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

by

Keith Murphy

A thesis
presented to the University of Manitoba
in fulfillment of the
thesis requirement for the degree of
MASTER OF SCIENCE
in
THE DEPARTMENT OF PLANT SCIENCE, UNIVERSITY OF MANITOBA.

Winnipeg, Manitoba

ISBN 0-315-47933-7

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

BY

KEITH MURPHY

A thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF SCIENCE

I hereby declare that I am the sole author of this thesis.

I authorize the University of Manitoba to lend this thesis to other institutions or individuals for the purpose of scholarly research.

Keith Murphy

I further authorize the University of Manitoba to reproduce this thesis by photocopying or by other means, in total or in part, at the request of other institutions or individuals for the purpose of scholarly research.

Keith Murphy

The University of Manitoba requires the signatures of all persons using or photocopying this thesis. Please sign below, and give address and date.

ABSTRACT

Murphy, Keith B. M.Sc. The University of Manitoba, January, 1988. Major Professor; Dr. E.N. Larter.

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.

ACKNOWLEDGEMENTS

I wish to thank my wife, Lee Anne, for all her support and assistance with this project.

I would also like to thank my advisor, Dr. E.N. Larter, for his guidance throughout this project. Thanks also to the members of my committee, Dr. A.K. Storgaard, Dr. K. W. Clark, and Dr. G.I. Paul, for their advice and support.

My appreciation also to L. Hopkins and other technical staff, for their assistance with the project.

The support of my family and friends is gratefully acknowledged.

CONTENTS

LIST OF TABLES

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 Grain Yield as Influenced by Plant Spacing

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).

3.1.2 Experimental Design

A separate randomized complete block design was established for each hybrid. The two hybrids could not be randomized within the same design because their height differential could conceivably introduce bias due to shading.

The experiment was conducted during the growing seasons of 1984 and 1985. Three experimental sites were used, these being located at Winnipeg, Carman and Ridgeville. Each site represented a different soil type as well as a different long-term average C.H.U. accumulaton (Table 1).

Plots consisted of 7 rows, each 6.7 m in length with 38.1 cm between rows. Plots within blocks were sown 1 m apart, while blocks were separated by a distance of 3 m. All sites consisted of 3 replications of each plant density, resulting in a total of 18 replications over 6 station years.

Row widths were kept constant at 38.1 cm while inter-row plant spacings varied depending upon the plant density required. The seeding operation involved the use of a hand-operated corn planter. Using this method, 2 seeds were sown per hill, which were later thinned to a single seedling per hill.

When seedlings had reached the 3 to 5 leaf stage, granular fertilizer was applied between rows as a side dressing at a depth of 2 to 3 cm. High rates of fertilizer were

TABLE 1

Physical description of experimental sites

Site	Soil type	Average CHU	Location
Winnipeg	Silty Clay	2483	The 'point' (U. of M.)
Carman	Almasippi very fine sand loam	2404	H. McKnights farm
Ridgeville	Springbank sandy loam	2579^	A. Loeppky's farm

^average value from the closest recording station, Emerson.

applied so that at no time was the nutrient level a limiting factor for maximum growth. The actual rates of nutrients applied among sites and between years varied due to different granular mixes used and the nature of application (Table 2).

Experimental plots were maintained in a weed-free state by both hand weeding and by the use of pre-plant incorporated herbicides. Spraying for the European Corn Borer [Ostrinia nubilalis (Hubner)] was also carried out when required using recommended insecticides. All plots were grown under dry-land conditions.

TABLE 2

Nutrient application on a per site/year basis

Actual nutrients applied (Kg/ha)						
	Winnipeg		Carman		Ridgeville	
Nutrient	1984	1985	1984	1985	1984	1985
Nitrogen (N)	157	183	145	168	129	164
Phosphate (P205)	81	91	61	70	54	68
Potassium (K20)	-	-	121	139	108	136
Sulfur (S)	-	-	18	21	16	21

3.1.3 Plant Measurements

The two outer rows of each 7-row plot were used as guard rows. In addition, the center row was also considered as a guard or spare row in the event of plot damage. The two remaining rows on each side of the center row were used to make all measurements including yields of either grain or silage.

The following is a description of the agronomic parameters evaluated with their respective units of measurement:

EMERGENCE: -measured as the number of days from seeding to the date when approximately 75% of the seedlings have emerge.

TILLERING: -the percentage of plants per plot with secondary stalks reaching a minimum height of 0.5 m by the time of plant maturity.

SILKING AND ANTHESIS: -the number of days from date of seeding to the time when 50% of the plants either show silk emergence or initial pollen shedding.

EAR AND PLANT HEIGHT: -a measurement of the distance between ground level to the shank supporting the ear and to the tip of the tassel, respectively. These measurements were recorded several days before silage harvest.

STALK BREAKAGE: -the percentage of plants per plot exhibiting broken stalks below the attachment of the ear. This information was recorded just prior to grain harvest.

ROOT LODGING: -the percentage of plants per plot which leaned at an angle of approximately 30 degrees or more at the time of grain harvest.

EAR BARRENNESS: -the percentage of plants per plot which failed to develop an ear. This information was recorded just prior to grain harvest.

EAR DROP: -the percentage of plants per plot in which the ear had become detached from the stalk and had dropped to the ground before grain harvest.

Grain and silage yield data were based on a standard number of plants harvested from each plot. Generally, this entailed the harvesting of approximately 6 m of the central portion of each row, thus leaving an unharvested length of approximately 0.3 m on each end where border effects might occur.

As recommended in the Manitoba Field Crop Recommendations (1984), silage plots were harvested when the kernels were well-glazed. Plants were cut by hand approximately 5 cm above ground level and fresh weights of plants of each plot were recorded. A chopped sample of harvested plants was bagged and placed in a freezer until further analysis. Upon completion of the field harvest, samples were removed from the deep freeze, weighed and oven-dried for 72 hours at 78°C and re-weighed. Based upon these data, silage moisture and dry matter yields in grams/m2 were calculated.

For grain yields, plots were harvested soon after the plants had reached full maturity. Ears from a plot were hand-harvested and threshed the same day. Grain test weights were recorded immediately, after which a 2000 gram sample was drawn for moisture determinations. These samples were air-dried for several weeks and then re-weighed. Moisture determinations on air-dried samples were analysed by use of a Dicky-John grain computer. From these data, final grain yields were calculated and expressed as grams/m2 at 15.5% moisture. The air-dried grain samples were also used to evaluate the following parameters:

GRAIN DENSITY: -the weight of 0.5 l of screened grain multiplied by 2 and expressed in grams/l.

1000 KERNEL WEIGHT: -the weight of 250 whole seeds multiplied by 4 and expressed as grams/1000 kernels.

PROTEIN: -percentages of nitrogen as determined by the Kjeldahl method based on 0% grain moisture and converted to percent protein using a conversion factor of 6.25.

General observations were also made on insect and disease levels where applicable.

3.2 STATISTICAL ANALYSIS

An analysis of variance for all parameters was completed on each hybrid for each station year. A homogeneity test (Bartlett, 1938) was then conducted to determine if the data from 6 station years, or a majority of them, could be pooled. If so, another analysis of variance was completed on the pooled data. If statistically significant, differences between plant densities of the same hybrid were determined via the Duncan's Multiple Range Test at a significance level of 0.05.

Once the optimum plant density for 391134R was derived, it was compared to the currently recommended plant density for Pioneer 3995. This was accomplished by use of a paired t-test for each station year.

Chapter IV

RESULTS AND DISCUSSION

In 1984, corn heat unit accumulations at all three sites were above normal and permitted full development of the two corn hybrids. After heavy rains in June, rainfall in the later months was below normal. However, drought conditions occurred only at the Carman site in 1984. In 1985, corn heat unit accumulations at all three sites were below normal and frost damage occurred at Ridgeville. Moisture did not appear to limit crop production in 1985.

4.1 GRAIN YIELD

The grain yield results of 391134R are shown in Table 3. The grain yields at the three highest plant densities (17.2, 13.8 and 11.5 plants/m2) were not significantly different when all data were pooled. The lowering of plant density from 11.5 to 8.6 plants/m2 resulted in a significant decrease in grain yield. A further decrease in plant density to 5.7 plants/m2 significantly decreased grain yield to the lowest value over all densities, stations and years.

Carman, in 1984, was the only site seriously affected by drought in this experiment. Grain yield at the highest

TABLE 3

The grain yield (grams/m2 at 15.5% moisture) of 391134R over six station years and varying plant densities

Plant density (pl/m2)	Winnipeg		Carman		Ridgeville		
	1984	1985	1984	1985	1984	1985	$\bar{X}$^
17.2	879 a*	701 ab	691 bc	844 a	978 a	558 a	775 a
13.8	887 a	704 ab	786 ab	764 b	971 a	554 a	778 a
11.5	858 ab	727 a	861 a	769 b	969 a	568 a	792 a
8.6	760 bc	637 b	786 ab	638 c	896 a	517 a	706 b
5.7	654 c	588 c	611 c	548 d	775 b	384 b	588 c
F value	9.02	8.32	9.92	53.44	10.86	16.64	66.03
C.V.	7.12	6.19	7.14	3.92	4.96	6.29	6.08

*means followed by the same letter are not significantly different at the P = 0.05 level.

^all 6 station years pooled.

plant density (17.2 plants/m2) measured a marked reduction when compared to the medium-to-high plant densities of 11.5 and 13.8 plants/m2, respectively. In 1985, the site of Ridgeville experienced poor environmental conditions for corn production, as mentioned previously. This resulted in greatly reduced yields for both corn hybrids.

