ZERO TILLAGE FOR CEREAL PRODUCTION ON FORAGE SODS IN MANITOBA

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GEORGE WILLIAM CLAYTON

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ABSTRACT

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The effects of zero, minimum and conventional tillage on soil water content, soil compaction and crop growth on a fine-textured soil previously sown to perennial forages was studied over a two year period. The effect of glyphosate, 2,4-D and dicamba, alone or in combination was evaluated for the control of established alfalfa on the experimental site.

Under zero tillage surface soil water was higher than under conventional or minimum tillage throughout the growing season, with the greatest differences occurring in the surface 10 cm. Infiltration rate was higher under zero tillage than under conventional or minimum tillage when the previous forage crop consisted of approximately 30 percent alfalfa. When the previous forage contained only bromegrass, the infiltration rate into untilled soils was less than into conventionally tilled soils. This result was attributed to the consolidated soil condition that occurred under zero tillage. The lower infiltration rate into minimum till soil in both years of study was attributed to low porosity, low random roughness or surface sealing.

The higher soil compaction found under zero tillage may have restricted root growth resulting in the lowest volumetric water content from the 30-60 cm soil depth compared to conventional or minimum tillage. Bulk density and penetrometer resistance were generally higher in the surface 10 cm in the untilled soil than in the tilled soil.

Seedling emergence, grain yield and water use efficiency were low under zero tillage due to poor seed placement and/or weed competition. When conventional cultivation did not control bromegrass in the plot area, grain yields and water use efficiency were no different than on untilled soil. When bromegrass was eliminated by cultivation, grain yields were highest under conventional tillage and least under zero tillage with yields under minimum tillage being intermediate.

The control of alfalfa by glyphosate 2,4-D and dicamba applied alone, or in combination, was unacceptable for crop production.

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Chapter I

INTRODUCTION

Most studies on zero tillage crop production in Manitoba have shown that tillage is not necessary for the successful growth and development of crops (Donaghy, 1973; Rourke, 1981). Only recently have studies been initiated on the effects of tillage on the soil environment begun (Gauer, 1981). Most of the research on the effects of zero tillage on soil conditions has been conducted outside of Canada.

In the absence of tillage, increased soil compaction and soil water content have been observed in the seedbed environment (Hill and Blevins, 1973). This result could be detrimental to crop growth on fine-textured soils in Manitoba where frequent spring rains occur. An increased infiltration rate such as that found under zero tillage on killed sod (Triplett *et al.*, 1968) and the improved soil structure attributed to the growing of forages may eliminate a potential soil problem that could occur on fine-textured soils.

The purpose of the present study was to compare the hydrological and physical properties of fine-textured soils under zero, minimum and conventional tillage and to assess the effect of these properties on crop growth. A further objective was to determine the effect of herbicides, alone and in combination, on the control of alfalfa in zero tillage wheat production.

Chapter II

LITERATURE REVIEW

2.1 EFFECTS OF FORAGES ON SOIL PHYSICAL PROPERTIES AND CROP PRODUCTION

In Chernozem, Chestnut, and Brown soil regions, legumes and grasses usually depressed yields of following crops and depleted soil moisture (Brown, from Ripley, 1969). Studies in Colorado determined that the water requirement of small grains was two times that of corn, whereas forages required three times as much water as corn to produce equivalent yields (Ripley, 1941). Under relatively dry conditions (semi-arid), moisture was found to be the most important single factor affecting crop growth. In field experiments at Ottawa, where precipitation was not limiting, the yield of corn, mangels, rye, oats and potatoes was consistently higher following sod-forming crops. The yields of succeeding crops did not follow in the reverse order of water requirements of preceding crops as was seen in the relatively dry areas (Ripley, 1941). Some other unidentified factor(s) seemed to be operative.

Campbell (1981) reported that 70 to 80 years of various wheat-summerfallow cropping resulted in losses of 40-60 percent of the soil organic matter from the top 15 cm of virgin soil. Poyser *et al.* (1957) found that Red River clay soils declined in organic carbon content on all plots studied, but the rate of decline was less rapid where legumes were used as green manure crops. Studies conducted in Iowa showed that soil organic matter increased by cropping with alfalfa (van Bavel and Schaller, 1950). These findings were in agreement with Bishop and Atkinson (1954) who found that after 40 years, in a 10-year rotation with six years of alfalfa, organic matter content increased 10.5 percent and nitrogen content 7.5 percent in the surface 15 cm of soil.

Doughty (1948) reported that losses of nitrogen and organic matter on brown soils after ploughing grassland was more rapid than the accumulation while in forage grasses. Page and Willard (1946) stated that by cropping to soil building crops such as legumes and grasses a definable improvement in soil structure could be obtained but concluded "it's highly significant that this improvement is by no means permanent."

Emmond (1971) found that rotations which included two consecutive hay crops had significantly higher levels of soil aggregation. Similar results have been shown by Page and Willard (1946), van Bavel and Schaller (1950), and Wilson and Browning (1945). Soil losses in Marshall silt loam were reduced significantly under long term meadow due to a developed soil physical condition (Wilson and Browning, 1945).

In experiments discussed by Page and Willard (1946) soils that were sown to meadow for two years appeared to be well aggregated and showed adequate drainage shortly after a heavy rainfall. Soils in which legumes and grasses were not included in the rotation appeared very puddled, muddy and sticky, and water accumulated on the surface, and there was little evidence of soil aggregation. Wilson and Browning (1945) stated "when alfalfa was killed by ploughing, the roots of 10-12 plants per square foot decomposed and left large channels through which water moved rapidly." Skidmore et al. (1975) found that the constant infiltration rate averaged 0.95 and 0.13 cm per hour for pasture and cultivated soils, respectively. The difference in infiltration was ascribed to the greater porosity and less-dense aggregates of the soil. Uhland (from Siemens, 1963) declared "All over the country one can observe the superior physical conditions of soils under sods. Where sod has been turned under for corn, more rapid infiltration and less runoff and erosion occur. Also microbial activity and aeration are greater than where corn has been grown annually."

Results of Page and Willard (1946) show that poor physical condition of the soil completely limited responses to fertilizer. The soils of continuous corn plots were in poor physical shape and additions of fertilizer could not mask the benefits of the forage rotation.

2.2 EFFECTS OF ZERO TILLAGE ON SOIL WATER

2.2.1 Effects of Crop Residue on Soil Water

Evaporation processes occurring on originally wetted soils have been characterized by three stages of water loss (Bond and Willis, 1969, Lemon, 1956). First stage evaporation, also called constant rate or steady state evaporation, was found to be dependent on liquid water flow through the soil and was affected by surface wetness of the soil, wind speed, temperature, relative humidity, and radiant energy (Lemon, 1956). Second stage evaporation, or falling rate evaporation, depended less on the above ground conditions and more on the drying soil to regulate moisture flow to the surface (Bond and Willis, 1969). Third stage evaporation was characterized by slow water movement at a constant rate dominated by "adsorptive forces over molecular distances at the solid-liquid interfaces in the soil" (Lemon, 1956) and has often been considered along with second stage evaporation.

In regions of limited rainfall, as in the Great Plains, the constant rate stage (Stage 1) was found to be of short duration while Stage 2 and 3 were operative much longer (Bond and Willis, 1969). Cereal residues on the soil surface have been shown to reduce the rate of evaporation loss and prolong the duration of the constant rate stage (Bond and Willis, 1969; Bond and Willis, 1970; Hanks and Woodruff, 1958; Hanks *et al*. 1961; Russel, 1939). Constant rate evaporation was decreased by approximately 0.1 cm/day per 560 kg/ha of wheat residue on the soil surface up to a maximum residue of 2,240 kg/ha, whereas, constant rate evaporation from a bare soil surface approached the rate from a free water surface (Bond and Willis, 1969).

Hanks and Woodruff (1958) found evaporation rates decreased as the depth of mulch (soil, gravel, or straw) was increased. A 0.625 cm mulch gave a 96 percent reduction in evaporation and appeared to be as efficient as a 3.75 cm mulch. Comparable results have been reported by Bond and Willis (1970) who observed that wheat residues greater than 4,480 kg/ha resulted in similar evaporation rates. Russel (1939) also observed that two tons per acre of wheat residue reduced the evaporation on the first day after wetting by 55 percent compared to bare soil, whereas 14 tons/acre more wheat residue reduced evaporation only by an additional 7 percent. Increasing surface residue rate decreased the evaporation rate, and the decrease in the constant rate evaporation resulted in a time lag in the cumulative evaporation (Bond and Willis, 1969). However, where surface soils began to dry, without the benefit of recurring rains, cumulative evaporation from soils with surface cereal residues eventually equaled that from bare soils (Army *et al*. 1961, Hanks *et al*. 1961, Russel, 1939).

For evaporation to occur, sufficient energy must reach the soil surface to evaporate the water, and the soil must be sufficiently moist (Peters and Russell, 1959). Fundamental principles involved in evaporation control by cereal residues include the reduction of net radiation levels (Hanks et al. 1961), the insulation of heat conductance downward (Lemon, 1956), and the reduction of wind velocity above the soil surface (Aase and Siddoway, 1980, Army et al. 1961), thus reducing evaporation potentials.

Hill and Blevins (1973) found soil water losses by direct evaporation from the surface soil to be as much as 31 mm less in the presence of killed sod residues in zero tillage plots, than from conventional tillage plots during the early growing period. But as the corn canopy developed, losses from both tillage treatments were about equal. The sod residue gave the zero tillage plots an advantage in soil moisture availability which was maintained throughout the growing season. Shannholtz and Lillard (1969) showed sod residues reduced water losses from zero tillage plots to a 30 cm depth. Where no precipitation events occurred two months after seeding corn, constant rate evaporation in the upper 30 cm was prolonged for two weeks on the zero tillage plots. Similar results have been observed by other researchers (Army et al. 1961; Hanks, et al. 1961; Gauer, et al. 1980; Lal, 1976; Russel, 1939).

Unger (1978), working in Texas, reported that increasing rates of wheat residue increased soil water storage, growing season water use, and sorghum grain and forage yields. Moody et al. (1963) found that wheat residues were effective in maintaining higher moisture levels throughout the growing season than where no residues were present. They suggested that higher infiltration rates, reduced runoff, and reduced evaporation were responsible for the higher soil moisture contents. Bennett *et al*. (1973) found that corn silage and grain yields in plots seeded into orchard grass (*Dactylis glomerata* L.) sod residue were higher than yields of corn under conventional tillage corn due to the differences in available soil water in the 0-60 cm depth that persisted throughout the growing season. They reasoned that lower soil temperatures under the orchard grass residue reduced evapotranspiration rates and reduced runoff resulting in a significantly higher amount of available soil moisture for plant growth.

Gauer *et al*. (1980) found soil moisture to be higher on zero tillage plots conducted in Manitoba regardless of whether residue had been removed or left on the soil surface. Differences in soil moisture were greater where residue was retained early in the season when constant rate evaporation was operative. Neutron-probe moisture meter measurements demonstrated that altering surface soil conditions resulted in moisture differences to the 135 cm soil depth. Soils under zero tillage were higher in volumetric water content down to 60 cm than soils under conventional tillage. These differences were found on clay soil as well as sandy soil.

Aase and Siddoway (1980) illustrated the effect standing stubble had on soil water conservation from fall to spring. Stubble plots gained the most water from snow catch making recropping on subble treatments more certain of success than recropping tilled bare ground. Good and Smika (1976) reported that retention of cereal residues with chemical fallow conserved an average of 6.25 cm more water in the soil than conventional stubble mulching in each fallow year over a period of eight years. From trials in central Alberta, Bentley (1978) showed soil moisture on zero tillage, continually cropped plots averaged at least as much as in plots that were summerfallowed the preceding year. There was no apparent enhancement of soil moisture storage as a result of summerfallowing. Schneider *et al.*, (1978) found significant increases in available stored water as the height of wheat residue increased at Williston, North Dakota. Stubble heights of 35 cm, 17.5 cm and 0 cm conserved 46.5 cm, 23.25 cm, and 14.0 cm of water, respectively in a 120 cm of soil. Johnson (1977) working at Swift Current, Saskatchewan showed, variable-height-swathing of 15 and 22.5 cm stubble trapped 4 cm more water from the snow catch than a uniform stubble height of 15 cm.

2.2.2 Effects of Soil Physical Properties on Soil Water

Lal (1976) and Blevins *et al*. (1971) found soil moisture differences in the surface soil due to changes in organic matter. Undisturbed soil was found to have a higher organic matter content in the surface soil (van Ouwerkerk and Boone, 1970; Lal, 1976), consequently increasing the water holding capacity. Bauemer and Bakermans (1973) reported that the water holding capacity was related to organic matter content, especially on sandy soils. On sod, water content at soil suction pF2 changed more in conjunction with organic matter than with porosity.

Bauer (1980) reported that, apart from surface residues, evaporation from the soil surface was affected by soil porosity and aggregate size. In a silt loam soil, at the same water content, the water vapour diffusion rates were about 23 percent higher with soil porosity of 58 percent than of 43 percent (Hanks, 1958). Cumulative water loss from a loam soil, initially at field capacity, was greater with coarse aggregates (6.4 - 19.0 mm) than with finer aggregates (0.84 - 2.00 mm) (Bauer, 1980). Dry soil mulches reduced the cumulative water loss over a 150-hr period, as compared to the losses a bare soil. Hanks et al. (1961) indicated that water vapour movement may not be important when the surface soil drys.

The presence of a killed sod residue (Hill and Blevins, 1973), wheat residue (Gauer et al., 1980) or corn residue (Jones et al., 1969) in zero tillage plots prolonged the constant rate evaporation stage, particularly in the early growing season when direct evaporation was operative. Gardner (1959) suggested that limiting direct evaporation with surface residues may have limited growing season benefits unless initial constant rate evaporation permitted greater downward percolation of surface water. Goss et al. (1978) in England, found significantly more soil water below the 50 cm depth on zero till soil than conventional till soils sown to winter wheat and spring barley, in dry years. Triplett et al. (1968) and Shannholtz and Tillard (1969) observed more vigorous corn growth on zero tillage plots than on conventional tillage plots, largely due to the availability of moisture.

A reduction in total pore space, particularly large pores > 60 mm, which at field capacity are filled with air, has been observed on zero tillage soils (Baeumer, 1970; Boone et al., 1976; Pidgeon, 1980; van Ouwerbark and Boone, 1970). The surface soil of zero tillage plots has been shown to have a higher moisture content and a corresponding lower air-filled porosity than conventionally tilled soils (Gantzer and Blake, 1978; Pidgeon and Soane, 1977). Van Ouwerkerk and Boone (1970) stated that improved moisture conditions on zero tillage plots might be advantageous in dry periods, because a larger part of the pore space is water filled. However, the amount of available water was the same with zero tillage and conventional tillage systems. Bauemer and Bakermans (1973) reported that zero tillage soils with a similar water content to conventional tillage soils, generally had a lower soil water tension indicating a smaller resistance to water uptake by plant roots and a higher water conductivity of soils. Pidgeon (1980) found no evidence from soil moisture tension data that drainage was impaired on the long-term zero tillage spring barley plots compared with plots that had been ploughed despite the lower number of pores > 60 mm existing in the zero tillage treatments. He concluded that better pore continuity was responsible for unimpaired drainage of zero till soils, despite reduced macroporosity. Greater pore continuity has been observed in Europe (Ehlers, 1975), North America (Triplett et al. 1968) and England (Goss et al. 1978) on widely differing soil types. Bauemer (1970) concluded that the total volume of draining pores is less important than their continuity.

Boone et al. (1976) reported on trials conducted on a fine textured river soil in the Netherlands, and found that water from a heavy rain tended to pond on zero till corn plots, due to slaking of the soil surface. Compared to conventionally tilled plots, a slower infiltration rate was found in the zero tilled plots, due to the absence of large vertical soil cracks that were present on the conventionally tilled plots. The frequency of ponding also was found to increase as the length of time the soil remained untilled increased.

Higher soil water use in zero till plots compared to conventional till plots has been demonstrated by Blevins _et al_. (1971), Blevins _et al_. (1973), Gallaher (1977), Goss _et al_. (1978), Lal (1978), Shannholtz and Lillard (1969) and Unger (1978). Shannholtz and Lillard (1969) in Virginia, showed that as corn, grown without tillage on grass sod residue, reached maturity, more soil water was used than on conventional tillage plots. Water use efficiency for zero tillage and conventional tillage systems were 81 percent and 57 percent, respectively. Enhancement of water use on zero till plots was attributed to significantly less runoff and evaporation. Goss _et al_. (1978) found 60 percent more water was withdrawn from the 50-100 cm soil depth on zero tillage winter wheat plots than on ploughed plots, from the end of the tillering to flowering. Unger (1978) found significantly higher sorghum grain yields with 8- and 12- metric tons of wheat residue on the soil surface. Sorghum plants were less stressed and entered the maturity development stage with more soil water storage in plots with 8- and 12- metric tons of wheat residue, than on plots with little or no wheat residue. Average water use efficiency increased to 115 kg/ha per cm water from 55 kg/ha per cm water with 12 metric tons wheat residue and no wheat residue, respectively.

Aase and Siddoway (1980) showed wheat on bare plots extracted water to a deeper depth (105 cm) than on stubble plots, but seasonal water use was the same on all plots in both years of their study. During parts of the season, the rate of water use was not necessarily the same. Olson and Schoeberl (1970), working with four types of conventional tillage, found that tillage did not affect the total water use or pattern of water use and therefore concluded that total water use was not a good indicator of total yield. Letey and Peters (1958) demonstrated that soil water consumption should be considered along with seasonal climate.

2.2.3 Infiltration

Richards (1952) defined infiltration rate as "the maximum rate at which a soil, in a given condition at a given time, can absorb rain. Also, the maximum rate at which a soil will absorb water impounded on the surface at a shallow depth when adequate precautions are taken regarding border or fringe effects."

Horton (1940) stated that infiltration rate was influenced mainly by conditions at or near the soil surface and included factors such as soil type and soil profile, biologic and macro structure within the soil and vegetative cover. Lal (1977) studied infiltration rate as it was influenced by crop residue and found that by increasing crop residues at the soil surface, infiltration rate was greatly increased, evaporation from the surface was reduced, and soil erosion by wind and water was reduced. Pillsbury and Richards (1952) found infiltration rates increased as the amount of surface organic matter increased.

Tisdale (1951) used a 30 cm diameter ring infiltrometer to investigate initial soil moisture and its relation to infiltration rate. He observed that the lower the initial soil moisture, the higher the infiltration rate. It was found that the longer the time of water application, initial soil moisture was less effective in controlling infiltration rates. Turner and Sumner (1978) reported that soils with large soil pores would be expected to have greater water flow than soils with small soil pores. Greater water flow can be expressed mathematically as Poiseuelle′s law where flow rate in a capillary is proportional to the fourth power of the radius of that capillary (Hillel, 1971). Parr and Bertrand (1960) reported that decreased volumes of soil pores in swelling clay soils decreased infiltration rates. Burwell and Larson (1969) and Steichen *et al*. (1979) found that by increasing surface roughness and pore space, infiltration rates were increased due to less runoff.

Poulovassilis (1972) found that entrapped air in an unsterilized soil decreased both infiltration rates and water conductivity of the soil.

Schroeder *et al*. (1979) reported that surface sealing due to high energy rainfall reduced infiltration rates. Surface sealing has been shown to be reduced by leaving crop residues on the surface to dissipate the kinetic energy of rainfall (Jones *et al*. 1969), by increasing organic matter content of the soil and by improving soil aggregation by including rotations that include forage grasses and legumes (Parr and Bertrand, 1960).

Some researches have developed physically based infiltration equations to represent infiltration in many different soil types (Green and Ampt, 1911; Horton, 1940; Kostiakov, 1932; Philip, 1957). Other researchers have measured infiltration directly in the field (Lal, 1976; Triplett *et al*., 1968; Turner and Sumner, 1978). Baver *et al*. (1972) was of the opinion that field infiltration data do not necessarily agree with theoretical calculations due to the fact that at the initiation of infiltration the soil profile and the soil water distribution are seldom uniform. Details of infiltration theory and equations are given by Marshall and Holmes (1979).

Osborne et al. (1977) demonstrated that when cultivation was reduced, the rate of infiltration was substantially increased. Conventional tillage treatments had a 2-3 fold increase in infiltration time compared to zero tillage treatments. During a 5 year study on a sloping, silt loam soil in Indiana, Mannering et al. (1966) found that minimum tillage corn plots had a 24 percent higher infiltration than conventional tillage plots, as well as a 34 percent decrease in soil loss.

Triplett et al. (1968) found that the infiltration rate after one hour was significantly higher with zero tillage with 80 percent residue cover, than with ploughed bare soil, zero tillage bare soil, and zero tillage with 40 percent residue cover. After high intensity rain storms, the moisture recharge was 45 percent of the total rainfall with the zero tillage 80 percent residue cover compared to 25 percent for the ploughed bare treatment. During low intensity rainfall, total infiltration had been no different among treatments, presumably because rainfall intensity had not exceeded the infiltration rates of any treatment. Ehlers (1975) found that almost all the earthworm channels reaching the undisturbed soil surface transmitted tension free water deeply into the soil profile. He indicated that water infiltrated through earthworm channels only at high rainfall intensities, because tension free water could not exist at the soil surface at low rainfall intensities. Water would have infiltrated according to hydraulic gradients in the soil matrix when low rainfall intensities dominated.

Higher infiltration into zero tillage soils, despite decreases in macroporosity in the surface soil (Pidgeon, 1980; van Ouwerkerk and Boone, 1970), has been attributed to greater pore continuity that resulted from earthworm channels and decayed roots (Bauemer, 1970; Goss _et al._, 1978). They concluded that the total volume of draining pores was less important than the pore continuity.

Shannholtz and Lillard (1969) working in Virginia, found on soils with a 6-8 percent slope that runoff water on zero tillage plots was 0.5 cm compared to 2.08 cm on conventional tillage plots. They suggested decaying root systems on the zero tillage plots provided continuous channels for water infiltration into the soil profile. Jones _et al._ (1969) showed that untilled plots of killed sod residue had runoff values of 1.6 cm in contrast to 10.4 cm for conventional bare plots. Corn yields were higher on the killed sod plots.

