oat, as compared to wheat and barley. Time of emergence in relation to that of the crop does affect the magnitude of yield loss (O'Donovan *et al*., 1985) and this factor was not accounted for in this study. Furthermore, the different environments may have affected the competitive ability of the crops examined, making it difficult to directly compare observed yield loss between oat, wheat and barley. The yield loss caused by an additional wild oat at observed wild oat density of 71, 79, 92 and 83 plants m^{-2} densities were 0.29, 0.20, 0.17 and 0.27% at Kernen 1999, Kernen 2000, Esk 2000 and Esk 2001, respectively. In comparison, O'Donovan *et al*. (1985) found that at a wild oat density of 164 plants m^{-2} the yield loss caused by an additional wild oat was 0.25%; however, in wheat yield loss of 0.29% were caused by an additional wild oat at a density of 197 plants m^{-2}. If wild oat emerged 3 days prior to the crop, yield loss caused by an additional wild oat were

greater, at 0.29 and 0.42% in wheat and barley, respectively. Although relative time of emergence was not accounted for in our study, wild oat generally emerged 1 to 3 days later than the crop in all site-years.

As expected, increasing wild oat density corresponded with increased wild oat biomass and seed production (Table 3.5 and 3.6). Both wild oat seed production and biomass exhibited significant linear increases ($P<0.01$) with increasing wild oat density (Table 3.5 and 3.6). Similarly, PWO also exhibited a linear increase to increasing wild oat density (Table 3.7). Averaged over all plant populations and genotypes, PWO remained below 1% at the lowest target wild oat density; however, at Kernen 1999, Esk 2000 and Esk 2001, PWO exceeded one percent at actual wild oat density of 36, 31 and 28 plants m^{-2}, respectively. It has been suggested that growers may be able to reduce the amount of wild oat seed in harvested samples by delaying swathing or harvesting until a time when wild oat has shed most of its seed (Shirtliffe et al., 2000). Because the current study was direct harvested when the plots were ripe, and considerable wild oat shed can be assumed to have occurred, PWO would have likely been much higher had the plots been swathed or harvested earlier.

Both physical and chemical measures are important in determining the milling quality of oat. Although the occurrence of wild oat affected PWO, other quality measures were relatively unaffected by wild oat competition. Groat percentage, which is the main indicator of milling yield, was unaffected by increasing wild oat density (Table 3.8). Similarly, others have observed that oat groat percentage is unaffected by kochia competition (Manthey *et al*., 1996). Percent plump kernels was unaffected by wild oat competition (Table 3.9). Nevertheless, at Kernen 1999 increasing wild oat

Table 3.8 The mean effect of oat genotype (G), target wild oat denisty (TWO) (plants m^{-2}) and oat target plant population (TPP) (plants m^{-2}), on percentage oat groat for each site year. Probability of main effect or interaction in parenthesis.

		Oat Groat (%)			
		Kernen 1999[a]	Kernen 2000	Esk 2000	Esk 2001
G	AC Mustang	56.8	67.0	67.1	51.4
	CDC Bell	62.0	70.1	71.8	49.3
	CDC Pacer	67.6	71.3	71.2	56.8
	OT 288	60.9	71.8	70.6	59.0
	Riel	63.4	75.1	74.0	55.0
	Triple Crown	66.0	71.8	69.9	43.3
	P[b]	(<0.0001)	(<0.0001)	(<0.0001)	(<0.0001)
	LSD (0.05)	5.2	0.8	1.80	4.9
TWO	0	62.5	71.3	70.5	52.3
	180	63.1	71.1	71.0	52.7
	P[b]	(0.7562)	(0.3813)	(0.3654)	(0.8972)
	LSD (0.05)	NS	NS	NS	NS
TPP	250	62.6	71.1	70.8	53.1
	500	62.9	71.3	70.8	51.9
	P[b]	(0.7942)	(0.4527)	(0.9912)	(0.3976)
	LSD (0.05)	NS	NS	NS	NS
G * TWO	P[b]	(0.9521)	(0.9963)	(0.5287)	(0.4373)
G * TPP	P[b]	(0.3784)	(0.3017)	(<0.0001)	(0.1932)
TWO * TPP	P[b]	(0.2572)	(0.6382)	(0.2137)	(0.0487)
G * TWO * TPP	P[b]	(0.7039)	(0.7156)	(0.3126)	(0.9963)

[a] Target wild oat densities in Kernen 1999 were 0, 10, 40 and 120 plants m^{-2}.

[b] Probability for main effect or interaction.

[c] Standard genotypes - AC Mustang, CDC Pacer, Riel and Triple Crown.

Table 3.9 The mean effect of oat genotype (G), target wild oat denisty (TWO) (plants m^{-2}) and oat target plant population (TPP) (plants m^{-2}), on percentage plump kernels for each site year. Probability of main effect or interaction in parenthesis.

		Plump kernel (%)			
		Kernen 1999[a]	Kernen 2000	Esk 2000	Esk 2001
G	AC Mustang	75.0	73.0	74.3	81.8
	CDC Bell	79.3	89.9	84.8	57.9
	CDC Pacer	78.7	74.7	68.3	64.6
	OT 288	72.2	72.7	69.2	72.7
	Riel	87.3	77.5	72.8	52.5
	Triple Crown	79.1	77.2	66.2	58.0
	P[b]	(0.7627)	(<0.0001)	(<0.0001)	(<0.0001)
	LSD (0.05)	NS	3.7	5.6	4.9
	OT288 vs. Std.[c]	(0.3286)	(0.0495)	(0.5857)	(0.0001)
	CDC Bell vs. Std.[c]	(0.9300)	(0.0001)	(0.0001)	(0.0016)
	OT 288 vs. CDC Bell	(0.4800)	(0.0001)	(0.0001)	(<0.0001)
TWO	0	76.3	77.8	74.4	61.3
	15	76.3	79.5	72.0	67.4
	60	74.6	76.2	72.7	67.2
	180	87.2	76.5	71.4	62.4
	P[b]	(0.4361)	(0.1160)	(0.5772)	(0.4037)
	LSD (0.05)	NS	NS	NS	NS
	Linear	(0.1228)	(0.1298)	(0.3286)	(0.6652)
	Quadratic	(0.6983)	(0.3349)	(0.7635)	(0.1980)
TPP	250	74.8	78.0	75.0	66.9
	500	82.5	77.0	70.2	62.3
	P[b]	(0.1874)	(0.3776)	(0.0007)	(0.0107)
	LSD (0.05)	NS	NS	2.7	3.3
G * TWO	P[b]	(0.7006)	(0.3566)	(0.5921)	(0.7040)
G * TPP	P[b]	(0.4422)	(0.7025)	(0.4374)	(0.0033)
TWO * TPP	P[b]	(0.1714)	(0.3287)	(0.9124)	(0.5563)
G * TWO * TPP	P[b]	(0.5189)	(0.4438)	(0.3840)	(0.7069)

[a] Target wild oat densities in Kernen 1999 were 0, 10, 40 and 120 plants m^{-2}.

[b] Probability for main effect or interaction.

[c] Standard genotypes - AC Mustang, CDC Pacer, Riel and Triple Crown.

density did cause a significant linear increase in percent thin kernels (Table 3.10). Even though percent thin kernels did increase, values were still below the 10% maximum allowed by oat mills. A linear ($P<0.00$) decrease in thousand-kernel weight was also observed at Esk 2000 (Table 3.11). Although statistically significant, the decrease in thousand-kernel weight was minimal at 3.2%. Test weight also exhibited a small, but significant ($P<0.00$) linear decrease in response to increased wild oat density (Table 3.12). Chemical measures of quality including protein (Table 3.13) and fat (Table 3.14) were more stable than physical measures and were not affected by wild oat competition. Conversely, Friesen *et al*., (1960) found that the removal of weeds in wheat, barley and oat resulted in elevated protein levels.

3.4.3 Effect of Plant Population on Oat Yield, Quality and Wild Oat Growth Parameters

Yield increased ($P<0.05$) with increased oat plant population in all site-years with the exception of Esk 2001 where there was no difference (Table 3.3). When averaged over all genotypes and wild oat density, increased plant populations resulted in yield increases of 7.8, 4.1 and 6.5% at Kernen 1999, Kernen 2000 and Esk 2000, respectively. Similarly, yield loss was reduced ($P<0.01$) with increased plant populations at all sites except Esk 2001 (Table 3.2); however, the general trend at Esk 2001 was a reduction in yield loss with increased plant populations.

Table 3.10 The mean effect of oat genotype (G), target wild oat density (TWO) (plants m^{-2}) and oat target plant population (TPP) (plants m^{-2}), on percentage thin kernels for each site year. Probability of main effect or interaction in parenthesis.

		Thin kernel (%)			
		Kernen 1999[a]	Kernen 2000	Esk 2000	Esk 2001
G	AC Mustang	3.89	6.54	6.70	4.64
	CDC Bell	3.53	2.76	3.13	14.40
	CDC Pacer	6.09	5.82	6.27	12.30
	OT 288	5.91	7.43	7.92	8.42
	Riel	5.82	4.90	7.16	19.10
	Triple Crown	3.15	5.68	8.64	20.30
	P[b]	(0.0001)	(0.0001)	(0.0001)	(0.0001)
	LSD (0.05)	1.3	1.2	1.7	2.3
	OT288 vs. Std.[c]	(0.0211)	(0.0006)	(0.2679)	(0.0001)
	CDC Bell vs. Std.[c]	(0.0171)	(0.0001)	(0.0001)	(0.7100)
	OT 288 vs. CDC Bell	(0.0003)	(0.0000)	(0.0001)	(0.0001)
TWO	0	3.81	5.57	6.92	14.90
	15	4.54	4.75	6.37	11.30
	60	4.83	5.56	6.85	11.70
	180	5.74	6.21	6.41	15.30
	P[b]	(0.0544)	(0.2102)	(0.8833)	(0.1871)
	LSD (0.05)	NS	NS	NS	NS
	Linear	(0.0143)	(0.0987)	(0.7183)	(0.2323)
	Quadratic	(0.2061)	(0.7619)	(0.8699)	(0.1285)
TPP	250	4.71	5.13	6.20	11.70
	500	4.75	5.91	7.08	14.70
	P[b]	(0.8699)	(0.0125)	(0.0717)	(0.0012)
	LSD (0.05)	NS	0.6	NS	1.5
G * TWO	P[b]	(0.6731)	(0.4023)	(0.1235)	(0.2424)
G * TPP	P[b]	(0.0307)	(0.6110)	(0.7194)	(0.0115)
TWO * TPP	P[b]	(0.2610)	(0.6542)	(0.1977)	(0.2020)
G * TWO * TPP	P[b]	(0.0051)	(0.6481)	(0.7020)	(0.2794)

[a] Target wild oat densities in Kernen 1999 were 0, 10, 40 and 120 plants m^{-2}.

[b] Probability for main effect or interaction.

[c] Standard genotypes - AC Mustang, CDC Pacer, Riel and Triple Crown.

Table 3.11 The mean effect of oat genotype (G), target wild oat density (TWO) (plants m^{-2}) and oat target plant population (TPP) (plants m^{-2}), on thousand kernel weight (g) for each site year. Probability of main effect or interaction in parenthesis.

		Thousand kernel weight (g)			
		Kernen 1999[a]	Kernen 2000	Esk 2000	Esk 2001
G	AC Mustang	30.9	30.9	31.7	24.8
	CDC Bell	35.5	37.3	37.0	23.6
	CDC Pacer	33.9	32.7	34.2	25.0
	OT 288	29.4	29.8	30.7	23.1
	Riel	32.4	32.6	33.2	20.9
	Triple Crown	34.6	32.5	32.3	17.8
	P[b]	(0.0001)	(<0.0001)	(<0.0001)	(<0.0001)
	LSD (0.05)	0.9	1.7	1.6	1.7
	OT288 vs. Std.[c]	(0.0001)	(0.0004)	(0.0010)	(0.1375)
	CDC Bell vs. Std.[c]	(0.0001)	(<0.0001)	(<0.0001)	(0.0331)
	OT 288 vs. CDC Bell	(0.0001)	(<0.0001)	(<0.0001)	(0.5883)
TWO	0	33.0	33.0	34.8	22.0
	15	33.0	32.8	32.7	23.3
	60	33.1	32.6	33.0	23.8
	180	32.0	32.1	32.2	21.1
	P[b]	(0.2764)	(0.5095)	(0.0011)	(0.2920)
	LSD (0.05)	NS	NS	1.3	NS
	Linear	(0.0665)	(0.1412)	(0.0040)	(0.2536)
	Quadratic	(0.7179)	(0.8042)	(0.1592)	(0.1428)
TPP	250	32.8	33.2	33.7	23.1
	500	32.8	32.0	32.7	22.0
	P[b]	(0.9796)	(0.0021)	(0.0272)	(0.1392)
	LSD (0.05)	NS	0.7	0.9	NS
G * TWO	P[b]	(0.0863)	(0.4393)	(0.0799)	(0.5825)
G * TPP	P[b]	(0.0004)	(0.0776)	(0.7385)	(0.0642)
TWO * TPP	P[b]	(0.0695)	(0.1471)	(0.0234)	(0.6045)
G * TWO * TPP	P[b]	(0.3942)	(0.2085)	(0.9210)	(0.7118)

[a] Target wild oat densities in Kernen 1999 were 0, 10, 40 and 120 plants m^{-2}.