The results obtained duplicated the parabolic grain yield-plant density function, as discussed by Holliday (1960). The grain yield-plant density curve peaked at the plant density of 11.5 plants/m2. Higher densities did not result in significant decreases in yield, however, a trend toward lower yields was evident. This was especially true at Carman where under drought stress in 1984, significant decreases in grain yield occurred with plant densities greater than optimum (11.5 plants/m2). Even under the poor environmental conditions of Ridgeville in 1985, the yield response curve followed the same pattern with optimum plant density being 11.5 plants/m2.

The grain yield results of Pioneer 3995 are shown in Table 4. The pooled data demonstrates that grain yield increased significantly with each increase in plant density. This relationship held true under the drought conditions found at Carman in 1984 and under the poor climatic conditions of Ridgeville in 1985.

TABLE 4

The grain yield (grams/m2 at 15.5% moisture) of Pioneer 3995 over six station years and varying plant densities.

Plant density (pl/m2)	Winnipeg 1984	Winnipeg 1985	Carman 1984	Carman 1985	Ridgeville 1984	Ridgeville 1985	$\bar{X}$^
8.6	779 a*	668 a	847 a	627 a	879 a	551 a	725 a
6.9	731 a	591 ab	751 ab	616 a	819 ab	478 b	664 b
5.7	673 b	562 b	716 bc	576 ab	749 b	452 b	621 c
4.9	637 b	524 bc	622 cd	520 bc	673 c	449 b	571 d
3.8	521 c	441 c	538 d	461 c	554 d	390 c	484 e
F value	32.41	9.58	12.13	7.88	35.28	12.72	85.70
C.V.	4.49	8.39	8.51	7.64	5.05	6.08	6.85

*means followed by the same letter are not significantly different at the P = 0.05 level.
^all 6 station years pooled.

Yields resulting from the plant density range used for Pioneer 3995 did not reproduce the parabolic function as discussed by Holliday (1960). However, other grain yield-plant density trials involving tall corn hybrids in Canada, produced results similar to those in this study (Giesbrecht, 1969; Hunter et al, 1970). Therefore, the optimum plant density for this particular hybrid appears not to have been reached under the experimental conditions employed in this study.

Since an optimum plant density for the standard tall corn hybrid Pioneer 3995 did not appear to have been reached, it's yield at the provincially recommended 5.7 plants/m2 was compared to the optimum plant density found for hybrid 391134R (Table 5). The overall grain yield of 391134R, at its optimum plant density (11.5 plants/m2), was significantly higher (27.5%) than Pioneer 3995 at its recommended plant density of 5.7 plants/m2. The grain yield results indicate that 391134R has merit to be produced commercially in southern Manitoba.

TABLE 5

The comparison of grain yield (grams/m2) of 391134R (at 11.5 plants/m2) and Pioneer 3995 (at 5.7 plants/m2).

Hybrid	Reps	Mean	Std Dev.	t	Prob > T
391134R	18	792.1	140.7	3.9653	0.0004**
Pioneer 3995	18	621.4	116.3	3.9653	0.0004**

**indicates significant difference at the 0.01 level.

4.2 SILAGE YIELDS

The dry matter yield of hybrid 391134R increased as plant density increased (Table 6). The two highest plant densities of 17.2 and 13.8 plants/m2 did not result in significantly different mean silage yields. Similarly at the plant densities of 11.5 and 8.6, the yields were similar and significantly lower than those of 17.2 and 13.8 plants/m2. The lowest plant density of 5.7 plants/m2 resulted in significantly lower dry matter yields over all stations and years.

As shown in table 7, the mean dry matter yield of Pioneer 3995 increased as plant densities increased. The two highest plant densities tested (8.6 and 6.9 plants/m2) resulted in the highest mean silage yields albeit not significantly different from one another. Similarly, the plant densities of 5.7 and 4.9 plants/m2 were not significantly different in terms of silage yield returns. The lowest plant density (3.8 plants/m2) resulted in lowest dry matter yield at all stations for both years, but these differences were not always statistically significant.

The results obtained for both corn hybrids substantiate the asymptotic dry matter-plant density yield curve as discussed by Holliday (1960). Dry matter yield for 391134R increased up to a density of 13.8 plants/m2 beyond which significant yield increases were not realized. Similarly, dry matter yields for Pioneer 3995 were not significantly

TABLE 6

The silage yield (grams/m2 of dry matter) of 391134R over five station years and varying plant densities.

Plant density (pl/m2)	Winnipeg 1984	Winnipeg 1985	Carman 1984	Carman 1985	Ridgeville 1984	Ridgeville 1985	$\bar{X}$^
17.2	-	1305 a*	1454 a	1682 a	1769 a	1286 a	1424 a
13.8	-	1201 ab	1419 a	1617 a	1612 b	1324 a	1381 a
11.5	-	1236 ab	1380 ab	1362 b	1645 ab	1213 ab	1270 b
8.6	-	1115 bc	1277 b	1358 b	1430 c	1106 b	1193 b
5.7	-	1052 c	1003 c	1114 c	1253 d	949 c	1038 c
F value	NA	6.56	28.89	14.20	19.62	14.95	31.92
C.V.	NA	5.70	4.49	7.35	5.13	5.78	6.50

*means followed by the same letter are not significantly different at the P = 0.05 level.
^1985 sites pooled.

TABLE 7

The silage yield (grams/m2 of dry matter) of Pioneer 3995 over five station years and varying plant densities.

Plant density (pl/m2)	Winnipeg		Carman		Ridgeville		X̄^
	1984	1985	1984	1985	1984	1985	
8.6	-	1165 a*	1522 a	1494 a	1504 a	1124 a	1261 a
6.9	-	1163 a	1324 ab	1367 ab	1396 a	1079 a	1203 a
5.7	-	1068 a	1381 ab	1279 abc	1319 ab	913 b	1087 b
4.9	-	1070 a	1386 ab	1157 bc	1390 a	877 bc	1035 bc
3.8	-	998 a	1159 b	1120 c	1110 b	794 c	971 c
F value	NA	1.64	1.90	5.65	4.79	24.19	15.98
C.V.	NA	8.77	12.20	8.71	8.64	5.13	8.06

*means followed by the same letter are not significantly different at the P = 0.05 level.
^1985 sites pooled.

increased with densities higher than 6.9 plants/m2. Therefore, the optimal plant density for dry matter yield of 391134R approached 13.8 plants/m2, while a density of 6.9 plants/m2 appears to be optimal for Pioneer 3995 in southern Manitoba. This plant density level is the currently recommended rate for silage corn in Manitoba (Field Crop Recommendations for Manitoba, 1984). The results of the t-test comparing these two optimal plant densities for silage (Table 8), demonstrate that 391134R outyields Pioneer 3995, but not significantly. The results of this study also reinforce the general recommendation that silage corn plant densities should be higher than those used for grain corn. This remains true as the semi-dwarf performs optimally for silage at a plant density level above that tested for optimum grain corn yields (ie. 13.8 vs. 11.5 plants/m2, respectively).

TABLE 8

The comparison of silage yield (grams/m2) of 391134R (at 13.8 plants/m2) and Pioneer 3995 (at 6.9 plants/m2).

Hybrid	Reps	Mean	Std Dev.	t	Prob > t
391134R	9	1380	195.4	2.0148	0.0612ns
Pioneer 3995	9	1203	178.9	2.0148	0.0611ns

ns not significantly different.

4.3 AGRONOMIC CHARACTERISTICS

In corn production, agronomic characteristics are considered very important. Many of the following traits affect grain and silage yields directly, while others are used as indicators of plant development and maturity. Several of these are also important in the way they affect harvest operations and crop rotation.

4.3.1 Stalk Breakage

The mean percentage values of stalk breakage are given in Table 9 for each corn hybrid at the eight plant densities tested. Pooling of sites and years was not possible due to the high variability in stalk breakage values observed. In general, stalk breakage increased as plant density increased for both hybrids. The semi-dwarf hybrid (391134R) displayed values which ranged from 0.4 to 7.9% while the conventional corn hybrid (Pioneer 3995) ranged from 7.4 to 18.9%. The values for 391134R over all plots averaged 4.0% while the overall mean for Pioneer 3995 was 13.8%.

As indicated previously, it is well known that the incidences of stalk breakage and root lodging increase as plant density 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). The same trend was apparent in this study.

TABLE 9

Mean percentage values of stalk breakage of both 391134R and Pioneer 3995 over six station years and varying plant densities.

Plant density (pl/m2)	Stalk breakage means (%)^	
	391134R	Pioneer 3995
17.2	7.9	-
13.8	5.5	-
11.5	3.5	-
8.6	2.5	17.2
6.9	-	18.9
5.7	0.4	16.5
4.9	-	9.2
3.8	-	7.4
Means (X)	4.0	13.8

^since variances were high, anaylsis was ineffective.
-not tested at this plant density.

The recommended plant density of 5.7 plants/m2 for Pioneer 3995 resulted in a stalk breakage value of 16.5%. This value can be considered close to the norm for most conventional type corn hybrids. On the other hand, hybrid 391134R had exceptional stalk breakage resistance. It's mean value of 3.5% at the optimal grain yield plant density of 11.5 plants/m2 is considered to be a very low incidence of stalk breakage for corn. The low occurrence of stalk breakage in plots of 391134R appears to be due to the semi-dwarf stature of the plant. The distance between the smaller corn ear and ground level is reduced in the semi-dwarf hybrid and appears to make for a relatively stronger stem due to reduced leverage effects.