Lindstrom and Voorhees (1980, 1981) reported on studies initiated in Minnesota, and found that the kinetic energy required to initiate runoff was always less for the zero tillage system of planting than for the conventional tillage system although the differences were not always significant. The differences in kinetic energy required to initiate runoff resulted in a detrimental effect on water runoff and infiltration. They concluded that 10 years of continuous, heavy corn residue on untilled plots effectively absorbed the kinetic energy of rainfall but that the consolidated soil surface that may have existed prior to zero tillage establishment had persisted. Burwell and Larson (1969) conducted trials on alfalfa/bromegrass plots, where the surface residues were removed before tillage, to determine the influence of tillage-induced random roughness and pore space on infiltration. Cumulative infiltration and rainfall energy required to initiate runoff were greater on the rough, porous surface created by the plough treatment. The smoother, untilled treatment offered less opportunity for infiltration. Steichen et al. (1979) showed that zero tillage plots had significantly less water infiltrated than any other tillage treatment primarily due to increased bulk density and decreased pore volumes. They concluded that high random roughness and high porosity enhance infiltration.

Lal (1978) found mean saturated hydraulic conductivities of the surface layer to be 7.1 and 6.1 cm per minute for zero tillage and ploughed plots, respectively. In contrast, Gantzer and Blake (1978) found that saturated hydraulic conductivities of surface soil were lower under zero tillage than under ploughing, averaging 14.6 and 38.2 cm/hr, respectively. Lower values for saturated hydraulic conductivity under zero tillage followed a corresponding increase in soil bulk density.

2.3 EFFECTS OF ZERO TILLAGE ON SOIL COMPACTION

2.3.1 Soil Suitability

The possibility of increased soil compaction and the reduction of root growth and plant growth under zero tillage compared to conventional tillage has been an expressed concern of many researchers. Deibert et al. (1980) stated that bulk density, penetrometer resistance and soil moisture are three interrelated soil physical parameters that express the degree of soil compaction. Van Ouwerkurk and Boone (1970) found that zero tillage soils were more dense and homogeneous than cultivated soils. The increased bulk density reduced the size and volume of pores and created smaller aggregates, thus a potential could occur for restriction of air, water movement, and root growth. Deibert et al. (1980) reported that bulk density and soil strength are a function of soil moisture and that dry soils are more resistant to compaction than wet soils (Chancellor, 1977), whereas, wet soils have the least resistance to penetrometers (van Ouwerkerk and Boone, 1970).

Zero tillage soils are generally consolidated, having a high bulk density, higher penetrometer resistance, and a small pore size (Bauemer and Bakermans, 1973; Pidgeon, 1980). Boone et al. (1976) found that compared to conventional tillage, zero tillage resulted in a more dense and homogeneous soil with little improvement in pore continuity, on soils in the Netherlands. They suggested that sandy soils with relatively low organic matter content and fine textured soils were unsuitable for zero tillage crop production. Pidgeon and Ragg (1979) defined suitable soils for zero tillage in Scotland to be well drained loamy soils, well-drained clays, and sandy soils with organic matter content greater than 2 percent. The least suitable soils were poorly drained, weakly structured clay soils. Soil compaction and restriction of root growth were the important factors in the assessment of soil suitability of zero tillage.

Bauemer (1970) reported that zero tillage caused a reduction in seedling emergence, plant density and grain yield. Zero tillage experiments failed when used on dry or consolidated soils and when used on leys on which the grass was not adequately killed.

2.3.2 Soil Bulk Density

Pidgeon and Soane (1977) from Scotland, found that equilibrium bulk density in the 0-21 cm depth was achieved after three years of zero tillage. Bulk density below the 21 cm depth reached an equilibrium after only one year. They found that bulk density was highest in the 0-15 cm surface soil on zero tillage plots compared to ploughed plots and the increase in bulk density corresponded to a decrease in total porosity from 49 percent to 44 percent. Gantzer and Blake (1978) established five year continuous corn tillage experiments in Minnesota, and reported that the bulk density under zero tillage soils increased in the surface 30 cm compared to conventional till soils. Lower air-filled porosity and hydraulic conductivity due to increased soil water content and bulk density on the zero tillage plots caused concern for restricted aeration.

Ellis _et al_. (1979), reported on winter wheat and spring barley field trials conducted on calcareous clay soils in the United Kingdom, and concluded that bulk densities did not change over the course of the four year experiment. The bulk density was higher after zero tillage than after ploughing at all depths down to 15 cm. On calcareous sandy loam soil, Ellis _et al_. (1977) found that bulk density was significantly higher on zero tillage than on ploughed treatments. Cannell _et al_. (1980) conducted winter cereal field trials on two non-calcareous clay soils, and showed that the zero till plots had significantly higher bulk densities than conventional till plots. Differences in bulk density between plots occurred throughout the experiment on the Denchworth soil with 50 percent clay, while the differences did not appear until the third year on the 35 percent clay soil of Lawford series. Grain yields on zero tillage plots were significantly higher on the Lawford soil and nearly equal on the Denchworth soil. However, winter cereal yields were 18 percent less on the zero till plots on the Denchworth soil in wet years.

Blevins _et al._ (1977) conducted trials on a bluegrass sod in Kentucky, and found that bulk density in the 0-8 cm depth was not significantly different for zero tillage and ploughed plots. This is in agreement with Moschler _et al._ (1969) who reported no significant differences in bulk density between treatments after long-term corn production and Hodgson _et al._ (1977) who found that zero tillage plots, sown to spring barley varied little in bulk density compared to other plots except in one dry year where the bulk density was higher in zero tillage plots compared to other plots.

Pidgeon (1980) found that the equilibrium bulk density in zero tillage plots was significantly higher in the 0-12 cm depth compared to the other tillage treatments. Below this depth the soils under zero tillage had a similar bulk density to soils in all other treatments but under zero tillage the bulk density remained higher than in deep plough treatments. Critical values of bulk density or aeration have been of limited value in determining the effects of compaction on plant growth (Soane and Pidgeon, 1975), partly due to the fact that single values are generally used rather than values for the whole soil profile. For zero till soils showing much shrink/swell behaviour and pore continuity, critical values have been relatively unimportant (Ellis _et al._ 1979).

2.3.3 Penetrometer Resistance

Van Ouwerkerk and Boone (1970) found that penetrometer resistance was generally higher on the zero tillage plots than on conventional tillage plots in the 0-20 cm depth due to the smaller volume of pore space. The increase in the distribution of small pores had a larger effect on the penetrometer resistance as the soil water content decreased.

Pidgeon and Soane (1977) from Scotland, showed that penetrometer resistance was significantly higher in the zero till soils than in the ploughed soils. The penetrometer resistance increased with depth under zero tillage and did not reach an equilibrium even after seven years of zero tillage, even though the bulk density had reached equilibrium. The increased penetrometer resistance under zero till was attributed to increased aggregate stability.

Ellis _et_ _al_. (1977) conducted trials on sandy loam soil, and reported that a highly significant positive correlation was established between mean bulk density and mean penetrometer resistance for all depths and tillage treatments. Penetrometer resistance was highest under zero tillage to the 7.5 cm depth. Ploughed treatments had the lowest penetrometer resistance to the 30 cm depth, below which all treatments were essentially equal. Ellis _et_ _al_. (1979) determined penetrometer resistance on clay soils seeded to winter wheat and spring barley. Penetrometer resistance to a depth of 23 cm was greater after zero tillage than after ploughing for both winter wheat and spring barley. The penetrometer resistance was intermediate for the shallow tine treatment, but below 7.5 cm penetrometer resistance was greater in this treatment than in the zero tillage treatment. Hodgson _et_ _al_. (1977) also showed that the penetrometer resistance was significantly greater to the 30 cm depth under zero tillage than when the soil was ploughed.

2.3.4 Root Growth

Cannell (1977) reported that roots penetrate the soil through existing pores against an external pressure. If the soil is of low penetrometer resistance, roots may readily extend through the soil, however root extension can be lessened by increased penetrometer resistance. Reduced rates of root elongation have also been associated with increased bulk density, since increasing bulk density resulted in a reduction of large pores.

Holmes (1976, from Pidgeon 1980) reported experiments conducted in the United Kingdom on soil with very poor physical condition, high bulk density (1.7 g cm) and poor subsoil drainage. He concluded that restricted root growth near the soil surface of zero tillage plots could not be overcome. Stibbe and Ariel (1970) demonstrated that germination and seedling growth were better under zero tillage than plough treatments, however, after one month plant leaves turned yellow and growth was retarded on the zero till plots. Greater soil compaction combined with lower nitrogen availability limited root growth in the topsoil of the zero till plots. Available water was limited which was reflected by earlier maturing and dying of plants.

In the early stages of winter wheat and spring barley seedling development, on calcareous sandy loam soil, Ellis *et al.* (1977) found typical effects of mechanical impedence to root growth (shorter root axes, elongation of lateral roots, and restriction of seminal root extension) in the zero till crop. Although early shoot development was restricted, compensatory shoot and root growth in later development stages offset any differences in yields of spring barley between the tillage treatments. On calcareous clay soil, Ellis et al. (1979) observed a significantly greater number of roots below the 10 cm soil depth under zero tillage compared to ploughed treatments in both winter wheat and spring barley, even though soil compaction was greater on the zero till plots. Plant density and grain yield was equivalent or higher under the zero tillage treatments.

Drew and Saker (1978) found greater root weights and lengths near the surface under zero tillage compared to ploughing supporting, earlier experiments by Stibbe and Ariel (1970) and Ellis et al. (1977). Contrary to earlier suggestions of restricted rooting depth under zero tillage (Holmes, 1976 from Pidgeon 1980; Stibbe and Ariel, 1970), there was deeper rooting during early spring of winter and spring sown crops in undisturbed clay soils. These findings were probably due to an increased frequency and continuity of fissures and worm channels (Drew and Saker, 1980).

Cannell et al. (1980) showed that root development of winter wheat on a non-calcareous Lawford clay soil appeared to be more prominent deeper in the profile of untilled soil. After wet winters, poor shoot growth and yield on zero till plots of the Denchworth soil (higher clay content) may have been caused by restricted root growth and availability of nitrogen.

Cannell and Finney (1973) reported that early root development of cereals has sometimes been restricted under zero tillage, compared to conventional tillage, though later growth and yield have not always been altered, indicating that soil compaction may not always be important. Higher rooting density after zero tillage in spring barley and winter wheat may have been a response to larger concentrations of phosphate found in the surface of zero till soils (Drew and Saker, 1980). Also the water retention capacity has been found to be greater (Lal, 1976) and capillary transport evident (Boone and Kuipers, 1970; Pidgeon and Soane, 1975) under zero tillage management so that root growth may continue for a longer period than under ploughing. Edwards and Lofty (1978) found root growth was promoted to deeper depths in the soil profile on zero tillage soils by soil invertabrates probably because they provided tunnels for roots to penetrate.

From studies conducted in Manitoba Donaghy (1973) showed that root development of cereals and oilseeds was not restricted under zero tillage and in fact appeared slightly superior under zero tillage than under conventional tillage.

2.3.5 Soil Structure

Some of the deleterious effects of compaction on root growth can be relieved by natural processes in undisturbed soil, including cracking in clay soils (Cannell, 1977; Ellis *et al.* 1979), increased aggregate stability (Cannell and Finney, 1973; Hughes and Baker, 1977; Soane and Pidgeon, 1975), and effective pore continuity by earthworm activity and decayed roots (Bauemer, 1970; Ehlers, 1975; Ellis *et al.* 1977). Mathews (1972), from New Zealand, was of the opinion that crop residues left on untilled soil absorbed kinetic energy of rainfall, prevented soil splash, maintained high rates of infiltrationand reduced runoff. He was of the opinion that in excess of 5,000 million tonnes of soil would not be exposed annually to erosion in New Zealand if crop residues were continually left on the soil surface.

Blevins *et al*. (1977) in Kentucky concluded that zero tillage cropping coupled with moderate applications of nitrogen rates and lime nearly maintained the soil characteristics of uncropped bluegrass plots. With zero tillage cropping, land could be cropped continuously and still remain in good chemical condition.

Cannell and Finney (1973) and Soane and Pidgeon (1975) reported that after grassland, the higher organic matter and aggregate stability in the surface soil of untilled land persisted for a longer period of time than in the ploughed treatments. Bauemer and Bakermans (1973) observed an increase in soil trafficability under zero tillage. Changes in soil conditions that occurred from continous zero tillage included the development of a surface tilth, increased concentrations of available nutrients in the surface soil, and increased earthworm activity, which may offset the restraints on plant growth caused by greater compaction of zero tillage soils (Ellis *et al*., 1977). Also, compacted layers which have developed at the plough depth in cultivated soil, have been broken up by biological activity after repeated zero tillage (Cannell and Finney, 1973).

Van Doren *et al*. (1976) showed that zero tillage corn yields grown on poorly drained soils were equal to ploughed treatments if grown in a corn- oats- meadow rotation. If corn was cropped continuously, yields were significantly less on zero till plots compared to ploughed plots.

2.4 WEED CONTROL

Meadow crops in rotation are traditionally destroyed and incorporated into the soil for grain crop production by moldboard ploughing (Triplett *et al.* 1979). Recently, the zero tillage system of crop production has developed and has resulted in a need for effective weed control on old pastures. Rowell *et al.* (1977) and Bauemer (1970) found that seeding directly into undisturbed pasture resulted in poor plant establishment and yields compared to seeding into disturbed or ploughed pastures. Poor yields were attributed to ineffective weed control of the species present in the old sward.

Nichols and Peters (1979) reported on field trials conducted in Conneticut and indicated that spring herbicide applications reduced the biomass of dandelion more effectively than fall herbicide applications and that a combination of dicamba and 2,4-D resulted in a greater reduction in the dandelion biomass than either herbicide alone. The mean dandelion biomass was one-third of the control for 2,4-D plus dicamba (0.8 + 0.3 kg/ha), one-half of the control for 2,4-D (0.8 or 1.6 kg/ha), and two-thirds of the control for dicamba (0.3 or 0.6 kg/ha). Peters and Dest (1973) showed silage corn yields to be highest after dandelions were effectively controlled by glyphosate at 2.25 kg/ha. They found dandelions were difficult to kill and that poor control existed with all treatments which included glyphosate at rates lower than 1.12 kg/ha. These findings are in agreement with Sellick and Baird (1981) who found that the control of dandelion was reduced when glyphosate was mixed with residual herbicides.

Waddington and Bowren (1976) found that two years after herbicide application there were fewer dandelions in plots treated with 2,4-D alone or in combination with dicamba or picloram than in the control plots. Glyphosate killed established dandelions but had no residual effect, thereby allowing an abundance of new seedlings to establish. Paraquat did not kill established dandelions but reduced the numbers present in the plots.

Moomaw and Martin (1976) found that 2,4-D plus dicamba (1.12 + 0.28 kg/ha) provided effective control of alfalfa that was equivalent to ploughing, and that spring treatments were better than fall treatments. Day time temperatures below 15.6 C shortly after spraying were detrimental to effective alfalfa control using all herbicides. Where alfalfa was not adequately controlled, a reduction in corn population, corn height and corn seed weight occurred. Siemens and Carder (1965) reported that one year old alfalfa was killed by picloram (0.275 kg/ha), by picloram plus 2,4-D (0.20 + 0.675 kg/ha) and by dicamba (0.55 kg/ha), however alfalfa recovered after being treated with 2,4-D amine (1.1 kg/ha) and 2,4-DB (2.25 kg/ha).

Bayer (1975) found that alfalfa control was more effective when residual herbicides were mixed with glyphosate. Post emergence applications of 2,4-D and dicamba also provided adequate control. Sellick and Baird (1981) reported that glyphosate applied at 1.7 ae kg/ha controlled 86 percent of the alfalfa 28 days after treatment whereas glyphosate applied at 3.4 ae kg/ha effectively killed 100 percent of the alfalfa 57 days after treatment.

Waddington (1980) showed a significant reduction in alfalfa density with applications of 2,4-D (1.1 kg/ha) and a delayed recovery due to competition from the perennial sow thistle that emerged after the herbicide application. When the competitive advantage was removed in a weed free environment, alfalfa in the treated plots recovered to produce seed yields equal to or better than the control treatment.

Chapter III

MATERIALS AND METHODS

The tillage experiments were conducted during 1980 and 1981 at the Glenlea Research Station on soils developed from weakly calcareous lacustrine clay with organic matter content of approximately 10 percent. The 1980 experimental site was located on a moderately drained Gleyed Black and Gleyed Rego Black soil of the Scanterbury and McTavish series with the surface soil consisting of approximately 7% sand, 23% silt, and 70% clay. The 1981 experimental site was located on a poorly drained Rego Humic Gleysol soil of the Osborne series with approximately 4% sand, 24% silt, and 72% clay and 10% organic matter in the surface soil. Cropping history for these sites are given in Table 1. A weed control experiment was conducted in 1981 on the Ron Hewett farm south of Winnipeg (SW 23-9-2E), on an Osborne clay soil with characteristics similar to the 1981 tillage experiment site at the Glenlea Research Station.

3.1 TILLAGE EXPERIMENTS

The tillage experiments were a completely randomized block design with three tillage treatments and four replicates. The tillage treatments consisted of zero tillage (ZT), minimum tillage (MT), and conventional tillage (CT). Description of tillage treatment preparation are given in Table 2. Treatments were initiated in the summer of 1979 for spring seeding in 1980, and in the summer of 1980 for spring seeding in

Table 1

Cropping History of the Experimental Plot Area at the Glenlea Research Station

Year	1980 Experimental Site	1981 Experimental Site
1971	Barley	Barley Underseeded to forage*
1972	Barley Underseeded to forage*	Forage
1973-1979	Forage	Forage
1980	Wheat	Forage
1981	Wheat	Wheat

*Forages underseeded at 5.6 kg/ha bromegrass, 2.24 kg/ha creeping red fescue, 2.24 kg/ha alsike, 2.24 kg/ha alfalfa and 67 kg/ha barley.

Table 2

Description of Treatments in the Tillage Experiments

Treatment		Year	Method of Preparation	Operations	
				Time	Number
Conventional tillage	Site 1 Seeded 1980	1979	rotovate	July	(1)
		1980	tandem disc	May	(2)
		1980	harrow	May	(2)
	Site 2 Seeded 1981	1980	rotovate	August	(1)
		1981	tandem disc	May	(2)
			harrow	May	(2)
Minimum tillage	Site 1 Seeded 1980	1979	herbicide*	August	(1)
		1979	tandem disc	September	(1)
		1980	tandem disc	May	(1)
			harrow	May	(1)
	Site 2 Seeded 1981	1980	herbicide***	August	(1)
		1980	tandem disc	September	(1)
		1981	tandem disc	May	(1)
			harrow	May	(1)
Zero tillage	Site 1 Seeded 1980	1979	herbicide*	August	(1)
		1980	herbicide**	May	(1)
	Site 2 Seeded 1981	1980	herbicide***	August	(1)
		1981	herbicide**	May	(1)

*Glyphosate + dicamba (1.75 + 0.28 kg/ha).
**Glyphosate + dicamba (0.42 + 0.28 kg/ha).
***Glyphosate + dicamba (2.24 + 0.28 kg/ha).

1981. The preparation of the plot area consisted of killing forage grasses and legumes with herbicides and/or tillage. The forage stand in the 1980 experimental site consisted mainly of bromegrass and other sod bound grasses. Alfalfa had been present but was killed due to spring flooding in 1979. The forage stand in the 1981 experimental site had little alfalfa due to competition from the grass species. The plots measured 15m x 60m in 1980 and 16m x 75m in the 1981 plots.

A single disc drill[1] (Figure 1) was used to seed spring wheat (cv. Glenlea) in all plots in both 1980 and 1981. Penetration of this seed drill on the chemically killed sod (zero tillage plots) was adequate, however, the packer wheels failed to pack the sod bound soil to provide adequate seed/soil contact (Figure 2). Certified Glenlea Wheat was seeded at 100 kg/ha and 97.5 kg/ha in 1980 and 1981, respectively. Seeding dates were May 21 in 1980 and May 11 in 1981.

Phosphate fertilizer (11-55-0) was applied with the seed at the rate of 45 kg actual P_2O_5 in 1980. In 1981 phosphate fertilizer (23-23-0) was applied with the seed at the rate of 46 kg actual P_2O_5. In both years additional N fertilizer (34-0-0) was broadcast prior to seeding on the plot area to bring the total N applied to 120 kg/actual N.

In addition to the herbicide used to prepare the forage land for tillage experiments, post emergent herbicide applications were applied to all the seeded plots to standardize weed control and herbicide effects on the crop (Table 3). On the tillage experiments all herbicides were applied in 10 gallons of water with a versatile field sprayer.

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[1] Manufactured by Amozonen-Werke, West Germany.

