REDUCED TILLAGE FIELD CORN (*Zea mays* L.) PRODUCTION IN MANITOBA

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David Alexander Wall

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Wall, David Alexander. M.Sc., The University of Manitoba, May, 1982. Reduced Tillage Field Corn (Zea mays L.) Production in Manitoba. Major Professor; Dr. E.H. Stobbe.

Field studies were conducted on field corn (*Zea mays* L.) under various conventional and reduced tillage cropping systems and straw management practices to determine the effect on soil physical properties, crop growth, development and yield. The performance of eight corn hybrids was evaluated under conventional and zero tillage to study the adaptability of hybrids to zero tillage cropping practices.

Corn under zero tillage exhibited delays in emergence, silking and maturity, reduced plant populations, dry matter, plant height and grain yields. The negative effects of zero tillage on crop performance were attributed to poorer seed placement and lower soil temperatures. The lower soil temperatures and higher soil water content which occurred under zero tillage were attributed to the presence of a barley straw mulch on the soil surface.

The performance of the corn grown under conventional tillage, in which the seedbed had been prepared the previous fall, was superior to all other treatments examined. The superior performance of the fall tillage treatment was considered to have resulted from improved seed placement and greater soil moisture.

The removal of the barley straw mulch from the soil surface promoted

earlier silking and maturity, increased plant heights, populations and grain yields in corn. The removal of the straw mulch resulted in increased soil temperatures relative to where the straw mulch had been retained.

The eight hybrids examined exhibited similar responses to zero till-age during the growing season. At harvest, however, the hybrids exhibited a differential yield response to tillage. Four hybrids; Pioneer 3995, Pride R102, Pride R108 and Pickseed 2322 were not affected by zero tillage, while the remaining hybrids; Pickseed 2111, Asgrow RX22, Pioneer 3992 and Funks G4065 exhibited reduced grain yields under the zero tillage treatment.

INTRODUCTION

The move to zero or no tillage for field corn production has been an important development in many areas of the U.S. corn belt. Emphasis has been placed on field corn production under zero tillage due to the importance of corn to the dairy industry. Much of the U.S. dairy production is located in areas where the land is to steep for cultivation without excessive soil erosion (Shear, 1968). Under zero tillage, corn may be grown on steep sloping land with a minimum amount of soil erosion. Corn yields under zero tillage have been reported to equal or exceed those recorded under conventional tillage (Moody et al., 1961; Jones et al., 1968). Current extimates of crop land under zero tillage in the U.S. are 2.9 million hectares or 3.2% of that under conventional tillage crop production (Willey, 1982).

A number of crops have been successfully grown under zero tillage on the Canadian prairies, including; wheat, barley, flax and rapeseed. Attempts to produce field corn under zero tillage, however, have not been successful.

The objective of this study was to compare the growth, development and yield of a corn crop under various tillage and straw management practices and to assess the effect of these practices on soil moisture and soil temperature. A further objective was to determine whether corn hybrids varied in adaptation to zero tillage cropping practices.

LITERATURE REVIEW

Tillage and Mulch Effects on Soil Moisture

Much of the success of corn production under systems of reduced tillage has been attributed to the conservation of soil moisture. A number of studies have shown soil moisture to increase in the surface layers of the soil under zero tillage relative to conventionally tilled soils (Jones et al., 1968; Triplett et al., 1968; Stanholtz and Lillard 1969; Blevins and Cook, 1970; Lal, 1974). Generally, the differences in soil moisture between zero and conventionally tilled soil decreased with increasing soil depth and also as the season progressed (Stanholtz and Lillard, 1969; Blevins and Cook, 1970). Several studies have shown that the ability of corn to survive periods of short term drought was increased with zero tillage cropping practices (Stanholtz and Lillard, 1969; Blevins and Cook, 1970; Gallaher, 1977). Gallaher (1977) reported that removing the mulch associated with the zero tillage treatments decreased the ability of the corn to withstand drought. The importance of the mulch was paramount to moisture conservation under zero tillage. Many of the moisture conserving attributes of zero tillage; reduced evaporative loss of soil moisture, reduced surface runoff and increased infiltration have been attributed to the surface mulches formed by the previous crop residues (Jones et al., 1968; Triplett et al., 1968; Blevins and Cook, 1970; Harrold et al., 1970; Lal, 1974).