[b] Probability for main effect or interaction.

[c] Standard genotypes - AC Mustang, CDC Pacer, Riel and Triple Crown.

Table 3.12 The mean effect of oat genotype (G), target wild oat density (TWO) (plants m^{-2}) and oat target plant population (TPP) (plants m^{-2}), on oat test weight (kg hl^{-1}) for each site year. Probability of main effect or interaction in parenthesis.

		Test weight (kg hl^{-1})			
		Kernen 1999[a]	Kernen 2000	Esk 2000	Esk 2001
G	AC Mustang	44.6	50.4	49.4	39.5
	CDC Bell	44.9	48.1	50.7	35.4
	CDC Pacer	47.9	50.6	50.0	41.4
	OT 288	49.2	51.7	50.1	41.2
	Riel	50.3	52.0	51.8	38.6
	Triple Crown	49.8	49.6	49.6	32.8
	P[b]	(0.0001)	(0.0001)	(0.0001)	(0.0001)
	LSD (0.05)	1.7	0.7	0.5	1.8
	OT288 vs. Std.[c]	(0.1179)	(0.0003)	(0.5598)	(0.0001)
	CDC Bell vs. Std.[c]	(0.0001)	(<0.0001)	(0.0131)	(0.0004)
	OT 288 vs. CDC Bell	(<0.0001)	(<0.0001)	(0.0153)	(0.0001)
TWO	0	48.8	50.6	50.0	37.5
	15	48.6	50.7	50.3	39.2
	60	47.8	50.0	50.3	39.1
	180	45.9	50.4	50.5	36.9
	P[b]	(0.0003)	(0.0563)	(0.7969)	(0.5198)
	LSD (0.05)	1.4	NS	NS	NS
	Linear	(0.0001)	(0.3230)	(0.3922)	(0.4123)
	Quadratic	(0.3735)	(0.0227)	(0.7651)	(0.3004)
TPP	250	47.9	50.2	50.5	38.2
	500	47.7	50.6	50.0	38.1
	P[b]	(0.6491)	(0.0447)	(0.0010)	(0.9545)
	LSD (0.05)	NS	0.3	0.3	NS
G * TWO	P[b]	(0.7715)	(0.9295)	(0.2705)	(0.8914)
G * TPP	P[b]	(0.5508)	(0.0614)	(0.0001)	(0.0565)
TWO * TPP	P[b]	(0.0083)	(0.8840)	(0.1241)	(0.2990)
G * TWO * TPP	P[b]	(0.1556)	(0.6394)	(0.0076)	(0.7534)

[a] Target wild oat densities in Kernen 1999 were 0, 10, 40 and 120 plants m^{-2}.

[b] Probability for main effect or interaction.

[c] Standard genotypes - AC Mustang, CDC Pacer, Riel and Triple Crown.

Table 3.13 The mean effect of oat genotype (G), target wild oat density (TWO) (plants m^{-2}) and oat target plant population (TPP) (plants m^{-2}), on percentage oat groat protein for each site year. Probability of main effect or interaction in parenthesis.

		Protein (%)			
		Kernen 1999[a]	Kernen 2000	Esk 2000	Esk 2001
G	AC Mustang	15.6	11.5	12.5	20.1
	CDC Bell	18.4	15.2	14.0	21.7
	CDC Pacer	16.0	13.4	12.9	19.0
	OT 288	18.9	14.3	13.9	21.6
	Riel	18.8	13.8	13.5	21.9
	Triple Crown	17.7	13.9	12.8	19.7
	P[b]	(0.0001)	(0.0001)	(0.0001)	(0.0001)
	LSD (0.05)	0.4	0.5	0.6	1.3
	OT288 vs. Std.[c]	(<0.0001)	(0.0001)	(0.0001)	(0.0089)
	CDC Bell vs. Std.[c]	(<0.0001)	(0.0001)	(0.0001)	(0.0043)
	OT 288 vs. CDC Bell	(0.0473)	(0.0006)	(0.9629)	(0.8270)
TWO	0	17.1	13.8	13.2	20.3
	15	17.8	13.4	13.4	21.5
	60	17.6	13.8	13.3	20.6
	180	17.7	13.6	13.1	20.5
	P[b]	(0.5127)	(0.7619)	(0.8741)	(0.2968)
	LSD (0.05)	NS	NS	NS	NS
	Linear	(0.5492)	(0.7781)	(0.6049)	(0.5566)
	Quadratic	(0.3476)	(0.7991)	(0.8226)	(0.8159)
TPP	250	17.4	13.7	13.1	20.6
	500	17.7	13.7	13.4	20.7
	P[b]	(0.0632)	(0.7982)	(0.0546)	(0.8070)
	LSD (0.05)	NS	NS	NS	NS
G * TWO	P[b]	(0.6198)	(0.7871)	(0.6696)	(0.5662)
G * TPP	P[b]	(0.1547)	(0.1452)	(0.7789)	(0.4566)
TWO * TPP	P[b]	(0.4882)	(0.2051)	(0.0489)	(0.8048)
G * TWO * TPP	P[b]	(0.2247)	(0.7818)	(0.1704)	(0.4385)

[a] Target wild oat densities in Kernen 1999 were 0, 10, 40 and 120 plants m^{-2}.

[b] Probability for main effect or interaction.

[c] Standard genotypes - AC Mustang, CDC Pacer, Riel and Triple Crown.

Table 3.14 The mean effect of oat genotype (G), target wild oat density (TWO) (plants m^{-2}) and oat target plant population (TPP) (plants m^{-2}), on percentage oat groat fat for each site year. Probability of main effect or interaction in parenthesis.

		Fat (%)			
		Kernen 1999[a]	Kernen 2000	Esk 2000	Esk 2001
G	AC Mustang	5.08	6.93	6.18	4.53
	CDC Bell	5.09	5.56	6.03	5.66
	CDC Pacer	6.05	6.78	7.04	4.95
	OT 288	6.22	7.05	7.21	5.86
	Riel	5.84	6.46	6.83	5.28
	Triple Crown	5.41	6.03	6.54	6.55
	P[b]	(0.0001)	(0.4837)	(0.0001)	(0.2061)
	LSD (0.05)	0.1	NS	0.2	NS
	OT288 vs. Std.[c]	(0.0001)	(0.4632)	(0.0001)	(0.4190)
	CDC Bell vs. Std.[c]	(0.0001)	(0.1490)	(0.0001)	(0.6164)
	OT 288 vs. CDC Bell	(0.0001)	(0.0871)	(0.0001)	(0.8097)
TWO	0	5.67	6.28	6.57	5.22
	15	5.59	6.20	6.71	5.30
	60	5.57	6.15	6.63	6.13
	180	5.63	7.24	6.63	5.25
	P[b]	(0.2261)	(0.4272)	(0.5783)	(0.5113)
	LSD (0.05)	NS	NS	NS	NS
	Linear	(0.7669)	(0.1392)	(0.9823)	(0.9568)
	Quadratic	(0.5200)	(0.4996)	(0.6788)	(0.1563)
TPP	250	5.61	6.71	6.67	5.16
	500	5.61	6.22	6.61	5.78
	P[b]	(0.9283)	(0.3525)	(0.2901)	(0.1979)
	LSD (0.05)	NS	NS	NS	NS
G * TWO	P[b]	(0.3482)	(0.4349)	(0.0383)	(0.4368)
G * TPP	P[b]	(0.3038)	(0.4040)	(0.0197)	(0.4293)
TWO * TPP	P[b]	(0.9051)	(0.4655)	(0.3946)	(0.3914)
G * TWO * TPP	P[b]	(0.0638)	(0.3727)	(0.7004)	(0.4422)

[a] Target wild oat densities in Kernen 1999 were 0, 10, 40 and 120 plants m^{-2}.

[b] Probability for main effect or interaction.

[c] Standard genotypes - AC Mustang, CDC Pacer, Riel and Triple Crown.

Yields at a plant population of 500 plants m^{-2} were expected to be considerably lower at Esk 2001 due to the dry conditions (Table 3.1). Nevertheless, yield was only reduced by 85 kg ha^{-1} as a result of increased plant populations. Consequently, increased plant populations in oat appear to provide a means by which to reduce the effect of wild oat on oat yield under varying environmental conditions. Similarly, Martin *et al*. (1987) found that increased wheat plant populations could reduce yield loss due to the presence of wild oat.

In both years at Kernen there was a differential yield response ($P<0.05$) to plant population among genotypes (Table 3.3). Although increased plant populations generally resulted in increased yields, differences were not significant for CDC Bell and Riel at Kernen 1999 (Figure 3.6). Differences in yields were not significant at Kernen 2000 for AC Mustang, CDC Pacer and Riel. As oat emergence was relatively uniform across all genotypes, the inconsistent response to plant population among genotypes may be a seed source effect as different seed lots were used in 1999 and 2000. Mohler (1996) suggests that less competitive species will exhibit the largest response to increased plant population while those that are highly competitive will exhibit little to no response. OT 288 and Triple Crown always exhibited a yield response to increased plant populations, suggesting that they may be among the least competitive of the genotypes examined.

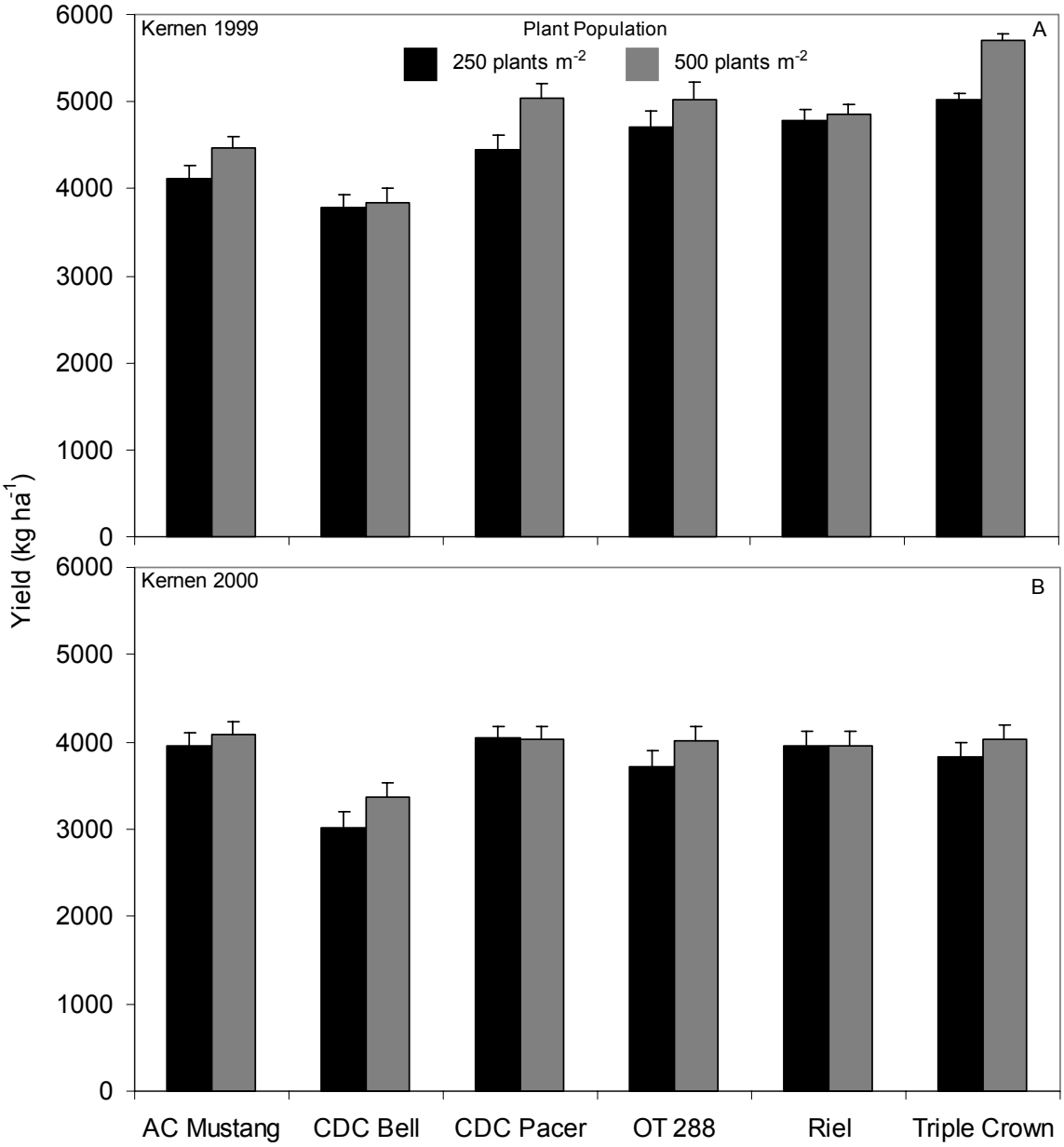


Figure 3.6 Effect of increasing plant population on grain yield (kg ha^{-1}) of six western Canadian oat genotypes averaged over four wild oat densities at Kernen 1999 (A) (0, 10, 40 and 120 plants m^{-2}) and Kernen 2000 (B) (0, 15, 60 and 180 plants m^{-2}). Standard error bars represent standard errors of the means.