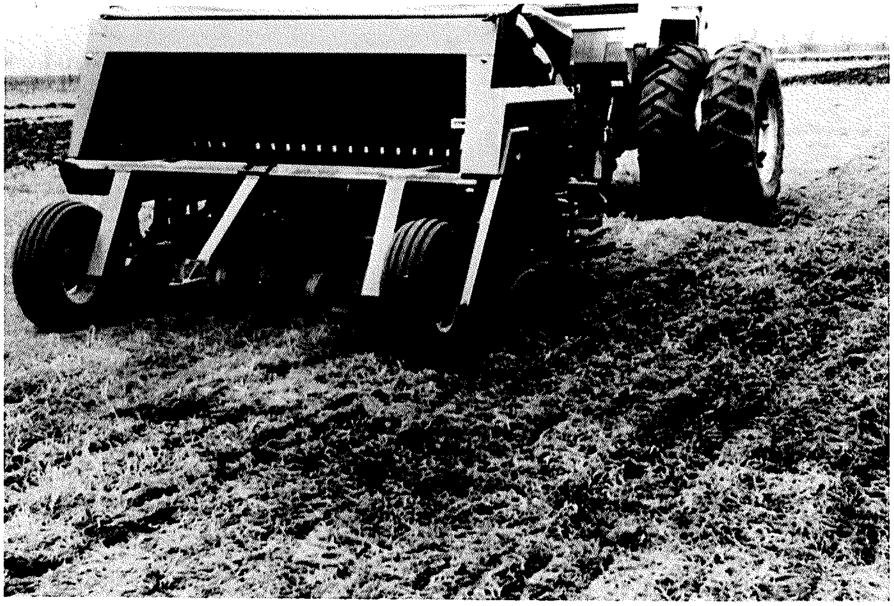

Figure 1 Single disc zero tillage drill

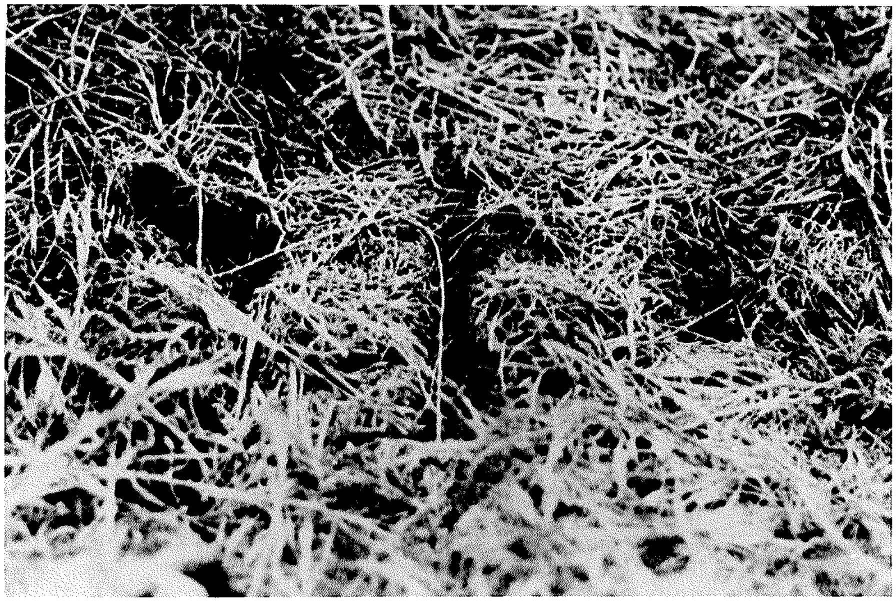

Figure 2 Seed slot opening on zero tillage plots

Table 3

In Crop Weed Control Practices on the Tillage Experimental Plot Area.

Year	Treatment	Rate	Date Applied
		(kg/ha)	
1980	MCPA(1) + TORCH(2)	0.55 + .28	July 2
1981	DOWCO 290(3)	0.3	June 12
	BUCTIL M(4)	0.55	June 26

(1) Chemical name 2-methyl-4-chlorophenoxyacetic acid.
(2) Chemical name 3,5-dibromo-4-hydroxybenzonitrile.
(3) Chemical name 3,6-dichloropicolinic acid.
(4) Chemical name 2-methyl-4-chlorophenoxyacetic acid plus 3,5-dibromo-4-hydroxybenzonitrile.

Soil physical properties and plant growth characteristics were assessed in both years from the tillage experiments.

3.1.1 Soil Bulk Density.

Soil cores of known volume were sampled at four depth intervals at four locations per plot using soil rings. The depth intervals were 0-5, 5-10, 10-15 and 15-20 cm. The soil from the soil ring was placed in a moisture tin, and dried in a convection oven for 48 hours at a 110 C. The mass of oven dry soil (g) divided by the volume of soil (cc) was calculated as bulk density (Table 4). Measurements of bulk density were collected throughout the growing season on all plots.

3.1.2 Soil Water Content.

Volumetric soil water of the surface 20 cm. was determined using the same samples that were used to measure bulk density. Gravimetric and volumetric water contents were computed using the formulas in Table 4. The volumetric soil water content for the 15-120 cm. depth were obtained using a neutron probe[2] (Figure 3). In each plot, three aluminum access tubes (51 mm O.D.) were placed in the soil to a depth of 1.4 m. Data was collected at the appropriate soil depths once a week, weather permitting, from the three access tubes per treatment.

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[2] Manufactured by Troxler Electronic Laboratories, Inc.; Model #3222, Source AM=241/BE.

Table 4

Mathematical Equations to Determine Bulk Density, Gravimetric Water Content, and Volumetric Water Content

(a) Bulk density (BD) (g/cc)

$$BD = \frac{\text{oven dry soil}}{\text{total volume of soil}}$$

(b) Gravimetric Water Content (W) (g/cc)

$$W = \frac{(\text{wet soil} + \text{tare}) - (\text{oven dry soil} + \text{tare})}{(\text{oven dry soil} + \text{tare}) - (\text{tare})}$$

(c) Volumetric Water Content (θ) (cc/cc)

$$\theta = W \times BD$$

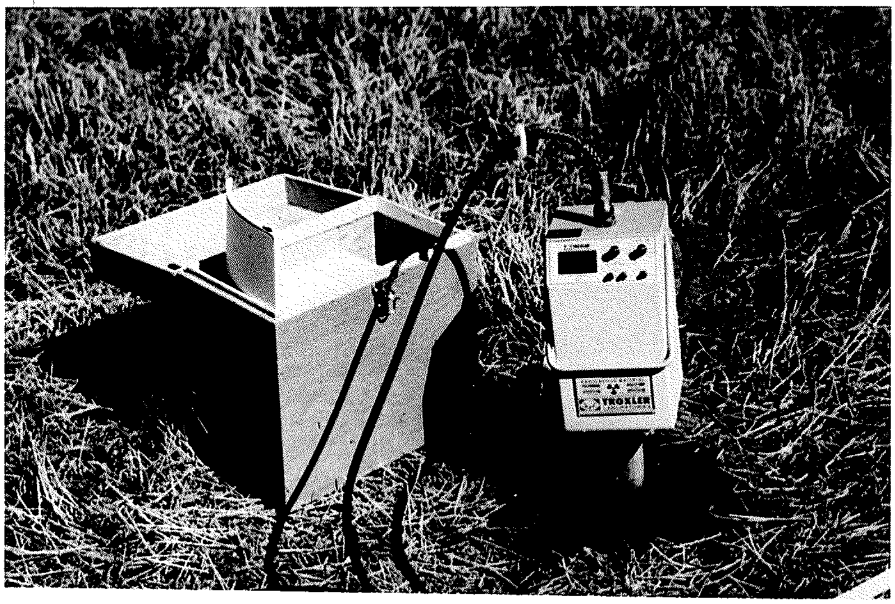

Figure 3 Neutron Probe Moisture Gauge

Figure 4 Double ring infiltrometer

3.1.3 Infiltration.

A double ring infiltrometer[3] (Figure 4) was used to measure the rate of water intake into the soil over time on the three tillage treatments. In the 1980 experiment measurements of one infiltrometer per plot were taken at the time of wheat emergence, whereas measurements from three infiltrometers per plot were taken at wheat emergence in the 1981 experiment. The infiltrometer rings were placed 10 cm into the soil. Water was ponded to the top of the double ring infiltrometer (15 cm), and the rate at which water moved into the soil was measured at time intervals of 1, 3, 5, 10, 20, 30, 60, 90, 120, 180 and 240 minutes. Soil water contents were measured at the time of infiltration.

3.1.4 Penetrometer Resistance.

In 1981 a hand operated penetrometer[4] (Figure 5) was used to measure soil resistance. The penetrometer resistance, (soil resistance), was defined as kg force per cm^2, measured to a soil depth of 60 cm. Ten locations per plot were tested once a week for one month after seeding and once every month thereafter.

3.1.5 Emergence.

Plant counts from ten one meter rows in each plot were taken for each treatment. Plants were counted for four weeks after seeding. The total number of plants emerged was determined from this data.

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[3] Manufactured by EIJKELKAMP, B.V., The Netherlands.

[4] Manufactured by Dan E. Little Machine and Instrument, Shafter, California.

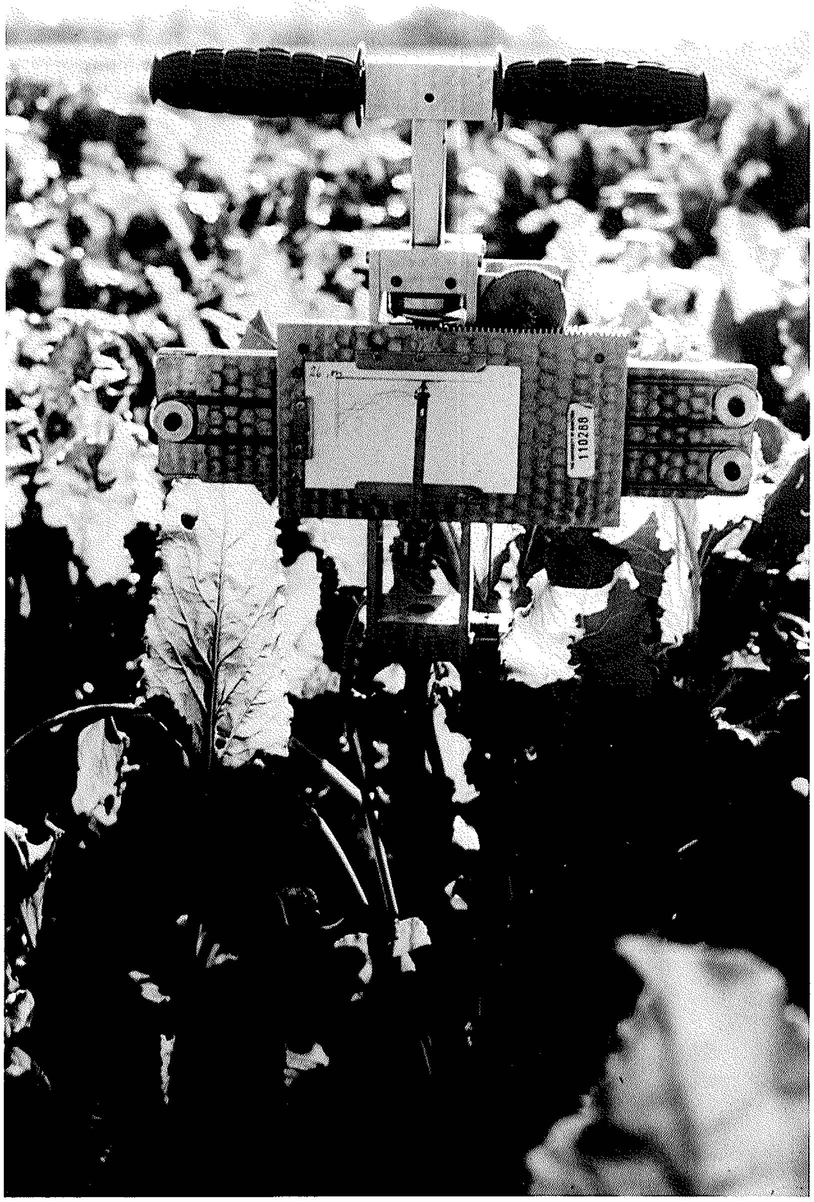

Figure 5 Hand operated penetrometer

3.1.6 Dry Matter.

The top growth of plants cut off at ground level were dried to a constant weight at 80 C and weighed. Dry matter accumulation was measured in 1980 by sampling two one m^2/plot at anthesis and at maturity. In 1981 two one m^2 samples were taken at anthesis and two quadrants 1/2 meter by 1/2 meter totalling a 1/4 m^2 sample at maturity.

3.1.7 Grain Harvest.

In 1980 grain was harvested with a small plot combine.[5] In 1981, the wheat was swathed prior to threshing with a small plot combine. The grain was cleaned and weighed and yield in kg per hectare was determined. Grain was harvested on August 26 in 1980 and August 22 in 1981.

3.1.8 Statistical Analysis

The results of this experiment were analyzed as a completely randomized block with four replications. Results for soil water contents and soil bulk density were analyzed with dates as a source of variation. Significant differences were detected using the LSD test at the 5 percent level.

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[5] Manufactured by Hege.

3.2 WEED CONTROL EXPERIMENT

A field experiment was initated in the summer of 1980 to study broad spectrum weed control on forage land for zero tillage crop production in 1981. The predominant species in the forage field were alfalfa and dandelions. The plots, 4m x 10m, were laid out in a split block experimental design having four replications. Herbicide treatments were sprayed on August 27, 1980 with a compressed air push type bicycle sprayer operated at 5.6 km/hr., and delivering 110 l/ha at 275 kPa. Seeding in the spring of 1981 was done with a single disc drill (Figure 2). Spring wheat (cv. Glenlea) was seeded on May 11, 1981 on half the plot area at a rate of 97.5 kg/ha into the chemically treated sod. Fertilizer was drilled with the seed at a rate of 46 kg actual P_2O_5 of 23-23-0. After seeding, just before the spring wheat emerged, an additional amount of glyphosate and dicamba and Agol 90 (0.42 + 0.28 + 0.42 kg/ha) was sprayed to kill germinating annual weeds.

Weed counts were taken on June 2-4, 1981 with a point analysis (10 locations per plot, 10 points per location) to determine the frequency of weeds in each plot. Due to the increasing presence of alfalfa and dandelion, 0.3 kg/ha Dowco 290 in 110 l water/ha was applied with a bicycle sprayer on half of each plot on June 27, 1981. Dry matter production and weed counts were taken July 17, 1981 from the plots using 1/8 m^2 for sampling. Grain yields were determined by taking wheat plants from 1/4 m^2 area on September 14, 1981.

The results of this experiment that included total weed frequency, alfalfa frequency and grain yield were analyzed as a split block with four replications. The alfalfa dry matter accumulation was analyzed as a split block split block with four replications. Only the means for the treatments were presented since the interaction between the treatments and whether or not seeding occurred and whether or not herbicide (Dowco 290) was applied was not significant. Significant differences were detected using the Duncan's Multiple Range Test at the 5 percent level.

Chapter IV

RESULTS AND DISCUSSION

4.1 EFFECTS OF TILLAGE ON PLANT GROWTH

Crop growth parameters measured were plant population, shoot dry weight and grain yield.

In both 1980 and 1981, plant populations were lower under zero tillage than under minimum and conventional tillage (Table 5). In 1981, plant populations on the minimum and conventional tillage treatments were not different. Poor emergence on all the treatments in both years can be attributed to the variable seeding depth of the single disc drill used on these trials. Wheat seeds were observed lying on the soil surface on all the treatments. On the zero tillage plots the single disc drill penetrated the sod-covered soil but failed to give adequate seed-soil contact to prevent desiccation of the germinated seed. Rainfall did not occur for 14 and 10 days after seeding in 1980 and 1981, respectively. These conditions resulted in less wheat seedling establishment in the zero tillage treatments compared to the tillage treatments. This result has been seen by others (Cannell and Graham, 1979; Rourke, 1981) who showed that wheat emergence on clay soils was reduced under zero tillage management compared to conventional tillage due to poor seed drill performance.

In 1980, wheat shoot dry weight at anthesis was lower on the zero tillage soil than on the conventional tillage soil (Table 5). The

Table 5

Emergence, shoot dry weight at anthesis and wheat yield of conventional, minimum and zero tillage in 1980 and 1981

Year	Tillage	Emergence*	Shoot** Dry Wt	Yield
		Plants/meter row	g/m	kg/ha
1980	Zero	13.2	561	1,501
	Minimum	15.2	597	1,998
	Conventional	17.5	646	2,705
	LSD (p=.05)	1.2	55	553
1981	Zero	9.1	486	1,473
	Minimum	16.6	543	1,906
	Conventional	16.3	519	1,380
	LSD (p=.05)	3.2	NS	162

*Mean of 40-1 meter row samples.

**Mean of 8-1 m samples.

shoot dry weights followed in a similar pattern to emergence, although the minimum till and conventional till treatments were not significantly different. In 1981, no significant differences were found among the treatments for wheat shoot dry weight, however, under zero till shoot dry weight appeared to be lower than on the tilled treatments, probably due to the lower emergence.

Results of the final grain yield are presented in Table 5. In 1980, conventional tillage plots had a higher grain yield than the other treatments, while in 1981 the minimum tillage treatment was the highest yielding treatment. In 1980, the lower zero tillage yields were attributed to a 24 percent decrease in wheat emergence compared to the conventional tillage plot. Also, there was bromegrass present in the zero tillage plot area that actively competed for moisture and nutrients resulting in low grain yields. In 1981, the minimum tillage treatment had very little bromegrass present in the plot area due to the combination of a herbicide treatment followed by tillage. There was some bromegrass present in the zero tillage plot area although it was less vigorous than in 1980. The conventional tillage plots were infested with bromegrass throughout 1981. Tillage operations in the summer of 1980 occurred at the time of recurring rainfall, possibly resulting in the survival of some of the bromegrass which continued to grow in 1981. Grain yields were approximately 27 percent less on the zero and conventional till plots compared to the minimum till plots.

4.2 EFFECTS OF TILLAGE ON SOIL WATER

Volumetric water content was investigated for three tillage treatments in two years (1980 and 1981) with measurements sampled from crop emergence to grain harvest. In 1980, soils under zero tillage had a greater water content in the surface 20 cm for the first two months of the growing season (Figures 6-9) compared to soils that were tilled, although these difference were not always significant. Differences in water content were greatest in the surface 10 cm (Figures 6 and 7) and diminished as the soil depth increased (Figures 8 and 9).

In periods of limited precipitation early in the growing season soil water was lost rapidly from both the tilled and zero tilled treatments, particularly from the surface 10 cm (Figures 6 and 7). Without the benefit of recurring rains, water contents on the untilled soil almost equalled that of conventional tilled soils in the surface 10 cm by June 13. At soil depths beyond 30 cm, water loss was not apparent from the tilled or untilled treatments (Figures 10 and 11).

During mid-summer from July 8-July 29, 1980, soil water was lost rapidly from all the treatments in the surface 20 cm of soil, due to a period of limited rainfall (Figures 6-9). Water contents were below or near permanent wilting point by the end of July for all treatments, however soil water was significantly higher under zero tillage by July 29 at the 5-10 cm soil depth (Figure 7). At the 45 cm depth, water loss was observed to occur by July 8 and continued until August 6 on all treatments (Figure 10), but water content decreases were greater on the soils using conventional tillage. Zero till and minimum till soils decreased in water content at approximately the same rate until the latter

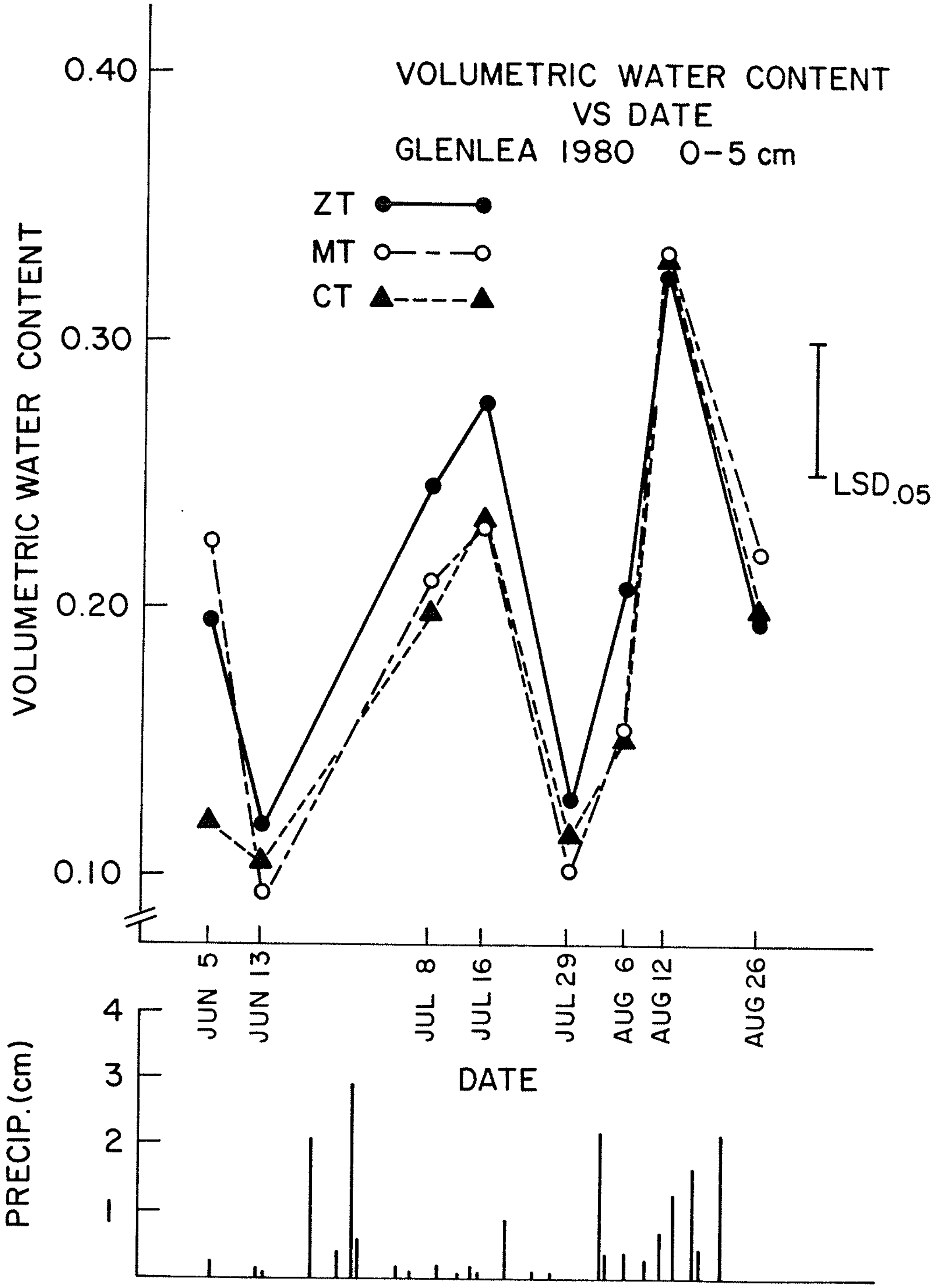

Figure 6 1980 Volumetric water content vs. date in the 0-5 cm soil depth in zero (ZT), minimum (MT) and conventional (CT) tillage

