CORN GROWN IN A STE. ROSALIE CLAY UNDER ZERO AND TRADITIONAL TILLAGE

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Silage corn was grown for three consecutive years (1978-1980) on a Ste. Rosalie clay soil that had not been subjected to any intercrop tillage. The growth and development of the second and third year zero-till crop were monitored regularly and were compared to corn in traditionally tilled plots. Soil properties such as void space, bulk density, water content, and soil temperature were determined at various depths, several times over the growing season and the results were related to their effects on growth and production of corn. The results of these trials show that in a season of moderate and regular rainfall, the zero-tilled plots produced significantly higher yields than control plots; whereas, in a season when rainfall at certain times was higher than average, the zero-tilled plots had yields similar to those of traditionally tilled plots. Study of soil bulk density and moisture data showed that the overall soil volume occupied by the mineral fraction decreased by about 2% with zero-tillage management. These results indicate that under high soil moisture conditions, air became limited to the plants, with air-filled volume approaching zero at some depths.

INTRODUCTION

Traditional tillage methods have changed little in the past. Although tillage fulfills the aim of controlling weeds and pests, burying crop residues and providing a seedbed conducive to good seed germination and plant growth (Cannell and Ellis 1979; Musick and Petty 1979; Vyn et al. 1979; Southwell and Ketcheson 1978; Tripplett and van Doren 1977), it requires large energy consumption and can result in field operations being done when the soil is too wet and susceptible to damage (Vyn et al. 1979; Davies et al. 1972). This is particularly true in an area such as southern Quebec where time for field preparation is very short and it must be done regardless of weather conditions.

Climate is a major factor affecting crop growth (Linville et al. 1978). The soil environment can also affect plant growth. The combined effects of both climate and soil environment may have further effects on plant growth. The farmer has no control over climate but he can attempt through tillage to maintain good soil conditions that will facilitate maximum benefit from climatic factors. Through tillage one can affect soil structure, bulk density, volumetric water content, air-filled porosity, the amount of earthworm holes, hydraulic conductivity and depth of continuous cracks (Cannell and Ellis 1979; Hope 1979; Gantzer and Blake 1978; Soane and Pidgeon 1975). The overall effect of these changes determines the soil’s ability to absorb, hold and supply water to the plant and also determines the total volume left for gaseous exchange. There is a critical balance between too much water and not enough, particularly in a fine-textured soil. Generally it is accepted that if the air volume is less than 10%, roots cannot develop property and microorganisms turn to anaerobic processes either metabolizing nutrients so that they are not available to plants or possibly producing toxic byproducts (Gantzer and Blake 1978; Russell 1959).

The present paper studies the performance of silage corn grown under traditional tillage management for 1 year and then under zero-tillage management for the next two growing seasons in an attempt to establish whether or not zero-tillage should be examined more closely as a feasible alternative to traditional tillage considering the often uncooperative climatic conditions of Quebec and the heavy clay soil, typical of the region.

EXPERIMENTAL METHODS

The experiment was carried out on a Ste. Rosalie clay soil which comprised eight plots, four replicates of two treatments, established following a randomized complete block design. The plots measured 10 m x 1.5 m, upon which three rows of corn were grown. Only the center row was considered in the experiment. The two treatments were zero-till and traditionally tilled or control. The treatment of the field spanned 3 yr, although zero-till results could only be obtained in the second and third years; therefore, only the results of the second (first year cycle) and third (second year cycle) years will be considered in this paper.

In the first year of the experiment, all the plots were traditionally prepared, including plowing, disking and fertilizer (138 kg N/ha, 39 kg P/ha, and 75 kg K/ha) and herbicide (2.4 kg atrazine/ha, 5.7 L ha-laslo) application. After this preparation the zero-till plots were left undisturbed by machinery traffic for three growing seasons. Each spring, the control plots were plowed and disked. To all plots herbicides (2.5 kg McPA/ha, 2.2 kg/ha Bas-gran, 2.5 kg lasso, 1.25 kg atrazine/ha) and fertilizer (138 kg N/ha, 39 kg P/ha and 75 kg K/ha) were applied, taking care not to drive upon them. Silage corn was hand-seeded at a depth of 0.03 to 0.08 m in three rows 0.75 m apart and spaced 0.20 m apart within the row, making a total of 50 plants per row, of which the center row was hand harvested. The planting dates were 14 May 1979 and 14 May 1980.