The difference in stalk breakage between Pioneer 3995 and hybrid 391134R at the recommended plant densities for grain yield (5.7 and 11.5 plants/m2, respectively) was 13.0% with 391134R having the distinct advantage. In actual practice, the obtainable yield of Pioneer 3995 (ie. the total amount of grain that can be picked up by a commercial harvest operation) would not reflect a decrease of 13.0% in relation to 391134R due to the fact that not all plants displaying stalk breakage would be lost in the harvest operation. From personal experience, it can be estimated that the ears from approximately 50% of the plants showing stalk breakage are harvestable. This in effect, increases the yield advantage of 391134R over Pioneer 3995 by 9% (Table 10). Overall,

TABLE 10

The comparison of mean grain yield of Pioneer 3995 (5.7 plants/m2) and 391134R (11.5 plants/m2) with estimated harvestable field losses accounted for.

Losses (cause)	Pioneer 3995 Loss (%)	Pioneer 3995 Yield (g/m2)	391134R Loss (%)	391134R Yield (g/m2)	Advantage of 391134R over Pioneer 3995 (%)
None	0.00	621	0.00	792	27.5
Stalk^ Breakage	8.25	570	1.75	778	36.5
Root^ lodging	3.15	552	0.00	778	40.9
Ear$ drop	1.70	543	0.10	777	43.1

^50% of mean value used as a field loss.
$100% of mean value used as a field loss.

this would result in a yield advantage of 36.5% for 391134R over Pioneer 3995.

The low stalk breakage value for Pioneer 3995 at the highest plant density (8.6 plants/m2) is uncharacteristic of conventional height corn hybrids. While plants at this high plant density displayed characteristic symptoms of high density stress (e.g. increased ear and plant height, thin stems and delayed silking), they did not display the expected severe losses from stalk breakage. Instead, values for stalk breakage among these plots were much more variable. This in itself is undesirable due to the increased unpredictability of the trait. Therefore, it would appear that a plant density lower than 8.6 plants/m2 should be used for the grain production of Pioneer 3995. The plant density of 6.9 plants/m2 significantly outyielded the provincially recommended 5.7 plants/m2. However, increases in stalk breakage and root lodging were associated with the higher plant density (6.9 plants/m2) but were not large enough to compensate for the yield increase observed. From these results, one might question whether or not 5.7 plant/m2 is an adequate plant density to be used for grain corn production of Pioneer 3995 or other similar types in Manitoba.

4.3.2 Root Lodging

The mean percentage values of root lodging are given in Table 11 for the two corn hybrids grown at the 8 prescribed plant densities. Pioneer 3995 demonstrated some susceptability to root lodging, with mean values ranging from 6.3 to 9.9%. Hybrid 391134R, however, had no appreciable occurrence of this trait.

One reason why 391134R is highly resistant to root lodging is that it forms an elaborate system of adventitious or prop roots which develop from as many as three nodes above the ground surface. In comparison, the development of prop roots on Pioneer 3995 was less extensive.

The difference in mean root lodging values between the two hybrids was relatively large with 6.3% for Pioneer 3995 and 0.0% for 391134R at the recommended plant densities of 5.7 and 11.5 plants/m2, respectively. Once again, it can be assumed that only 50% of lodged plants will be lost during the harvest operation (personal experience). This, in effect, increases the obtainable yield advantage of 391134R over Pioneer 3995 to 40.9% (Table 10).

In this experiment, there was no apparent relationship between varying plant density and root lodging. In the literature, however, stalk breakage and root lodging are reported to increase as plant density increases (Dungan et al. 1958; Rutger and Crowder 1967 a; Giesbrecht 1969, 1976;

TABLE 11

Mean percentage values of root lodging of both 391134R and Pioneer 3995 over six station years and varying plant densities.

Plant density (pl/m2)	Root lodging (%)^	
	391134R	Pioneer 3995
17.2	0.2	-
13.8	0.2	-
11.5	0.0	-
8.6	0.1	7.8
6.9	-	7.3
5.7	0.0	6.3
4.9	-	9.9
3.8	-	8.3
Means (X)	0.1	7.9

^since variances were very high, anaylsis was ineffective.

-indicates no tests at this particular plant density.

Milbourn et al. 1978; Remison and Akinleye 1978; Troyer and Rosenbrook 1983). These differences in findings may be explained on the basis that other experiments have combined the data for stalk breakage and root lodging. If both traits were combined in the present experiment, a relationship as described in the literature would be observed.

4.3.3 Ear Drop

Depending upon genotype, ear drop (ie. breakage of the attachment of ear to the stalk) can occur near the time of maturity. The mean percentage values for ear drop are given in Table 12. It is apparent that ear drop was a relatively rare event for both corn hybrids. The occurrence of this trait was observed with higher frequencies at the higher plant densities of both Pioneer 3995 (5.7 to 8.6 plants/m2) and 391134R (11.5 to 17.2 plants/m2).

The semi-dwarf corn hybrid appears to be almost completely resistant to ear drop (with a mean of 0.0% overall) while Pioneer 3995 exhibited a low mean value of 0.9% for this trait. The shank, which attaches the ear to the stalk, appeared to be much stronger in 391134R than in Pioneer 3995, as was confirmed from experience when hand picking the ears at harvest. This, along with a proportionately smaller ear (ie. reduced leverage effect), could be the reason for the difference in ear drop between the two hybrids.

TABLE 12

Mean percentage values of ear drop of both 391134R and Pioneer 3995 over six station years and varying plant densities.

Plant density (pl/m2)	Ear drop (%)^	
	391134R	Pioneer 3995
17.2	0.1	-
13.8	0.0	-
11.5	0.1	-
8.6	0.0	1.1
6.9	-	1.4
5.7	0.0	1.7
4.9	-	0.5
3.8	-	0.0
Means (X)	0.0	0.9

^since variances were very high, anaylsis was ineffective.

-indicates no tests at this particular plant density.

It is impossible for a conventional harvest operation to retrieve dropped ears. Therefore, any value attributed to ear drop is considered to be a 100% loss of grain for those ears. The difference in ear drop between the two hybrids at the recommended plant densities is equal to 1.6% in favor of 391134R. This, in effect, increases the obtainable yield advantage of 391134R over Pioneer 3995 to 43.1% (Table 10).

Since ear drop is a rare event, it is difficult to establish a relationship with plant density on a small plot basis with a limited number of replications. This is perhaps why most of the literature makes no comment on such a relationship. However, after completing a large experiment, Troyer and Rosenbrook (1983) demonstrated that the incidence of ear drop significantly increased as plant density increased. The results obtained from the present experiment appear to follow this same trend (Table 12).

4.3.4 Ear Barrenness

Ear barrenness refers to the number or percentage of plants which fail to develop an ear. While this trait was a relativly rare event in the present study, a relationship of increasing ear barrenness with increasing plant density is apparent (Table 13). The corn hybrid 391134R expressed this trait particularly at the two highest plant densities tested, 13.8 and 17.2 plants/m2, with values of 0.4 and 1.1%

TABLE 13

Mean percentage values of barren plants of 391134R and Pioneer 3995 over six station years and varying plant densities.

Plant density (pl/m2)	Barrenness (% plants)^	
	391134R	Pioneer 3995
17.2	1.1	-
13.8	0.4	-
11.5	0.0	-
8.6	0.0	1.9
6.9	-	1.7
5.7	0.2	1.1
4.9	-	0.2
3.8	-	0.3
Means (X)	0.3	1.0

^since variances were very high, anaylsis was ineffective.

-indicates no tests at this particular plant density.

recorded, respectively. At all other plant density levels ear barrenness values were negligible. However, Pioneer 3995 demonstrated appreciable levels of ear barrenness at medium to high plant densities (ie. from 5.7 to 8.6 plants/m2 with a range of values from 1.1 to 1.9%).

It has been established that ear barrenness values increase as plant density increases (Lang et al. 1956; Dungan et al. 1958; Mortimore and Wall 1965; Rutger and Crowder 1967 a; Giesbrecht 1969; Iremiren and Milbourn 1980 and Troyer and Rosenbrook 1983). A similar relationship was apparent in the present experiment. Ear barrenness is considered to reflect a reaction to high density stress whereby competition for nutrients, moisture and light is great. As a result, a plant that is barren probably did not receive sufficient nutrients to support ear development.

While 391134R showed negligible ear barrenness values at the optimum grain plant density (11.5 plants/m2), Pioneer exhibited a value of 1.1% at the recommended plant density of 5.7 plants/m2. Thus, 391134R appears to be more tolerant to high plant density stress than does Pioneer 3995. The difference in values for this trait do not affect the yields obtained, since barren plants (ie. plants with no grain) did not contribute to the harvest yield figures presented in Tables 5 and 6.

4.3.5 Tillering

It has been established that tillering decreases as plant density increases (Dungan et al. 1958; Mortimore and Wall 1965; Giesbrecht 1969). The results of the present experiment support this relationship (Tables 14 and 15). As plant density increases from one level to the next, the percentage of tillering decreases for both corn hybrids.