Generally, increased plant population resulted in increased yield and elevated tolerance to wild oat competition; however, increased plant population also affected wild oat biomass production, which decreased with increased plant populations in all site-years (Table 3.5). Under the increased plant population, wild oat biomass was

reduced by 40, 43, 24 and 24% at Kernen 1999, Kernen 2000, Esk 2000 and Esk 2001, respectively. Similar findings have been reported by Lemerle *et al*. (1996), who reported a 25% reduction in annual ryegrass biomass by doubling the seeding rate of wheat. Differences in wild oat biomass production (Table 3.5) were similar to differences in wild oat seed production as increased plant populations reduced seed production by 43, 32, 22 and 21% ($P<0.01$) at Kernen 1999, Kernen 2000, Esk 2000 and Esk 2001, respectively. Other reported results have been similar, as increasing wheat seeding rate from 260 to 530 seeds m^{-2} reduced cheat grass (*Bromus secalinus* L.) seed production by 25% (Koscelny *et al*., 1990).

Both wild oat biomass and seed production were generally reduced under increased plant population (Tables 3.5 and 3.6); however, genotypes responded differently to increased plant population at Kernen 2000 and Esk 2001. Wild oat biomass was generally reduced with increased plant population at Kernen 2000 and Esk 2001; however, wild oat biomass only differed ($P<0.05$) between plant population for AC Mustang and OT 288 at Kernen 2000, while differences ($P<0.05$) are only observed for CDC Bell and OT 288 at Esk 2001 (Figures 3.7A and 3.7B). Paradoxically, wild oat biomass was greater ($P<0.05$) at the high plant population in those plots sown to Triple Crown at Esk 2001. Triple Crown was the lowest yielding of all genotypes under the drought conditions experienced at Esk 2001 (Table 3.1). The interaction between genotype and plant population was also significant for wild oat seed return at Esk 2001 (Table 3.6). Wild oat seed production was reduced ($P<0.05$) by increased plant population only in CDC Bell and OT 288 at Esk 2001 (Figure 3.8), reflecting the results for wild oat biomass (Figure 3.7B). The reduction in wild oat biomass from increased

plant population were larger for OT 288 than the other genotypes providing further proof that increased plant populations have a greater effect on non-competitive genotypes (Figure 3.7).

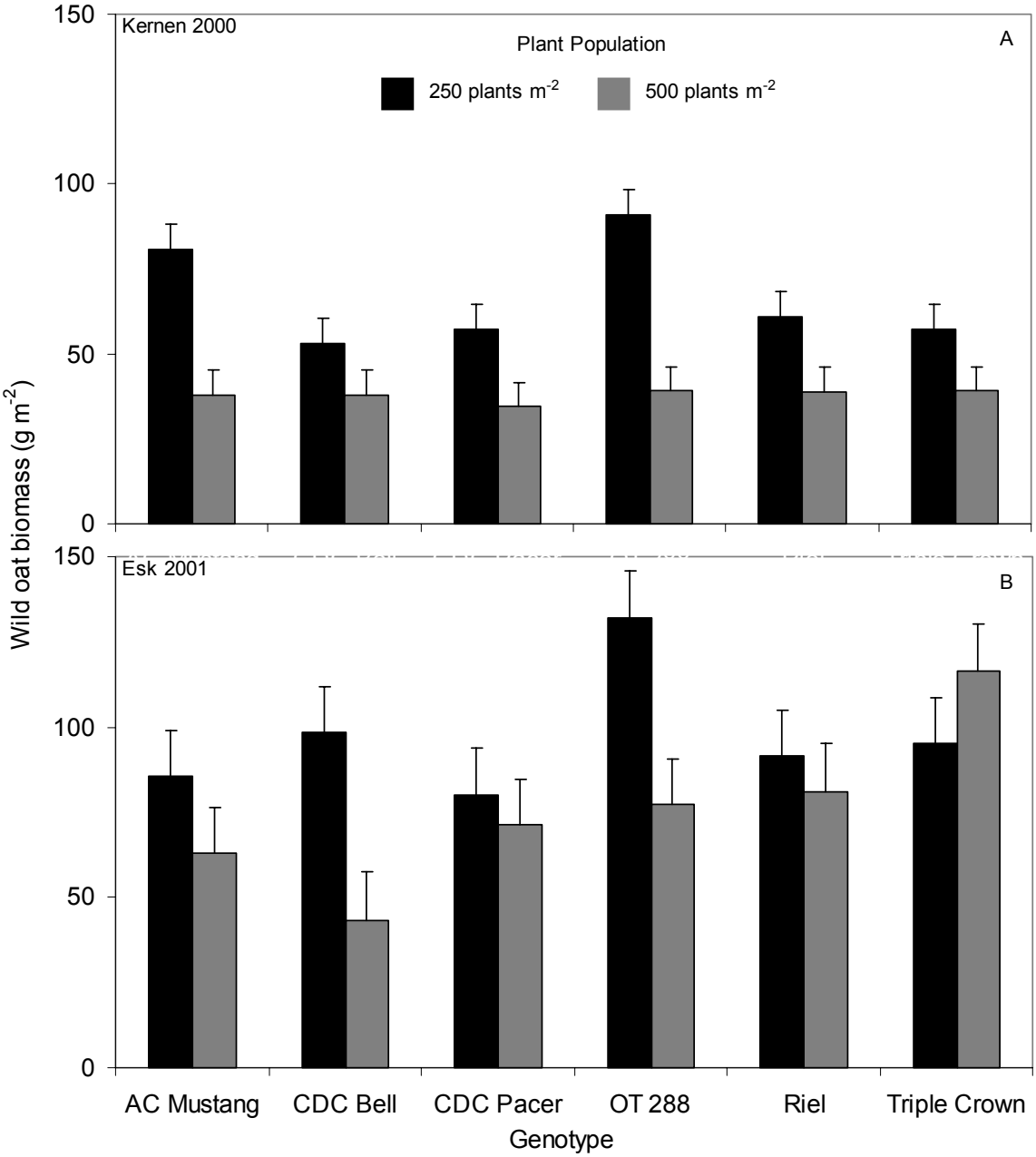


Figure 3.7 Effect of increasing plant population on wild oat biomass (g m^{-2}) of six western Canadian oat genotypes averaged over three wild oat densities at Kernen 2000 (A) and Esk 2001 (B). Standard error bars represent standard errors of the means.

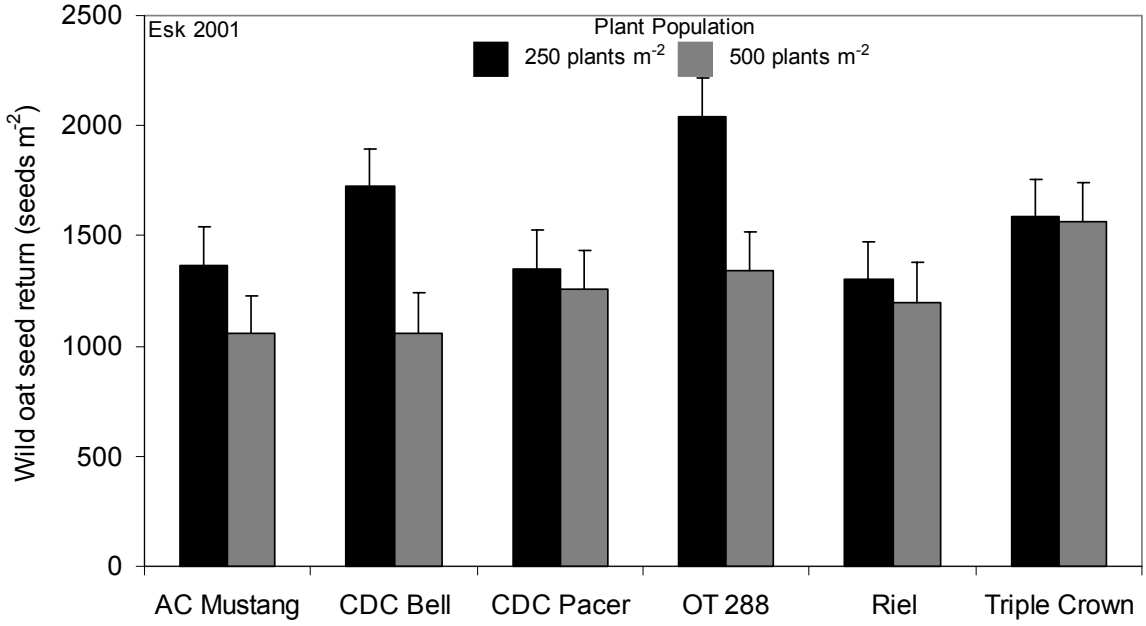


Figure 3.8 Effect of increasing plant population on wild oat seed return (seeds m^{-2}) of six western Canadian oat genotypes averaged over three wild oat densities at Esk 2001. Standard error bars represent standard errors of the means.

Oat plant population had a greater effect on wild oat biomass at higher wild oat densities in all years with the exception of Esk 2001 ($P<0.05$) (Table 3.5, Figure 3.9). Although differences were only observed at higher wild oat densities, the general trend was a reduction in wild oat biomass with increased plant population. In both years at Kernen, plant population only had an effect on wild oat biomass production at the two highest wild oat densities. At Kernen 1999, increased plant population resulted in wild oat biomass being reduced by 44 and 37% at target wild oat density of 40 and 120 plants m^{-2}, respectively. Similarly at Kernen 2000, wild oat biomass was reduced by 49 and 40% as a result of increased plant population at target wild oat density of 60 and 180 plants m^{-2}. Wild oat biomass only differed ($P<0.05$) between plant population at a target wild oat density of 180 plants m^{-2} at Esk 2000. Wild oat density by plant population interactions were also significant for wild oat seed production at Kernen