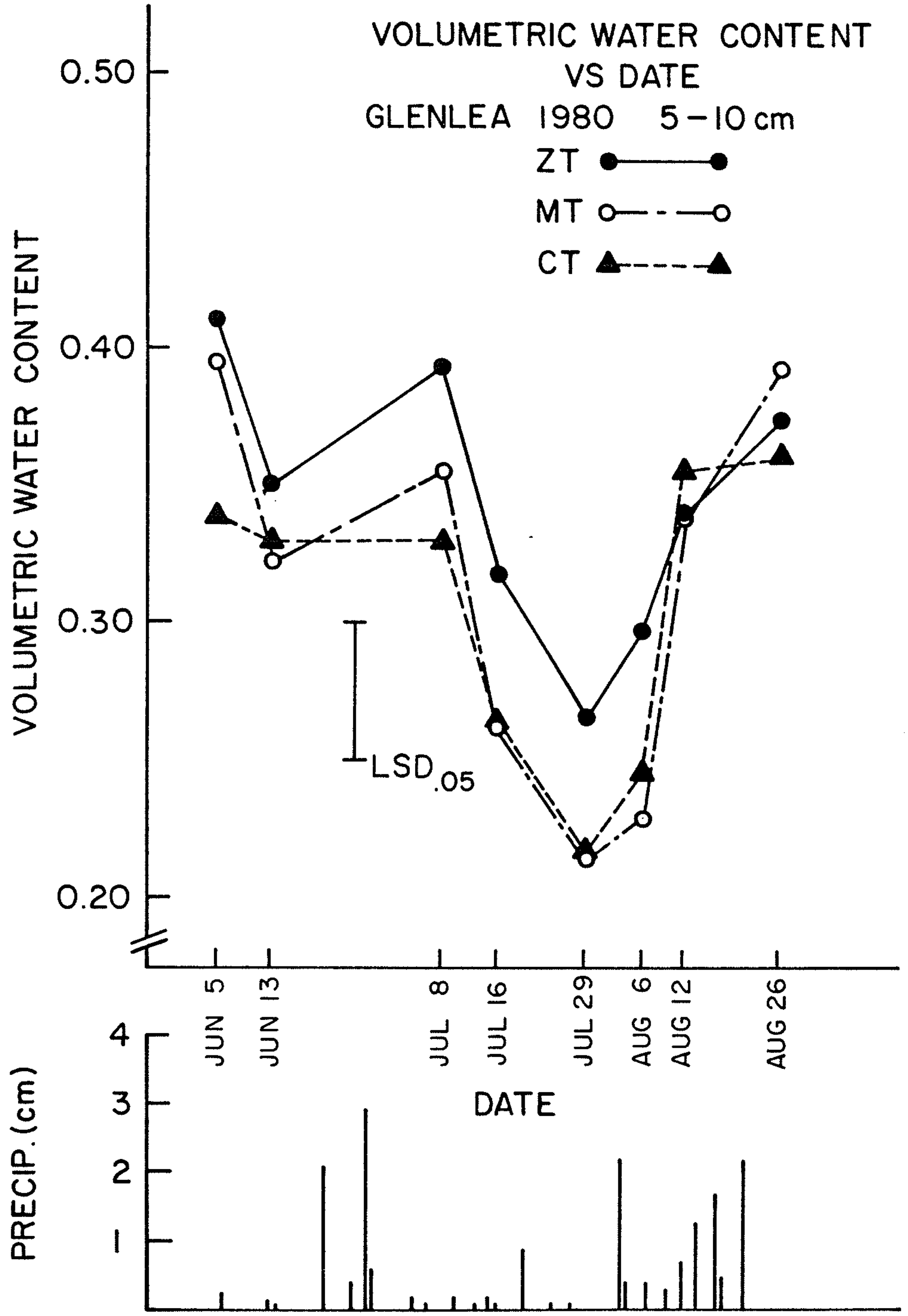

Figure 7 1980 Volumetric water content vs. date in the 5-10 cm soil depth in zero (ZT), minimum (MT) and conventional (CT) tillage

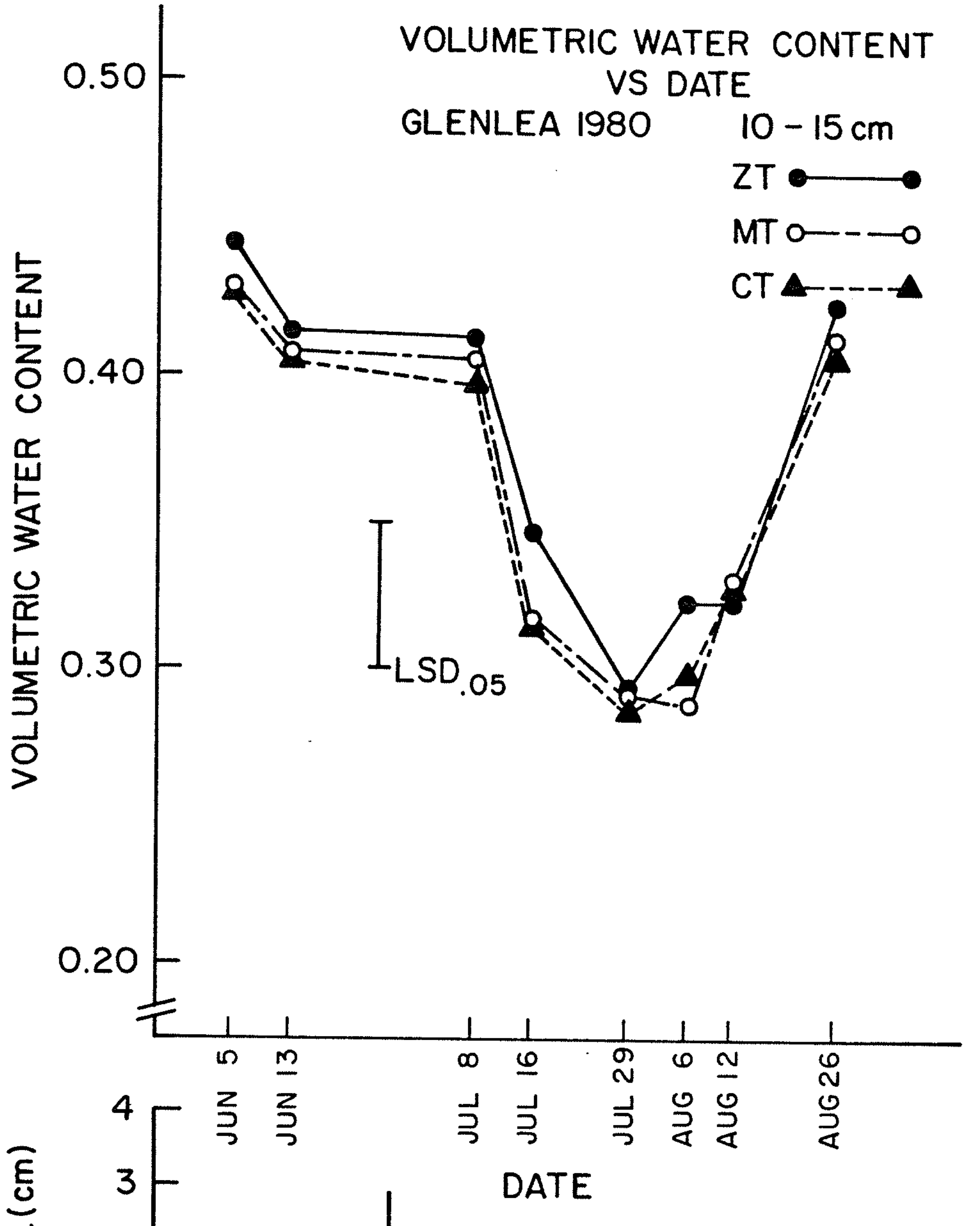

Figure 8 1980 Volumetric water content vs. date in the 10-15 cm soil depth in zero (ZT), minimum (MT) and conventional (CT) tillage

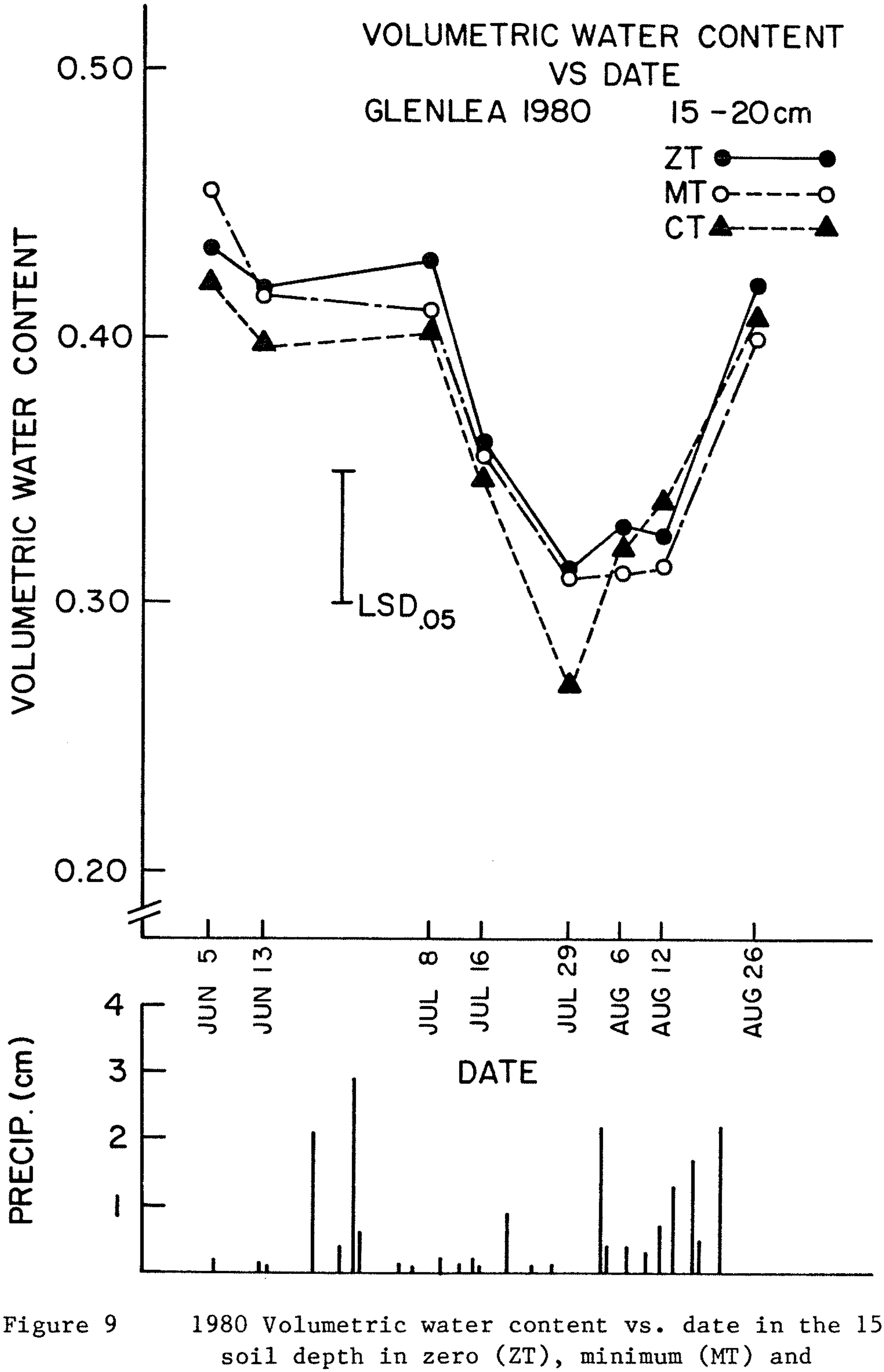

Figure 9 1980 Volumetric water content vs. date in the 15-20 cm soil depth in zero (ZT), minimum (MT) and conventional (CT) tillage

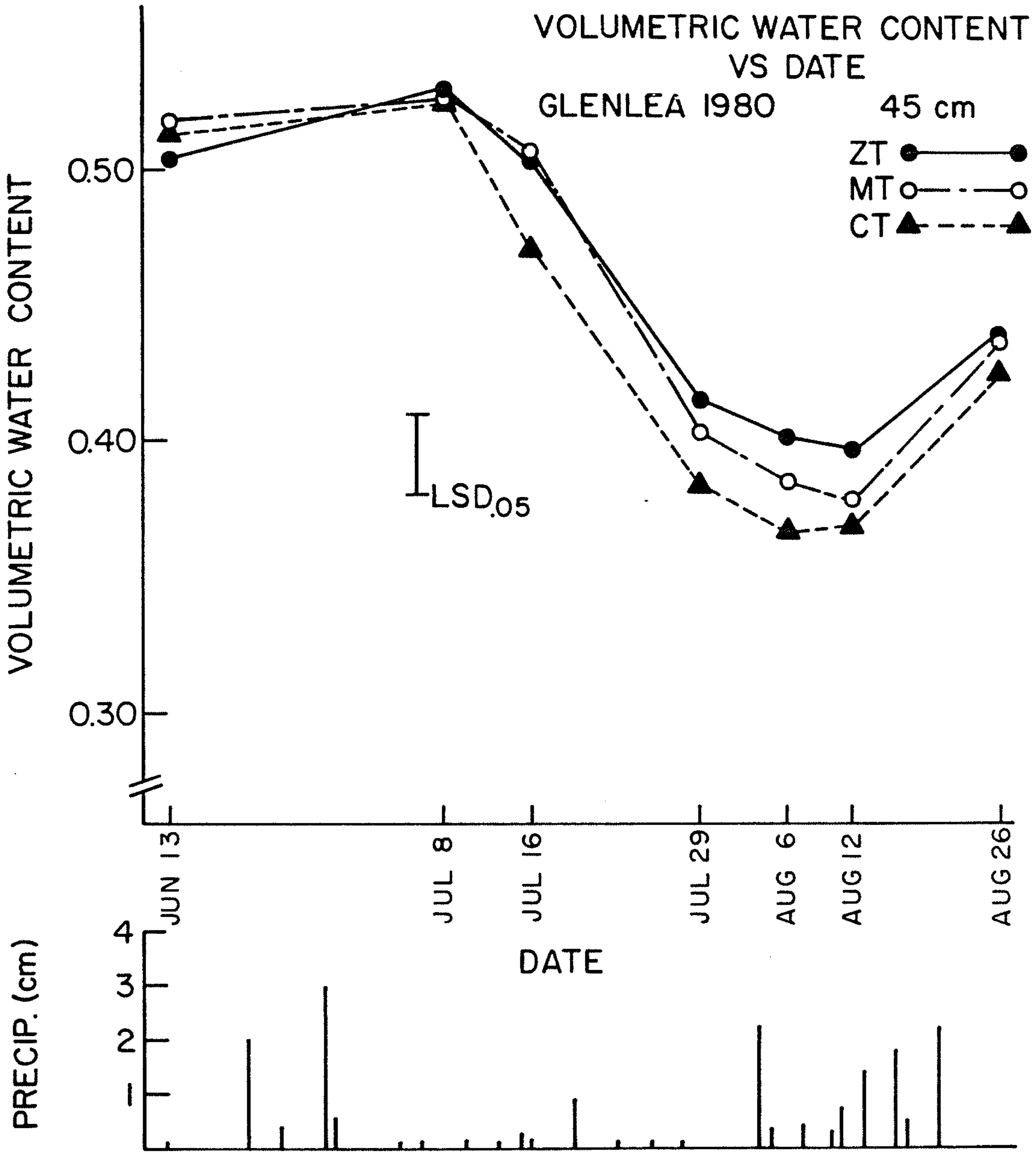

Figure 10 1980 Volumetric water content vs. date in the 45 cm soil depth in zero (ZT), minimum (MT) and conventional (CT) tillage

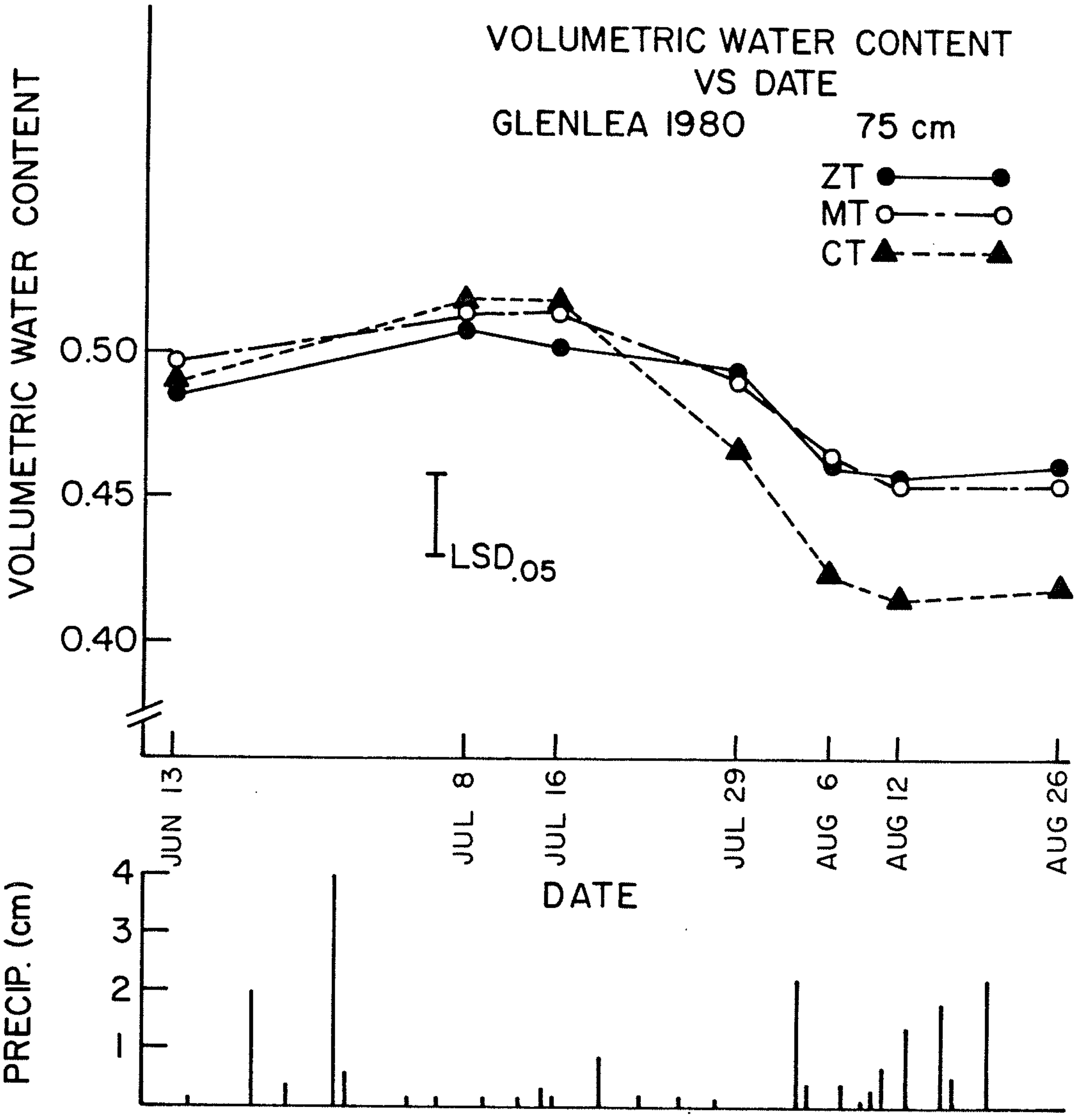

Figure 11 1980 Volumetric water content vs. date in the 75 cm soil depth in zero (ZT), minimum (MT) and conventional (CT) tillage

part of July after which time the water loss was greater on the minimum till soil. Water contents decreased at the 75 cm soil depth from July 16-August 6, 1980 on all treatments (Figure 11) with the soil under conventional tillage having a greater decrease in water content than the zero tillage or minimum tillage soils. The depletion of water occurring during this period was attributed to water extraction by plant roots.

When rainfall occurred in the 1980 growing season the soil water content was rapidly increased in all treatments in the surface 10 cm. Effective rainfall occurred between June 13 and July 8 causing water contents to increase in the surface 5 cm (Figure 6) and in the 5-10 cm depth (Figure 7) for both tilled and untilled soil, but water contents on the untilled soil exceeded those of the tilled soil. Below the 10 cm soil depth, management systems did not effect the water content at this time (Figure 8-12).

During the last month of the growing season prior to grain harvest, water from precipitation permeated the soil and the water contents increased in all plots to the 60 cm soil depth (Figures 6-10). By grain harvest, water contents were similar for both the tilled and the zero tilled treatments. During this time the grain was in the seed filling stage, placing high demands on the soil water, and may be the reason why soil moisture did not increase at the 75 cm depth (Figure 11). Zero till and minimum till soils had similar water contents at this depth and were significantly higher than the conventional till soil at the time the wheat was harvested.