During each growing season, soil bulk density was determined in each plot at 0.05-m depth intervals to a depth of 0.30 m at approximately 2-wk intervals over the growing season, using a Troxler Model 2301 surface moisture-density gauge. The measurements were taken in a different location each time but always immediately adjacent to the center row of corn. At the same time and in the same location, soil moisture content was determined gravi-
Figure 1. Monthly cumulative rainfall for 1978 to 1980 and the 29-yr average for the area.

Figure 2. Daily rainfall for 1980 and fluctuation of water table for both treatments.
metrically at 0.10-m depth intervals to a depth of 0.30 m.

Soil temperature was measured at depths of 0.0, 0.05, 0.25, 0.50 and 0.75 m weekly in all plots using a Yellow Springs temperature probe and recorder. Rainfall data were obtained from the Macdonald College weather station and water table data were recorded regularly from water table wells installed in each experimental block.

Crop performance was monitored. Days to emerge, tassel and silk were observed and when 80% of the plants were evident or had reached a certain stage of maturity, that was considered to be the number of days required to emerge, tassel or silk for that plot. The rate of growth of plants was measured approximately every 2 wk during the season by randomly selecting five plants in each plot and measuring the height of the plant from the soil surface to the base of the last fully unfolded leaf. At harvest time, the plant, ear and grain yield were measured.

RESULTS AND DISCUSSION

The cumulative monthly rainfall data for southern Quebec in the years 1978, 1979, 1980 and the average for the previous 29 years are plotted in Fig. 1. During the 1979 growing season the rainfall was slightly above average with the rainfall being consistent. There was no period when rainfall was unusually high or unusually low. In 1980, in the month of May, the rainfall was below average and in July it was above average. In Fig. 2 which shows the daily rainfall for 1980, it can be seen that most of the rain that fell in July was towards the end of the month, making the fields very wet during that time. This figure also illustrates the fluctuations of the water table for the years 1978, 1979 and 1980. During 1979 the expected gradual deepening of the water table over the summer is seen with a rise beginning near harvest time. In 1980, the high rainfalls during July are reflected in the sudden increase in water table depth. This occurred at the peak growing time of the plants, at which time almost half the rooting depth of the plants was flooded. In this type of situation, plants with an ideal rooting environment would suffer stresses and if any flaws existed in the rooting zone, these stresses would be significantly increased. Under these circumstances small reductions in bulk density could reduce the damage done to the plants.

The profiles of percentage of the total soil volume occupied by the mineral fraction, water and air of the control and zero-till treatments for 1979 and 1980 are shown in Fig. 3. The results are average values obtained for the four replicates and for all the measuring times. It can be seen that in 1979 the volume of soil occupied by air for both tillage methods was near but not below the critical level of 10% at any depth. Considering that the rainfall was consistent during that year, it is unlikely that there was any extended period during the season when the rooting environment would have become anaerobic long enough for any root decay to take place. The profiles of the percentage of space occupied by the mineral fraction in the control plots are almost the same for 1979 and 1980. Although the exact period of anaerobiosis was not noted, in 1980 it is very likely that considerable root damage resulted from anaerobiosis, both in control and zero-till plots.

Figure 4 shows a comparison of temperature profiles for the control plots in 1979 and 1980. At greater depths the temperatures for both years followed a similar pattern, but surface temperatures showed much more fluctuation in 1980 and overall temperatures were higher in 1979. Analysis of the data showed that tillage treatment did not significantly affect soil temperature.

The differences in crop performance during the 2 years are attributed mainly to
climatic factors rather than to soil conditions. Corn emergence in 1979 took 17 days in the control plots as compared to 10 in zero-till, whereas in 1980 the difference was only two days, namely 12 days for the control and 10 days for zero-till. Corn growth and maturity in 1980 were similar on both the zero-till and control plots, taking 74 and 75 days, respectively, to tassel and both taking 77 days to silk. In 1979 the corn on the control plots took 77 and 79 days to tassel and silk, respectively, compared to that on the zero-till plots which took 70 and 72 days. These differences are the same as the differences in days to emerge so that the zero-till corn had a faster start compared to that of the control plot and maintained this lead until maturity.