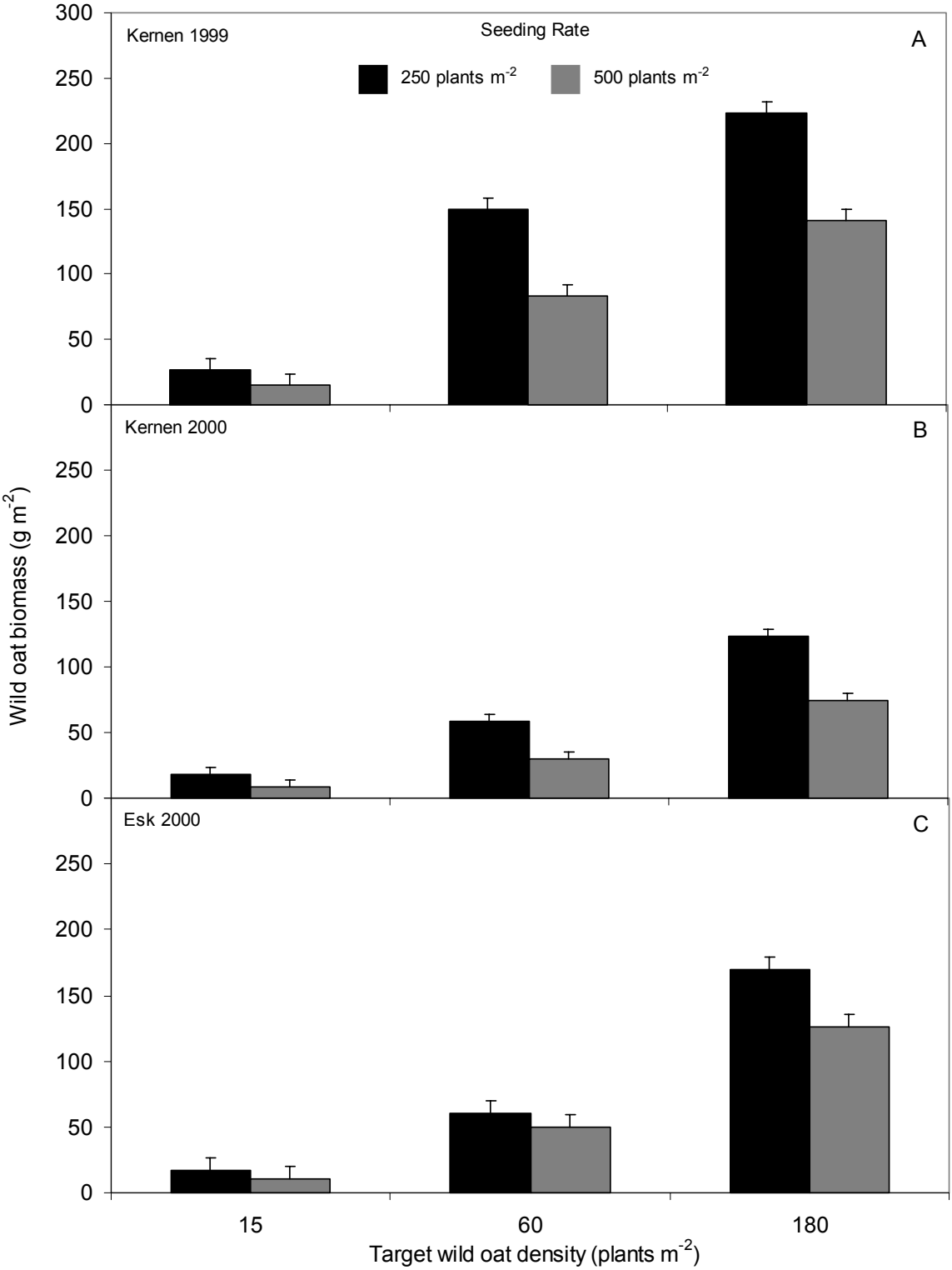


Figure 3.9 Effect of plant population (250 and 500 plants m^{-2}) and target wild oat density on wild oat biomass at Kernen 1999 (A) (Target wild oat density :10, 40 and 120 plants m^{-2}), Kernen 2000 (B) and Esk 2000 (C) (Target wild oat density : 15, 60 and 180 plants m^{-2}). Values are presented as means of all genotypes. Standard error bars represent standard errors of the means.

1999 and Esk 2000, with seed production only varying between plant populations at target wild oat density of 40 and 120 plants m^{-2} at Kernen 1999 and at a wild oat density of 180 plants m^{-2} at Esk 2000 (Table 3.6). A three-way interaction was also observed ($P<0.00$) for wild oat biomass at Kernen 2000, but no logical pattern in the interaction could be discerned.

As increased plant population reduced wild oat biomass and seed production, PWO also varied ($P<0.00$) between plant populations over all site-years (Table 3.7). PWO was 0.55, 0.81, 1.11 and 0.82% lower at a plant population of 500 plants m^{-2} than at a plant population of 250 plants m^{-2} at Kernen 1999, Kernen 2000, Esk 2000 and Esk 2001, respectively. In all years, with the exception of Kernen 2000, the effect of increased plant populations on PWO was consistent among genotypes (Table 3.7). Nevertheless, PWO did not vary between plant populations for CDC Bell at Kernen 2000, possibly reflecting the greater competitive ability of this genotype. Additionally, a three-way interaction was observed ($P<0.05$) for PWO at Kernen 2000. Comparable to the findings for wild oat biomass and seed production, PWO only varied between plant populations at higher wild oat density, as indicated by the presence of a wild oat density by plant population interaction (Table 3.7). PWO varied ($P<0.05$) between plant populations at the highest wild oat density at Kernen 1999, Esk 2000 and Esk 2001, while differences were significant at the two highest densities at Kernen 2000 (Figure 3.10). Although increasing plant population reduced wild oat growth, they may also negatively affect physical measures of oat quality with the exception of PWO. The lack of moisture received during the critical grain-filling stages (Table 3.1) may be why a reduction in plump kernels was observed at higher plant populations at Esk 2000 and

Esk 2001 (Table 3.9). Furthermore, only 12 millimeters of precipitation was received between May 21 and July 13 at Esk 2001. This precipitation was followed by considerable rainfall in the last half of July resulting in secondary growth. Early-season drought, coupled with secondary growth at Esk 2001 may account for the reduction in plump kernels. Increased plant population also resulted in an increase in thin kernels at Kernen 2000 and Esk 2001 (Table 3.10); however, percent thin kernels only exceeded the milling industry standard of 10% at Esk 2001, under drought conditions. This increase in thin kernels is inconsequential as under these growing conditions none of the treatments resulted in milling quality oat. The effect of increased plant population on percent thin kernels is greater for some genotypes than others, as indicated by the presence of genotype by plant population interactions at Kernen 1999 and Esk 2001 (Table 3.10). At Kernen 1999, percent thin kernels only varied ($P<0.05$) between plant populations for CDC Bell; however, CDC Bell was not developed for milling purposes and therefore one would expect milling characteristics of this genotype to be affected more than the others. Under the dry conditions experienced at Esk 2001, percent thin kernels varies ($P<0.01$) between plant populations for CDC Bell, Riel and Triple Crown. Although a three-way interaction was observed ($P<0.01$) for percent thin kernels at Kernen 1999 (Table 3.10) it is of little practical significance.

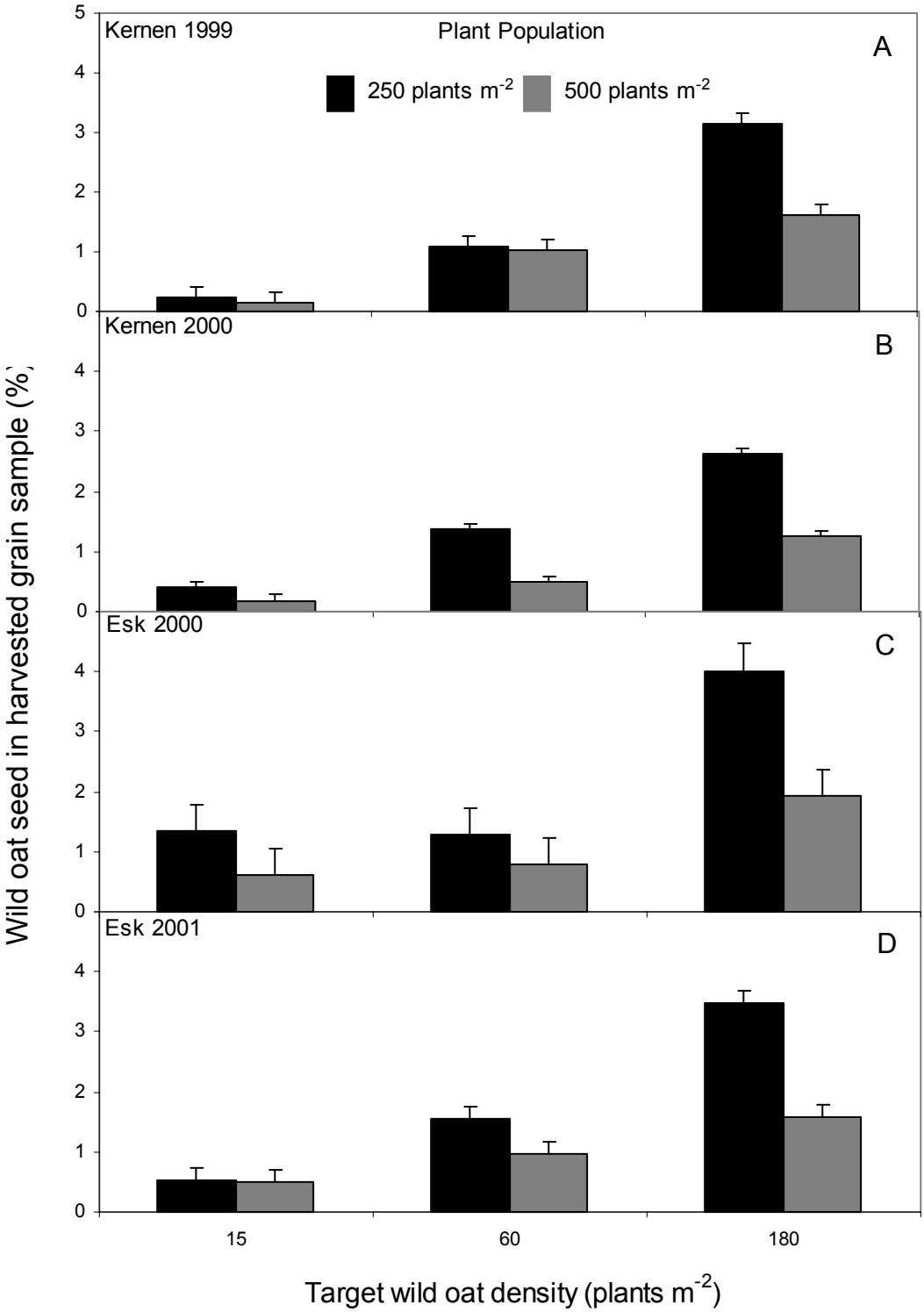


Figure 3.10 Effect of plant population (250 and 500 plants m^{-2}) and target wild oat density on wild oat seed in harvested samples (%) at Kernen 1999 (A) (Target wild oat density : 10, 40 and 120 plants m^{-2}), Kernen 2000 (B) and Esk 2000 (C) (Target wild oat density : 15, 60 and 180 plants m^{-2}) and Esk 2001 (D) (Target wild oat density : 15, 60, 180 plants m^{-2}). Values are presented as means of all genotypes. Standard error bars represent standard errors of the means.

The effects of increased plant population on test weight were inconsistent (Table 3.12) as test weight varied ($P<0.05$) between plant population at both sites in 2000. Test weight increased by 0.35 kg hl^{-1} at Kernen 2000 and fell by 0.52 kg hl^{-1} at Esk 2000 as a result of doubling plant populations. Furthermore, genotype response to increased plant population varied ($P<0.00$) at Esk 2000, as increased plant population only affected the test weight of AC Mustang and CDC Pacer. Furthermore, a three-way interaction ($P<0.01$) was observed for test weight at Esk 2000; however, no real effect was apparent. Groat percentage (Table 3.8), which provides a measure of milling yield was unaffected by increased plant populations.

Chemical characteristics measured on whole oat samples included fat and protein. These characteristics were more stable in their response to increase plant populations than the physical characteristics. Plant population did not have an effect on either protein or fat (Tables 3.13 and 3.14). Genotype by plant population interactions were significant at Esk 2000 for oat fat; however, interactions do not follow a trend and appear to be the result of environment.

3.5 Summary and Conclusions

This experiment investigated the effect of genotype and seeding rate on oat and wild oat competition. The effect of increased seeding rate and wild oat competition on oat quality was also examined. The results suggest that oat genotypes do differ in competitive ability with wild oat and can therefore be used as part of an integrated weed management system.

The semi-dwarf genotype, OT 288, was negatively affected to the greatest extent by wild oat competition; however, when the seeding rate of this genotype was increased, the effects of wild oat competition were reduced. CDC Bell, the genotype possessing the morphological characteristics most associated with strong competitive ability, was the most competitive; however, this genotype lacked the weed-free yield potential that the other genotypes displayed. This genotype was able to both tolerate the presence of wild oat as well as interfere with their growth.

The use of increased seeding rates reduced both yield loss and wild oat seed production. This practice did however negatively impact oat quality in some cases, namely percent plump kernels, and may impact the marketability of the harvested product. Furthermore, oat quality was not reduced by wild oat competition, with the exception of percent plump kernels. These results suggest that the use of increased seeding rate and the use of competitive genotypes may play a vital role in the integrated management of wild oat in oat production.

4.0 Effect of Genotype, Seed Size and Osmotic Moisture Stress on Germination Characteristics of Oat

4.1 Introduction

The competitive advantage obtained by earlier emerging plants is often due to the development of a size bias and resulting asymmetric competition in which one plant obtains a disproportionately large portion of the available resources (O'Donovan *et al*., 1985; Gonzalez Ponce, 1987; Freckleton and Watkinson, 2001). Although the growth of both competing species may be reduced, those species emerging later are most affected by competition. Research examining the effect of time of wild oat emergence on wheat and barley yield indicated that the relative time of emergence of the respective species might have considerable effects on crop yield loss (O'Donovan *et al*., 1985). Wild oat emerging successively earlier than wheat or barley affect grain yield more than those emerging later. Rapid germination and subsequent emergence of a crop may therefore result in a competitive advantage.

Differences germination rate have been identified among crop genotypes (Ashraf and Abu-Shakra, 1978; Lafond and Baker, 1986b). Middle-eastern wheat genotypes exhibited differential rates of germination under low temperature and moisture stress (Ashraf and Abu-Shakra, 1978). These differences indicate the potential to select for genotypes that have rapid germination and emergence.