Surface soil conditions had essentially no effect on soil water contents beyond the 90 cm depth throughout the growing season since water

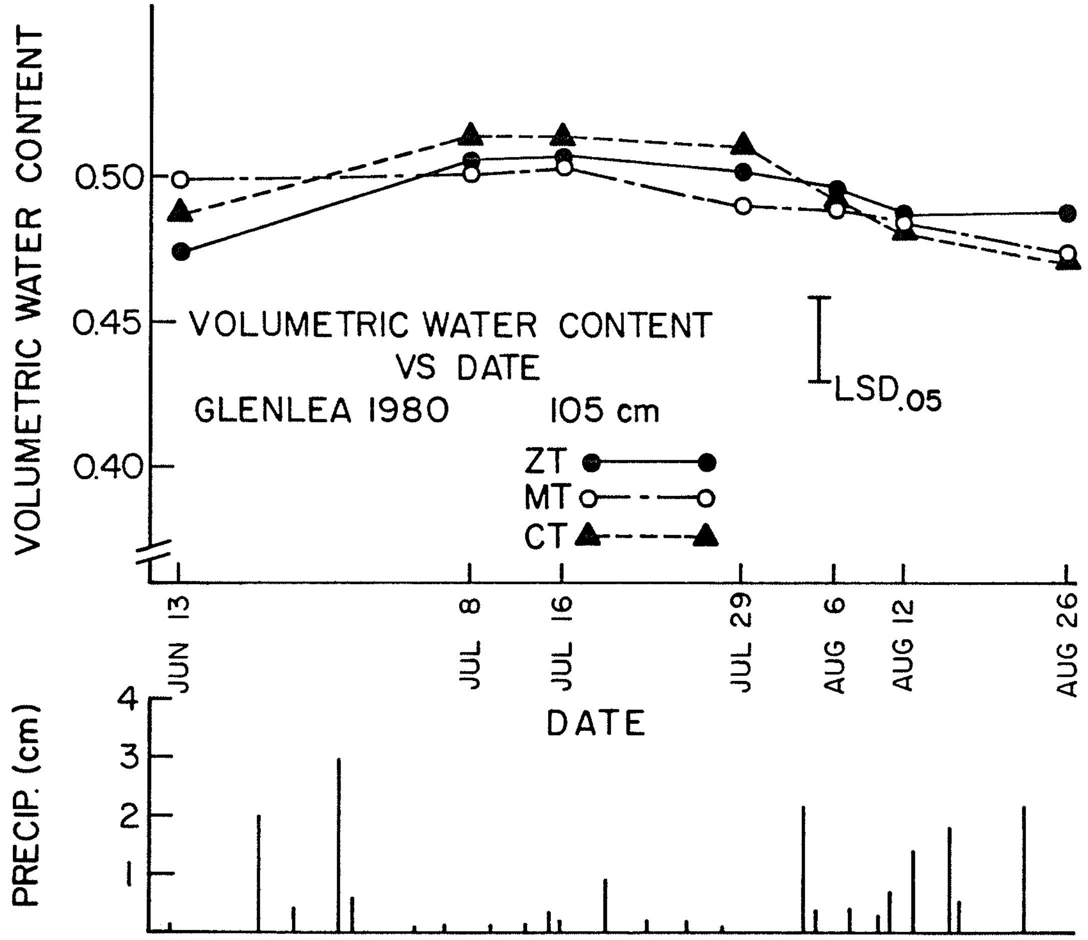

Figure 12 1980 Volumetric water content vs. date in the 105 cm soil depth in zero (ZT), minimum (MT) and conventional (CT) tillage

contents remained relatively similar from crop emergence to grain harvest during periods of limited rainfall and periods of recurring precipitation (Figure 12).

In 1981, the effects of tillage on soil water were quite similar to the 1980 plots. Water content of soils was higher on zero tilled plots than on tilled plots throughout the growing season in the surface 20 cm (Figures 13-16) with the greatest differences occurring in the surface 10 cm (Figures 13 and 14), although these differences were not always significant. As in 1980, differences in water content were greatest in the surface 10 cm (Figures 13 and 14) and diminished as the soil depth increased (Figures 15 and 16).

Prior to the spring rains early in the growing season, water contents decreased until they were almost equal in both the tilled and untilled soil (Figure 13). After precipitation occurred on May 22 increases in water content were evident in all treatments but particularly in the surface 15 cm of the zero tillage plots (Figures 13-15). During this early rainfall period the tillage system had very little effect on the water contents beyond the 30 cm depth (Figures 15-17).

During the months of June and July the water content in the 0-20 cm depth continued to decrease in all the treatments (Figure 13-16), but on occasion, rainfall that occurred immediately prior to sampling the soil resulted in an increased water content in the surface 5 cm (Figure 13). Zero tillage soils continued to have higher water contents than the tilled soils with the greatest differences occurring in the 5-10 cm depth (Figure 14). Beyond a depth of 30 cm, water loss patterns were

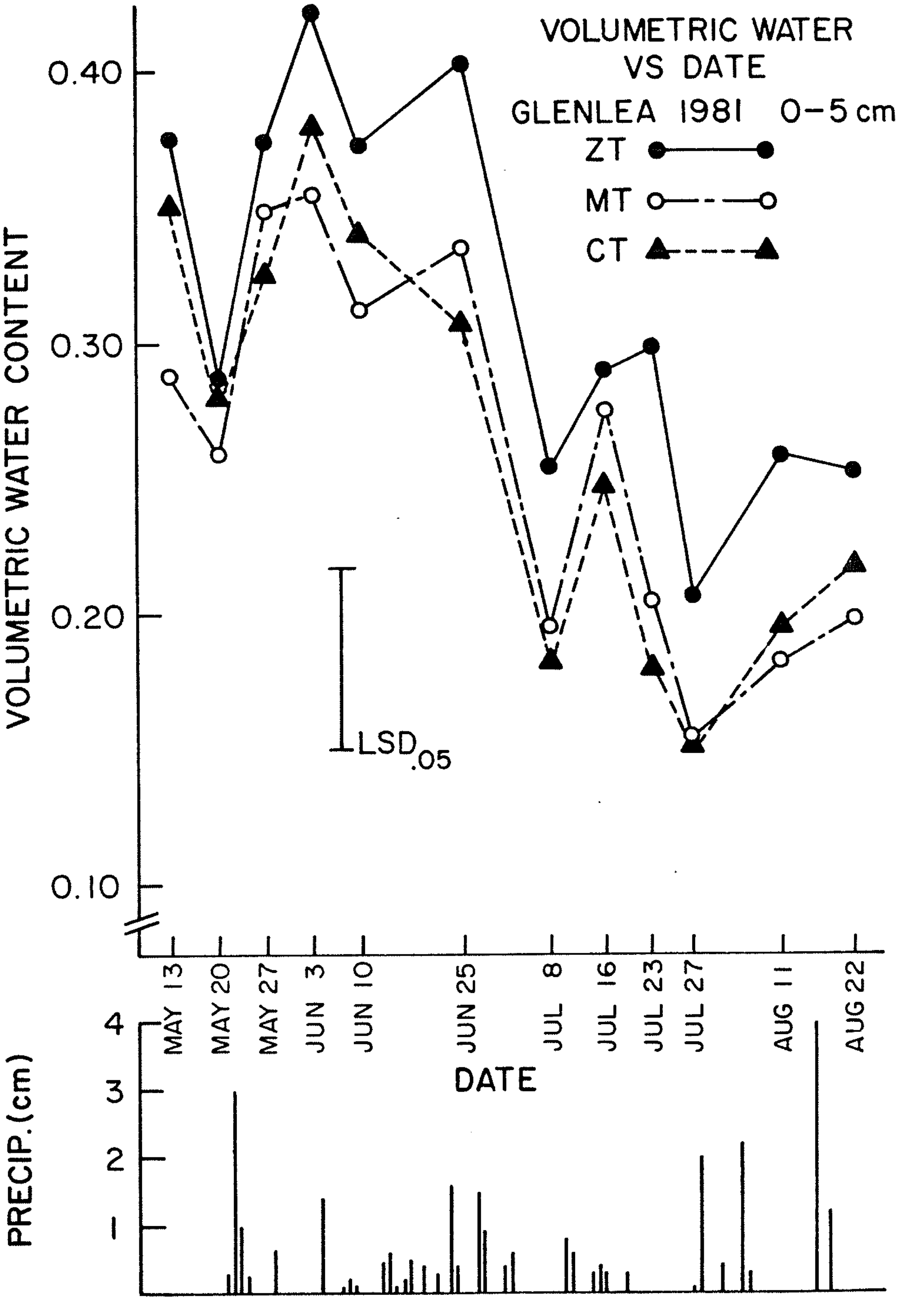

Figure 13 1981 Volumetric water content vs. date in the 0-5 cm soil depth in zero (ZT), minimum (MT) and conventional (CT) tillage

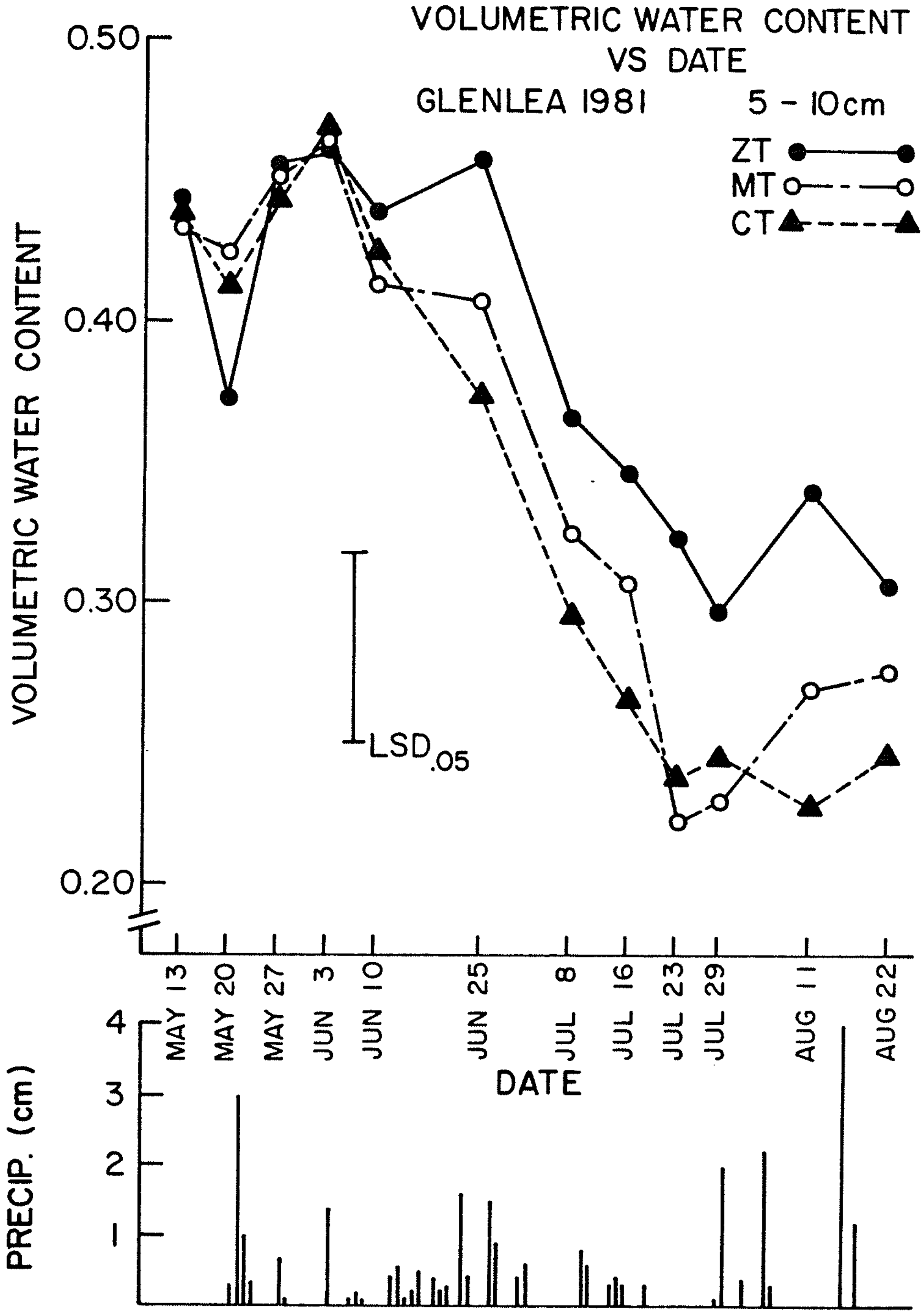

Figure 14 1981 Volumetric water content vs. date in the 5-10 cm soil depth in zero (ZT), minimum (MT) and conventional (CT) tillage

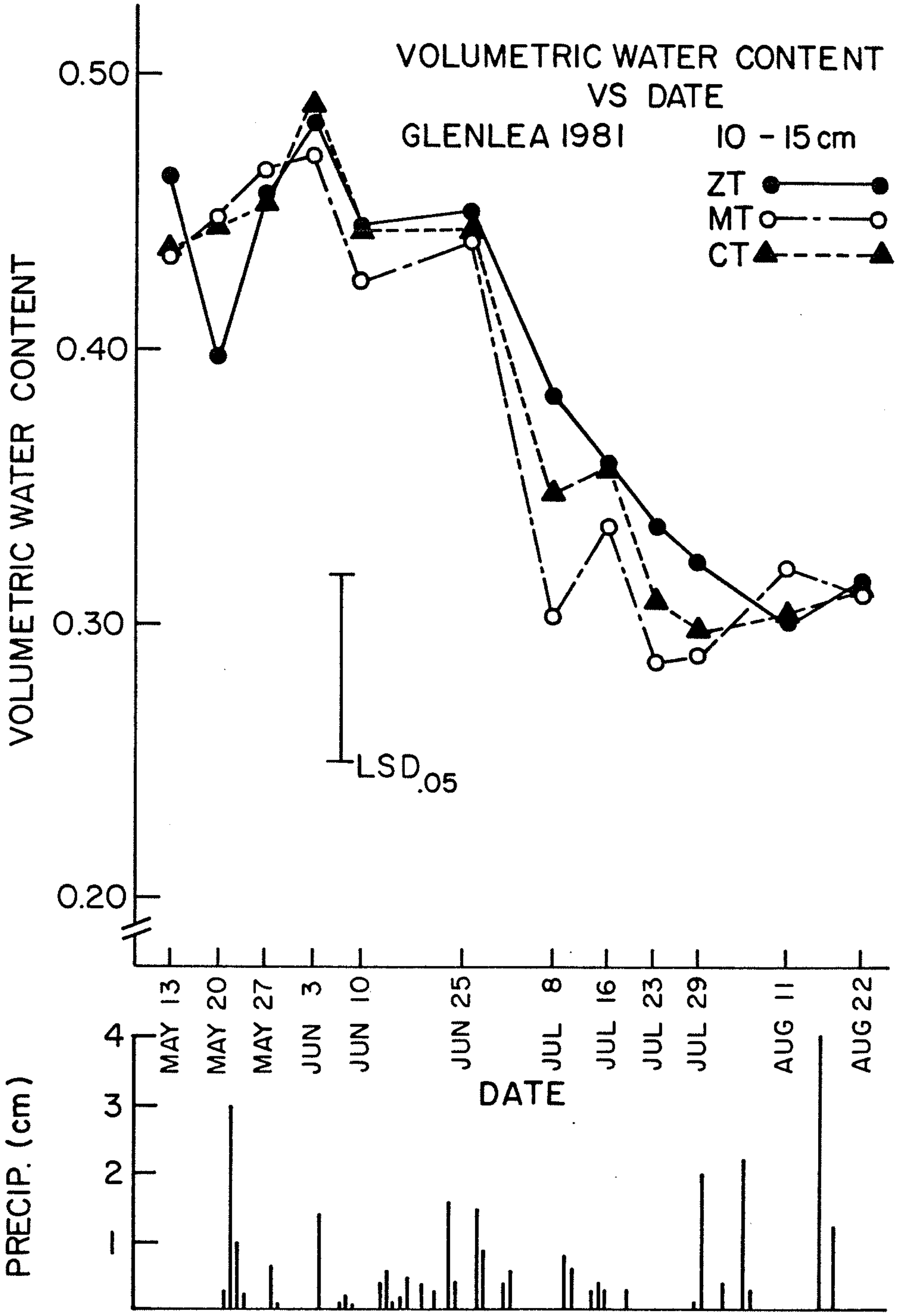

Figure 15 1981 Volumetric water content vs. date in the 10-15 cm soil depth in zero (ZT), minimum (MT) and conventional (CT) tillage

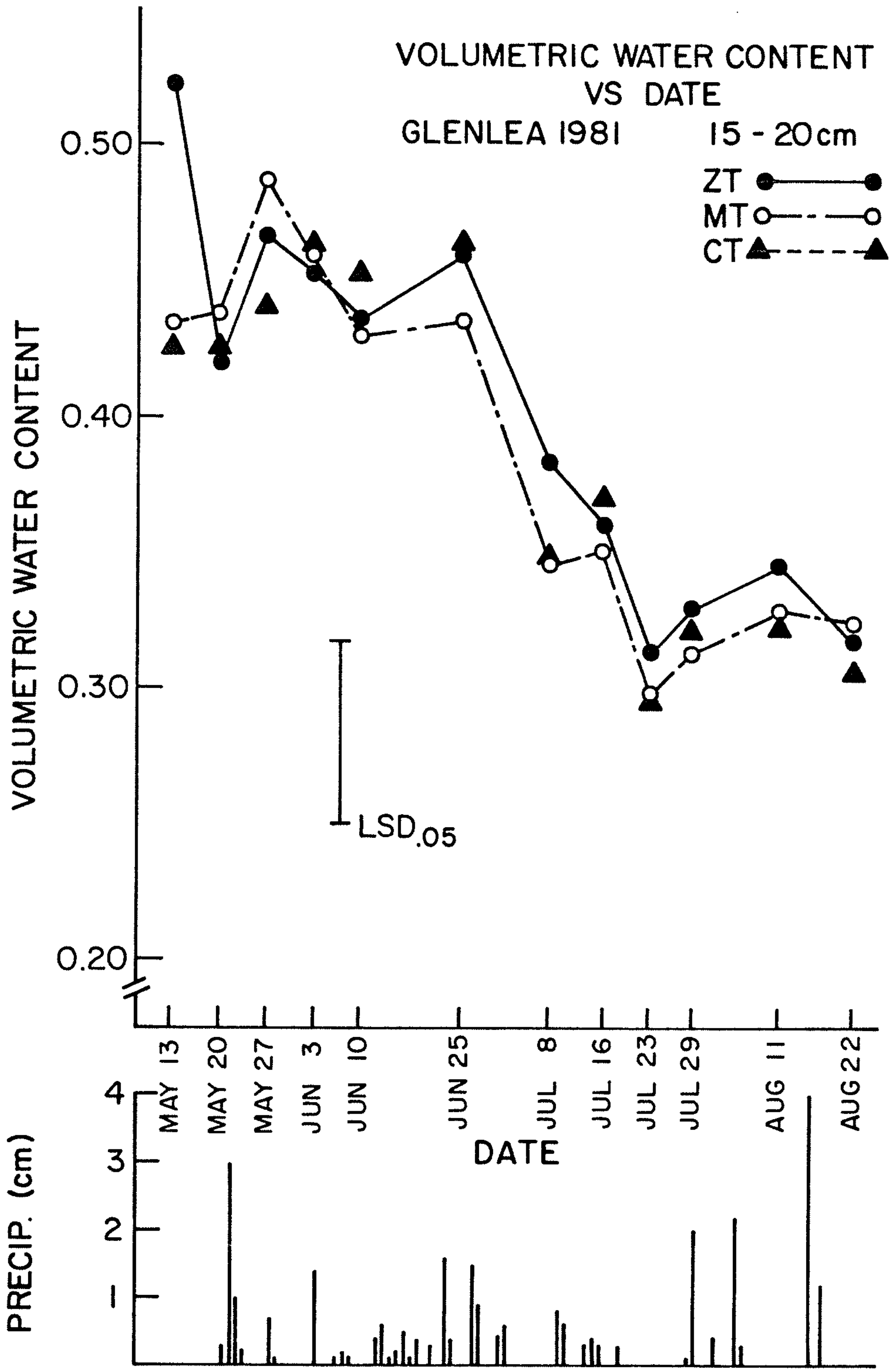

Figure 16 1981 Volumetric water content vs. date in the 15-20 cm soil depth in zero (ZT), minimum (MT) and conventional (CT) tillage

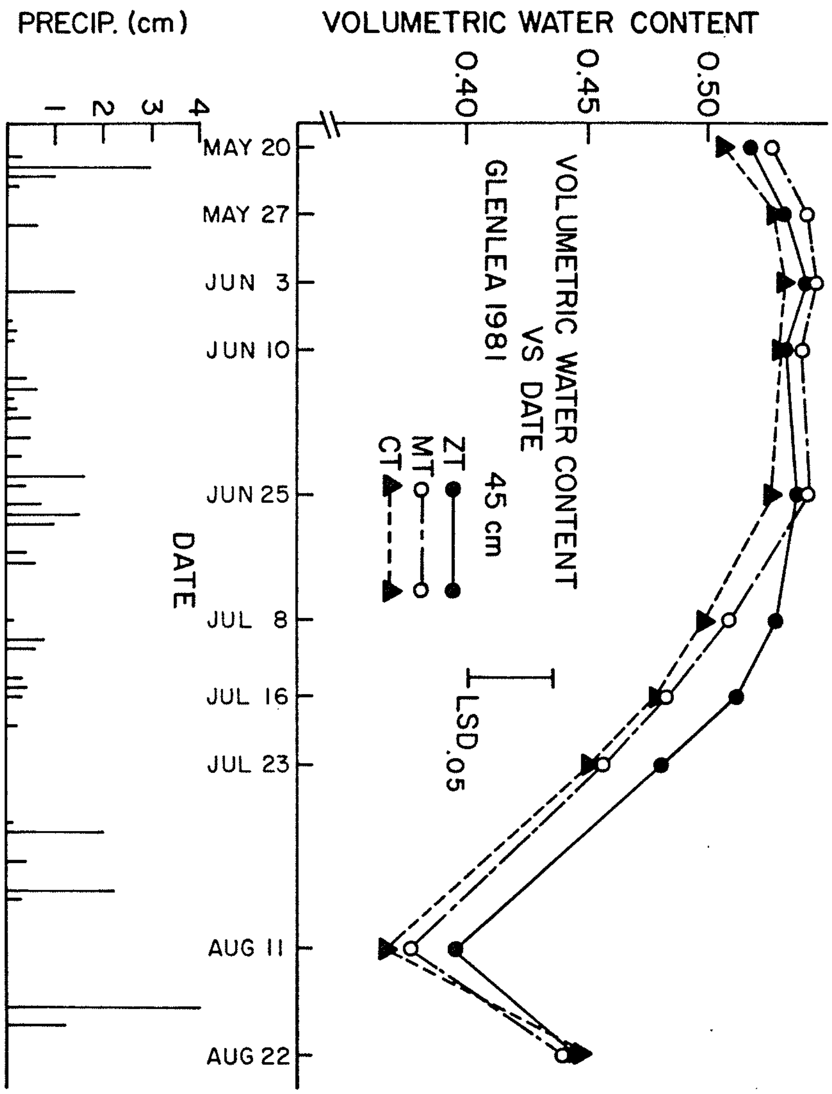

Figure 17 1981 Volumetric water content vs. date in the 45 cm soil depth in zero (ZT), minimum (MT) and conventional (CT) tillage

similar to 1980 with the exception that water loss occurred over a longer period of time. Water contents at the 45 cm depth were observed to decline on June 25 and continued to decrease until August 11, with water loss occurring more rapidly on the tilled soils between June 25 and July 16 (Figure 17). Between July 16 and August 11 water content decreased at similar rates for all the treatments. Water content at the 75 cm depth changed very little over the first month and a half of the growing season with both tilled and zero tilled soils having similar water contents, although the conventional tillage treatment had a slightly lower water content (Figure 18). Water loss was observed to occur on July 8 from all treatments and by August 11 there was significantly less water in the conventional tillage treatment than in the zero tillage or minimum tillage treatment.