Studies examining the use of mulches have shown soil moisture to be increased in the surface layers of the soil (Larson et al., 1960; Moody et al., 1961; Moody et al., 1963). Moody et al. (1963) reported a seven fold decrease in surface runoff when 3 tons/acre of wheat straw was applied to a bare soil surface. Triplett et al. (1968) reported increased infiltration with increasing amounts of chopped corn stover mulch. Decreased runoff and increased infiltration may account for the initial increase in soil moisture during and/or after periods of precipitation, but it does not directly account for the greater soil moisture, relative to bare ground, observed during periods of drying. Increased soil moisture during soil drying occurred primarily due to a reduction in the evaporative loss of moisture from under mulches (Russel, 1939; Moody et al., 1961; Jones et al., 1968; Blevins and Cook, 1970; Stanholtz and Lillard, 1969; Blevins et al. 1971). Russel (1939) determined that mulch -es prolonged soil drying which allowed greater penetration of water, further, mulches decreased evaporation, in part by obstructing solar radiation. Bond and Willis (1969) reported that mulches reduced the initial rate of evaporation, but, given prolonged periods of drying the cumulative evaporative losses were nearly equal for all levels of mulch and bare soil. The reduction of evaporative moisture loss from the soil was greatest when the soil cover was complete, (Willis, 1962). Grebb (1966) reported that evaporative losses of soil moisture decreased in a linear relationship to the amount of straw applied to the soil surface, up to 90% soil coverage (3,360 kg/ha). Russel (1939) found that light applications of straw (2 tons/acre or 4,500 kg/ha) were almost as effective in reducing evaporation as were heavy applications (16 tons/acre or 35,900 kg/ha). Moisture conservation by mulches occurred primarily when the cumulative evaporation between successive rainfalls was less than that of bare soil (Russel, 1939; Bond and Willis, 1969).

As previously stated, the difference in soil moisture between bare and zero tilled (mulched) soils decreased as the season progressed. Stanholtz and Lillard (1969) suggested that the decrease in moisture differences between zero tilled and bare soils occurred due to the 'evapotranspiration phenomenon' whereby early season losses of soil moisture occurred primarily by evaporation from the soil surface. Later in the season the growing plants shaded the soil surface and reduced evaporation, at this point transpirational losses were the main pathway of soil moisture loss. Transpirational losses would be assumed to be similar for both zero tillage and conventionally grown corn.

Tillage Effects on Soil Bulk Density

The effects of zero tillage on soil compaction vary according to the soil type. Cannel and Finney (1973) found that the bulk density of soils under zero tillage was greater than on conventionally tilled soils, except on light textured and high organic matter soils. Several studies have shown increased soil bulk density where corn was produced under zero tillage (Triplett et al., 1968; Harrold et al., 1970; Lal, 1974). Harrold et al. (1970) reported no difference in soil bulk density below the surface 7.5 cm of zero and conventionally tilled soils. Shear and Moschler (1969) and Blevins and Cook (1970) reported no difference in soil bulk density between zero and conventionally tilled soils when the soil type was a loam.

Tillage and Mulch Effects on Soil Temperature

The importance of soil temperature at seeding is due to the minimum temperature at which corn will germinate, generally this is accepted to be about $10^{o}C$ (Arnon, 1975; Sprague, 1977). At the time of seeding, soil temperatures below $10^{o}C$ may delay and/or reduce germination. Soil temperatures may be influenced by a number of factors, including; tillage, crop residues and shading of the soil surface by the growing plant.

Allmaras et al. (1972) found that soil temperatures at planting were up to $2^{o}C$ warmer on conventionally tilled soil where plowing had been done in the fall as opposed to spring plowing. The timing of the tillage operations appeared to influence soil temperatures at seeding. In the absence of tillage, there is evidence to indicate that soil temperatures are lower than on tilled ground (Stanholtz and Lillard, 1969; Blevins and Cook, 1970; Griffith et al., 1973; Lal, 1974; Mock and Erbach, 1977; Gauer, 1981). However, Olson and Schoeberl (1970) found that soil temperatures during the early season were not different between conventional and reduced tillage treatments.