Tillering is considered to be a response to environmental conditions which are capable of supporting higher plant densities than those actually present (Dungan et al. 1958). Therefore, if the tillering percentage is relatively high, it can be argued that the optimal plant density has not yet been reached. In this study, the semi-dwarf displayed a low level of tillering at the optimal plant density of 11.5 plants/m2 for grain production. With lower plant densities (8.6 and 5.7 plants/m2) increases in tillering were measured, while higher densities (13.8 and 17.2 plants/m2) showed insignificant decreases. Pioneer 3995 generally had high levels (45.4%) of tillering at the recommended grain plant density of 5.7 plants/m2. However, under the stressful conditions observed in Ridgeville in 1985, tillering values were much lower than at other sites and years. The lowest overall value for this trait for Pioneer 3995 (10%) was recorded with the highest plant density of 8.6 plants/m2. The high levels of tillering measured for Pioneer 3995 can probably be considered a characteristic of this particu-

TABLE 14

The amount of tillering (%) of 391134R over five station years and varying plant densities.

Plant density (pl/m2)	Winnipeg 1984	Winnipeg 1985	Carman 1984	Carman 1985	Ridgeville 1984	Ridgeville 1985	$\bar{X}$^
17.2	0.0 c*	0.9 b	0.2 c	0.4 c	-	0.0 b	0.15 c
13.8	0.3 c	0.5 b	0.0 c	0.3 c	-	0.0 b	0.13 c
11.5	0.6 c	0.6 b	0.3 c	1.9 cb	-	0.0 b	0.69 c
8.6	6.2 b	8.3 b	3.3 b	4.1 b	-	0.8 ab	3.62 b
5.7	37.6 a	19.9 a	18.2 a	14.1 a	-	2.5 a	18.11 a
F value	123.9	8.1	119.0	33.2	NA	2.5	235.5
C.V.	28.3	84.8	28.2	41.8	NA	164.1	38.4

*means followed by the same letter are not significantly different at the P = 0.05 level.
^Winnipeg (1985 data) excluded due to invalidation (Bartletts test).
-data not available.

TABLE 15

The amount of tillering (%) of Pioneer 3995 over five station years and varying plant densities.

Plant density (pl/m2)	Winnipeg 1984	Winnipeg 1985	Carman 1984	Carman 1985	Ridgeville 1984	Ridgeville 1985	$\bar{X}$^
8.6	8.7 e*	18.7 c	10.9 c	10.8 d	-	0.8 b	10.0 e
6.9	45.5 d	33.8 c	28.1 c	32.8 c	-	5.2 b	29.1 d
5.7	68.6 c	60.3 b	51.9 b	43.6 c	-	2.5 b	45.4 c
4.9	96.3 b	79.7 ab	81.2 a	66.0 b	-	8.7 b	66.4 b
3.8	125.5 a	89.8 a	88.0 a	116.7 a	-	24.1 a	88.8 a
F value	71.9	24.8	28.7	43.7	NA	4.8	150.5
C.V.	13.6	18.5	20.6	19.6	NA	89.3	20.3

*means followed by the same letter are not significantly different at the P = 0.05 level.

^all five station years pooled.

lar genotype, but may also be considered a disadvantage because tillers generally produce no grain and can hamper harvest operations.

4.3.6 Plant and Ear Height

The results found in Tables 16 and 17 demonstrate that plant and ear height increased for Pioneer 3995 (from 202 to 215 cm, and from 70 to 80 cm, respectively) when plant densities increased from 3.8 to 8.6 plants/m2. Results obtained from 391134R (Tables 18 and 19) demonstrate a relationship of increasing plant and ear height (from 136 to 150 cm, and from 45 to 55 cm, respectively) as plant densities were increased from 5.7 to 11.5 plants/m2. However, plant densities higher than 11.5 plants/m2 indicated that a plateau had been reached for both traits. These results obtained for hybrid 391134R are unique. They differ from those obtained for Pioneer 3995 and they also did not agree with other research findings that maximum height was obtained at medium plant densities (Dungan et al. 1958; Bunting 1973).

From the data obtained, it can be seen that 391134R is indeed a semi-dwarf corn hybrid. This hybrid appears to be reduced in size approximately by one-third that of Pioneer 3995.

TABLE 16

Plant height (cm) of Pioneer 3995 over six station years and grown at varying plant densities.

Plant density (pl/m2)	Winnipeg 1984	Winnipeg 1985	Carman 1984	Carman 1985	Ridgeville 1984	Ridgeville 1985	$\bar{X}$^
8.6	227 a*	185 a	237 a	230 a	232 a	204 a	215 a
6.9	222 ab	177 ab	235 a	223 a	227 ab	202 a	210 b
5.7	218 bc	184 ab	235 a	227 a	223 b	196 ab	210 b
4.9	218 bc	176 b	230 a	222 a	222 bc	197 ab	207 b
3.8	213 c	176 b	230 a	217 a	215 c	187 b	202 c
F value	9.67	3.06	0.36	1.83	8.06	3.84	16.41
C.V.	1.25	2.47	3.84	2.83	1.68	2.99	2.31

*means followed by the same letter are not significantly different at the P = 0.05 level.
^Carman (1984 data) excluded due to invalidation (Bartletts test).

TABLE 17

Ear height (cm) achieved by Pioneer 3995 over six station years and varying plant densities.

Plant density (pl/m2)	Winnipeg		Carman		Ridgeville		
	1984	1985	1984	1985	1984	1985	$\bar{X}$^
8.6	81 a*	66 a	90 a	88 a	77 a	63 a	80 a
6.9	76 b	66 a	88 a	86 ab	73 ab	58 ab	76 b
5.7	73 bc	62 bc	85 a	83 abc	71 ab	56 bc	74 c
4.9	71 c	63 b	82 a	79 bc	70 b	55 bc	71 cd
3.8	70 c	60 c	82 a	77 c	67 b	52 c	70 d
F value	13.29	11.11	1.59	4.78	3.98	7.46	19.84
C.V.	2.69	2.18	5.88	4.58	4.59	4.51	4.71

*means followed by the same letter are not significantly different at the P = 0.05 level.

^Winnipeg (1985 data) excluded due to invalidation (Bartletts test).

TABLE 18

Plant height (cm) of 391134R over six station years and varying plant densities.

Plant density (pl/m2)	Winnipeg		Carman		Ridgeville		
	1984	1985	1984	1985	1984	1985	$\bar{X}$^
17.2	155 a*	133 a	150 bc	167 a	160 a	144 a	152 a
13.8	157 a	134 a	165 a	163 a	158 a	141 ab	151 a
11.5	153 a	134 a	163 ab	163 a	157 a	144 a	150 a
8.6	143 b	132 a	158 abc	151 b	148 b	134 bc	142 b
5.7	137 c	127 b	147 c	145 c	138 c	131 c	136 c
F value	31.53	7.88	3.59	27.66	83.71	7.39	102.46
C.V.	1.79	1.43	4.72	1.96	1.12	2.60	1.84

*means followed by the same letter are not significantly different at the P = 0.05 level.
^Carman (1984 data) excluded due to invalidation (Bartletts test).

TABLE 19

Ear height (cm) of 391134R over six station years and varying plant densities.

Plant density (pl/m2)	Winnipeg		Carman		Ridgeville		
	1984	1985	1984	1985	1984	1985	$\bar{X}$^
17.2	60 ab*	47 ab	60 a	63 a	56 a	45 a	55 a
13.8	61 a	48 a	63 a	62 a	55 a	44 a	56 a
11.5	56 bc	46 ab	65 a	62 a	55 a	45 a	55 a
8.6	54 c	44 b	62 a	56 b	49 b	39 b	50 b
5.7	46 d	41 c	55 b	49 c	45 c	37 b	45 c
F value	23.36	10.91	8.93	13.41	19.01	6.21	67.05
C.V.	3.76	3.30	3.55	4.69	3.74	6.61	4.29

*means followed by the same letter are not significantly different at the P = 0.05 level.
^all six station years pooled.

4.3.7 Plant Development and Maturity

There are several stages of plant development which can be used to measure the rate of progress of the crop towards maturity. Thus, it is important that comparisons be made both between and within the two corn hybrids.

The first visible stage of development is emergence. In the present study it was measured that 391134R emerged in an average of 13.3 days while Pioneer 3995 required an average of 14.4 days.

The next stages measured were 50% silking and anthesis. Silking was significantly delayed and anthesis was unaffected as plant densities increased for both corn hybrids (Tables 20, 21, 22, and 23). Comparisons between the two hybrids indicated that Pioneer 3995 (at the recommended 5.7 plants/m2) was earlier than 391134R (at it's optimum of 11.5 plants/m2) by approximately three days in reaching 50% silking. However, the difference between the hybrids in time to anthesis was only 0.5 days in favor of Pioneer 3995. Silking and anthesis were more synchronized for 391134R than for Pioneer 3995.

The grain moisture of 391134R (11.5 plants/m2) was approximately five percentage points higher at harvest than that of Pioneer 3995 at 5.7 plants/m2 (Tables 24 and 25). Contrary to some published reports (Rutger and Crowder 1967 a; Hunter et al. 1970; Bunting 1973) the present study did

TABLE 20

The number of days to 50% silk by 391134R over six station years and varying plant densities.

Plant density (pl/m2)	Winnipeg		Carman		Ridgeville		
	1984	1985	1984	1985	1984	1985	$\bar{X}$^
17.2	77 a*	79 a	66 a	71 a	75 a	83 a	75 a
13.8	76 ab	79 a	64 b	71 a	74 ab	82 bc	74 b
11.5	76 ab	79 ab	63 b	70 a	73 bc	83 ab	74 b
8.6	76 a	78 bc	62 c	71 a	72 cd	81 c	73 c
5.7	75 b	78 c	62 c	69 b	72 d	81 c	73 c
F value	3.14	5.50	46.0	5.29	9.74	7.43	43.67
C.V.	0.64	0.57	0.61	0.69	0.85	0.59	0.66

*means followed by the same letter are not significantly different at the P = 0.05 level.
^all six stations years pooled.

