The Influence of Plant Densities on Yields and Agronomic Performance of a Semi-dwarf and a Conventional Type Corn Hybrid in Southern Manitoba

by

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THE INFLUENCE OF PLANT DENSITIES ON YIELDS AND AGRONOMIC PERFORMANCE OF A SEMI-DWARF AND A CONVENTIONAL TYPE CORN HYBRID IN SOUTHERN MANITOBA

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A thesis submitted to the Faculty of Graduate Studies of
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ABSTRACT

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Plant density (number of plants/unit area of land) is an important factor in both grain and silage corn production. Optimum plant densities result in the highest level of production per unit area of land, therefore it is important that they be determined for the specific area in which the corn hybrids are grown.

The recent introduction of a semi-dwarf corn hybrid in Ontario has prompted optimum semi-dwarf corn plant density studies such as the one described in this thesis. Original studies with semi-dwarf corn in Ontario, pegged optimum plant densities at 172,000 plants/ha, which is approximately three times that of current recommendations for conventional hybrids. Grain yields from populations sown at this plant density were comparable with yields from conventional hybrids sown at the recommended plant density of approximately 50 - 60,000 plants per hectare.

The present study was undertaken to determine the optimum plant density of the semi-dwarf hybrid (391134R) for both grain and silage production in southern Manitoba. It was

also intended to compare the semi-dwarf's yield to those of a commonly grown corn hybrid in Manitoba.

The two corn hybrids (391134R and the check hybrid - Pioneer 3995) were grown at 3 locations over the growing seasons of 1984 and 1985. The replicated tests included 5 plant densities for each hybrid for the over-all six station year testing program. Besides grain and silage yields, measurements on development and agronomic characteristics were recorded and analysed.

The results indicated that the plant densities of 11.5 and 13.8 plants/m2 were optimum for 391134R for grain and silage yields, respectively. Although an optimum grain yield for the conventional hybrid, Pioneer 3995, was not clearly defined by this experiment, an optimum silage yield for this hybrid was determined to be 6.9 plants/m2. This result corresponds with the provincially recommended seeding rates for silage corn.

The semi-dwarf hybrid (391134R) significantly outyielded Pioneer 3995 (at the recommended 5.7 plants/m2) consistently in this experiment. Agronomic advantages for 391134R were also measured in comparison to Pioneer 3995, the greatest of which was the semi-dwarfs' relatively low values for stalk breakage and root lodging.

Although 391134R matured a few days later than Pioneer 3995, it met all of the criteria put forth in this study to be considered a viable hybrid in this province.

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Chapter I

INTRODUCTION

Corn production in southern Manitoba started after the Second World War. From that time until 1978 the number of hectares grown was highly variable from year to year and total production was low. Since 1978 grain corn production has increased dramatically from 9,700 to a peak of 91,000 hectares in 1981. Today, grain corn production in this province is in a slump, however, mainly due to several poor years in the 1980's where severe losses were incurred because of low Corn Heat Unit accumulations and early killing frosts. However, there are signs that grain corn production is on the rise in 1987 with an estimated 20,500 hectares in production. This along with the exceptional growing season and resulting high grain yields, in 1987, augers well for continued expansion of corn production in Manitoba.

Most of the grain corn in Manitoba is grown in the Mordon, Carman, and Altona triangle. The reason is that this area has the highest average corn heat unit accumulations in the province as well as having light to medium type soils which are conducive to corn production. Expansion of corn into other areas of the province is difficult with existing hybrids because of the insufficient Heat Unit number in these areas which increases the risk of growing corn. As well, there is a considerable capital investment needed for specialized farm equipment for the handling of grain corn. This makes it difficult for producers to 'try' corn on a small acreage basis or to grow corn as one of many diversified crops. The investment in specialized equipment would only be considered feasible if corn was grown on a significantly greater acreage in these areas currently considered marginal for corn production.

Several years before the present study was started, PAG Seeds (Cargill Ltd.) had developed several semi-dwarf corn hybrids. It was confirmed by PAG representatives that the semi-dwarf hybrids could be seeded and harvested with minor adjustments to conventional equipment used for cereal cropping. This was demonstrated on small field plots in southern Ontario. Thus the rationale was that if the semi-dwarfs could perform competitively with conventional corn hybrids, specialized corn equipment would not be necessary. This advantage could lead to the expansion of corn into areas which are considered marginal for corn production. It also provides the producer the option of diversifying their crop base by growing small acreages of corn economically.