Seed size can affect crop germination (Mathur *et al*., 1982; Lafond and Baker, 1986a; Lafond and Baker 1986b; Guberac *et al*., 1998), growth (Kaufmann and Guitard,

1967; Ries and Everson, 1973) and yield (Kaufmann and McFadden, 1960). Lafond and Baker (1986a; 1986b) found small seed size to be associated with a high rate of germination and emergence in wheat cultivars; however, the subsequent plants accumulated less dry matter and could therefore be presumed to be less competitive than plants grown from larger seeds. Nevertheless, seed size does not always have an effect on yield (Mian and Nafziger, 1992; Gan and Stobbe, 1998).

Planting oat genotypes or sized seed lots that have the ability to germinate quickly may impart a competitive advantage over wild oat. The objective of this study was to determine if differential rates of germination exist among different oat seed sizes and different oat genotypes.

4.2 Materials and Methods

A three – factor, completely randomized design was used to test the effects of osmotic stress (OMS) and seed size (S) on the germination of six oat genotypes (G). Experiments were conducted at the University of Saskatchewan. Each treatment was replicated four times and the study was performed in October and December of 2001. The study was conducted in a Hotpack growth cabinet (Hotpack Corporation, Philadelphia, PA.) under total darkness at a temperature of 5°C. Genotypes examined included AC Mustang, CDC Bell, CDC Pacer, OT 288, Riel and Triple Crown. The seedlots used came from a common field experiment grown in 2000. All genotypes exhibited germination over 97% in distilled water. The seed was separated into three fractions using number 5, 6 and 7 sieves (Canada Seed Equipment Limited, 332 Packham Avenue, Saskatoon, Saskatchewan, Canada, S7N 2T1), with openings of 1.95, 2.35 and 2.74 by 8.33 mm, respectively. For each genotype seed samples were selected from the seed retained on the number 5 (medium) and 6 (large) sieves as well as from the seed passing through the number 5 (small) sieve. Subsequent to fractionation, further culling was done to remove all damaged seeds. Two 200 seed sub – samples were used to determine the 1000-kernel weight (KWT) for each fractionated seed size (Table 4.1).

Table 4.1 Thousand-kernel weights (g) of fractionated seed samples for each genotype

Genotype	Small	Medium	Large
AC Mustang	13.9	26.4	32.8
CDC Bell	10.2	30.9	40.9
CDC Pacer	16.4	29.2	38.7
OT 288	16.4	27.2	39.1
Riel	14.8	29.4	40.0
Triple Crown	12.7	27.8	36.4

Forty seeds of each sample were placed in disposable petri dishes (10-cm diameter) that were lined with two pieces of Whatman No. 8 filter paper. Eight ml of distilled water or osmotic solution (-0.2, -0.4 MPa) were added to each dish. Each petri dish constituted an experimental unit. Polyethylene glycol 8000 (Sigma Chemical Company, St. Louis MO.) was used as an osmoticum as it can increase osmotic potential but cannot enter the seed and disrupt germination (Hardegree and Emmerich, 1994). Osmotic potentials was corrected for temperature and determined as described by Michel (1983). Germinated seeds were enumerated and removed every 24 hours for a period of two weeks. After two weeks, seeds that failed to germinate were counted. Germination was assumed to have occurred when the radicle emerged and grew to a length of approximately 2 mm.

Median germination time (MGT) was used to characterize germination, as described by Lafond and Baker (1986b). The following steps were used to determine median germination time (MGT) and germination rate. First, cumulative percent germination (P_t) was determined at each measurement interval using the following equation:

$$P_t = n_t / N \qquad [1]$$

Where n_t is the number of seeds germinated at time t, and N is the total number of seeds germinated. All P_t values were then transformed to logits in order to linearize the germination curve, using the following relationship:

$$\text{logit } P_t = \ln [P_t / (1-P_t)] \qquad [2]$$

The logit was then regressed against the natural log of time using a weighted linear regression in the REG procedure of SAS (SAS Inst., 1996) with weights:

$$Wt = N(Pt)(1-Pt) \quad [3]$$

The a and b values which represent the logit transformation of the intercept and the logit transformation of the slope, respectively, are determined from the weighted regression on each experimental unit. Using a weighted linear regression reduces the importance of the asymptotes and places more prominence on the slope of the curve. The a and b values were then used to estimate MGT:

$$MGT = \exp(-a/b) \quad [4]$$

The following equation characterized seed germination:

$$P_t = 1 / [\ 1 + \exp\ (-a - b(\ln t))] \quad [5]$$

P_t is the cumulative percent germination, a is the y-intercept, b is the slope and t is the time in hours from the commencement of the experiment. Data however was not directly fit to this equation.

Median germination time provides a measure of the point in time (hours) at which 50% of seed that have germinated at the conclusion of the experiment have germinated. Nevertheless, median germination time alone is not an adequate descriptor of germination characteristics as two treatments may have the same median germination time yet the seeds may germinate at different rates. Germination rate was therefore used to further describe the germination characteristics for each treatment. The germination rate was obtained from the b value, which represents the logit transformation of the slope. Furthermore, total percent germination was obtained by dividing the number of seeds germinated at completion of the experiment by the total number of seeds within each experimental unit. Differences in median germination time, cumulative germination rate and percent germination were tested using PROC

GLM of SAS (SAS Inst., 1996). All treatment factors were fixed. Individual runs of the experiment were analyzed individually. Means were separated with a protected least significant difference at the $P < 0.05$ level.

4.3 Results and Discussion

4.3.1 Treatment Effects on Median Germination Time of Oat Genotypes

Three – way interactions were significant for MGT in both run 1 (P<0.01) and run 2 (P<0.01) (Table 4.2), indicating that seed size affected the median germination time in different oat genotypes at different osmotic stress levels. Examination of the three – way interaction in run 1 indicated that the large seed size CDC Bell and Riel were relatively unaffected by increasing osmotic stress (Figure 4.1).

Table 4.2 Analysis of variance of main effects and interactions for median germination time (h) for six oat genotypes (G), three seed sizes (S) and three osmotic stress (OMS) levels for two runs of the experiment.

Source	DF	Type III SS	Mean Square	F Value	P
			Run 1		
G	5	47571.66	9514.33	37.26	(<0.0001)
S	2	28664.84	14332.42	56.12	(<0.0001)
OMS	2	169468.12	84734.06	331.81	(<0.0001)
G * S	10	30336.54	3033.65	11.88	(<0.0001)
G * OMS	10	56589.34	5658.93	22.16	(<0.0001)
S * OMS	4	11727.83	2931.96	11.48	(<0.0001)
G * S * OMS	20	54203.46	2710.17	10.61	(<0.0001)
			Run 2		
G	5	41467.83	8293.57	54.78	(<0.0001)
S	2	23353.09	11676.55	77.12	(<0.0001)
OMS	2	156047.44	78023.72	515.31	(<0.0001)
G * S	10	18083.74	1808.37	11.94	(<0.0001)
G * OMS	10	20600.05	2060.00	13.61	(<0.0001)
S * OMS	4	1800.37	450.09	2.97	(0.0200)
G * S * OMS	20	7861.41	393.07	2.60	(<0.0001)

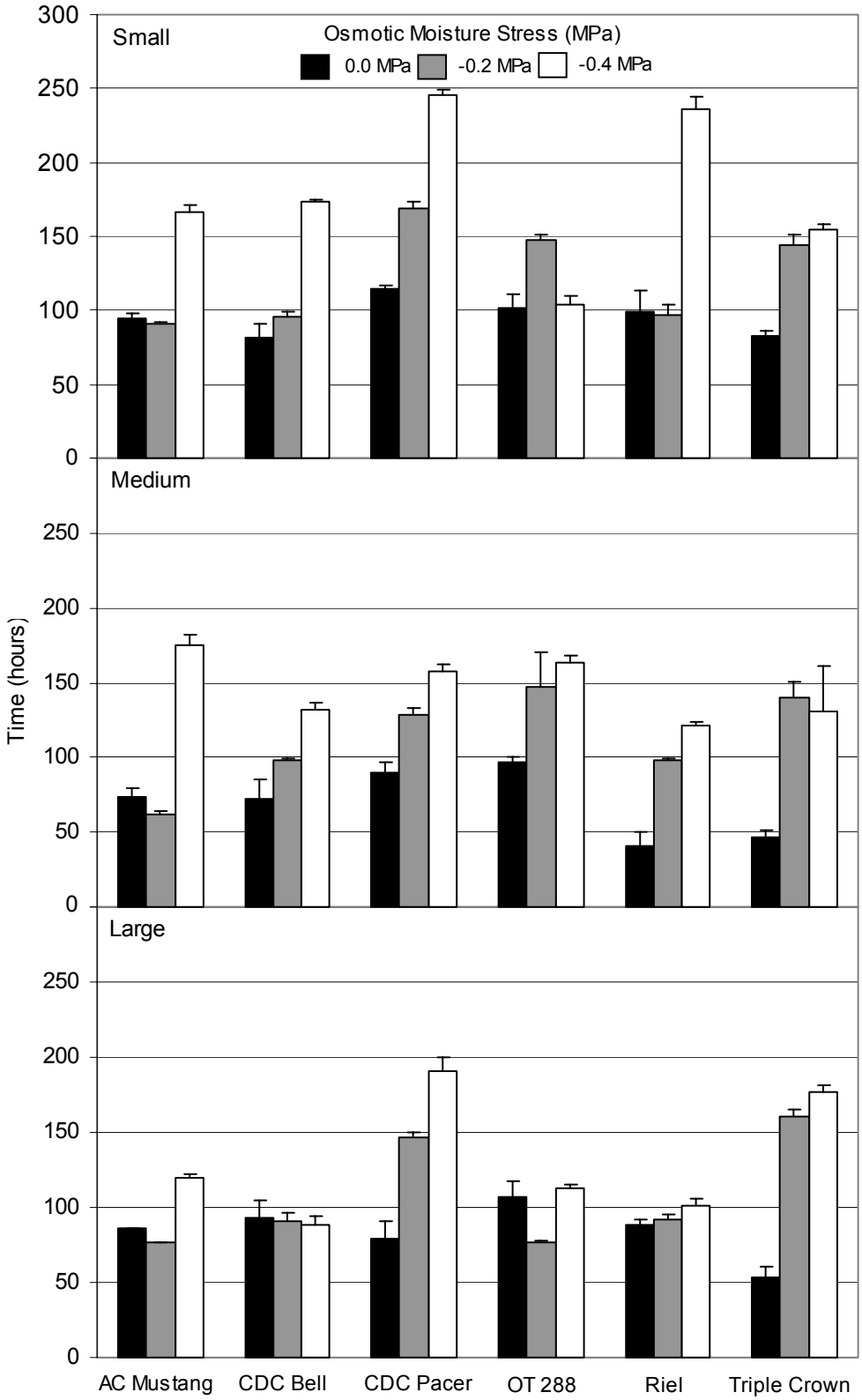


Figure 4. 1 Run 1 - Effect of seed size and osmotic stress on the median germination time of six western Canadian oat genotypes. Standard error bars represent standard errors of the means.

When the small and medium sized fractions of CDC Bell and Riel were subject to increasing osmotic stress, an increase in median germination time was observed; however, when the large fraction of the seedlot was subject to increasing osmotic stress, increases in median germination time were nominal. The difference in median germination time between the Riel samples (large seed fraction) subjected to 0.0 and –0.4 MPa moisture stress was only 12.3 hours, while the CDC Bell sample (large seed fraction) subjected to –0.4 MPa moisture stress had a median germination time 5.3 hours less than the sample not subjected to moisture stress. These findings are of agronomic importance, as there appear to be genotypes and seed sizes that are better able to germinate under dry spring soil conditions. Furthermore, if the ability to germinate under moisture stress was associated with the ability to emerge under poor moisture conditions, competitive ability may improve as early emergence has been coupled with increased competitive ability (O'Donovan *et al*., 1985).

Although the three – way interaction was significant for the second run of the experiment (Table 4.2), the same trends were not observed for CDC Bell and Riel (Figure 4.2). This discrepancy may be due to changes in the germination characteristics of the seedlot. Prior to the run of the first experiment, all seed was stored under cool conditions at the Kernen Research Farm, Saskatoon, Saskatchewan. During the time elapsed between the first and second runs of the experiment the seed was stored under room temperature. This change in storage conditions may have affected the germination rate, median germination time and percent germination of the seedlots.

The common trend observed in the thee – way interactions in run 1 and 2 was that all seed fractions of AC Mustang were relatively unaffected by increasing osmotic

stress until it reached –0.4 MPa (Figures 4.1 and 4.2). Conversely, all other genotypes, with the exception of CDC Bell and Riel, tended to exhibit increased median germination times with an increase in OMS from 0.0 to –0.2 MPa. This finding is of particular importance as AC Mustang also had the second lowest mean median germination time of the six genotypes examined in both runs 1 and 2 (Table 4.3). The low median germination time observed in AC Mustang as well as its ability to maintain median germination time under moderate moisture stress may be due to the ability of the seed to rapidly imbibe. Agronomically, it appears as though AC Mustang would be the genotype to plant if seeding into dry conditions, as it is the least affected by increasing osmotic stress and also has a low median germination time.