Water content of all the soils increased during the month of August due to a few effective rains. Soil water recharge occurred early in August in the surface 20 cm (Figures 13-16) but did not occur until August 11 at the 45 and 75 cm depths (Figures 17 and 18).

Soil management systems had very little effect on soil water content below the 90 cm depth (Figure 19).

Although differences in water content were not significant on every date sampled, a general trend appeared for soil water contents in both 1980 and 1981. For the first two months of the growing season in 1980 soil water in the 10 cm soil layer was highest under zero tillage (Figures 6 and 7) while in 1981 zero tilled soil moisture in the surface 10 cm was higher in the untilled soils than in the tilled treatments

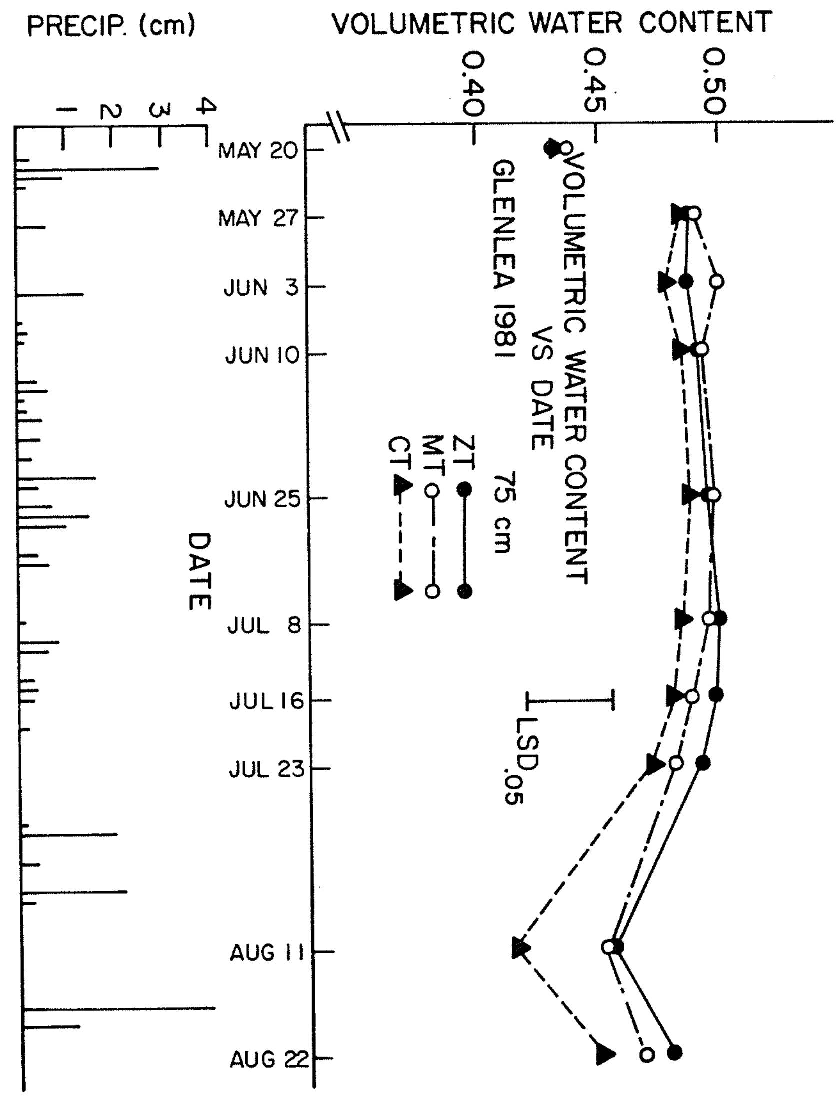

Figure 18 1981 Volumetric water content vs. date in the 75 cm soil depth in zero (ZT), minimum (MT) and conventional (CT) tillage

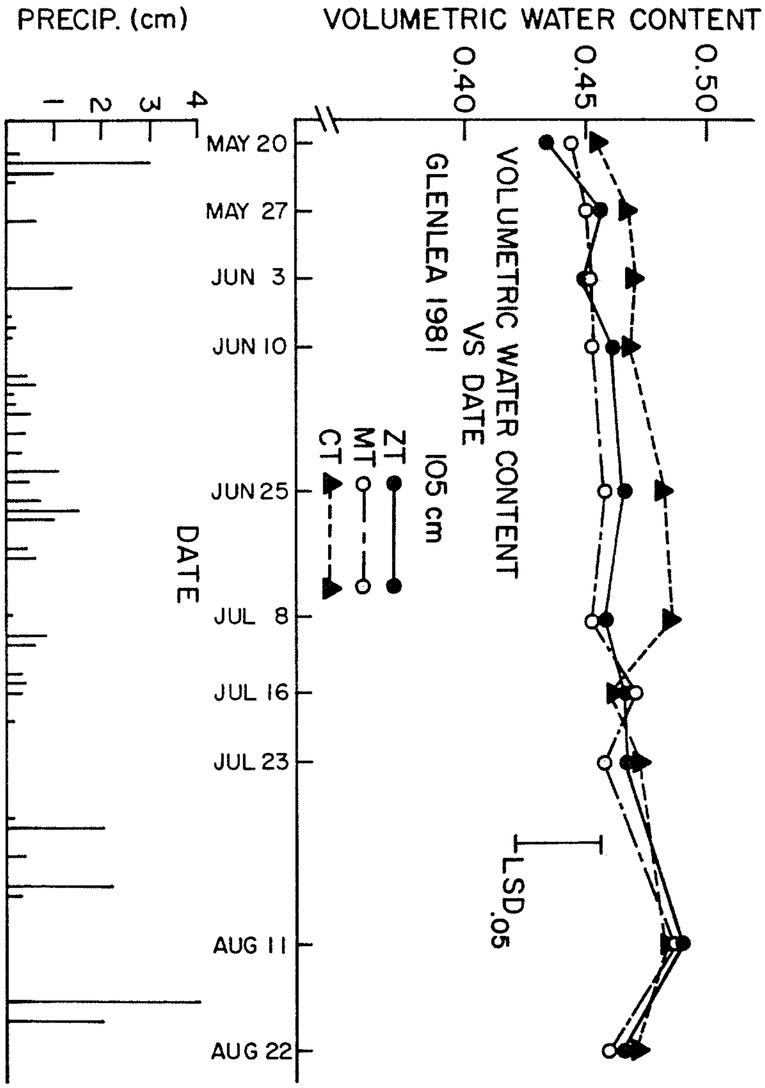

Figure 19 1981 Volumetric water content vs. date in the 105 cm soil depth in zero (ZT), minimum (MT) and conventional (CT) tillage

throughout the entire growing season (Figures 13 and 14). The difference in tilled and untilled soil water contents might be anticipated because of the evaportranspiration factor. These results are in agreement with Shannholtz and Lillard (1969) and Hill and Blevins (1973). During the period from seedbed preparation to when the crop canopy covers the soil, evaporation dominates the evapotranspiration process (Peters, 1960; Peters and Russell, 1959). As the crop canopy develops to shade the soil surface evaporation losses decrease, while transpiration becomes the major source of water loss. The water losses over the season average about 50 percent for both evaporation and transpiration (Peters, 1960). In this study, the residue mulch from the chemically killed sod insulated the upper soil profile to reduce evaporation losses during the early stages of growth. With frequently recurring rains, the sod residue gave the zero tillage plots an advantage in soil moisture availability which was maintained throughout the growing season (Figures 13 and 14).

Early in the growing season water losses occurred in all the treatments in both years (Figures 6, 7, 13 and 14). In periods of limited rainfall the zero tillage treatments maintained a higher water content than the conventional tillage treatment for a longer time, but eventually water contents in all treatments became nearly equal. This result suggests that the sod residue can prolong constant rate evaporation for a short period of time. It has been shown that increasing surface residue rate decreased the evaporation rate, and a decrease in the constant rate evaporation resulted in a time lag in the cumulative evaporation (Bond and Willis, 1970). However, where surface soils began to dry, without the benefit of recurring rains, cumulative evaporation from surface soils with cereal residues eventually equalled that from bare soils (Hanks et al. 1961, Russell, 1939).

Water contents declined in the 90 cm soil depth throughout the month of July in both 1980 and 1981. The crop canopy would cover the soil surface at this time and transpiration would be the major source of water loss. Between the 30-90 cm soil layer water losses were higher on the conventional tillage soils than on the zero or minimum till soils in both years (Figures 10, 11, 17 and 18). The greater water loss on the convential tillage soil suggests rooting density is greater than on the other treatments resulting in higher water extraction from these depths. These results are in agreement with Aase and Siddoway (1980) who showed that wheat on bare plots extracted water to a deeper depth (105 cm) than on stubble plots. In contrast, Goss et al. (1978) found 60 percent more water was withdrawn from the 50-100 cm soil depth on zero tillage winter wheat plots than on ploughed plots, from the end of tillering to flowering. On some soil types, zero tillage has been associated with shallower rooting (Cannell and Finney, 1973; Ellis et al. 1977) while others have found no evidence of root restriction under zero tillage (Donaghy, 1973; Drew and Saker, 1980).

Seasonal means for water content are given in Figure 20 and 21. Results of the seasonal water content for 1980 (Figure 20) shows that water content was generally higher on the zero tillage treatment compared to the conventional tillage treatment to the 90 cm depth. Minimum tillage water content was intermediate to the 60 cm depth, after which the

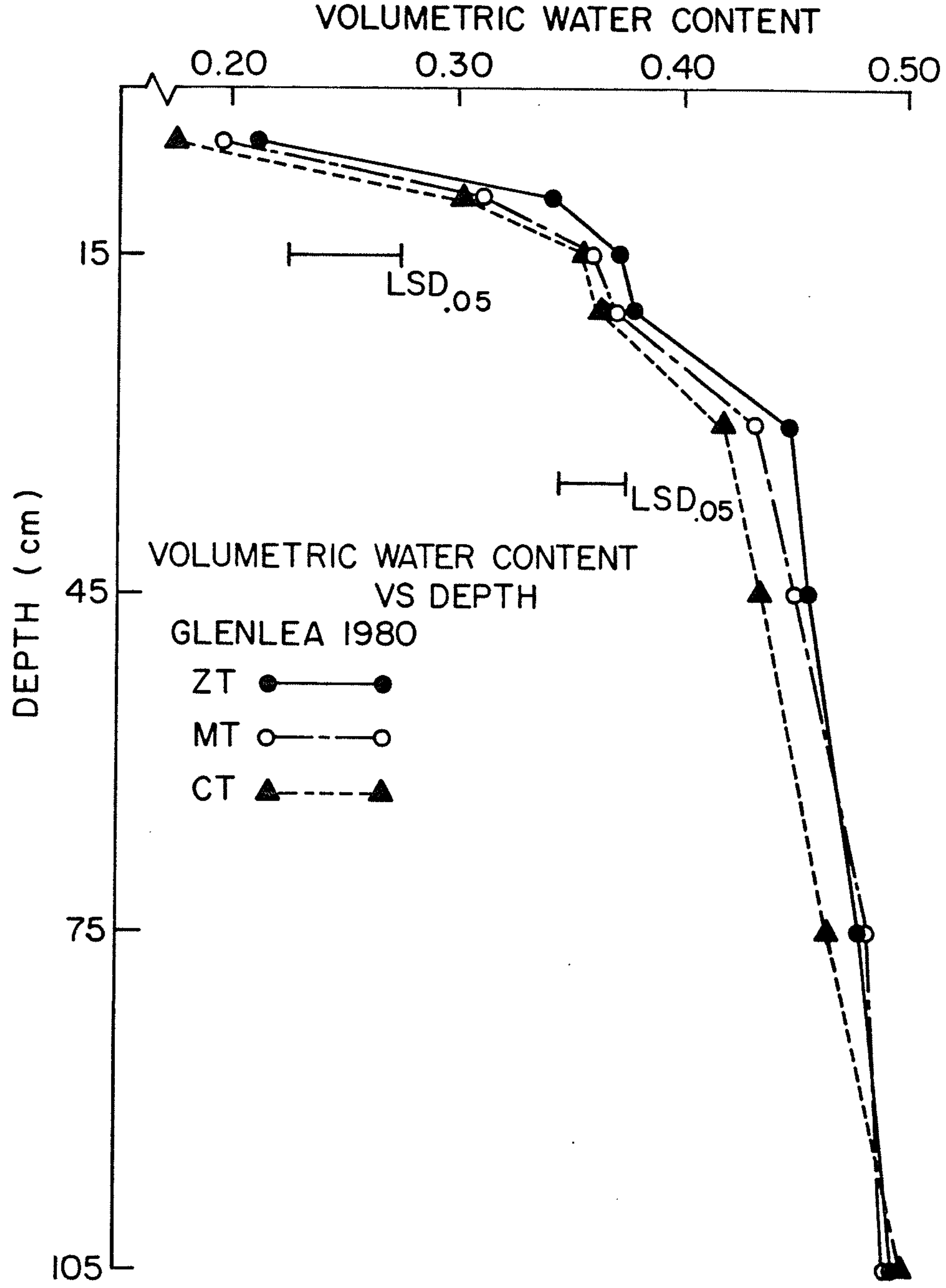

Figure 20 1980 Seasonal mean for volumetric water content vs. soil depth in zero (ZT), minimum (MT) and conventional (CT) tillage

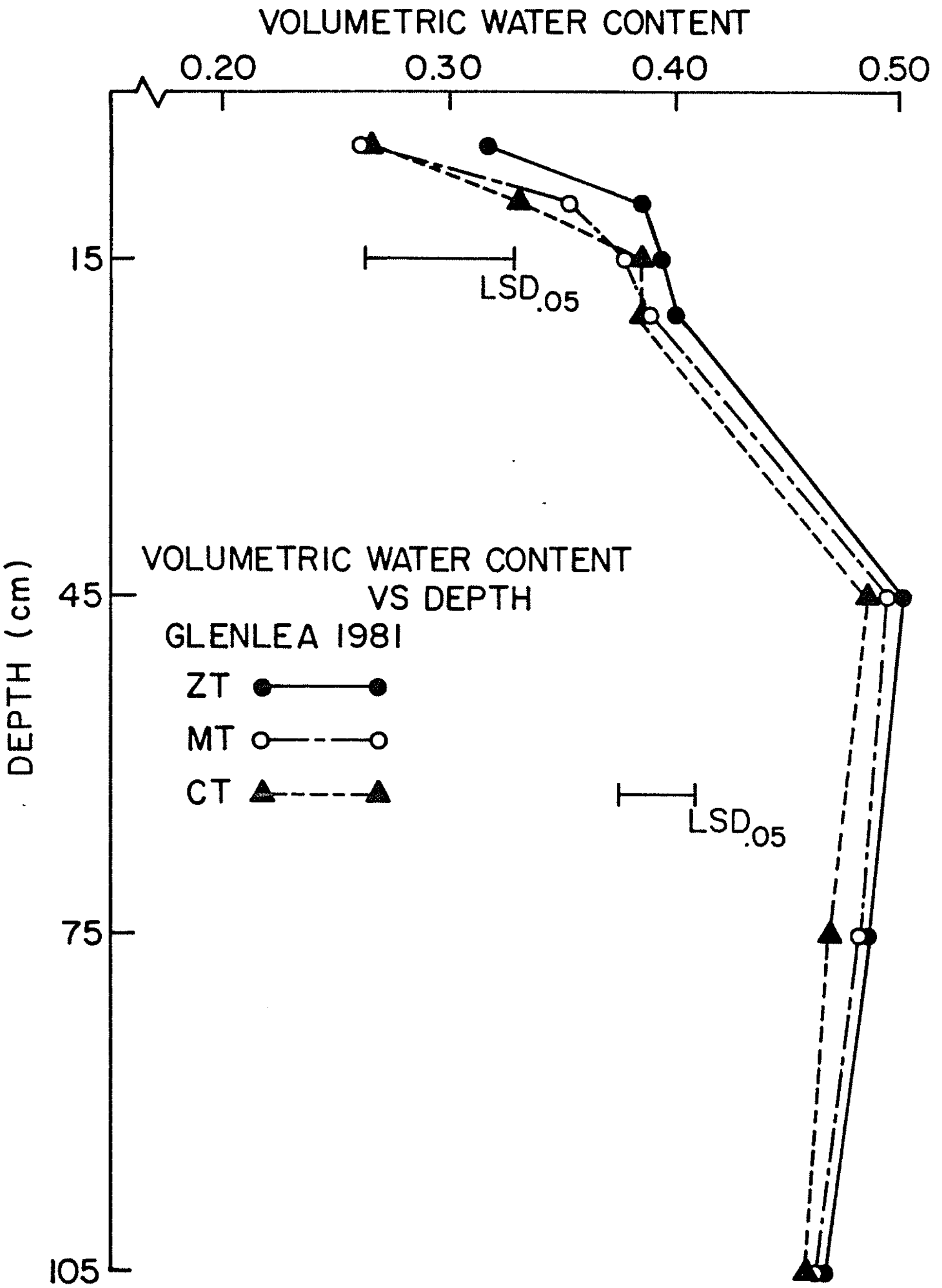

Figure 21 1981 Seasonal mean for volumetric water content vs. soil depth in zero (ZT), minimum (MT) and conventional (CT) tillage water content became essentially equal to the zero tillage water content. Similar trends in water content in each of the treatments was observed in the 1981 season (Figure 21). Seasonal means mask the minimum and maximum water contents that occur throughout the growing season, particularly in the surface soil at crop emergence. Generally, zero tillage soils have a higher water content in the surface soil at seeding that provides an improved moisture condition for germinating small grains and oilseeds. Rourke (1981) showed that increased moisture under zero tillage promoted a more rapid and even germination of rapeseed on clay soils.

Water use efficiency of wheat grown under the three management systems was determined by dividing the grain yield by the water used by the crop Water use was determined from the soil water loss from seeding to harvest plus the seasonal precipitation. Water use efficiency of spring wheat, grown on zero, minimum and conventional tillage was greatest on the conventional tilled soil in 1980 and greater on the minimum tillage in 1981 (Table 6). The differences in water use efficiency were due to the fact that the grain yields were significantly higher on the conventional tillage and minimum tillage treatments in 1980 and 1981, respectively, than on the zero tillage treatment.

In 1980 water use efficiency was 86.8, 67.2 and 54.7 kg/ha/cm H_2O for conventional, minimum and zero tillage, respectively. Grain yields were 2705, 1998 and 1501 kg/ha for the conventional minimum and zero tillage systems, respectively, which followed in the same order as water use efficiency. In 1981, grain yields expressed as kg/ha followed by water use efficiency in brackets expressed as kg/ha/cm H_2O were 1906 (68.96),

Table 6

Water Use and Efficiency of Spring Wheat as Affected
By Three Tillage Systems at Glenlea

Crop Year	Tillage	Total Water To 120 cm Depth		Water Used(1)			Grain Yield	WUE(2)
		Seeding	Harvest	Soil Loss	Precip.	Total		
		(cm)			(cm)		(Kg/Ha)	(Kg/Ha/cm)
1980	Zero	57.50	53.51	3.99	23.46	27.45	1501	54.7
	Minimum	57.86	51.57	6.29	23.46	29.75	1988	67.2
	Conventional	57.16	49.45	7.71	23.46	31.17	2705	86.8
	LSD					1.75	553	19.1
1981	Zero	51.56	53.36	(1.80)	28.18	26.38	1473	55.8
	Minimum	51.55	52.09	(0.54)	28.18	27.64	1906	68.9
	Conventional	50.67	52.66	(1.99)	28.18	26.19	1380	52.7
	LSD					NS	202	9.7

(1) Soil water loss from seeding to harvest plus precipitation.

(2) Water use efficiency.

1473 (55.84) and 1380 (52.69) for the minimum, zero and conventional tillage systems, respectively. Soil water storage was usually higher in the surface 30 cm under the zero tillage treatment compared to the tilled treatments, but because of lower seedling populations which resulted from inadequate seed placement, grain yields were significantly lower than the highest yielding treatment in the following years. Yields on the conventional tilled treatment in 1981 were not significantly different than the yields of the untilled treatment because the tillage failed to adequately control the bromegrass from the previous forage crop, subsequently water use efficiency was also decreased. Seeding equipment which will penetrate the residue-covered soil and ensure adequate seed-soil contact is needed to take advantage of the higher soil water content in the surface soil at seeding on zero tillage soils compared to conventional tillage soils, thus obtaining improved seedling establishment, increased grain yields and improved water use efficiency under zero tillage These results are in agreement with Bauer (1980) who showed that water use efficiencies were lowest under zero tillage systems compared to other systems, resulting in poor seedling establishment and subsequently the lower grain yields. Shannholtz and Lillard (1969) found that zero tillage systems conserved water more efficiently and enhanced water use efficiency in corn production. They found zero tillage corn yielded higher than yields from conventional tillage systems.

Water use from all the treatments were significantly different in 1980 but were not significantly different in 1981. Water use was determined from the soil water loss plus the seasonal precipitation. The

1980 water use was 31.17, 29.75 and 27.45 cm for the conventional, minimum and zero tillage treatments, respectively. Soil water loss was greatest from the conventional till soil and least for the zero till soil. In 1981, the increased seasonal precipitation resulted in soil water gains from seeding to harvest of 1.99, 1.80 and 0.54 cm for conventional, zero, and minimum tillage, respectively. An inverse relationship between soil water loss and growing season precipitation was apparent, hence the 1981 wheat crop was less dependent on stored soil water than the wheat crop in 1980 (Table 6). These results are in agreement with Bauer (1980) who found that as seasonal precipitation increased, the water removed from soil decreased. In years where water use by the crop is mostly from precipitation, soil water benefits under zero tillage may be less important than the other benefits accredited to zero tillage, such as an improved soil structure (Blevins et al. 1977) and reduction in soil erosion (Mathews, 1972).