Under zero tillage, maximum soil temperatures were reduced to a greater extent than were the minimum soil temperatures (Stanholtz and Lillard, 1969; Blevins and Cook, 1970; Gauer, 1981). The effect of zero tillage on soil temperature has been found to decrease with increasing soil depth (Stanholtz and Lillard, 1969). The observed reductions in the temperature of zero tilled soil were attributed to the presence of previous crop residues which formed a mulch over the soil surface (Blevins and Cook, 1970; Griffith et al., 1973; Mock and Erbach, 1977). Under reduced tillage, as the amount of residues increased the soil temperature decreased (Griffith et al., 1973; Mock and Erbach, 1977). Larson et al. (1970) reported that the residues from a 100 bu/acre corn crop reduced soil temperatures at the 10 cm depth by about 1.1^{o}C or about 0.4^{o}C for each 900 kg of crop residues. Burrows and Larson (1962) and McCalla and Duley (1946) reported that soil temperatures decreased with increasing rates of crop residues. Gauer (1981) at the University of Manitoba, reported that no depression in soil temperatures occurred under zero tillage when the crop residues had been removed. Further, it was also reported that zero tilled soils with a crop residue mulch were periodically warmer in the early spring than conventionally tilled soil or zero tilled soils from which the mulch had been removed.

A number of studies have reported the effects of straw mulches on soil temperature similar to those of tillage. Mulches tend to affect maximim soil temperatures more than minimum soil temperatures (Van Wijk et al., 1959; Burrows and Larson, 1961; Moody et al., 1963; Onderdonk and Ketcheson, 1973a). The effect of depressing maximum soil temperatures without extensively altering the minimum temperatures resulted in a decrease in the diurnal fluctuation of soil temperatures. The diurnal fluctuation decreased with increasing rates of mulch, as well as with increasing soil depth, (McCalla and Duley, 1946; Burrows and Larson, 1962). The effects of mulches on maximum, minimum and mean daily soil temperature decreased with both increasing soil depth and as the season progressed, however, the effect of the mulch never completely disappeared. As the plants grew and began to shade the soil the difference between mulched and bare soil became less, shading had the same effect as a small amount of mulch, (McCalla and Duley, 1946; Burrows and Larson, 1961). Mulches tended to result in warmer soils when the soils were cooling, as in the fall, and cooler soils when the soils were warming, as in the spring (McCalla and Duley, 1946; Burrows and Larson, 1962).

Several mechanisms are involved in the reduction of soil temperatures by mulches. Shading of the soil surface by the mulch or by the growing plant resulted in the occlusion of solar radiation, (Blevins and Cook, 1970). As the solar radiation is occluded it is unable to warm the soil. Dead grass sod and straw mulches contain non-moving air which acts as an insulator, as a result, straw mulches have low heat conductivities, this may reduce the rate of heat penetration and release leading to delays in soil warming and cooling. Reflectivity or albedo is perhaps the most important property of straw mulches affecting soil temperature. Burrows and Larson (1961) stated that soil temperatures under mulches are reduced because less heat energy reaches the soil surface due to the reflection of heat by the straw. McCalla and Duley (1946) determined that bright clean straw reduced soil temperatures to a greater extent than did decayed straw. Decayed residues, after six months, did not reduce soil temperatures by more than 1 or 2^{o}C. The reflectivity of the surface residues decreases as the residues undergo decomposition and weathering (Cruse et al., 1980). A combination of increased decomposition and weathering of crop residues as well as increased shading of the soil by the growing plants may account for the decreased effects of mulches on soil temperature, relative to bare ground, later in the season.

The Effects of Tillage and Mulches on the Performance of Field Corn

Germination and Emergence

Few references were found concerning the effects of tillage on the germination and emergence of corn. Mock and Erbach (1977) reported that corn seedlings emerged earlier from conventionally tilled soils than from those under reduced tillage, the reduced tillage treatments had the lowest seed row temperatures. Unlike many of the annual cereals; wheat, barley or wild oats, which are relatively unaffected by soil temperature during germination and emergence (Dubetz et al., 1962), corn exhibits specific temperature requirements. It is generally accepted that little, if any, germination take place at/or below 10^{o}C (Arnon, 1975; Sprague, 1977). Dubetz et al. (1962) and Alessi and Power (1971) determined that no germination occurred at temperatures of 6.0 and 6.7^{o}C, respectively.

The effect of straw mulches on emergence may simulate emergence under reduced tillage cropping. Delayed emergence under straw mulches corresponded to observed reductions in soil temperature beneath mulches (Willis et al., 1957; Burrows and Larson, 1962). Emergence occurred later with increasing rates of mulch, at 8 tons/acre it was physically impossible for the corn seedlings to emerge through the mulch (Burrows and Larson, 1962).