Table 4. 3 The mean effect of genotype, seed size and osmotic stress (MPa) on median germination time (h) for each experimental replication.

	Median Germination Time (Hours)	
	Run 1	Run 2
Genotype		
AC Mustang	104.8	180.2
CDC Bell	102.9	176.2
CDC Pacer	146.7	215.0
OT 288	117.3	199.8
Riel	108.7	207.2
Triple Crown	121.2	192.5
LSD	7.48	5.75
Seed Size		
Small	133.7	209.5
Medium	109.6	187.9
Large	107.9	187.9
LSD	5.28	1.02
Osmotic Moisture Stress		
0.0 MPa	83.3	162.6
-0.2 MPa	114.4	193.3
-0.4 MPa	153.4	228.7
LSD	5.47	4.07

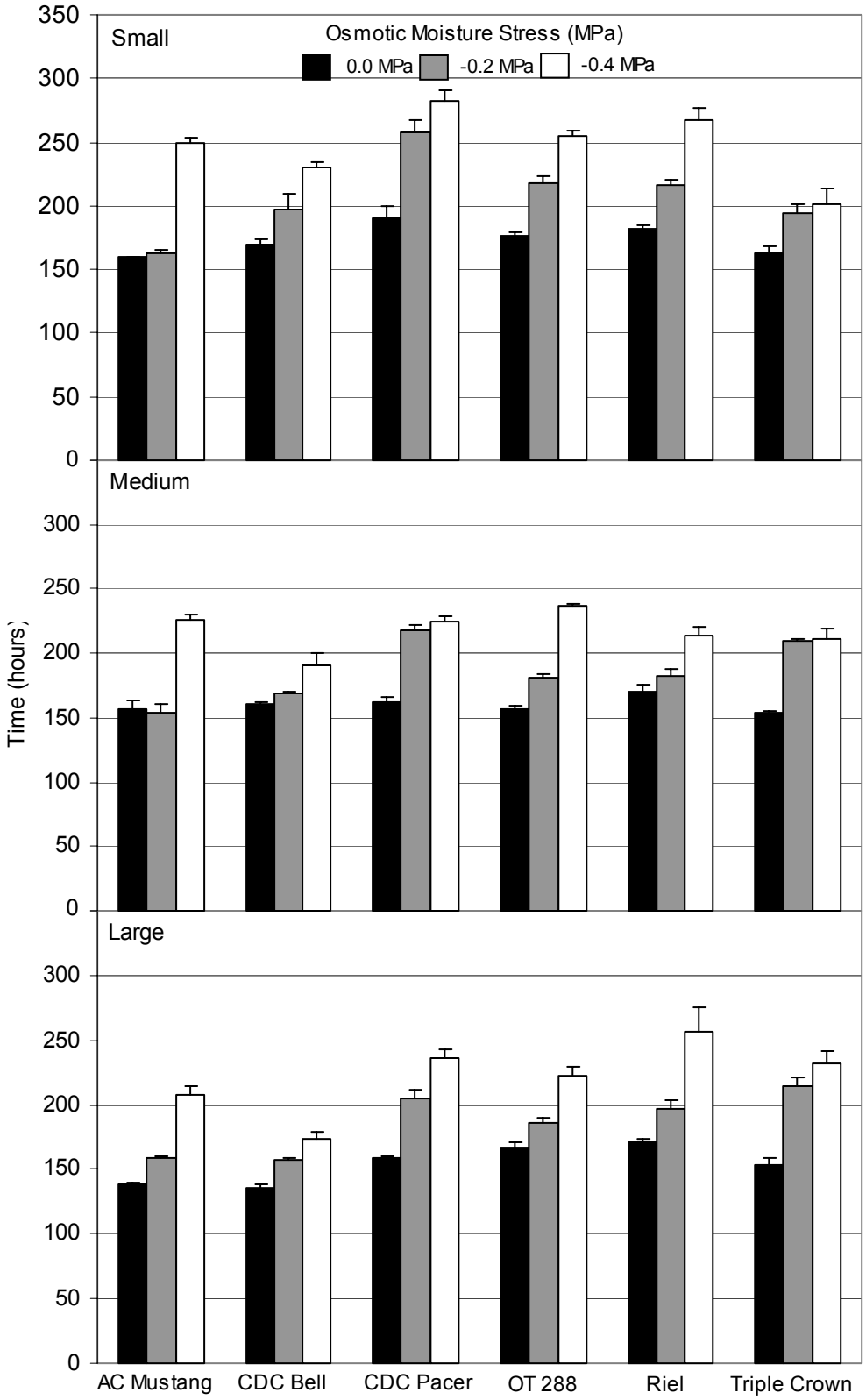


Figure 4.2 Run 2 – Effect of seed size and osmotic stress on the median germination time of six western Canadian oat genotypes. Standard error bars represent standard errors of the means.

OT 288, the semi-dwarf genotype , was expected to have the highest median germination time based on field observations and the poor competitive ability of the genotype. Furthermore, semi-dwarf winter wheat genotypes have been found to have a slower rate of coleoptile elongation (Allan *et al*., 1962); however the median germination time of OT 288 was close to that of Triple Crown and Riel (Table 4.3). Had we measured median emergence time rather than median germination time, OT 288 may have been slower as we could then accurately assess coleoptile elongation.

Larger differences in median germination time may also have been identified if a more diverse range of genotypes had been examined, as all of the genotypes we examined were adapted to western Canadian conditions. In their examination of the effect of genotype, temperature and osmotic stress on the germination of wheat, Lafond and Baker (1986b) observed differences in the median germination time of nine wheat genotypes, except at a temperature of 5°C. Of these genotypes, three were of Mexican origin. Furthermore, the Mexican genotypes tended to have the lowest median germination time under a range of temperatures.

It could also be possible that differences in median germination time could be related to the hull percentage of each genotype. The oat hull may act as a barrier and inhibit moisture from reaching the embryo and endosperm of the seed, hence slowing germination. AC Mustang however had the second lowest median germination time in both experimental runs, yet it had the lowest groat and highest hull percentage in 2 of 4 years of another experiment (Table 3.8). As seedlots were fractionated on a whole seed basis, rather than by groat size, observed differences may have been smaller than if

seedlots had been sized based on groat size. AC Mustang for example has a low groat percentage (Table 3.8), therefore, the small seed fraction of AC Mustang would have had smaller groats than the same fraction of another seedlots. AC Mustang still however had among the lowest MGT.

The general trend observed in the three – way interactions was a reduction in median germination time with increasing seed size (Figures 4.1 and 4.2). In run 1 of the experiment, two treatment combinations have median germination times that are in excess of 200 hours at an osmotic stress level of –0.4 MPa; however, as seed size increased none of the treatment combinations exceed a median germination time of 200 hours. Observations in the second run of the experiment were not as clear for the three – way interaction, possibly the result of modified germination characteristics due to the nature of seed storage. Nevertheless, in both runs 1 and 2 the main effect of increasing seed size is a reduction in median germination time (Table 4.3). The difference observed in run 1 between the small and large seeds is 25.86 hours, while that observed in experimental run 2 is 21.64 hours. The differences observed in both runs were minimal between medium and large seeds (Table 4.3). To the contrary, Lafond and Baker (1986b) found that smaller wheat seeds had lower median germination times at temperatures of 8, 12, 20 and 30°C; however at a temperature of 5°C differences were not significant. Although small wheat seed germinated (Lafond and Baker, 1986b) and emerged (Lafond and Baker, 1986a) faster, seedlings developed from large seeds accumulate more shoot biomass than plants grown from small seeds.

Physiological differences between the seed fractions may be the cause of the observed differences in median germination time among oat seed lots. Small seeds are

often formed at the distal end of the panicle and therefore may accumulate less photosynthate, possibly affecting germination. These findings are of agronomic importance as they indicate the necessity to remove smaller fractions from seedlots, especially under adverse seedbed moisture conditions.

As expected, the general trend observed in the three – way interactions for both experimental runs was an increase in median germination time with increasing osmotic moisture stress (Figure 4.1 and 4.2). In run 1 of the experiment median germination time increased by 70.1 h when osmotic stress increased from 0.0 to –0.4 MPa (Table 4.3). Similarly, in run 2 of the experiment, the same increase in osmotic stress resulted in a 66.12 h increase in median germination time. These findings were expected as germination begins with the imbibition of water, and the rate of imbibition is dependent upon the water content of the medium in which the seed lies. Consequently, any reduction in the amount of moisture available for seed uptake will inhibit or slow the process of germination, as observed here. Similarly, Lafond and Baker (1986b) found that an increase in osmotic stress from 0.0 to –0.8 MPa resulted in a 66 hour increase in median germination time.

4.3.2 Treatment Effects on Germination Rate of Oat Genotypes

Three – way interactions were significant for germination rate in both run 1 ($P<0.00$) and run 2 ($P<0.00$) (Table 4.4). Nevertheless, findings were inconsistent and no trends were discerned upon examination of the data (Figure 4.3 and 4.4)

Table 4.4 Analysis of variance of main effects and interactions for germination rate (seeds hr^{-1}) for six oat genotypes (G), three seed sizes (S) and three osmotic stress (OMS) levels for two runs of the experiment.

Source	DF	Type III SS	Mean Square	F Value	P
			Run 1		
G	5	88.27	17.65	4.55	(<0.0001)
S	2	18.61	9.30	2.40	(0.0900)
OMS	2	2.79	1.39	0.36	(0.7000)
G * S	10	100.98	10.10	2.60	(0.0100)
G * OMS	10	116.60	11.66	3.00	(<0.0001)
S * OMS	4	61.23	15.31	3.94	(<0.0001)
G * S * OMS	20	199.94	10.00	2.57	(<0.0001)
			Run 2		
G	5	225.95	45.19	4.72	(<0.0001)
S	2	1.57	0.78	0.08	(0.9200)
OMS	2	793.48	396.74	41.39	(<0.0001)
G * S	10	298.80	29.89	3.12	(<0.0001)
G * OMS	10	166.92	16.69	1.74	(0.0800)
S * OMS	4	92.51	23.13	2.41	(0.0500)
G * S * OMS	20	578.37	28.92	3.02	(<0.0001)

The general trend among genotypes was that AC Mustang and OT 288 had the highest germination rate in both experimental runs (Table 4.5). This further supports the qualities observed in AC Mustang for median germination time. This genotype has among the lowest median germination time as well as a high germination rate, indicating that it is able to germinate relatively quickly and that once germination begins it is rapid. Surprisingly, OT 288 had among the highest germination rate; however, the median germination time of this genotype is still among the lowest (Table 4.3), indicating that although this genotype has a high germination rate, it took much

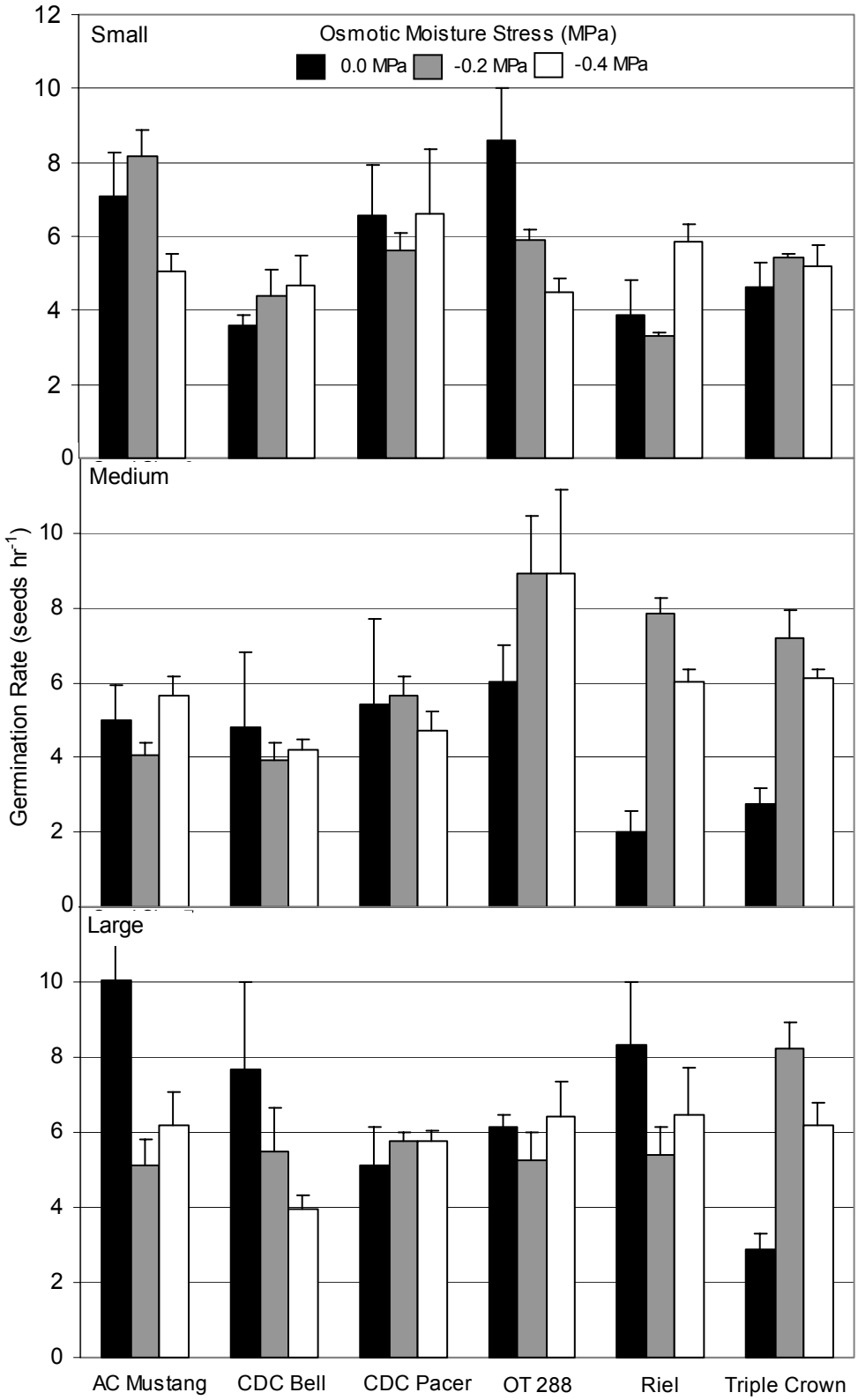


Figure 4.3 Run 1 - Effect of seed size and osmotic stress on the germination rate (seeds hr^{-1}) of six western Canadian oat genotypes. Standard error bars represent standard errors of the means.