TABLE 21

The number of days to 50% silk by Pioneer 3995 over six station years and varying plant densities.

Plant density (pl/m2)	Winnipeg		Carman		Ridgeville		
	1984	1985	1984	1985	1984	1985	$\bar{X}$^
8.6	75 a*	79 a	62 a	71 a	72 a	81 a	72 a
6.9	75 a	78 a	61 b	70 bc	71 ab	82 a	71 b
5.7	74 a	78 a	61 b	70 b	71 bc	80 a	71 b
4.9	75 a	78 a	61 b	70 bc	70 bc	80 a	71 b
3.8	75 a	78 a	61 b	69 c	70 c	80 a	70 c
F value	1.00	0.82	10.00	15.14	5.04	1.92	16.66
C.V.	0.35	0.68	0.56	0.49	0.87	1.12	0.62

*means followed by the same letter are not significantly different at the P = 0.05 level.
^Ridgeville (1985 data) excluded due to invalidation (Bartletts test).

TABLE 22

The number of days to 50% anthesis by 391134R over six station years and varying plant densities.

Plant density (pl/m2)	Winnipeg		Carman		Ridgeville		
	1984	1985	1984	1985	1984	1985	X̄^
17.2	75 a*	79 a	62 a	71 a	73 a	82 a	74 a
13.8	76 a	79 a	62 a	71 a	73 a	81 a	74 a
11.5	76 a	79 a	62 a	71 a	73 a	82 a	74 a
8.6	76 a	79 a	62 a	71 a	72 a	81 a	73 a
5.7	76 a	79 a	62 a	71 a	73 a	81 a	74 a
F value	1.43	0.50	1.00	0.33	0.54	0.77	1.09
C.V.	0.90	0.57	0.51	0.77	0.91	0.81	0.77

*means followed by the same letter are not significantly different at the P = 0.05 level.
^all six station years pooled.

TABLE 23

The number of days to 50% anthesis by Pioneer 3995 over six station years and varying plant densities.

Plant density (pl/m2)	Winnipeg		Carman		Ridgeville		$\bar{X}$^
	1984	1985	1984	1985	1984	1985	
8.6	75 a*	78 bc	61 a	71 a	72 a	81 ab	73 a
6.9	75 a	78 c	61 a	70 a	72 a	82 a	73 a
5.7	75 a	79 abc	61 a	71 a	72 a	81 b	73 a
4.9	76 a	79 a	61 a	71 a	72 a	81 ab	73 a
3.8	75 a	79 ab	61 a	71 a	71 a	80 b	73 a
F value	0.45	4.55	0.29	0.57	0.37	2.80	0.97
C.V.	0.80	0.54	0.97	0.96	1.18	0.80	0.88

*means followed by the same letter are not significantly different at the P = 0.05 level.
^all six station years pooled.

TABLE 24

Grain moisture (%), at time of harvest of 391134R over five station years at varying plant densities.

Plant density (pl/m2)	Winnipeg		Carman		Ridgeville		$\bar{X}$^
	1984	1985	1984	1985	1984	1985	
17.2	38 a*	45 a	30 b	40 a	36 a	-	38 a
13.8	37 a	44 ab	34 a	39 ab	37 a	-	38 a
11.5	37 a	44 ab	33 ab	39 ab	37 a	-	38 a
8.6	39 a	43 b	34 a	38 b	36 a	-	38 a
5.7	38 a	43 b	33 ab	36 c	33 b	-	37 b
F value	1.31	2.34	3.80	13.14	3.46	NA	4.33
C.V.	2.80	1.31	4.64	1.78	3.19	NA	2.79

*means followed by the same letter are not significantly different at the P = 0.05 level.
^all five station years pooled

TABLE 25

Grain moisture (%), at time of harvest of Pioneer 3995 over six station years at varying plant densities.

Plant density (pl/m2)	Winnipeg		Carman		Ridgeville		
	1984	1985	1984	1985	1984	1985	X̄^
8.6	31 b*	42 a	28 a	34 a	28 a	44 a	35 a
6.9	31 b	42 a	29 a	32 a	28 a	45 a	34 a
5.7	31 b	40 a	27 a	34 a	27 a	40 b	33 b
4.9	34 a	41 a	28 a	33 a	28 a	41 b	34 a
3.8	35 a	41 a	28 a	32 a	29 a	40 b	34 a
F value	4.04	1.31	1.52	2.66	1.25	7.24	2.80
C.V.	4.78	3.71	7.95	4.19	4.20	2.80	4.61

*means followed by the same letter are not significantly different at the P = 0.05 level.
^all six station years pooled.

not show any relationship between harvest grain moisture and plant density.

In general, 391134R emerged earlier but Pioneer 3995 was an earlier maturing corn hybrid. Pioneer 3995 is rated at 2150 C.H.U. for Manitoba but since 391134R is as yet unregistered for Manitoba, no rating exists for it. From the results of the experiment, the CHU rating for 391134R would likely be in a range from 2200 to 2250 CHU.

4.3.8 Seed Characteristics

The results of grain protein, 1000 kernel weight, and grain density measurements from the two hybrids are listed in Tables 26 to 32 inclusive.

Grain protein displayed an inverse relationship with plant density (Tables 26 and 27). Significant increases in protein content were observed for each hybrid as plant densities decreased. Mean differences in protein content between hybrids, however, were not significant. The inverse relationship between plant density and grain protein agrees with the results of Zuber et al. 1954; Lang et al. 1956; Genter et al. 1956; and Pendleton and Seif 1961.

Environmental factors affected the level of protein content. Values of this trait for both corn hybrids at Carman (1984), where drought conditions existed, were higher than

TABLE 26

The percent protein (at 0% moisture) of 391134R over six station years and varying plant densities.

Plant density (pl/m2)	Winnipeg 1984	Winnipeg 1985	Carman 1984	Carman 1985	Ridgeville 1984	Ridgeville 1985	$\bar{X}$^
17.2	10.7 c*	10.3 b	12.2 ab	10.0 c	10.2 cd	10.2 b	10.7 c
13.8	10.9 bc	10.3 b	11.3 d	10.1 c	10.0 d	10.6 ab	10.5 c
11.5	11.1 b	10.4 b	11.9 bc	10.5 b	10.4 bc	10.7 ab	10.9 b
8.6	11.5 b	10.8 ab	11.5 cd	10.5 b	10.7 ab	10.6 ab	11.0 b
5.7	11.6 a	11.0 a	12.5 a	11.0 a	10.7 a	11.2 a	11.4 a
F value	29.84	3.57	9.11	18.29	10.15	2.68	34.61
C.V.	1.16	2.53	2.34	1.63	1.60	3.68	1.94

*means followed by the same letter are not significantly different at the P = 0.05 level.
^Ridgeville (1985 data) excluded due to invalidation (Bartletts test).

TABLE 27

The percent protein (at 0% moisture) of Pioneer 3995 over six station years and varying plant densities.

Plant density (pl/m2)	Winnipeg		Carman		Ridgeville		
	1984	1985	1984	1985	1984	1985	$\bar{X}$^
8.6	11.2 c*	10.6 b	11.3 b	9.7 b	9.7 d	9.9 b	10.4 d
6.9	11.8 b	10.7 b	11.4 b	10.3 a	10.1 c	10.0 ab	10.7 c
5.7	11.9 b	10.9 b	11.7 b	10.3 a	10.6 b	9.8 b	10.8 c
4.9	12.4 a	11.3 ab	12.4 a	10.6 a	10.9 ab	10.0 ab	11.3 b
3.8	12.8 a	11.7 a	12.5 a	10.8 a	11.3 a	10.4 a	11.6 a
F value	18.99	3.56	21.22	6.85	23.69	3.93	53.19
C.V.	1.96	3.67	1.78	2.70	2.18	2.10	2.47

*means followed by the same letter are not significantly different at the P = 0.05 level.
^all six station years pooled.

the means from other stations and years. Conversely, protein measurements were lower for both hybrids from Ridgeville in both years, but for different reasons. In 1984, the Ridgeville site experienced very good growing conditions which led to the highest grain yield levels recorded. The protein content most likely declined in relative proportion due to the high levels of carbohydrates incorporated into the grain. At the same site in 1985 growing conditions were generally adverse. The likely reason for a lower protein content is that the production of seed protein suffered more than carbohydrate production.

Results obtained from 1000 kernel weight measurements demonstrated a significant inverse relationship with plant density for both corn hybrids (Tables 28 and 29). With each increment in plant density for 391134R (from 5.7 to 17.2 plants/m2) a significant decrease in 1000 kernel weight was realized. Similarly, Pioneer 3995 had a significant decrease in this trait for each increase in plant density (from 3.8 to 8.6 plants/m2) with the exception of the two densities of 5.7 and 6.9 plants/m2 which were not significantly different. The relationship found in the present experiment agrees with findings from other workers (Dungan et al. 1958; Rutger and Crowder 1967 a; Iremiren and Milbourn 1980).

When comparisons were made between the two corn hybrids, it was found that the mean 1000 kernel weight of 391134R was

TABLE 28

The 1000 kernel weight (grams) of 391134R over six station years and varying plant densities.