Soil temperature effects on germination and emergence have been studied extensively. McAdam and Hayes (1978) have shown certain genotypes to germinate more readily at lower temperatures than other genotypes. In general, soil warming reduced the time for germination (Rykbost et al., 1975; Cooper and Law, 1978). Iremiren and Milbourn (1979) have shown that soil warming improved the percentage germination. Tillage or mulch treatments resulting in increased soil temperatures decreased the time between sowing and emergence (Willis et al., 1957; Dubetz et al., 1962; Adams, 1967; Ketcheson, 1970; Alessi and Power, 1971; Phillips and Cochrane, 1975; Rykbost et al., 1975; Iremiren and Milbourn, 1979).

Root Growth and Development

The effects of tillage on corn root growth and development have not been extensively studied. Tillage is known to affect a number of soil physical properties, including; bulk density, moisture and temperature, which in turn may influence root growth and development. Lal (1974) reported root growth during the early stages of growth to be depressed by zero tillage. Greater compaction of zero tilled soils has been attributed to restricting the extension of the seminal roots in spring barley (Ellis et al., 1977). Barber (1971) characterized corn roots grown under zero tillage as being of a larger diameter and fewer in number, with the zone of maximum root density located within 10 cm of the soil surface. Similar findings have been reported by Onderdonk and Ketcheson (1973a), having shown that under a mulch of chopped corn stover, corn roots were typical of nodal adventitous roots. Further, it was determined that soil temperatures were reduced by the mulch while soil moisture was increased only after periods of precipitation. Barber (1971) suggested that decreased root growth under zero tillage may be attributed to inhibitory decomposition products released by the straw as it undergoes decomposition.

Straw mulches associated with zero tillage have been found to delay the death of corn plants by maintaining root activity for a longer period of time (Gallaher, 1977). Gallaher (1977) has shown greater root activity deeper in the soil in the presence of a straw mulch, this suggested a more developed root system existed under the mulch, which was better able to utilize soil moisture than the corn root system formed under zero tillage in the absence of the mulch.

The effects of soil temperature on corn root growth are understood to a greater extent than are the effects of tillage. Geotropic response mechanisms which determine the direction of radicle growth may respond to soil temperature. High soil temperatures have been found to result in verticle growth of corn radicles, while decreasing soil temperatures (to 17^{o}C) resulted in horizontal radicle growth (Mosher and Miller, 1972; Onderdonk and Ketcheson, 1973b). Below 17^{o}C Onderdonk and Ketcheson (1973b) reported a return to verticle radicle growth.

Optimum soil temperatures for root growth have been suggested in several studies. Walker (1969) determined that the optimum temperature for corn root growth was 26^{o}C, with significant reductions in root dry matter accumulation occurring at temperatures on either side of this optimum. Grobbelaar (1963) stated that the optimum soil temperature for corn root growth occurs between 20 and 30^{o}C. Root growth was practically inhibited at 5^{o}C. The 26^{o}C optimum should be considered only in general terms as other studies have suggested that the optimum soil temperature for root growth is determined by the genotype of the corn under study (Porter and Moraghan, 1975; McAdam and Hayes, 1978).

Seeding into cold soils (12^{o}C) has been shown to delay root growth (Cal and Obendorf, 1972). Beauchamp and Lathwell (1967) have reported increase root branching and dry weights at low soil temperatures (15°C). Little is known about root configuration under various soil moisture and temperature regimes. The work of Allmaras and Nelson (1971 and 1973) has suggested that root configuration is affected by soil moisture and soil temperature such that straw placement may be an important factor in determining the configuration of the corn root system.

Shoot Dry Matter

Reduced tillage systems tended to result in increased plant dry matter (Moody et al., 1961; Moody et al., 1963; Jones et al., 1968; Shear and Moschler, 1969). These studies have often shown increased dry matter production corresponding to increased soil moisture and/or reductions in the amount of tillage. Other studies have, however, shown plant dry matter, particularly that of corn seedlings, to decrease when grown under reduced tillage (Mock and Erbach, 1977). Along with the reduction in dry matter there occurred a corresponding decrease in soil temperature with decreasing amounts of tillage (Mock and Erbach, 1977).