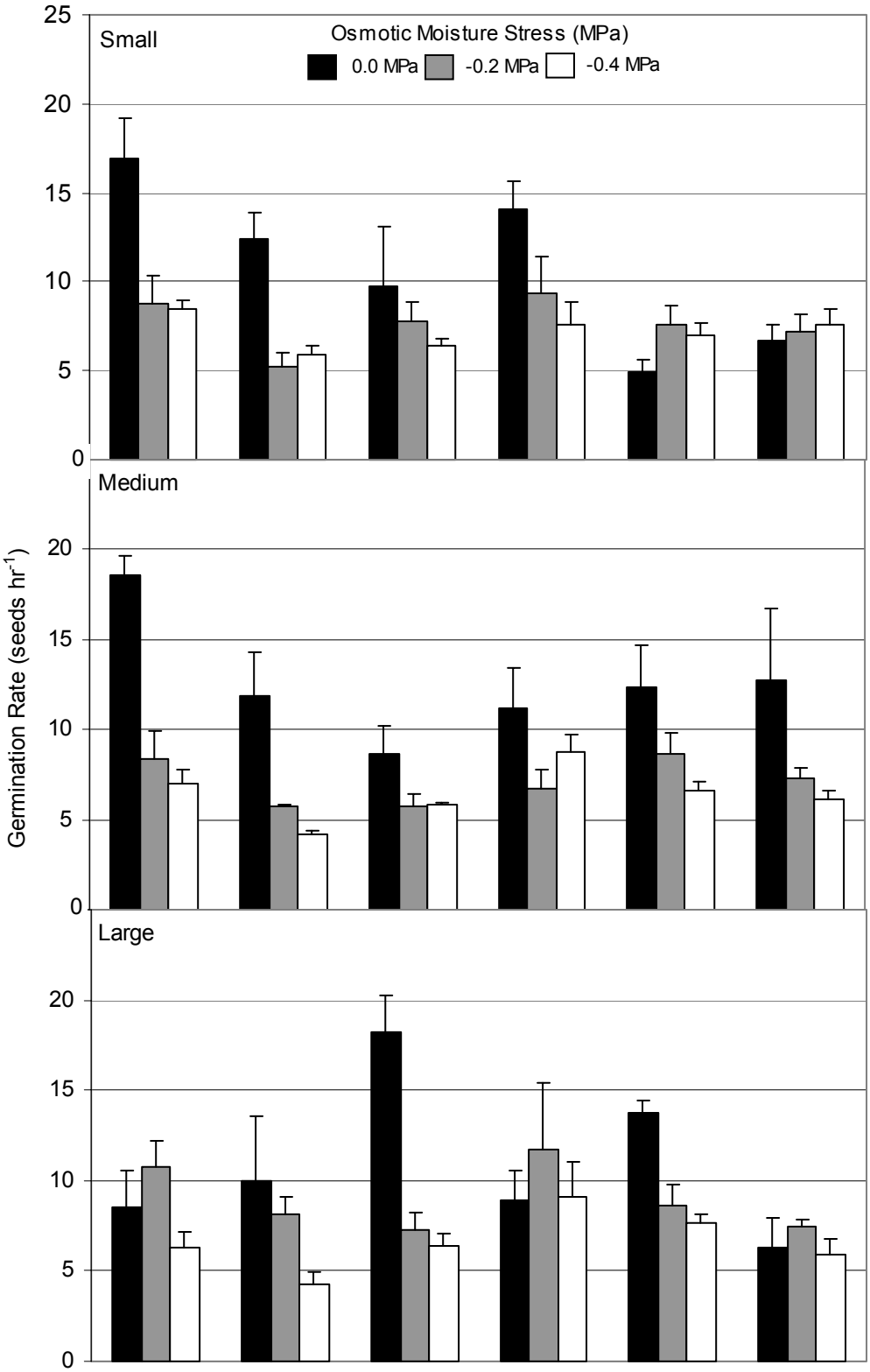


Figure 4.4 Run 2 - Effect of seed size and osmotic stress on the germination rate (seeds hr^{-1}) of six western Canadian oat genotypes. Standard error bars represent standard errors of the means.

Table 4.5 The mean effect of genotype, seed size and osmotic stress (MPa) on germination rate (seeds h^{-1}) of six western Canadian oat genotypes.

	Germination Rate (seeds h^{-1})	
	Run 1	Run 2
Genotype		
AC Mustang	6.26	10.34
CDC Bell	4.24	7.52
CDC Pacer	5.69	8.45
OT 288	6.74	9.70
Riel	5.47	8.38
Triple Crown	5.41	7.48
LSD	0.92	1.45
Seed Size		
Small	5.53	8.55
Medium	5.51	8.60
Large	6.13	8.78
LSD	0.65	0.98
Osmotic Moisture Stress		
0.0 MPa	5.61	11.36
-0.2 MPa	5.87	7.91
-0.4 MPa	5.69	6.73
LSD	0.68	1.02

longer for germination to begin than it did in AC Mustang. CDC Bell and Triple Crown had the lowest germination rate in both run experimental run 1 and 2, although not statistically different from the other genotypes examined (Table 4.5). Although germination rate is important, median germination time is of more agronomic importance as it indicates when 50% of the seeds have germinated. Assuming that these results correlate with emergence, those genotypes that have the lowest median germination time would begin competing sooner and more effectively than those genotypes with a higher median germination time.

In both runs of the experiment the largest seed fraction had the highest germination rate (Table 4.5); however, the differences observed between seed sizes were minimal with less than a 1 seed hr^{-1} difference observed in both runs. Furthermore, differences were not statistically different. Consequently, it appears as though seed size is of little to no importance with respect to germination rate.

The effect of osmotic stress varied considerably between separate runs. In the first run, the highest germination rate was observed for seed subjected to –0.2 MPa moisture stress, although not statistically different from the other treatments, while in the second run, seed not subject to moisture stress had the highest germination rate, as expected (Table 4.5). Differences between osmotic stress treatments were also much greater in the second run of the experiment. One would expect findings similar to those observed in run 2 of the experiment, with germination rate falling off substantially with even a slight increase in osmotic stress. As this was not observed in both runs, another replication of the experiment should be completed to further substantiate these findings.

4.3.3 Treatment Effects on Percent Germination of Oat Genotypes

Three – way interactions were observed in both run 1 ($P < 0.00$) and run 2 ($P < 0.00$) (Table 4.6); however, observations were not consistent between runs and no trends can be discerned (Figure 4.5 and 4.6). In run 1, the three – way interaction is a result of the much lower germination percentage in the small seed fractions of CDC Pacer and Riel that are subject to –0.4 MPa moisture stress. As compared to the first run, more variation was observed in percent germination in the second run. This

variation appeared to be due to changes in the germination characteristics of the seedlot due to altered storage conditions between experiment runs.

Table 4.6 Analysis of variance of main effects and interactions for percent germination for six oat genotypes (G), three seed sizes (S) and three osmotic stress (OMS) levels for two runs of the experiment

Source	DF	Type III SS	Mean Square	F Value	P
			Run 1		
G	5	234.22	46.84	4.33	(<0.0001)
S	2	184.2	92.1	8.52	(<0.0001)
OMS	2	612.97	306.48	28.34	(<0.0001)
G * S	10	273.32	27.33	2.53	(0.0100)
G * OMS	10	463.63	46.36	4.29	(<0.0001)
S * OMS	4	438.68	109.67	10.14	(<0.0001)
G * S * OMS	20	493.78	24.69	2.28	(<0.0001)
			Run 2		
G	5	1598.06	319.61	16.98	(<0.0001)
S	2	1195.35	597.68	31.75	(<0.0001)
OMS	2	756.74	378.37	20.10	(<0.0001)
G * S	10	1132.45	113.24	6.02	(<0.0001)
G * OMS	10	643.05	64.30	3.42	(<0.0001)
S * OMS	4	195.50	48.87	2.60	(0.0400)
G * S * OMS	20	1544.80	77.24	4.10	(<0.0001)

Differences observed among genotypes with respect to percent germination were negligible (Table 4.7). The largest differences observed between genotypes in both experiment runs were between AC Mustang and CDC Pacer. Differences in run 1 were minimal, with AC Mustang having a germination percentage 2.9% better than that of CDC Pacer, while in run 2 the difference 8.6%.

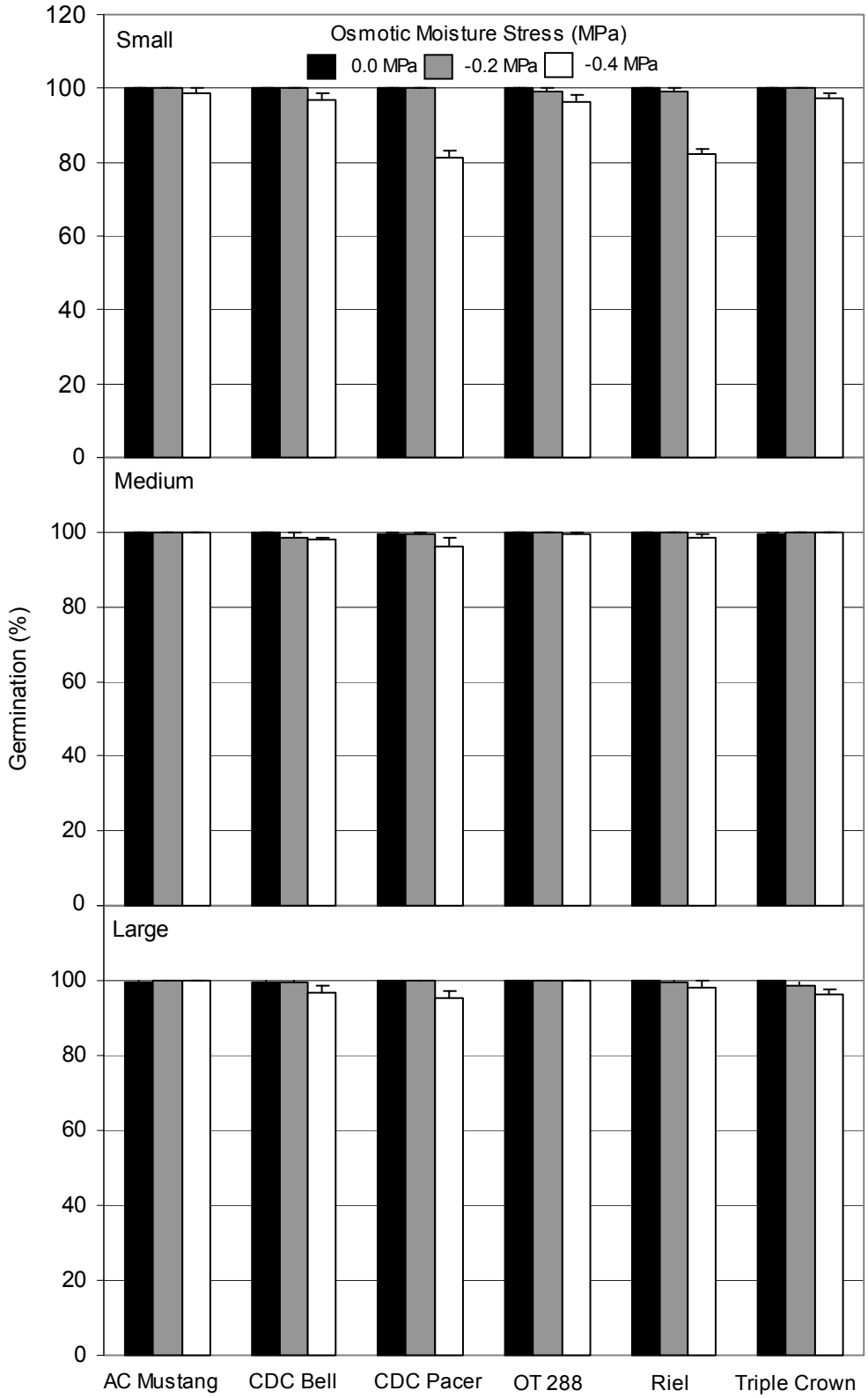


Figure 4.5 Run 1 - Effect of seed size and osmotic stress on percent germination of six western Canadian oat genotypes. Standard error bars represent standard errors of the means.