4.3 EFFECTS OF TILLAGE ON INFILTRATION

The use of a double ring infiltrometer was useful in determining comparative values for infiltration rates at the time of crop emergence among the tilled and untilled treatments. For all the treatments in 1980, vertical water entry into the soil decreased with time until a steady state infiltration rate was attained, usually within 30 minutes (Figure 22a). Differences in accumulated infiltration between the tilled and untilled soils occurred during the initial stages of infiltration, however, significant differences did not occur until at least two hours after the time infiltration was started (Figure 22b). After a

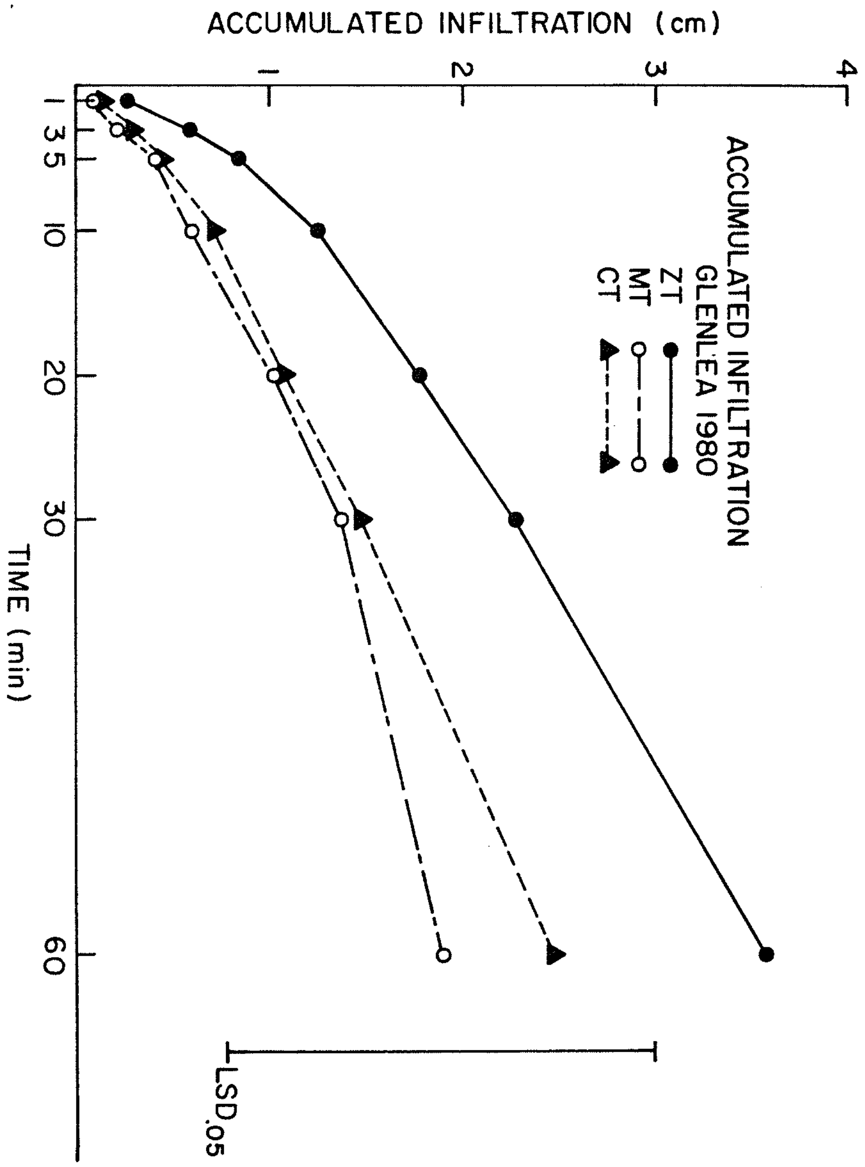

Figure 22a 1980 Accumulative infiltration (i) as a function of time (t) for zero (ZT), minimum (MT) and conventional (CT) tillage

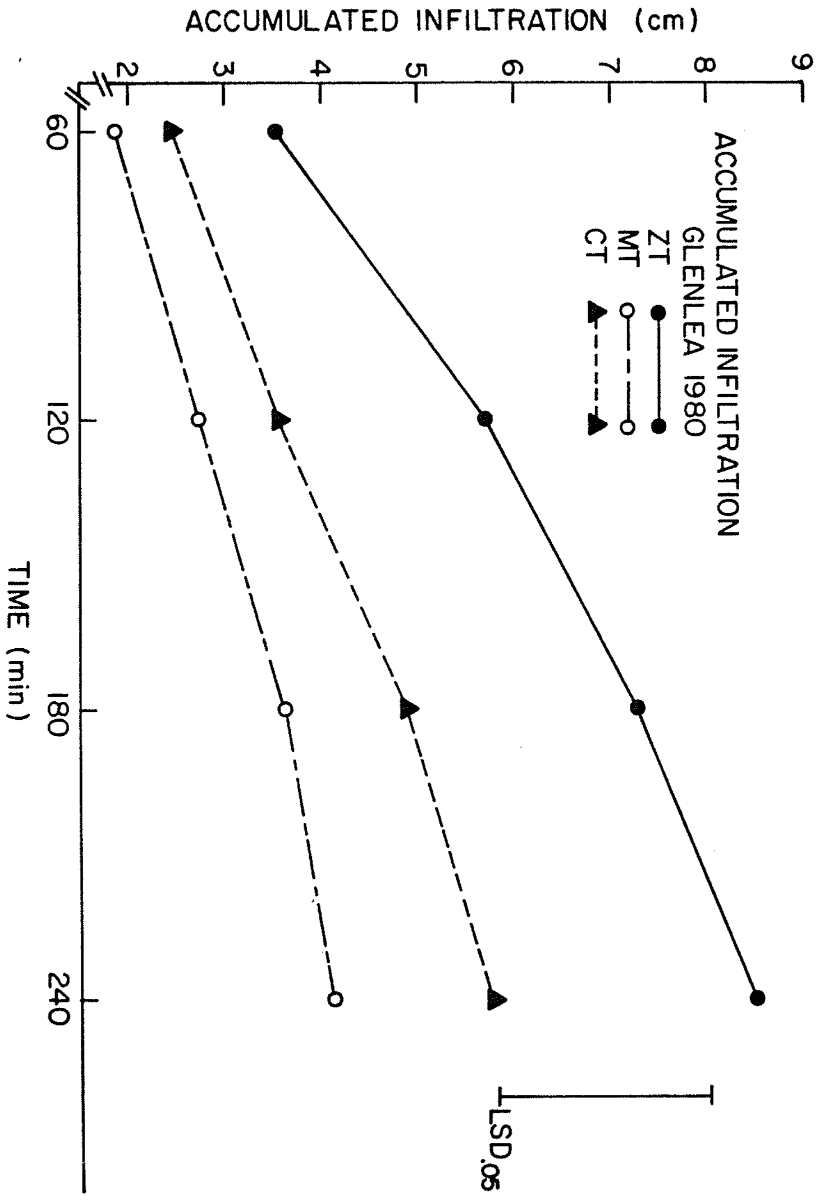

Figure 22b 1980 Accumulative infiltration (i) as a function of time (t) for zero (ZT), minimum (MT) and conventional (CT) tillage period of four hours, accumulated infiltration was 33 percent greater on the zero tillage plots than on the conventional tillage plot and 53 percent greater than the minimum tillage plot (Figure 22b). Soil in the zero tilled plots had a higher infiltration capacity than the tilled soils, (Figure 22b) probably due to the continuous channels to the soil surface which were left from decaying alfalfa roots. This result is in agreement with Triplett _et_ _al_. (1968) who showed that infiltration rates were significantly higher under zero tillage with 80 percent residue cover than with ploughed bare soil. Higher infiltration in zero tillage soils has been attributed to greater pore continuity that resulted from earthworm channels and decayed roots (Ehlers, 1975; Goss _et al_., 1978).

In 1981, the overall pattern of water entry into soil was similar to 1980 in that water entry decreased with time until steady state infiltration occurred at approximately 30 minutes (Figure 23a). Differences in accumulated infiltration between the tilled and zero tilled soil became significantly different after 60 minutes of ponded infiltration. In contrast to the 1980 results, conventional tillage treatments had an accumulated infiltration rate that was 32 and 40 percent higher than the zero or minimum tillage treatments, respectively, in 1981 (Figure 23b).

The different infiltration results could be due to the fact that the soil was a poorly drained Osborne clay and the previous forage consisted mainly of bromegrass with very little alfalfa present. The 1980 experimental site had approximately 30 percent alfalfa on the previous forage crop and the soil was moderately drained. As a result, continuous channels left from decaying alfalfa taproots were non existent in the 1981

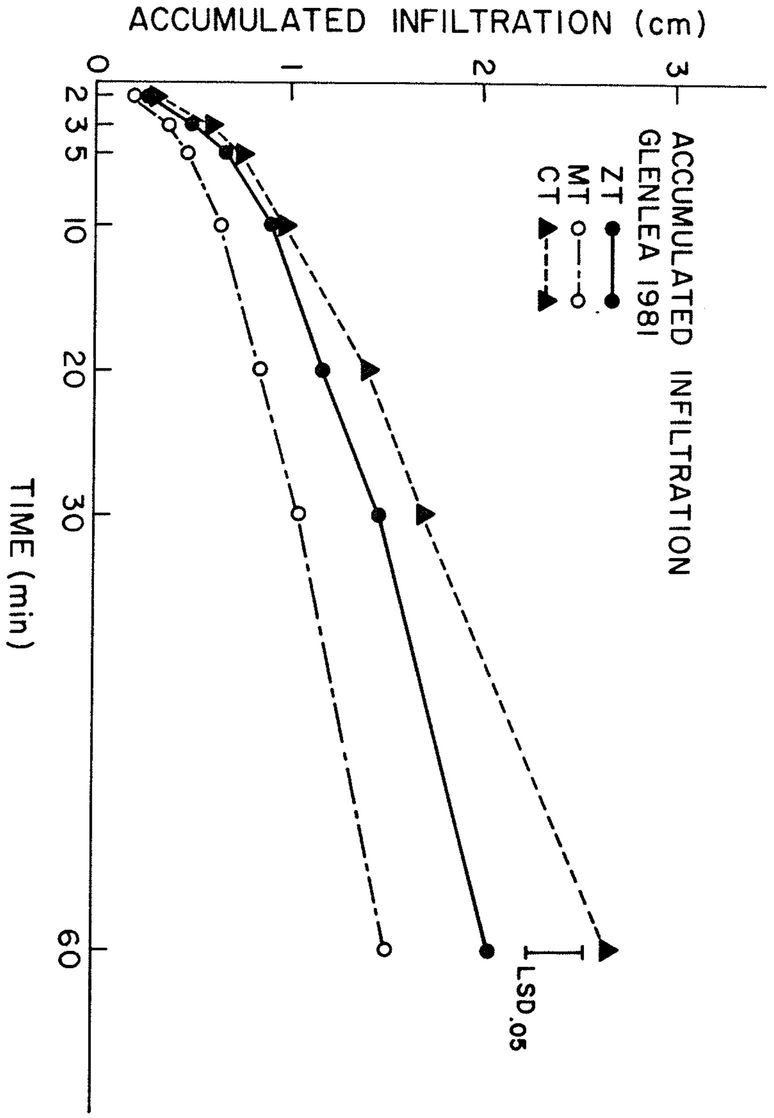

Figure 23a 1981 Accumulative infiltration (i) as a function of time (t) for zero (ZT), minimum (MT) and conventional (CT) tillage

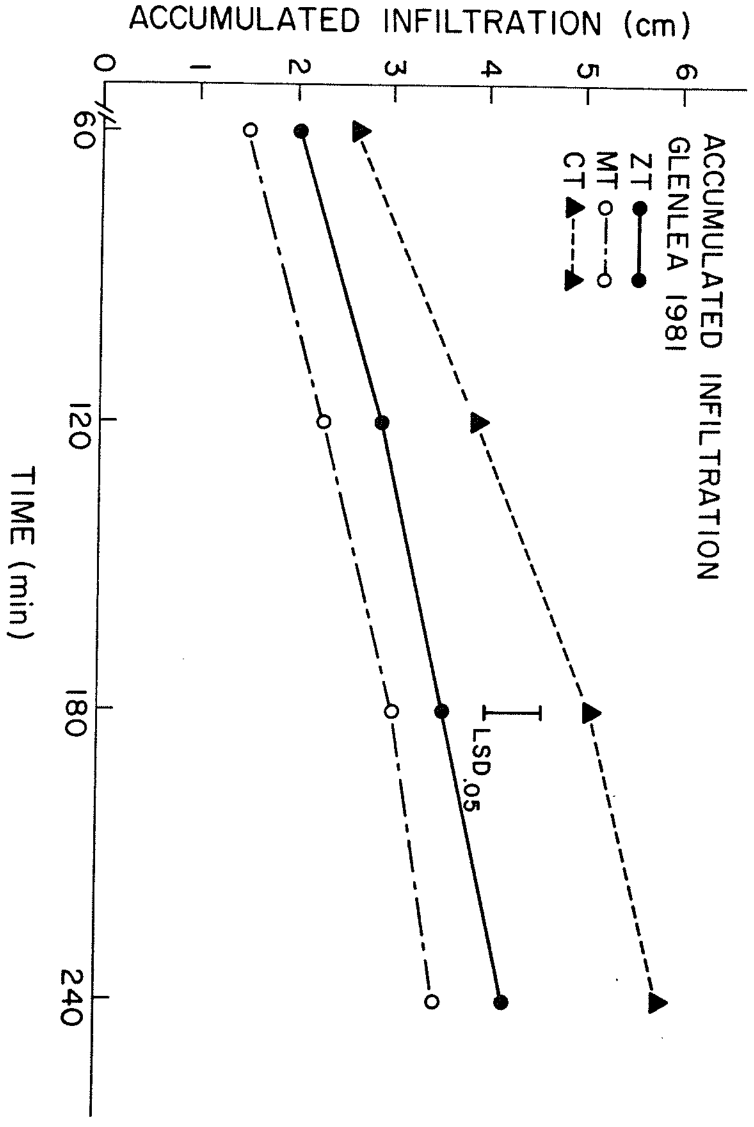

Figure 23b 1981 Accumulative infiltration (i) as a function of time (t) for zero (ZT), minimum (MT) and conventional (CT) tillage experimental site, with the expected result being that the infiltration potential would be less. The vertical channels usually left unaltered after alfalfa on an untilled soil condition were absent on the zero tillage plot, thus water had to travel through a more tortuous channel system left by the fibrous root system of bromegrass. Tillage treatments reduced bulk density, which in effect could increase soil porosity, allowing the flow of water into the soil to be greatly enhanced, as suggested by Poiseuille's law which implies that a small increase in the radius of a capillary results in a considerable increase in flow rate (Hillel, 1971).

Steichen et al. (1979) showed that soil on zero till plots had a significantly lower infiltration rate than on conventional till soils primarily due to increased bulk density and decreased pore volume. High random soil roughness and high soil porosity caused increased infiltration of water on the conventional till soil. Lindstrom et al. (1981) concluded that untilled soils effectively absorbed kinetic energy from rainfall but that the consolidated soil surface that may have existed prior to zero tillage establishment had persisted, resulting in a detrimental effect on water runoff and infiltration. These factors seems to be responsible for the lower infiltration rate under zero till soils than conventional till soils in 1981.

It seems that antecedent soil moisture did not influence the infiltration rate between the treatments since soil water contents at the time of initiation of ponded infiltration were not significantly different (Table 7).

Table 7

Antecedent Soil Moisture at the Time of Ponded Infiltration

		% Soil Moisture			
Year	Depth	Zero Tillage	Minimum Tillage	Conventional Tillage	
	(cm)		cc/cc		LSD
1980	0-5	.16	.16	.13	.05
	5-10	.38	.36	.33	.05
1981	0-5	.40	.33	.36	.08
	5-10	.45	.44	.45	.08

Soil in the minimum tillage treatments had the lowest accumulated infiltration of water compared to conventional and zero tillage soils in both years (Figure 22 and 23). Possible causes for reduced infiltration on the minimum tillage soils could be lower porosity, reduced random roughness, reduced pore size, or susceptibility to surface sealing. It seems that where forage is broken for crop production too little cultivation may be detrimental to potential entry of water into soil.

4.4 EFFECTS OF TILLAGE ON SOIL COMPACTION

4.4.1 Bulk Density.

Two indexes of soil compaction used to compare the tilled and zero tilled soils were soil bulk density in the surface 20 cm and soil strength expressed as penetrometer resistance. Soil bulk density was measured throughout the growing season in both 1980 and 1981 and penetrometer resistance was measured in 1981.

In 1980, the bulk density of the soil in the surface 5 cm was similar for all the treatments (Figure 24). Differences in bulk density were small, inconsistent and not significant. The bulk density of the soil under zero tillage was greater at the 5-10 cm depth than the tilled treatments, although significant differences did not occur on every date sampled (Figure 25). Differences in bulk density below the 10 cm depth were not apparent (data not shown), however, there was less variation in bulk density over the season under zero tillage than there was on the tillage treatments.

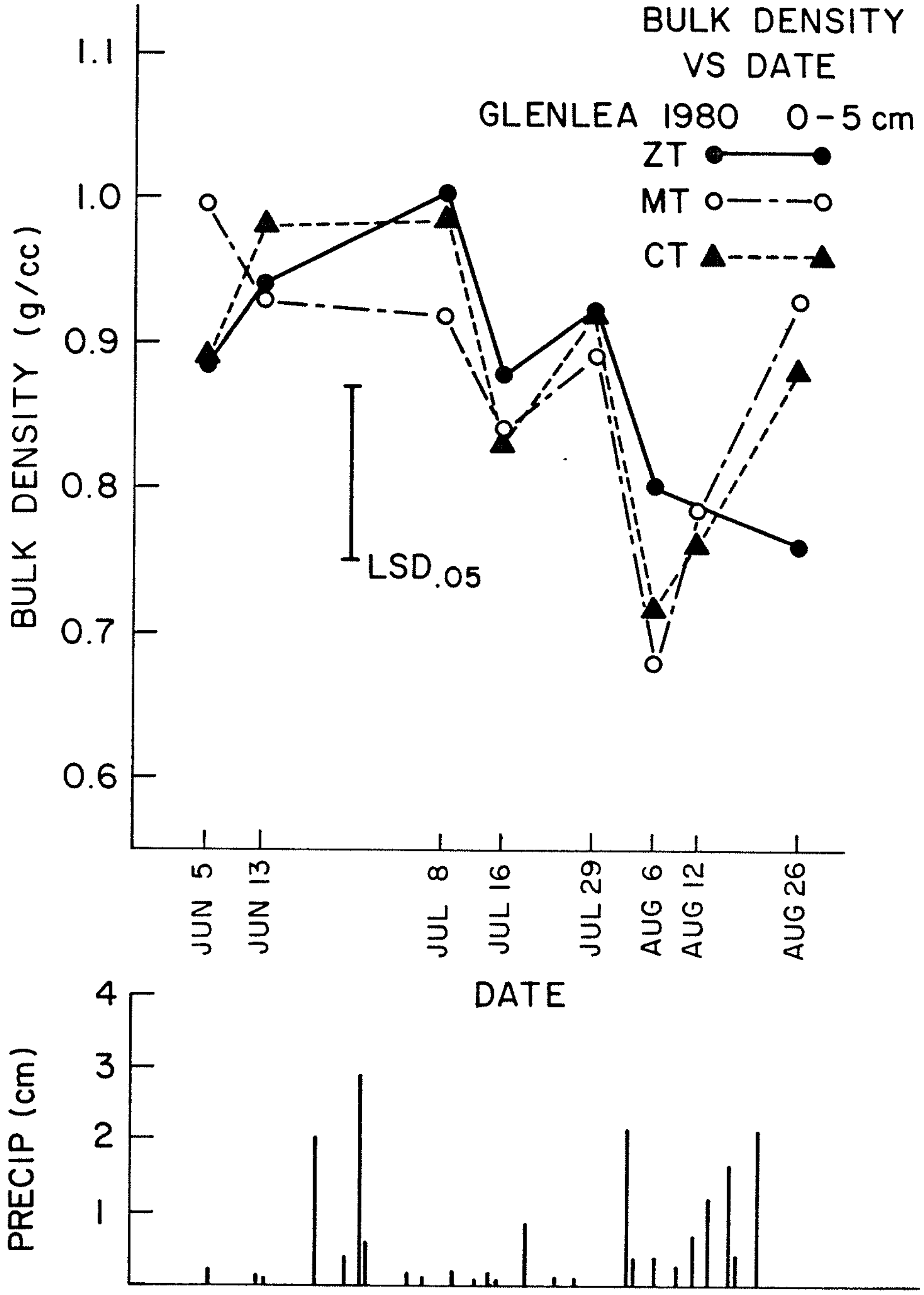

Figure 24 1980 Soil bulk density vs. date in the 0-5 cm depth in zero (ZT), minimum (MT) and conventional (CT) tillage