Walker (1969) has shown the optimum soil temperature for shoot dry matter production in corn seedlings to be 26°C, the same as that reported for root dry matter production. Temperatures on either side of the optimum resulted in a reduction in the dry matter production. Several studies have concluded that the average weight of dry matter per plant increases with increasing root zone temperatures for both seedlings (Burrows and Larson, 1961; Mederski and Jones, 1963; Walker, 1969; Ketcheson, 1970; Phillips and Cochrane, 1975; Mock and Erbach, 1977) and the mature plants (Mederski and Jones, 1963; Ketcheson, 1968;

Phillips and Cochrane, 1975). However, Beauchamp and Lathwell (1967) reported that at predetermined growth stages, seedling dry matter decreased with increasing root temperatures from 15 to 25^{o}C.

Where the soil surface is covered by a straw mulch, reductions in soil temperature could be expected to result in decreased seedling dry weights and possibly reductions in the mature plant dry matter content.

Plant Height

The rate of plant growth under systems of reduced tillage appears to be related to those factors, in the soil enviroment, most limiting to the rate of growth and which may be influenced by the degree of tillage; soil moisture and soil temperature. Plant height is frequently used as an indicator of corn growth. Under zero tillage greater plant heights have been reported relative to conventional tillage (Moody et al., 1961; Jones et al., 1968). Increased plant height under zero tillage may relate to the presence of cereal straw or corn stover mulches. Triplett et al. (1968) reported that plant heights increased with increasing amounts of chopped corn stover. Increased plant height in the presence of mulches has been attributed to increased soil moisture beneath the mulches. Other studies have shown plant heights, particularly during the early stages of growth, to be depressed by reduced tillage (Griffith et al., 1973; Mock and Erbach, 1977). Griffith et al. (1973) have shown reductions in plant height corresponding to decreased amounts of tillage and increasing ground cover (crop residues). Mulches have been found to depress soil temperatures resulting in decreased plant heights. Increasing rates of mulch were found to result in further depressions in soil temperature which corresponded to reductions in plant height (Larson et al., 1960; Burrows and Larson, 1961). Increasing the root zone temperatures have been observed to stimulate corn growth resulting in greater plant heights (Willis et al., 1957; Mederski and Jones, 1963; Jones and Mederski, 1963; Kleinendorst and Bouwer, 1970; Watts, 1972a; Watts, 1972b).

Reductions in corn growth in response to suboptimal root zone temperatures occurs by two mechanisms. By separately regulating the temperature of both the roots and the meristematic region, Kleinendorst and Bouwer (1970) were able to show that while the meristematic region was maintained at a temperature conducive to growth, the rate of leaf extension was relatively unaffected by suboptimal root temperatures. It was further shown that maintaining the roots at a temperature favorable for growth would not compensate for reductions in the rate of growth caused by maintaining the meristematic region at low temperatures. Reductions in the rate of growth induced by soil temperature effects on the meristematic region persist only while the meristematic region remains below ground. Once it is elevated above the soil surface, air temperature regulated the temperature of the meristematic region (Cooper and Law, 1978). Reductions in growth at low meristematic temper -atures are thought to result from a supression of biological processes; cell division, cell elongation and cellular respiration (Beauchamp and Lathwell, 1967; Kleinendorst and Bouwer, 1970; Watts, 1972b).

The second mechanism by which low soil temperatures depress plant growth is by a loss of leaf turgor pressure (Kleinendorst and Bouwer, 1970; Barlow et al., 1977). Decreased leaf water potential resulted from a reduction in the permeability of the root to water at low root temperatures. Barlow et al. (1977) have suggested, however, that the loss of turgor was due to a reduction in the root hydraulic conductivity at the low root temperatures.

Suboptimal root zone temperatures affect both the root and the meristematic region resulting in decreased leaf elongation. Temperature reductions, in the root zone, below 15^{o}C have been found to affect the growth reductions induced by the roots to a greater extent than those reductions induced by the meristematic region (Barlow et al., 1977). At 12.5^{o}C, Barlow et al. (1977) determined that leaf elongation ceased.

Leaf Production

Mock and Erbach (1977) had determined that corn seedlings grown under reduced tillage produced significantly fewer leaves than those grown under conventional tillage practices. Similarly, Cal and Obendorf (1972) reported that seeding into seedbeds with low soil temperatures resulted in juvenile plants having fewer leaves than those sown into warm seedbeds. A greater number of leaf primordia were found to be initiated in the warm soils, resulting in an increase in the final number of leaves produced per corn plant (Cooper and Law, 1977). Similar increases in final leaf numbers were attributed to warmer soils during early plant development (Beauchamp and Lathwell, 1966; Cooper and Law, 1978).

Silking and Maturity

A number of studies have examined the effects of mulches and soil