Plant density (pl/m2)	Winnipeg 1984	Winnipeg 1985	Carman 1984	Carman 1985	Ridgeville 1984	Ridgeville 1985	$\bar{X}$^
17.2	171 c*	148 c	143 e	150 d	176 c	123 d	148 e
13.8	179 bc	154 c	168 d	163 c	185 c	131 c	160 d
11.5	192 ab	170 b	185 c	173 bc	200 b	140 b	174 c
8.6	203 a	183 a	205 b	183 ab	213 a	156 a	188 b
5.7	210 a	190 a	230 a	191 a	222 a	159 a	198 a
F value	8.89	74.53	225.50	23.64	45.11	55.52	316.0
C.V.	4.90	2.15	2.08	3.35	2.49	2.53	2.56

*means followed by the same letter are not significantly different at the P = 0.05 level.
^Winnipeg (1984 data) excluded due to invalidation (Bartletts test).

TABLE 29

The 1000 kernel weight (grams) of Pioneer 3995 over six station years and varying plant densities.

Plant density (pl/m2)	Winnipeg		Carman		Ridgeville		
	1984	1985	1984	1985	1984	1985	$\bar{X}$^
8.6	217 c*	205 c	219 c	204 c	216 b	139 b	212 d
6.9	230 b	216 bc	232 bc	217 bc	236 ab	167 ab	226 c
5.7	234 b	221 ab	244 abc	220 bc	246 a	187 ab	233 c
4.9	248 a	224 ab	247 ab	236 ab	247 a	198 a	240 b
3.8	255 a	232 a	261 a	248 a	260 a	203 a	251 a
F value	26.54	6.52	4.38	8.03	4.84	2.58	31.30
C.V.	2.17	3.04	5.42	4.69	5.30	15.70	4.36

*means followed by the same letter are not significantly different at the P = 0.05 level.
^Ridgeville (1985 data) excluded due to invalidation (Bartletts test).

174 grams at it's optimum plant density for grain yield (11.5 plants/m2). This figure is approximately 75% of the corresponding 1000 kernel weight of 233 grams for Pioneer 3995 when grown at its recommended density (5.7 plants/m2). This is in accord with the proportionately reduced size of the semi-dwarf 391134R relative to Pioneer 3995.

Another criteria of kernel quality, grain density, was found to significantly decrease as plant density increased for both corn hybrids (Tables 30 and 31). Pioneer 3995 ranged from a mean of 717 grams/l at 8.6 plants/m2, to 726 grams/l at a density of 3.8 plants/m2. In comparison, the semi-dwarf corn hybrid (391134R) ranged from a mean of 697 grams/l at 17.2 plants/m2, to 715 grams/l at a density of 5.7 plants/m2. Significant differences were found in these small ranges due to the low level of variance computed. When the two corn hybrids were compared, Pioneer 3995 had a higher grain density (724 grams/l at 5.7 plants/m2) than hybrid 391134R, but the difference was not significant (Table 32).

In general, seed protein content of both corn hybrids was not significantly different. There was, however, a large difference in seed size and weight between hybrids. This difference may have an impact on the seeding, handling and drying of the grain. The mean grain density of the two hybrids overall was 715 grams/l, which is larger than the general average of 700 grams/l (Field Crop Recommendations

TABLE 30

The grain density (grams/litre) of 391134R over six station years and varying plant densities.

Plant density (pl/m2)	Winnipeg		Carman		Ridgeville		
	1984	1985	1984	1985	1984	1985	$\bar{X}$^
17.2	759 a*	628 c	757 a	621 c	767 a	652 c	697 c
13.8	766 a	637 abc	753 a	633 b	773 a	673 b	706 b
11.5	771 a	632 bc	761 a	630 bc	770 a	675 ab	707 b
8.6	769 a	645 a	754 a	637 b	770 a	681 ab	710 ab
5.7	760 a	642 ab	758 a	655 a	781 a	694 a	715 a
F value	1.14	3.55	0.39	16.78	0.78	6.55	10.15
C.V.	1.15	0.99	1.19	0.85	1.31	1.56	1.21

*means followed by the same letter are not significantly different at the P = 0.05 level.
^all six station years pooled.

TABLE 31

The grain density (grams/litre) of Pioneer 3995 over six station years and varying plant densities.

Plant density (pl/m2)	Winnipeg		Carman		Ridgeville		$\bar{X}$^
	1984	1985	1984	1985	1984	1985	
8.6	755 a*	659 a	743 bc	646 d	784 a	604 b	717 b
6.9	749 a	668 a	738 c	666 b	783 a	621 ab	721 ab
5.7	749 a	669 a	759 a	652 cd	789 a	656 a	724 ab
4.9	755 a	664 a	752 ab	664 bc	787 a	635 ab	725 a
3.8	741 a	667 a	753 a	685 a	786 a	648 ab	726 a
F value	1.64	0.32	7.56	14.42	0.31	2.36	2.75
C.V.	1.07	1.82	0.71	1.03	0.92	3.73	1.14

*means followed by the same letter are not significantly different at the P = 0.05 level.
^Ridgeville (1985 data) excluded due to invalidation (Bartletts test)

TABLE 32

Comparison of the grain densities (grams/l) of 391134R and Pioneer 3995.

Hybrid	Mean	Std Dev.	t	Prob > T
391134R	706.7	64.9	-0.277	0.7834 ns
Pioneer 3995	712.3	57.6	-0.277	0.7834 ns

ns indicates difference is not significant.

for Manitoba, 1984), thus the grain density of these two hybrids are comparable with other conventional hybrids.

4.3.9 Disease and Insect Levels

Corn smut (*Ustilago maydis*) was observed on Pioneer 3995 at low levels, but not on hybrid 391134R over the entire two-year experiment. This apparent tolerance of 391134R to corn smut is desirable and may make this hybrid more suitable for continuous corn production than other corn hybrids.

Rust (*Puccinia sorghi*) was observed in 1985 on both corn hybrids. However, levels were low and any effect on plant growth and development was minimal. European corn borer populations were high in 1984 but with chemical control measures (spraying one to three times with a recommended insecticide), the insect populations were reduced to low levels at the sites of Winnipeg and Ridgeville. However, the corn borer population at the Carman site in 1984 was not effectively controlled, resulting in increased stalk breakage. In 1985, corn borer infestations were less severe originally and chemical control measures were very effective.

Chapter V

SUMMARY

The grain yields of the two hybrids were considered one of the most important of the criteria set forth in this study. An optimum plant density for grain production for 391134R had been measured at 11.5 plants/m2. However, an optimum plant density for grain yield was not reached by Pioneer 3995 in this experiment. Yield response in relation to plant density was still increasing at the highest densities used. Thus, when comparisons were made between the two hybrids, the currently recommended plant density of 5.7 plants/m2 for Pioneer 3995 was compared to the optimum plant density (11.5 plants/m2) for 391134R based on the present study. This comparison indicated that the semi-dwarf (391134R) had a significantly higher yield potential than Pioneer 3995 and on this basis, could be considered a viable corn hybrid for southern Manitoba.

Optimum plant densities for silage yield for 391134R and Pioneer 3995 were 13.8 and 6.9 plants/m2, respectively. A direct comparison between these two densities shows a dry matter yield advantage for hybrid 391134R, but this yield difference was not significantly greater than that of Pioneer 3995. These results endorse 391134R's use as a silage crop, as it is comparable to Pioneer 3995. However, since seed costs of the three-way cross semi-dwarf hybrid will likely be 50 to 100% higher than conventional hybrids due to higher plant densities required, the use of 391134R as a silage may not be economical.

Based upon agronomic characteristics, 391134R appears to have a definite advantage over Pioneer 3995. For example, the difference in values of stalk breakage and root lodging between the two hybrids is significant. As well, 391134R appears to be less prone to ear drop and more tolerant of high plant density stress which can result in barren plants. These advantages might well be seen in a commercial harvest operation where a higher proportion of the crop can be harvested.

Pioneer 3995 is a corn hybrid which is one of the earliest in maturity recommended for Manitoba (rated at 2150 C.H.U.). The results of the present experiment indicate that 391134R rates at 2200 to 2250 C.H.U., and although later than Pioneer 3995, it can still be classified as relatively early when compared with the rankings of the other currently recommended hybrids for Manitoba (Field Crop Variety Recommendations for Manitoba, 1984).

Analysis of the measurements taken on protein and grain density found no significant differences between the two hybrids. Thus, the grain samples of the two hybrids appear to be of the same quality. Hybrid 391134R is described as a semi-dwarf and as such, it's size is proportionately reduced by approximately one-third of that of conventional hybrids.

In conclusion, the semi-dwarf corn hybrid 391134R has satisfactorily met all of the criteria put forth in this experiment and can be considered a viable hybrid for production in southern Manitoba. With modifications to common cereal seeding equipment, this hybrid can be seeded reasonably close to its optimal plant density of 11.5 plants/m2 for grain and 13.8 plants/m2 for silage. As well, the same crop can be harvested with only modifications to conventional cereal harvesting equipment.

Future experiments involving various planting techniques, fertilizer rates and other management factors may lead to better understanding and recommendations for commercial production. Genetic studies could also add insight into the nature of the dwarfing gene(s) when incorporated into inbreds or other hybrids. Further studies on these and other aspects of the semi-dwarf type of hybrid could result in their use in expanding corn production in southern Manitoba.

LITERATURE CITED

ADELANA, B.O. and MILBOURN, G.M. 1972. The growth of maize. I. The effect of plant density on yield of digestable dry matter and grain. J. Agric. Sci., Camb. 78:65-71.