Semi-dwarf corn, however, is not without its disadvantages. Weed control becomes more difficult because the very narrow row spacings do not allow inter-row cultivation, thus the producer becomes more dependent on herbicides. Another disadvantage is that the seed of the a semi-dwarf hybrid is and will remain more expensive than conventional corn hybrids on a per hectare basis. This is simply due to the fact that higher plant densities are required for optimum returns from semi-dwarf corn hybrids.

In order to determine the value of the semi-dwarf hybrid in southern Manitoba, the following objectives were employed:

(1) To determine optimum plant densities (plant number/ unit area of land) for grain and silage yields of the semi-dwarf hybrid (391134R) as well as a conventional type corn hybrid (Pioneer 3995).

(2) To compare the yields of the semi-dwarf to those of Pioneer 3995 at the optimum plant densities for grain and silage yields.

(3) To evaluate the semi-dwarfs agronomic and developmental characteristics.

Chapter II

LITERATURE REVIEW

In general, the relationship between plant density (number of plants per unit area of land) and grain yield of most crops, including corn, is parabolic in function (Holliday 1960; Eddowes 1969; Fery and Janick 1971; and Adelana and Milbourn 1972). For a given genotype, a specific plant density results in a maximum yield response. However, an optimum plant density for a particular genotype in one geographic region can be quite different from that in another region. Cropping history of the land in question, consequently it's fertility, are also variables affecting conclusions and recommendations resulting from plant density studies. For this reason, the following review attempts to categorize the results of such studies according to geographic location and where possible, to the agronomic practices pertaining to the region concerned.

2.1 INFLUENCE OF PLANT DENSITY ON YIELD OF GRAIN CORN

There have been many investigations into the effect of plant density on grain yield. Most of these studies have been conducted in the U.S.A., but an appreciable number have also been carried out in Canada and in Great Britain.

In the U.S.A., Rutger and Crowder (1967a) tested 6 corn hybrids at various plant densities and found the optimum density for grain yield to be 7 pl/m2. However, because of the greater mechanical losses that occur at high plant densities, they recommended a plant density of 6 pl/m2 be used in commercial practice.

Other studies have been conducted to compare the differences in crop response when corn is sown at two plant densities. One of these studies (Stickler and Laude 1960), made the comparison using plant densities of 10,450 and 15,680 pl/ha. Grain yields at these two plant densities were not significantly different. Stivers et al. (1971) conducted tests on 11 sites in Indiana, using 3 hybrids sown at plant densities of 54 and 69,000 pl/ha. On average, the yield from the 69,000 pl/ha density was 2.3% lower than that from the 54,000 pl/ha density. A large study completed by Troyer and Rosenbrook (1983) in the northern Corn Belt of the U.S.A., compared 84 hybrids established at plant densities of 51,600 and 64,500 pl/ha over a nine-year period. The higher density reduced mean yield from 76 to 73 quintals/ha and also increased the range of variability of yield among hybrids.

In Britain, where the growing seasons are long, cool, and moist, optimum plant densities have been found to be higher than those in the U.S.A.. Bunting (1973), demonstrated that the optimum plant density for 'Inra 200', the standard corn variety in Britain, ranged from 8 to 10 pl/m2. In testing several corn hybrids in southeastern England, Milbourn et al. (1978) reported optimum plant densities to be in the range of 8 to 12 pl/m2. Since yields were reduced at densities less than 7 pl/m2, they recommended a plant density of 8 to 9 pl/m2 be used. Adelana and Milbourn (1972), working in the same area, found that under irrigated conditions, 10.8 pl/m2 was optimum; a result attributed to improved soil moisture. Prior to this time, the recommended plant density for corn for this same region was 8.3 pl/m2.

In Canada, optimum plant densities for commercial production of grain corn have been difficult to pinpoint. For example, Giesbrecht (1969) tested 4 hybrids at plant densities of 30, 40, 60 and 75,000 pl/ha. Where moisture was not limiting, yields increased with correspondingly higher plant densities. However, when moisture was a limiting factor for maximum yield response, a 60,000 pl/ha density was optimum. It was concluded that 60-75,000 pl/ha is the maximum plant density that should be recommended for Manitoba. In comparison, Hunter et al. (1970) tested 5 short-season hybrids at

48,620 and 72,000 pl/ha at Guelph, Ontario. They found a near linear increase in grain yield with increasing plant density and concluded that the optimum density for these hybrids had not been reached under the experimental conditions employed.