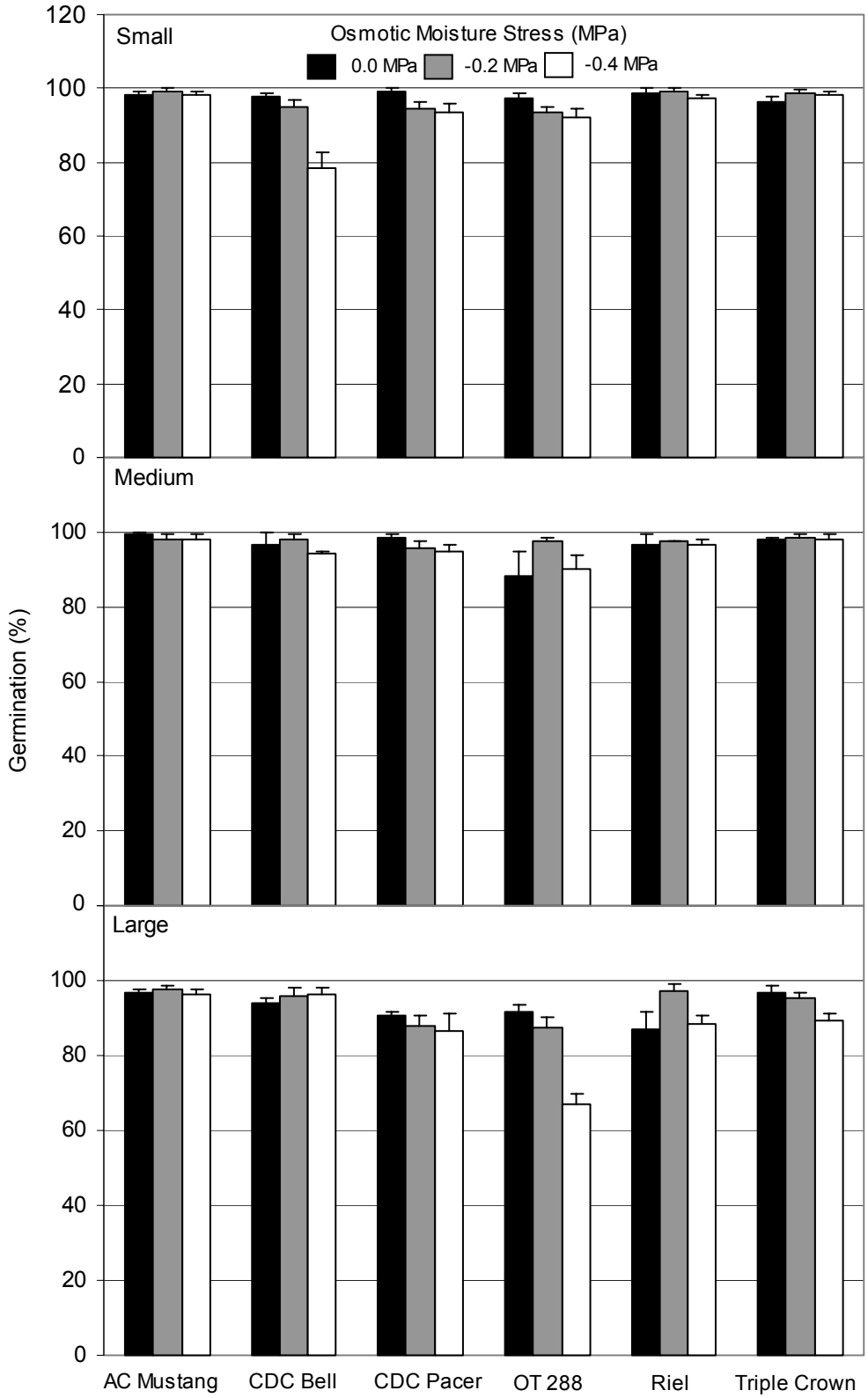


Figure 4.6 Run 2 – Effect of seed size and osmotic stress on percent germination of six western Canadian oat genotypes. Standard error bars represent standard errors of the means.

Table 4.7 The mean effect of genotype, seed size and osmotic stress (MPa) on percent germination of six western Canadian oat genotypes.

	Percent Germination	
	Run 1	Run 2
Genotype		
AC Mustang	99.77	97.97
CDC Bell	98.89	94.08
CDC Pacer	96.90	89.41
OT 288	99.37	93.53
Riel	97.44	95.41
Triple Crown	99.08	96.63
LSD	1.08	2.02
Seed Size		
Small	97.29	95.92
Medium	99.40	96.41
Large	99.04	91.19
LSD	1.36	1.97
Osmotic Moisture Stress		
0.0 MPa	99.86	95.71
-0.2 MPa	99.67	95.94
-0.4 MPa	96.20	91.86
LSD	1.08	1.42

Large differences in percent germination were not expected among genotypes as all seedlots were germinated in distilled water prior to the first run of the experiment and exhibited germination in excess of 97%.

Similar to genotype, seed size had little effect on percent germination. In the first run of the experiment, the smallest seed fraction had a slightly lower germination percentage than the medium and large seed fractions (Table 4.7). The observed difference is minimal at 2.11 %, while there was no difference observed in percent germination between the medium and large seed fractions. In the second run of the experiment more variation was observed and this may be due to reasons already

discussed. Contrary to our expectations, the largest seed fraction had the lowest percent germination at 91.19%, a 5.22% difference from the medium fraction. Observed differences in percent germination were so small that they are of little or no agronomic importance. Furthermore, the variation observed between runs of the experiment indicate that further replications are required in order to discern if seed size does affect percent germination.

Contrary to expectation, increasing osmotic stress had little effect on percent germination. Overall observations indicated a slight reduction in percent germination with increasing osmotic stress (Table 4.7). A difference of 3.7% was observed between seed subject to 0.0 MPa and –0.4 MPa moisture stress in the first run, while a difference of 3.9% was observed in the second run when osmotic stress was increased from 0.0 MPa to –0.4 MPa. These findings indicate that low levels of osmotic stress have minimal effect on percent germination, but do impact median germination time and germination rate.

4.4 Summary and Conclusions

This experiment investigated the effect of genotype, seed size and osmotic moisture stress on the germination characteristics of oat. This research was performed with the hypothesis that oat genotypes differed in median germination time and germination rate under adverse moisture conditions. Of the genotypes examined, AC Mustang appeared to be the most suited to dry spring soil conditions. The median germination time of AC Mustang was the least affected by increasing osmotic stress and it had the lowest MGT. Both of these characteristics would be beneficial in the

development of a competitive plant stand early in the growing season. Furthermore, AC Mustang had the highest germination rate of the genotypes examined, indicating that this genotype has able to germinate relatively quickly and once germination begins, it is rapid.

Genotype appears to be more important in determining the germination characteristics of oat than does seed size. General observations indicated a reduction in median germination time with increasing seed size; however, the differences observed between the large and small seed sizes were minimal and would be of little agronomic importance. Seed size had no effect on germination rate. Assuming that our findings correlate to emergence time in the field, genotype selection appears to be the best means by which to ensure the rapid development of a uniform plant stand.

5.0 Summary and Conclusions

This research investigated the effect of genotype and seeding rate on oat and wild oat competition. Furthermore, it to examined the effects of wild oat competition and increased oat seeding rate on physical and biochemical oat quality parameters. This research was conducted with the hypothesis that cultural control measures including the use of competitive crop genotypes and increased seeding rates, can play a fundamental role in integrated weed management systems.

The first step in the research was to determine if differences in competitive ability are present among western Canadian oat genotypes. Of those genotypes examined, the two that possessed the most distinct morphological characteristics differed from the standard genotypes in competitive ability. As expected, OT 288, the semi-dwarf genotype with the traits of a non-competitive ideotype, was affected by wild oat competition more than the other genotypes. Conversely, CDC Bell, the genotype possessing many of the traits associated with competitive ideotypes, was the most competitive. Furthermore, this genotype was able to both tolerate wild oat competition as well as interfere with wild oat growth. These findings support the concept of developing crop genotypes that can maintain yield under weedy conditions while reducing weed growth.

Although oat genotypes did differ in competitive ability, the most competitive genotype lacked weed-free yield potential in comparison to the other genotypes. Therefore, increased seeding rate was examined as a means of increasing the competitive ability of oat. With increased seeding rates both yield loss and wild oat seed return were reduced.

This study suggested that the selection of competitive oat cultivars and increased seeding rates can improve the tolerance of oat to wild oat competition. Additionally, the use of competitive genotypes and increased seeding rate can increase the ability of the crop to interfere with wild oat growth, reducing weed seed production and addition of wild oat seed to the weed seed bank. Furthermore, this research suggests oat quality is not affected by wild oat competition, but may be affected by increased seeding rates.

The adoption of competitive genotypes, such as CDC Bell, as part of an integrated weed management system may provide growers with a means by which to reduce weed seed production and minimize future weed problems. Organic growers may particularly benefit from the use of highly competitive genotypes; however, the adoption of competitive genotypes by conventional growers may be limited due to the reduced yield associated with competitive ability. The development of crop genotypes has been towards ideotypes with shorter stature and higher harvest indicies. Although these characteristics lend themselves well to high input agricultural systems, the ability to utilize these genotypes as a tool in integrated weed management systems is being lost. The genotype OT 288 which is well suited to high input production systems is an example of this. Under weed-free conditions, the yield of this genotype is among the highest of those examined; however, the ability of this genotype to maintain yield under

weedy conditions is very poor. The challenge lies in developing highly competitive genotypes that possess high weed-free yield potential; however, the development of such genotypes is dependent on the determination of which traits contribute the most to competitive ability. Path analysis may provide the method by which the effect of individual traits impact on competitive ability can be measured. Furthermore, procedures must be developed that allow for the screening of large numbers of genotypes.

Increased plant populations can act as a modifier of competitive ability, providing growers with the means to enhance the competitive ability of all genotypes. Increased seeding rate provides a cost-effective means by which to reduce yield loss as well as wild oat seed production. For example, increasing oat seeding rate from 250 plants m^{-2} to 500 plants m^{-2} requires an additional 82.5 kg ha^{-1} of seed. The use of high seeding rate may however affect oat quality and the marketability of the product. The use of increased seeding rate as a means of improving the competitive ability of the crop must therefore be closely examined in those crops where physical characteristics in particular, are critical in determining the marketability of the product.

An examination of the germination characteristics of oat indicated that variation does exist among western Canadian oat genotypes for characteristics such as median germination time. It was evident, even among the small group of genotypes examined, that some are able to germinate more rapidly and uniformly under adverse moisture conditions. This may be of considerable benefit if further advances can be made in identifying and improving the germination characteristics of oat genotypes.

Although no relationship was identified between rate of germination of oat and competitive ability with wild oat, the impact of rapid germination and subsequent stand establishment cannot be disregarded. Although no large discrepancies in time of emergence were noted among genotypes or between wild oat and oat, rate of seedling emergence was not measured in this study. Had this variable been accounted for, differences between genotypes may have been more apparent.

The use of highly competitive genotypes and increased plant populations may provide growers with excellent tools to use as part of an integrated weed management system. Increasing consumer demand for organic and pesticide-free products may encourage the development of competitive genotypes that are suitable to western Canadian agricultural systems. Future research is needed to correlate specific morphological or physiological traits with competitive ability. Furthermore, high yielding competitive genotypes need to be developed in order to ensure the adoption of competitive genotypes by growers.

The goal of this project was to identify if oat genotypes differ in competitive ability and whether increased seeding rate can be used to modify the competitive relationship between crop and weed species while maintaining quality. This goal was accomplished in that the results indicated that differences do exist in competitive ability among oat genotypes and that increased oat seeding rate can reduce the effect of wild oat on oat yield with minimal quality reductions.

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