Plants were taller in the zero-till plots of 1979 than in the control plots (significant at 0.05 level), whereas the differences were not significant in 1980. The overall final plant heights in the zero-till plots were nearly equal whereas in the control plots the plants in 1979 were about 0.2 m shorter than those in the other plots of both years. Plots of plant heights for both treatments in the two test years are shown in Fig. 5.

Harvest results shown in Table 1 illustrate the difference in overall performance for the 2 years. The corn yields were similar from the control plots in both years, regardless of the weather. These were not significantly different, at the 0.05 level, than the yields in the zero-till plots of 1980. In 1979, however, a more "normal" year, the yields in the zero-till plots were significantly (0.05 level) greater than the control plots. Here the zero-till plots produced 25%, 45% and 47% more plant, ear and grain yield, respectively, when compared to the control plots; whereas in 1980, although not significantly different, the ear and grain yield in the zero-till plots were 3–5% more than those of the control plots. These yields were higher by about 5% than those reported for the region by the Conseil des Productions Végétales du Québec (Anonymous 1979–1980). Colyn (1983) reports a reduction in grain yield.
TABLE I. AVERAGE VALUES FOR PLANT, EAR AND GRAIN YIELD FOR 1979 AND 1980

<table>
<thead>
<tr>
<th>Year</th>
<th>Treatment</th>
<th>Plant (kg/ha)</th>
<th>Ear yield</th>
<th>% of plant yield</th>
<th>Grain yield (kg/ha)</th>
<th>% of plant yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979</td>
<td>Control</td>
<td>11956a</td>
<td>7408a</td>
<td>62a</td>
<td>6428a</td>
<td>54a</td>
</tr>
<tr>
<td></td>
<td>Zero-till</td>
<td>150216</td>
<td>10723b</td>
<td>71b</td>
<td>9443b</td>
<td>63b</td>
</tr>
<tr>
<td>1980</td>
<td>Control</td>
<td>10243a</td>
<td>6902a</td>
<td>67a</td>
<td>5973a</td>
<td>58a</td>
</tr>
<tr>
<td></td>
<td>Zero-till</td>
<td>9437a</td>
<td>7099a</td>
<td>75a</td>
<td>6295a</td>
<td>67a</td>
</tr>
</tbody>
</table>

a,b Means with the same letter are not significantly different.

up to 3% in no-till plots compared to the conventional tillage on a Haldimand clay soil located in the farm plots of the University of Guelph. The difference in this result compared to that of the present study could be attributed to one or more of the following factors: (i) difference in the type of clay, (ii) weather pattern, (iii) residue management and (iv) method of seeding. Among these, the punch type of planting done by hand in Quebec provides less soil disturbance and better seed-soil contact leading to better results. This point should be borne in mind by the machinery manufacturers for producing a better planter to be used for the zero-till condition. It was further noted by Colwell (1983) that even a reduction of 0.2 tonnes/ha of corn yield on zero-till plots compared to the conventional tillage methods in Ontario, still produced a net saving of $40 per ha in terms of 1983 dollars. Similar cost comparisons were also done by Raghavan et al. in 1981.

Higher values of grain yield expressed as a percentage of plant yield are observed for both years (Table I); this demonstrates better availability of water in the zero-till plots compared to the controls. There were no disease or pest problems observed during the period of the study.

CONCLUSIONS
Corn grown in plots left with no intercrop tillage for three growing seasons showed yields at least equal to the control or traditionally-tilled plots and, in 1979, the yields were 8% higher in the zero-till plots than in the control. Considering these results, it was concluded that in the absence of clay soils of southern Quebec, absence of tillage did not cause significant reduction in yield even in an abnormally wet year. In a "normal" year yields were increased by zero-tillage management. Further studies in this area should be done as zero-tillage could be an alternative, considering that spring weather in Quebec can be unreliable, and there are many springs when seeding is delayed due to wet fields. Fall weather also can be unreliable and field preparation sometimes have to be left for the spring. If excessive field preparation can be eliminated, at least in inclement springs, without concern for yield reductions, damage to the soil could be reduced and corn crops, which may otherwise not be seeded or may be seeded very late, could be planted at more opportune times.

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REFERENCES