ALESSI, J. and POWER, J.F. 1965. Influence of moisture, plant population, and nitrogen on dryland corn in the northern plains. Agron. J. 57: 611-612.

ANDREW, R.H. and PEEK, J.W. 1971. Influence of cultural practice and field environment on consistency of corn yields in northern areas. Agron. J. 63: 628-633.

BARTLETT, M.S. 1938. The approximate recovery of information from replicated field experiments with large blocks. J. Agric. Sci. 28: 418-427.

BUNTING, E.S. and WILLEY, L.A. 1959. The cultivation of maize for fodder and ensilage. Part 11: The effect of changes in plant density. J. Agric. Sci., Camb. 52: 313-319.

BUNTING, E.S. 1971. Plant density and yield of shoot dry material in maize in England. J. Agric. Sci., Camb. 77: 175-185.

BUNTING, E.S. 1973. Plant density and yield of grain maize in England. J. Agric. Sci., Camb. 81: 455-463.

BUNTING, E.S. 1976. Effects of grain formation on dry matter distribution and forage quatity in maize. Exper. Agric. 12: 417-428.

CASTLE, M.F., FOOT, A.S. and ROWLAND, S.J. 1951. American hybrid maize for silage in the south of England. Part 1. The yield and composition with special reference to plant population and nitrogenous fertilizer. J. Agric. Sci., Camb. 41: 282-287.

DAYNARD, T.B. and HUNTER, R.B. 1975. Relationships among whole-plant moisture, grain moisture, dry matter yield, and quality of whole-plant corn silage. Can. J. Plant Sci. 55: 77-84.

DAYNARD, T.B. and MULDOON, J.F. 1981. Effects of plant density on the yield, maturity and grain content of whole-plant maize. Can. J. Plant Sci. 61: 843-849.

DUNGAN, G.H., LANG, A.L. and PENDLETON, J.W. 1958. Corn plant population in relation to soil productivity. Advances in Ag. 10: 435-473.

DUNCAN, E.R. 1954. Influences on varying plant population, soil fertility and hybrid on corn yields. Soil Sci. Soc. Amer. Proc. 18: 437-440.

DUNCAN, W.G. 1958. The relationship between corn population and yield. Agron. J. 50: 82-84.

EDDOWS, M. 1969. Physiological studies of competition in Zea mays L. 11 Effect of competition among maize plants. J. Agric. Sci., Camb. 72: 195-202.

FAIREY, N.A. 1982. Influence of population density and hybrid maturity on productively and quality of forage maize. Can. J. Plant Sci. 62: 427-434.

FERY, R.L. and JANICK, J. 1971. Response of corn (Zea mays L.) to population pressure. Crop Sci. 11: 220-224.

FULTON, J.M. 1970. Relationships among soil moisture stress, plant populations, row spacing and yield of corn. Can. J. Plant Sci. 50: 31-38.

GENTER, C.F., EHEART J.F., and LINKOUS W.N. 1956. Effects of location, hybrid, fertilizer, and rate of planting on the oil and protein contents of grain corn. Agron. J. 48: 63-67.

GIESBRECHT, J. 1969. Effect of population and row spacing on the performance of four corn (Zea mays L.) hybrids. Agron. J. 61: 439-441.

GIESBRECHT, J. 1976. Plant population and the performance of corn hybrids. Can. J. Plant Sci. 56: 426.

GLOVER, D.V. 1970. Location of a gene in maize conditioning a reduced plant stature. Crop Sci. 10: 611-612.

HEMKEN, R.W., CLARK, N.A., GOERING, H.K. and VANDERSALL, J.H. 1971. Nutritive value of corn silage as influenced by grain content. Dairy Sci. 54: 383-389.

HOFF, D.J. and MEDERSKI, H.J. 1960. Effect of equidistant corn plant spacing on yield. Agron. J. 52: 295-297.

HOLLIDAY, R. 1960. Plant population and crop yield. Nature 186: 22-24.

HUNTER, R.B., KANNENBERG, L.W. and GAMBLE, E.E. 1970. Performance of five maize hybrids in varying plant populations and row widths. Agron. J. 62: 255-256.

IREMIREN, G.O. and MILBOURN, G.M. 1980. Effects of plant density on ear barrenness in maize. Exper. Ag. 16: 321-326.

KRALL, J.M., ESECHIE, H.A., RONEY, R.J., CLARK, S., TENEYCK, G., LUNDQUIST, M., HUMBURG, N.E., AXTHELM, L.S., DAYTON, A.P. and VANDERLIP, R.L. 1977. Influence of within-row variability in plant spacing on grain corn yield. Agron. J. 69: 797-799.

LANG, A.L., PENDLETON, J.W. and DUNGAN, G.H. 1956. Influence of population and nitrogen levels on yield and protein and oil content of nine corn hybrids. Agron. J. 48: 284-289.

LUTZ, J.A. Jr., CAMPER, H.M. and JONES, G.D. 1971. Row spacing and population effects on corn yields. Agron. J. 63: 12-14.

MANITOBA CORN COMMITTEE. 1984. Field corn production in Manitoba. Agdex 111.

MANITOBA AGRICULTURE. 1984. Field crop recommendations for Manitoba. Pages 74-82.

MILBOURN, G.M., TILEY, G.E.D. and CARR, M.K.V. 1978. Planting density for grain maize in south-east England. Exper. Ag. 14: 261-268.

MORTIMORE, C.G. and WALL, R.E. 1965. Stalk rot of corn in relation to plant population and grain yield. Can. J. Plant Sci. 45: 4877-492.

NELSON, O.E. Jr. and OHLROGGE, A.J. 1957. Differential response to population pressures by normal and dwarf lines of maize. Science 125: 1200.

PENDLETON, J.W. and SEIF, R.D. 1961. Plant population and row spacing studies with brachytic-2 dwarf corn. Crop Sci. 1: 433-435.

PHIPPS, R.H. 1975. A note on the effect of genotype, density and row width on the yield and quality of forage maize. J. Agric. Sci., Camb. 84: 567-569.

PHIPPS, R.H., FULFORD, R.J. and WELLER, R.F. 1981. The effect of maize silage grain content on live-weight gain of beef cattle. Maydica 26: 93-99.

REMISON, S.U. and AKINLEYE, D. 1978. Relationship between lodging, morphological characters and yield of varieties of maize (Zea mays L.). J. Agric. Sci., Camb. 91: 633-638.

ROBINSON, D.L. and MURPHY, L.S. 1972. Influence of nitrogen, phosphorus and plant population on yield and quality of forage corn. Agron. J. 64: 349-351.

RUTGER, J.N. and CROWDER, L.V. 1967 a. Effect of high plant density on silage and grain yields of six corn hybrids. Crop Sci. 7: 182-184.

RUTGER, J.N. and CROWDER, L.V. 1967 b. Effect of population and row width on corn silage yields. Agron. J. 59: 475-476.

SOWELL, W.FF., OHLROGGE A.J., and NELSON O.E., Jr. 1961. Growth and ruiting of compact and Hy normal corn types under a high population stress. Agron. J. 53: 25-28.

STICKLER, F.C. and LAUDE, H.H. 1960. Effect of row spacing and plant population on performance of corn, grain sorghum and forage sorghum. Agron. J. 52: 275-277.

STICKLER, F.C. 1964. Row width and plant population studies with corn. Agron. J. 56: 438-441.

STIVERS, R.K., GRIFFITH, D.R. and CHRISTMAS, E.P. 1971. Corn performance in relation to row spacings, populations, and hybrids on five soils in Indiana. Agron. J. 63: 580-582.

TERMONDE, D.E., SHANK, D.B., and DIRKS, V.A. 1963. Effects of population levels on yield and maturity of maize hybrids grown on the northern great plains. Agron. J. 55: 551-555.

THOMSON, A.J. and ROGERS, H.H. 1968. Yield and quality components in maize grown for silage. J. Agric. Sci., Camb. 71:393-403.

TROYER, A.F. and ROSENBROOK, R.W. 1983. Utility of higher plant densities for corn performance testing. Crop Sci. 23: 863-867.

ZUBER, M.S., SMITH, G.E. and GEHRKE, C.W. 1954. Crude protein of corn grain and stover as influenced by different hybrids, plant populations, and nitrogen levels. Agron. J. 46: 257-261.

Appendix A

APPENDIX

The combined analysis of variance for 391134R of the six station years for grain yield (grams/m2)

Source of Variation	DF	Sum of Squares	Mean Square	F
Site (Year)	4	539134.5	134783.6	68.78**
Reps (Site*Year)	12	102896.7	8574.7	4.38**
Density	4	517540.4	129385.1	66.03**
Year	1	836366.4	836366.4	426.82**
Density*Year	4	14085.0	3521.3	1.80ns
Site*Density*Year	16	84149.9	5259.3	2.68**
Error	48	94256.7	1959.5	
Total	89	2188429.6		

** indicates significant difference at the 0.01 level.
ns not significant.

The combined analysis of variance for Pioneer 3995 of the six station years for grain yield (grams/m2)

Source of Variation	DF	Sum of Squares	Mean Square	F
Site (Year)	4	123004.2	30751.1	17.42**
Reps (Site*Year)	12	47698.1	3974.8	2.25*
Density	4	605050.6	151262.7	85.70**
Year	1	666672.4	666672.4	377.72**
Density*Year	4	38070.4	9517.6	5.39**
Site*Density*Year	16	19643.3	1227.7	0.70ns
Error	48	84720.5	1765.0	
Total	89	1584859.0		

* indicates significant difference at the 0.05 level.
** indicates significant difference at the 0.01 level.
ns not significant.