2.1.1 Optimum Plant Density as Influenced by Genotype

The optimum plant density for a particular hybrid or genotype in a designated area, is not necessarily the same as that for a different hybrid. This was clearly demonstrated by Bunting (1973) where 'Inra 200' produced maximum yields when established at plant densities of 8 to 10 pl/m2. However, other flint-dent hybrids grown in the same area, performed optimally at densities of only 6 to 8 pl/m2. In contrast, an early flowering, short-statured, experimental hybrid produced maximum yields at a plant density of 14 pl/m2.

Besides responding to specific optimum plant densities, corn hybrids also exhibit marked differential tolerance to increased plant density stress (Duncan 1954; Bunting 1973). Further studies (Lang et al. 1956; Iremiren and Milbourn 1980) revealed that tolerant hybrids had a low occurrence of barren plants, while the reverse was true for the intolerant hybrids. However, Giesbrecht (1969) found that relatively tall, late-maturing hybrids were generally tolerant to high plant densities.

2.1.2 Plant Density Effect on Grain Yield as Influenced by Soil Fertility and Moisture Relationships

High levels of fertility are known to be supportive of increased plant densities (Dungan et al. 1958; Duncan 1958). Therefore, the nature of the soil and the cultural practices applied are important factors in recommending an optimum plant density for a particular area.

The amount of moisture available to a corn crop also influences the level of plant density found to be optimum (Termond et al. 1963; Andrew and Peek 1971). Adequate moisture favored high plant densities, while the opposite trend was true when moisture was limiting. In fact, yields from plots sown at high plant densities were drastically reduced under drought conditions. It has been demonstrated (Alessi and Power 1965; Fulton 1970) that adequate moisture was needed before high plant densities with the necessary addition of fertilizer improved yields.

2.1.3 Grain Yield as Influenced by Row Widths

The effect of reducing row widths within corn populations has been studied by many researchers. In general, grain yields were increased with decreasing row-widths.

In tests conducted over 11 station years in Indiana, Stivers (1971) used plant densities equivalent to 54 and

69,000 pl/ha in row-widths of 102, 76 and 51 cm. Yields from the 51 cm and 76 cm rows were respectively 7.3 and 4.4% greater than yields of the commonly used 102 cm row widths. Similar results have been reported by other workers (Stickler 1964; Fulton 1970; Hunter et al. 1970; Lutz et al. 1971). Such a response was attributed to an higher frequency of barren plants as a result of inter-row distances (Stickler 1964; Stivers et al. 1971). Conversely, Stickler and Laude (1960) and Giesbrecht (1969) observed no effect of varying inter-row widths on grain yield.

2.1.4 <u>Grain Yield as Influenced by Plant Spacing</u>

Several studies have been conducted to measure the influence of plant spacing on grain yield within rows of a corn population. Some of these experiments have involved equidistant planting (ie. all plants being equidistant from adjacent plants both within and between rows), which is believed to make the most efficient use of land area.

Krall et al. (1977) demonstrated that as the variability in plant spacing increased (ie. less precision), corn grain yields decreased. Hoff and Mederski (1960) stated that increased yields, due to more precise spacing, may be due to increased shading of the soil surface. Thus, improved utilization of solar energy and conservation of soil moisture were responsible for improved yields.

2.2 DWARF CORN AS INFLUENCED BY PLANT DENSITY

There are many dwarf corn lines which have been found to be due to single recessive gene mutations (Glover 1970). Little information is available, however, on dwarf corn yield responses to varying plant densities.

Nelson and Ohlrogge (1957) considered the agronomic possibilities of a compact strain, a semi-dwarf mutation occuring in an inbred of Hy2. The compact strain demonstrated high levels of tolerance to high plant density pressure, which was not true for other dwarf lines and for the isogenic normal line. Furthermore, the compact strain outyielded the other genotypes at plant densities of 26,000 pl/ha or greater. The authors stated that this yield response curve cannot be extrapolated to the response of a hybrid that contains the compact gene, but that some hybrids displayed similar yield curve responses as their respective inbreds. They suggested that yield increases could be obtained by incorporating the gene for compactness into conventional hybrids.

Sowell et al. (1960) continued experiments on the compact strain. They characterized the dwarf mutant strain as having a proportionate reduction in morphological development of the entire plant. In-depth studies on plant development proved that the compact strain ceased vegetative growth at the flowering stage, while the normal (Hy2) strain continued growing until physiological maturity. Therefore, the cessation of vegetative growth at flowering was a major factor responsible for the compact's superior yield at high plant densities. Presumably the normal strain under high density stress, could not supply enough carbohydrates to satisfy both vegetative and reproductive growth.

A study (Pendleton and Seif 1961) reported that a brachytic-2 double cross hybrid displayed a yield response curve (over plant densities) that was similar to that of normal corn hybrids of standard height. The optimum plant density was found to be 20,000 pl/ac.