Test for homogeneity of variances for grain yield of 391134R

Location and year of experiment	Individual Experiments: degrees of Freedom (fi)	Mean Squares (si2)	logesi2	filogesi2
WPG - 1984	8	3308.5	8.1043	64.8340
WPG - 1985	8	1695.2	7.4356	59.4845
Car - 1984	8	2848.3	7.9545	63.6360
Car - 1985	8	780.5	6.6599	53.2791
Rid - 1984	8	2072.1	7.6363	61.0907
Rid - 1985	8	1052.4	6.9588	55.6705
Totals	48	11757.0	44.7494	357.9948

X2 = 0.9536424 (48*7.5804-357.9948) = 5.593 ns can pool all six.

Test for homogeneity of variances for grain yield of Pioneer 3995

Location and year of Experiment	Individual Experiments: Degrees of Freedom (fi)	Mean Squares (si2)	logesi2	filogesi2
WPG - 1984	8	901.2	6.8038	54.4301
WPG - 1985	8	2183.0	7.6885	61.5078
Car - 1984	8	3500.7	8.1607	65.2858
Car - 1985	8	1833.6	7.5141	60.1125
Rid - 1984	8	1376.1	7.2270	57.8159
Rid - 1985	8	795.4	6.6788	53.4304
Totals	48	10590.0	44.0729	352.5825

X2 = 0.9536424 (48*7.4759-352.5825) = 5.9705 ns can pool all six.

Test for homogeneity of variances for stalk breakage of 391134R

Location and year of experiment	Individual Experiments: Degrees of Freedom (fi)	Mean Squares (si2)	logesi2	filogesi2
WPG - 1984	8	1.059	0.057	0.456
WPG - 1985	8	10.849	2.384	19.073
Car - 1984	8	26.828	3.289	26.315
Car - 1985	8	2.318	0.841	6.726
Rid - 1984	8	2.353	0.856	6.846
Rid - 1985	8	1.235	0.211	1.689
Totals	48	44.906		61.105

X2 = 0.9536424 (48*2.013-61.105) = 33.872** can not pool.

Test for homogeneity of variances for stalk breakage of Pioneer 3995

Location and year of experiment	Individual Experiments: Degrees of Freedom (fi)	Mean Squares (si2)	logesi2	filogsi2
WPG - 1984	8	18.653	2.926	23.408
WPG - 1985	8	45.049	3.808	30.462
Car - 1984	8	129.265	4.862	38.895
Car - 1985	8	96.968	4.574	36.595
Rid - 1984	8	15.083	2.714	21.595
Rid - 1985	8	15.893	2.766	22.127
Totals	48	319.977		173.196

X2 = 0.9536424 (48*3.976-173.196) = 16.857** can not pool.

Analysis of variance for the emergence of 391134R at the site of Ridgeville in 1984

Source of Variation	DF	Sum of Squares	Mean Square	F
Reps	2	2.1333	1.0667	3.37ns
Density	4	1.0667	0.2667	0.84ns
Error	8	5.7333	0.7167	
Total	14	8.9333		

ns not significant

Analysis of variance for the emergence of Pioneer 3995 at the site of Ridgeville in 1984

Source of Variation	DF	Sum of Squares	Mean Square	F
Reps	2	1.200	0.600	0.71ns
Density	4	0.400	0.100	0.12ns
Error	8	8.400	1.050	
Total	14	10.000		

ns not significant

Stalk breakage (%) of 391134R for each station year tested

Plant Density (pl/m2)	Winnipeg 1984	Winnipeg 1985	Carman 1984	Carman 1985	Ridgeville 1984	Ridgeville 1985
17.2	0.9a	11.4ab	24.5a	7.2a	2.1a	1.3a
13.8	1.6a	12.2a	14.3b	2.1b	2.1a	0.5a
11.5	1.3a	5.0bc	10.1bc	0.6b	1.9a	1.9a
8.6	0.0a	5.8abc	7.5bc	0.8b	0.8a	0.0a
5.7	0.0a	0.0c	2.6c	0.0b	0.0a	0.0a
F value	1.51	6.93	7.64	10.95	1.15	1.68
C.V.	138	48	44	71	110	150

Stalk breakage (%) of Pioneer 3995 for each station year tested

Plant Density (pl/m2)	Winnipeg 1984	Winnipeg 1985	Carman 1984	Carman 1985	Ridgeville 1984	Ridgeville 1985
8.6	8.3a	48.3a	19.2a	15.0a	8.3ab	4.2a
6.9	5.2a	45.8a	23.9a	22.9a	11.4a	4.1a
5.7	9.0a	43.6a	10.3a	19.2a	5.1abc	11.5a
4.9	2.9a	21.7b	14.5a	5.8a	2.9bc	7.2a
3.8	3.7a	20.4b	5.6a	11.1a	0.0c	3.7a
F value	1.19	12.54	1.21	1.40	4.00	2.08
C.V.	74	19	77	67	70	65

Root lodging (%) of 391134R for each station year tested

Plant Density (pl/2)	Winnipeg 1984	Winnipeg 1985	Carman 1984	Carman 1985	Ridgeville 1984	Ridgeville 1985
17.2	0.0a	0.0a	1.3a	0.0a	0.0a	0.0a
13.8	0.5a	0.0a	0.5ab	0.0a	0.0a	0.0a
11.5	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a
8.6	0.8a	0.0a	0.0a	0.0a	0.0a	0.0a
5.7	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a
F value	0.69	-	2.42	-	-	-
C.V.	296	-	172	-	-	-

Root lodging (%) of Pioneer 3995 for each station year tested

Plant Density (pl/m2)	Winnipeg 1984	Winnipeg 1985	Carman 1984	Carman 1985	Ridgeville 1984	Ridgeville 1985
8.6	0.8a	13.3a	17.5a	14.2a	0.8a	0.0a
6.9	1.0a	13.5a	2.1b	27.1ab	0.0a	0.0a
5.7	1.3a	19.2a	5.1ab	19.2ab	0.0a	0.0a
4.9	0.0a	30.4a	0.0b	29.0a	0.0a	0.0a
3.8	0.0a	27.8a	5.57ab	16.7ab	0.0a	0.0a
F value	0.42	1.66	2.99	2.90	1.00	-
C.V.	252	51	113	31	387	-

The comparison of ear height (cm) of 391134R (at 11.5 pl/m2) and Pioneer 3995 (at 5.7 pl/m2) by using the t-test

Hybrid	Reps	Mean	Std Dev	t	Prob > T
391134R	18	54.9	7.91	-5.25	0.0001**
Pioneer 3995	18	71.7	11.07	-5.25	0.0001**

** indicates significant difference at the 0.01 level.

The comparison of plant height (cm) of 391134R (at 11.5 pl/m2) and Pioneer 3995 (at 5.7 pl/m2) by using a t-test

Hybrid	Reps	Mean	Std Dev	t	Prob > T
391134R	18	152.4	11.53	-11.47	0.0001**
Pioneer 3995	18	213.9	19.62	-11.47	0.0001**

** indicates significant difference at the 0.01 level.

The comparison of the number of days to silk (50%) of 391134R (at 11.5 pl/m2) and Pioneer 3995 (at 5.7 pl/m2) by using a t-test

Hybrid	Reps	Mean	Std Dev	t	Prob > T
391134R	18	74.1	6.55	0.72	0.475ns
Pioneer 3995	18	72.5	6.36	0.72	0.475ns

ns not significantly different.

The comparison of the number of days to 50% anthesis of 391134R (at 11.5 pl/m2) and Pioneer 3995 (at 5.7 pl/m2) by using a t-test

Hybrid	Reps	Mean	Std Dev	t	Prob > T
391134R	18	73.8	6.41	0.36	0.723ns
Pioneer 3995	18	73.1	6.64	0.36	0.723ns

ns not significantly different.

The comparison of the grain moisture content (%) of 391134R (at 11.5 pl/m2) and Pioneer 3995 (at 5.7 pl/m2) by using a t-test

Hybrid	Reps	Mean	Std Dev	t	Prob > T
391134R	15	37.9	3.83	2.876	0.0077**
Pioneer 3995	17	32.9	5.86	2.802	0.0088**

** indicates significant difference at the 0.01 level.

The comparison of the protein content (%) of 391134R (at 11.5 pl/m2) and Pioneer 3995 (at 5.7 pl/m2) by using a t-test

Hybrid	Reps	Mean	Std Dev	t	Prob > T
391134R	15	10.78	0.612	0.5597	0.5803ns
Pioneer 3995	15	10.64	0.751	0.5597	0.5801ns

ns not significantly different.

The comparison of 1000 kernel weight (g) of 391134R (at 11.5 pl/m2) and Pioneer 3995 (at 5.7 pl/m2) by using a t-test

Hybrid	Reps	Mean	Std Dev	t	Prob > T
391134R	18	176.6	20.79	-6.75	0.0001**
Pioneer 3995	18	225.2	22.33	-6.75	0.0001**

** indicates significant difference at the 0.01 level.

The comparison of the emergence (days too) of 391134R (at 11.5 pl/m2) and Pioneer 3995 (at 5.7 pl/m2) by using a t-test

Hybrid	Reps	Mean	Std Dev	t	Prob > T
391134R	18	13.56	3.434	-0.73	0.4704ns
Pioneer 3995	18	14.39	3.415	-0.73	0.4704ns

ns not significantly different.