Dwarf hybrids are considered to have potential due to their superior lodging resistance at high plant densities. However, it has been observed that incomplete filling of the cobs can occur at these high densities (Dungan et al. 1958).

2.3 SILAGE CORN YIELD AS INFLUENCED BY PLANT DENSITY

When dealing with the yield of vegetative material, an asymptotic yield-plant density curve exists with most crops (Holliday 1960). Corn is no exception to this general relationship (Bunting and Willey 1958; Thomson and Rogers 1968; Castle et al. 1951; Rutger and Crowder 1967 a,b; Eddowes 1969; Bunting 1971; Ferry and Janick 1971; Stivers et al. 1971; Adelana and Milbourn 1972; Phipps 1975). Thus, yields are maximized at a particular plant density and then plateau irrespective of further increase in plant density levels.

Studies in the U.S.A. have demonstrated that 7 to 9 pl/m2 was the optimum plant density on the asymptotic curve for corn silage yields (Rutger and Crowder 1967 a,b; Stivers et al. 1971). In Great Britain the optimum plant density for corn silage yield was found to be in the range of 9 to 12 pl/m2 (Bunting and Willey 1958; Thomson and Rogers 1968; Castle et al. 1951; Bunting 1971; Adelana and Milbourn 1972; Phipps 1975).

Comparatively, Daynard and Muldoon (1981), working in Ontario, Canada, reported a optimum plant density of 6.3 pl/m2 for corn silage hybrids. However, Robinson and Murphy (1972) reported that silage yields were primarily a function of nitrogen fertilization rate under irrigated conditions. Varying plant densities and phosphate levels did not produce significant effects on forage yield.

In general, it is recommended that plant densities for silage corn be increased above those found optimum for grain corn in a particular area (Adelana and Milbourn 1972; Field Crop Recommendations for Manitoba 1984).

2.4 AGRONOMIC-QUALITY CHARACTERISTICS OF CORN AS INFLUENCED BY PLANT DENSITY

As documented in the previous sections, the levels of plant density influence grain and silage yields of corn. However, when deciding on an optimum density, the agronomic and quality characteristics of the corn crop must also be considered. The following sections deal with these relationships, including the secondary influences of such on yield, crop losses, and harvestability.

2.4.1 Stalk Breakage and Root Lodging

The heaviest losses in commercial corn production occur as a result of stalk breakage (stalk is broken below the ear) and root lodging (the entire plant leans at an angle of 30° or greater). It is known that as plant densities are increased, the incidence of stalk breakage and root lodging also increases (Dungan et al. 1958; Rutger and Crowder 1967 a; Giesbrecht 1969, 1976; Milbourn et al. 1978; Remison and Akinleye 1978; Troyer and Rosenbrook 1983). This direct association is attributed to decreased stalk diameter and increased plant ear height as plant densities are increased (Dungan et al. 1958; Milbourn et al. 1978). However, studies done in a tropical climate revealed that lodging was positively associated with plant ear height but not with stem diameter (Remison and Akinleye 1978).

2.4.2 Ear Barrenness

Ear barrenness refers to a condition whereby a corn plant fails to develop an ear. It is known that barrenness is more prevalent in populations of high plant density (Lang et al. 1956; Dungan et al. 1958; Mortimore and Wall 1965; Rutger and Crowder 1967 a; Giesbrecht 1969; Iremiren and Milbourn 1980; Troyer and Rosenbrook 1983). Lang et al. (1956) discovered that plant density, nitrogen level, and plant genotype are factors which significantly affect ear barrenness. Low levels of nitrogen generally increased the frequency of barrenness at high plant densities, although various genotypes displayed differential responses. Giesbrecht (1969) also reported that moisture deficiencies amplified the ear barrenness-plant density relationship.

2.4.3 Ear Drop

Ear drop is a condition in which the ear becomes detached from the stalk prior to harvest and consequently falls to the ground. This results in a direct yield loss since 'dropped' ears cannot be recovered by conventional harvesting practices. Troyer and Rosenbrook (1983) reported that the occurrence of ear drop increased as plant densities were increased.

2.4.4 Ear Development

The morphological and physiological characteristics of the individual corn ear directly influence grain yield and therefore, are important aspects when considering optimum plant densities. It is known that ear weight declines as plant densities are increased (Lang et al. 1956; Dungan 1958; Stickler 1964; Mortimore and Wall 1965; Rutger and Crowder 1967 a; Iremiren and Milbourn 1980). This has been attributed to reduced ear size, fewer seeds per ear, and reduced seed weight from plants grown under high plant densities (Dungan et al. 1958; Rutger and Crowder 1967 a; Iremiren and Milbourn 1980).

2.4.5 Tillering

Tillering involves the development of secondary stems which are considered to be of little value in grain corn production. They rarely produce significant quantities of grain and will also hinder harvest operations due to increased bulk. Dungan et al. (1958) stated that tillering occurs in response to environmental conditions which are capable of supporting higher plant densities than those actually present. It has been found therefore, that the number of tillers per plant decreases as plant densities increase (Dungan et al. 1958; Mortimore and Wall 1965; Giesbrecht 1969).

2.4.6 Plant Height

Plant height within corn populations is influenced by plant density. For example, Dungan et al. (1958) and Bunting (1973) both reported that plant height from populations of medium plant densities were greater than those from either higher or lower plant densities. Conversely, Giesbrecht (1976) reported that plant heights increased significantly as plant densities were raised from 30 to 100,000 pl/ha.

2.4.7 Plant Maturity

It has been shown that the maturity rate of corn hybrids is retarded with increased plant densities (Giesbrecht 1976; Milbourn 1978). Other researchers (Rutger and Crowder 1967 a; Hunter et al. 1970; Bunting 1973), have reported that corn grown under high plant densities had relatively higher grain moisture content than that produced at low densities. Furthermore, the time required to reach the silking stage is prolonged with increases in plant density. However, the anthesis stage is not affected by such increases in plant density (Bunting and Willey 1958; Dungan et al. 1958; Bunting 1973; Iremiren and Milbourn 1980).

2.4.8 Grain Protein Content

Protein content of grain corn is a nutritional factor and therefore, has importance relative to feed rations. It has been demonstrated that protein content is inversely related to plant density (Zuber et al. 1954; Lang et al. 1956; Genter et al. 1956; Pendleton and Seif 1961). The early work by Zuber et al. (1954) revealed that corn genotypes at a given plant density, can have varying crude protein levels in the grain.

2.4.9 Silage Quality

Silage corn is used to feed ruminant animals. The feeding value or quality of such silage is measured according to either weight gain per unit silage consumed or by in-vitro studies. These studies have shown that the dry matter content of the silage is the most important factor in the assessment of its quality (Hemken et al. 1971; Bunting 1976; Phipps et al. 1981; Fairey 1982). In other words, plant density has little effect on the feeding value or quality of silage corn. Therefore, when growing corn for silage, optimum plant densities should be high (in accordance with the asymptotic curve) in order to achieve maximum dry matter yields.

Chapter III

MATERIALS AND METHODS

Two 3-way cross corn hybrids were used for this experiment, including a standard tall genotype and an experimental semi-dwarf hybrid. The semi-dwarf hybrid was developed by PAG Seeds (Cargill Ltd., Ontario) and is designated by the experimental number 391134R. The plant type represented by this hybrid is one which is proportionately reduced in size by approximately one third compared to conventional corn hybrids. As well as having a high yield potential, it is believed that 391134R could be seeded and harvested with conventional cereal equipment which is considered a distinct advantage. This hybrid reaches a height of approximately 1.6 m and matures with approximately 2200 Corn Heat Units (C.H.U.). The second hybrid used in this study was Pioneer 3995, a hybrid which has been widely grown in Manitoba for many years. In comparison with other recommended corn hybrids in Manitoba, it represents a standard plant type with respect to height (2.4 m) and is classified as a 2150 C.H.U. hybrid.

3.1 METHODS

The objectives of this experiment were to determine an optimum plant density for both the semi-dwarf and standard hybrids under the environmental conditions of southern Manitoba. Comparisons of grain and silage yields, as well as other agronomic traits were made between the two hybrids to determine if the semi-dwarf had merit as a commercially viable hybrid. The methodology outlined in the following sections was employed in an attempt to meet these objectives.

3.1.1 Plant Densities

Each hybrid was grown at 5 plant densities. The semi-dwarf hybrid was grown in densities of 5.7, 8.6, 11.5, 13.8 and 17.2 plants/m2, while Pioneer 3995 was tested at 3.8, 4.9, 5.7, 6.9 and 8.6 plants/m2. The rationale for selecting these densities was based upon initial reports from PAG Seeds indicating that 391134R was expected to reach it's optimum performance at relatively high plant densities. Conversely, currently recommended plant densities for standard corn hybrids in Manitoba are 4.9 to 5.7 plants/m2 for grain corn and 6.9 plants/m2 for silage corn (Manitoba Field Crop Recommendations, 1984).