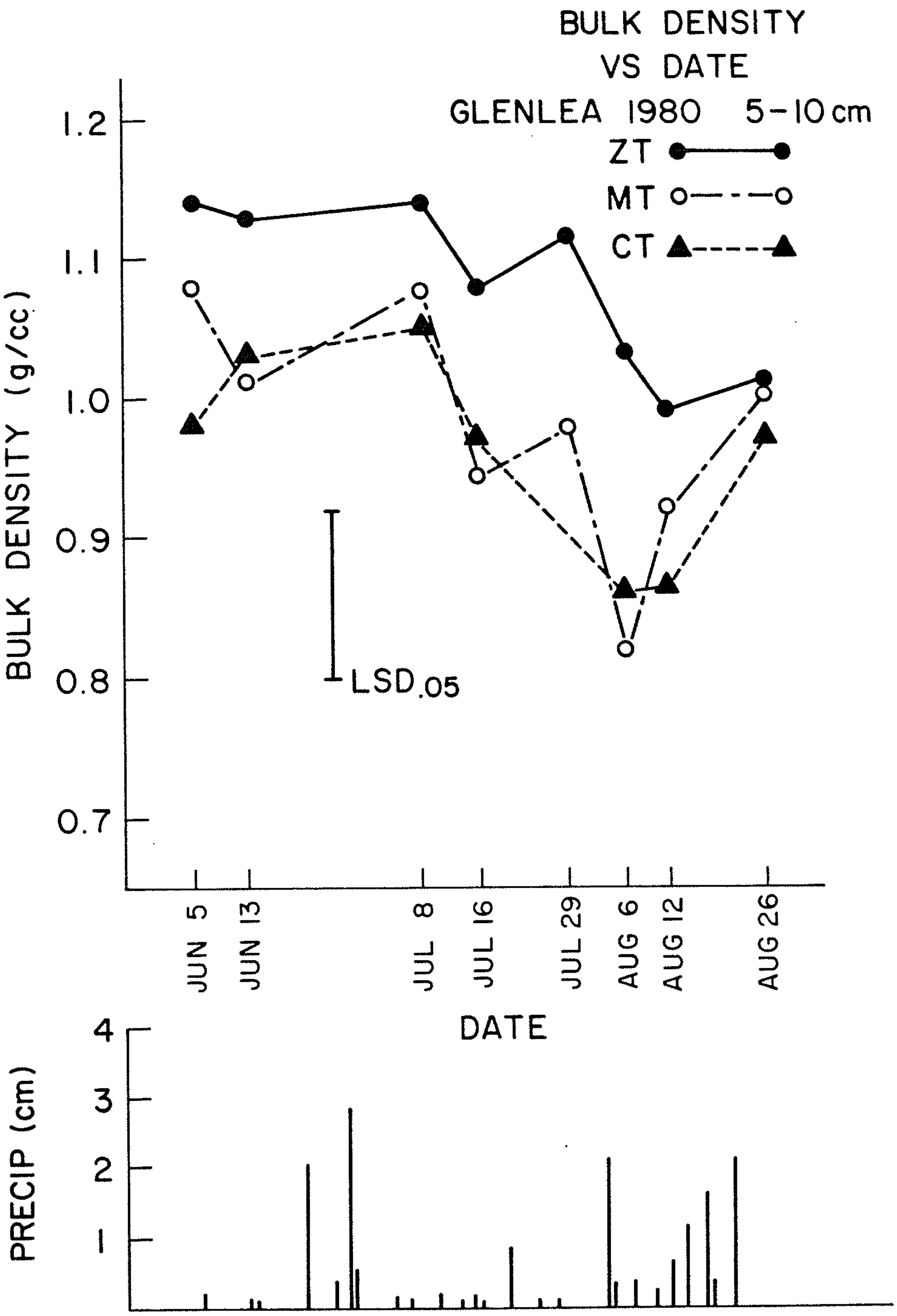

Figure 25 1980 Soil bulk density vs. date in the 5-10 cm depth in zero (ZT), minimum (MT) and conventional (CT) tillage

In 1981, bulk density of the soil was greater under zero tillage in the 0-5 cm depth than the tillage treatments throughout the growing season, although significant differences did not occur on every tampling date (Figure 26). In the 5-10 cm depth soil bulk density was higher on the zero tillage treatment throughout the growing season season, significant differences between the treatments occurring on most sampling dates (Figure 27). Beyond the 10 cm depth bulk densities were similar for all the treatments, with the exception of a few dates where tilled soils had a higher bulk density than the zero tilled soils (data not shown).

For the 1980 growing season, bulk density of the zero till soil was greater in the 5-10 cm depth than the soil in the other treatments (Figure 28). For all treatments bulk densities increased as the soil depth increased. In 1981, bulk density of the soil was higher under the zero tilled treatment than under the two tilled treatments at all depths, and differences were greater in the surface 10 cm (Figure 29). As the soil depth increased bulk densities became greater.

The higher soil bulk density found under zero tillage compared to tilled treatments in the surface 10 cm are in agreement with the results of Pidgeon and Soane (1977) and Ellis et al. (1979) who found that bulk density in the surface 15 cm was greater on zero till soils compared to ploughed soils. Gauer (1981) also showed soil bulk density to be greater on zero tillage soils. Blevins et al. (1977), reported on trials on bluegrass sod in Kentucky and showed that bulk density in the 0-8 cm depth was not significantly different for zero tillage and ploughed soils. In the present investigation, bulk density in the surface 20 cm

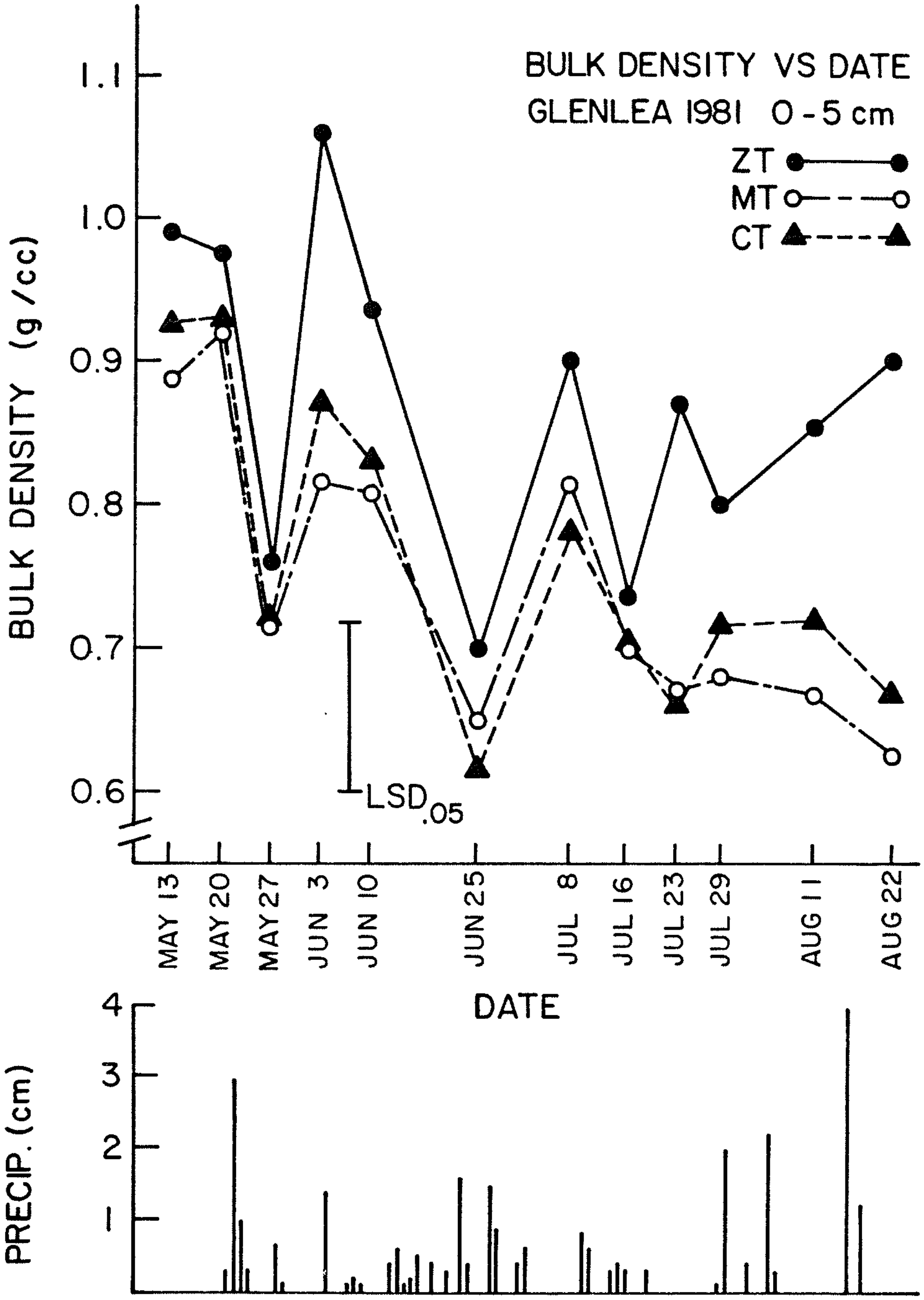

Figure 26 1981 Soil bulk density vs. date in the 0-5 cm depth in zero (ZT), minimum (MT) and conventional (CT) tillage

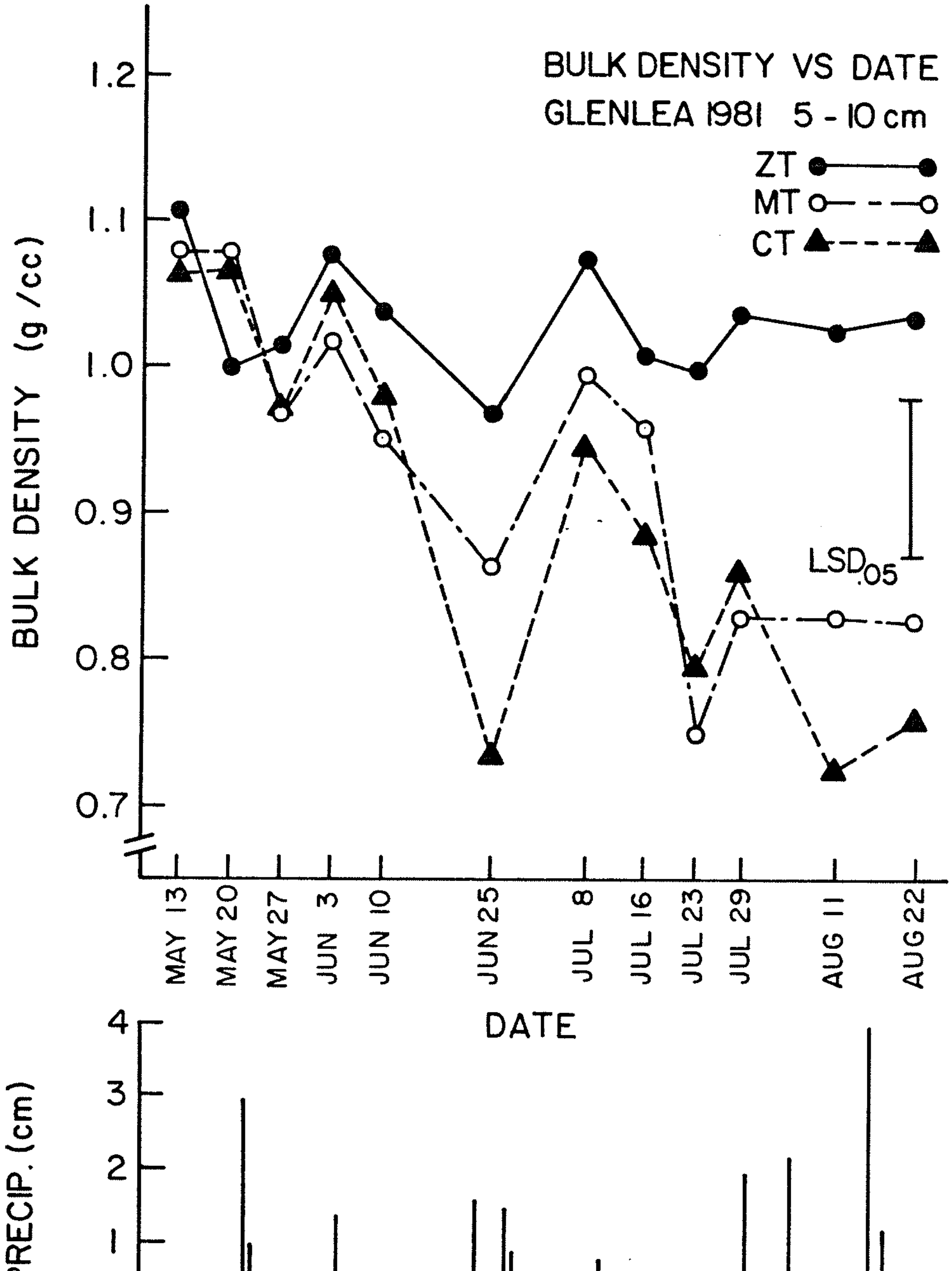

Figure 27 1981 Soil bulk density vs. date in the 5-10 cm depth in zero (ZT), minimum (MT) and conventional (CT) tillage

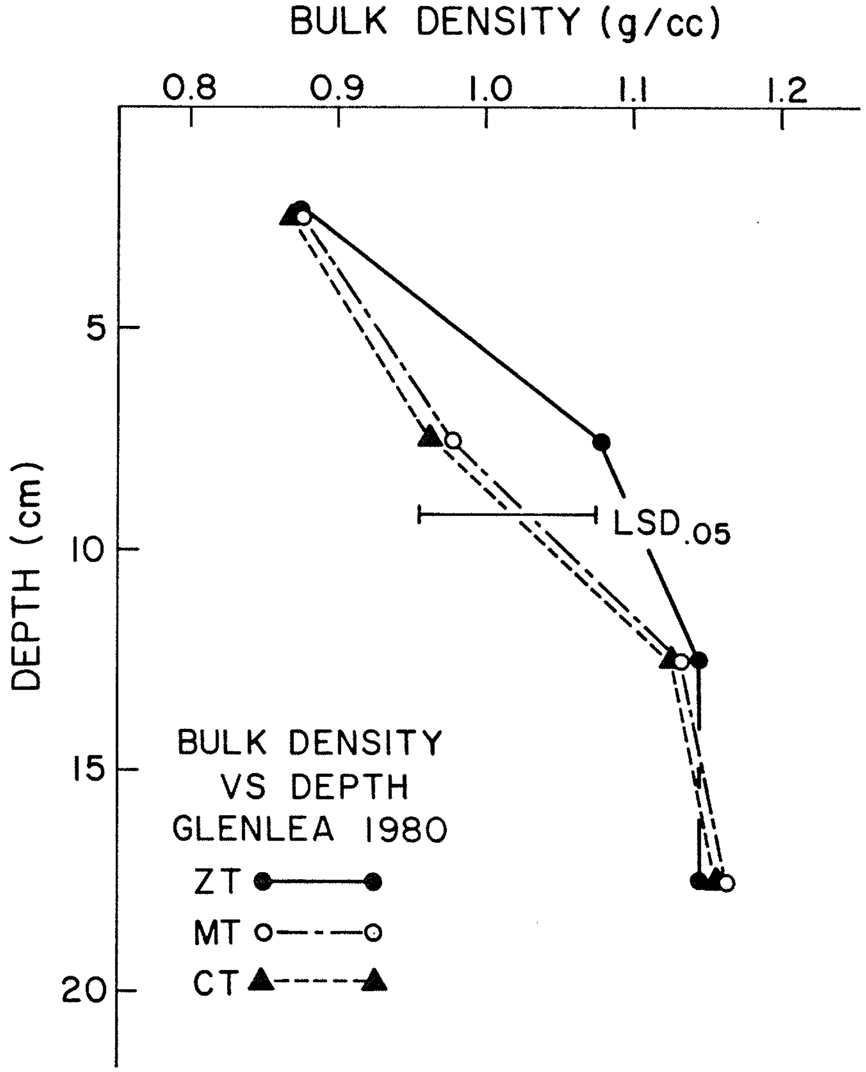

Figure 28 1980 Seasonal mean for soil bulk density vs. soil depth for zero (ZT), minimum (MT) and conventional (CT) tillage

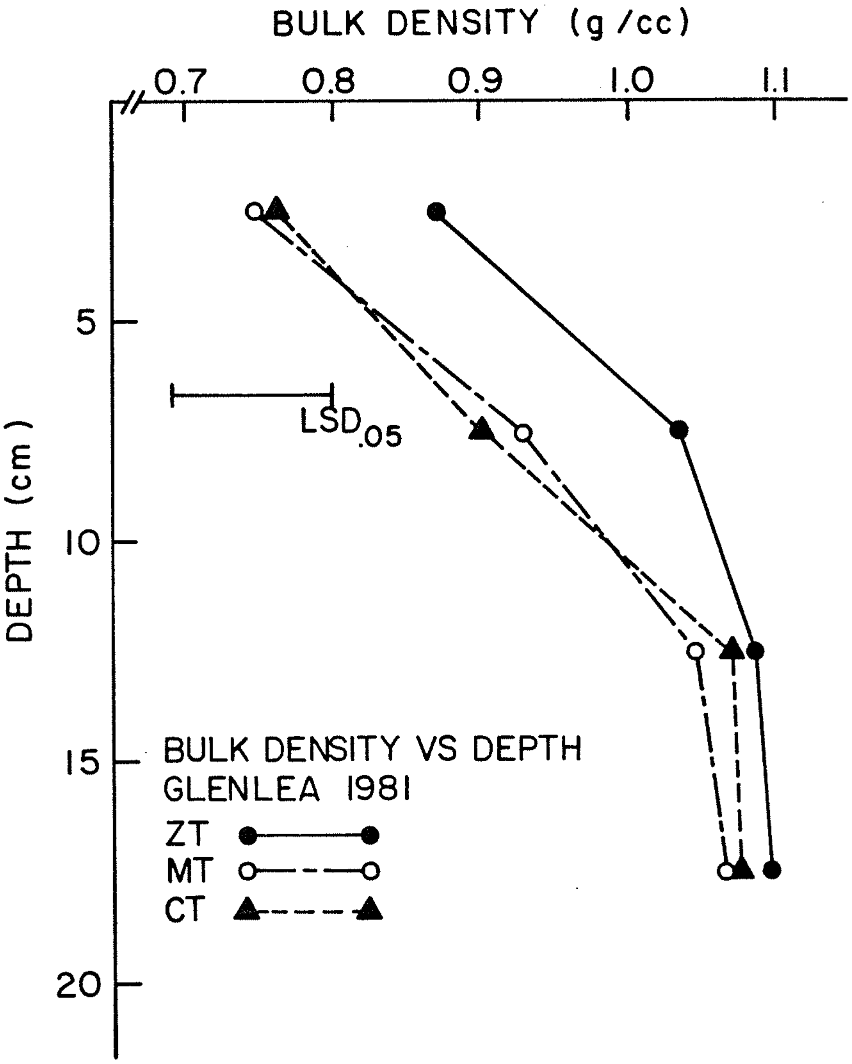

Figure 29 1981 Seasonal mean for soil bulk density vs. soil depth for zero (ZT), minimum (MT) and conventional (CT) tillage rarely produced values above 1.2 g/cc in any of the treatments, so although the zero tillage soils had a higher bulk density the effect on crop growth should not be critical. Critical values of bulk density have been of limited value in determining the effects of compaction on plant growth (Soane and Pidgeon, 1975) partly due to the fact that single values are generally used rather than values for the whole soil profile. For zero till soils showing much shrink/swell behavior and pore continuity, critical values have been considered relatively unimportant (Ellis *et al*. 1979).

4.4.2 Penetrometer Resistance.

A comparison of penetrometer resistance values in the surface 5 cm at seeding show significantly higher soil resistance to penetrometers under zero tillage soils than either minimum or conventional tillage in 1981 (Figure 30). Since the soil water content and bulk density did not differ among the treatments, a meaningful increase in penetrometer resistance existed under zero tillage.

Below the 20 cm depth, penetrometer resistance was similar for all the treatments, although the zero tillage treatment appeared to be lower below the 30 cm depth.

After a substantial rainfall occurred, the penetrometer resistance in the soil on June 10 decreased under all treatments in the surface 10 cm (Figure 31). As the water content of the soil was increased the resistance to penetrometers was reduced.

Seasonal means for penetrometer resistance are given in Table 8. The zero tillage soils had a significantly higher penetrometer resistance in

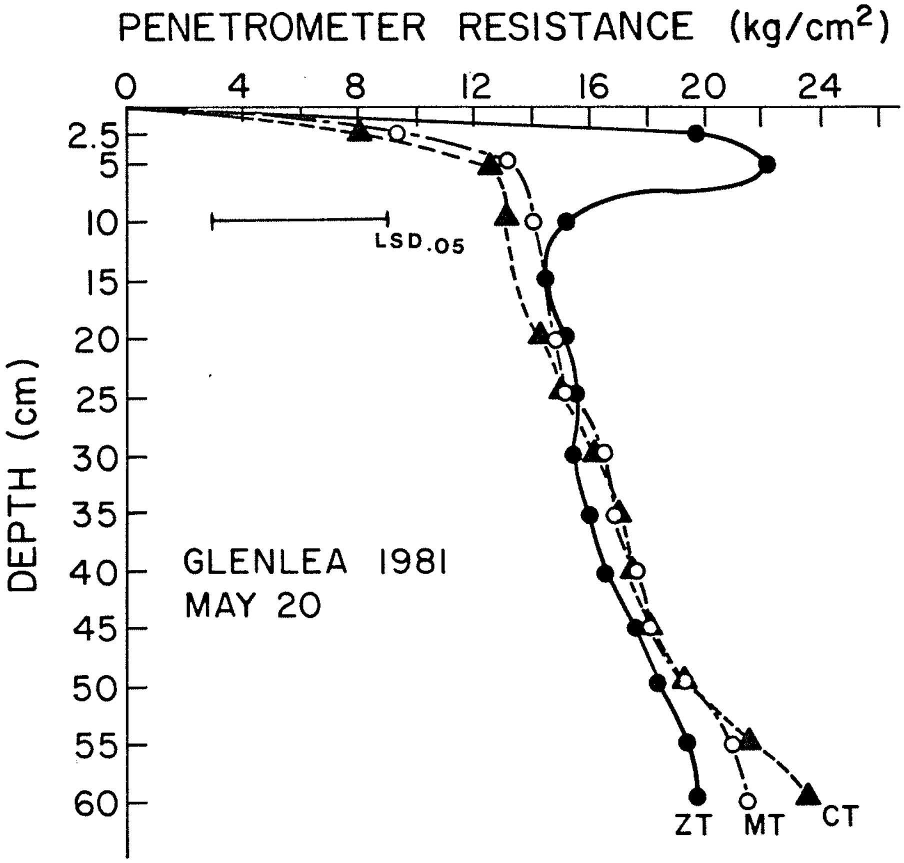

Figure 30 Penetrometer resistance vs. soil depth at seeding for zero (ZT), minimum (MT) and conventional (CT) tillage

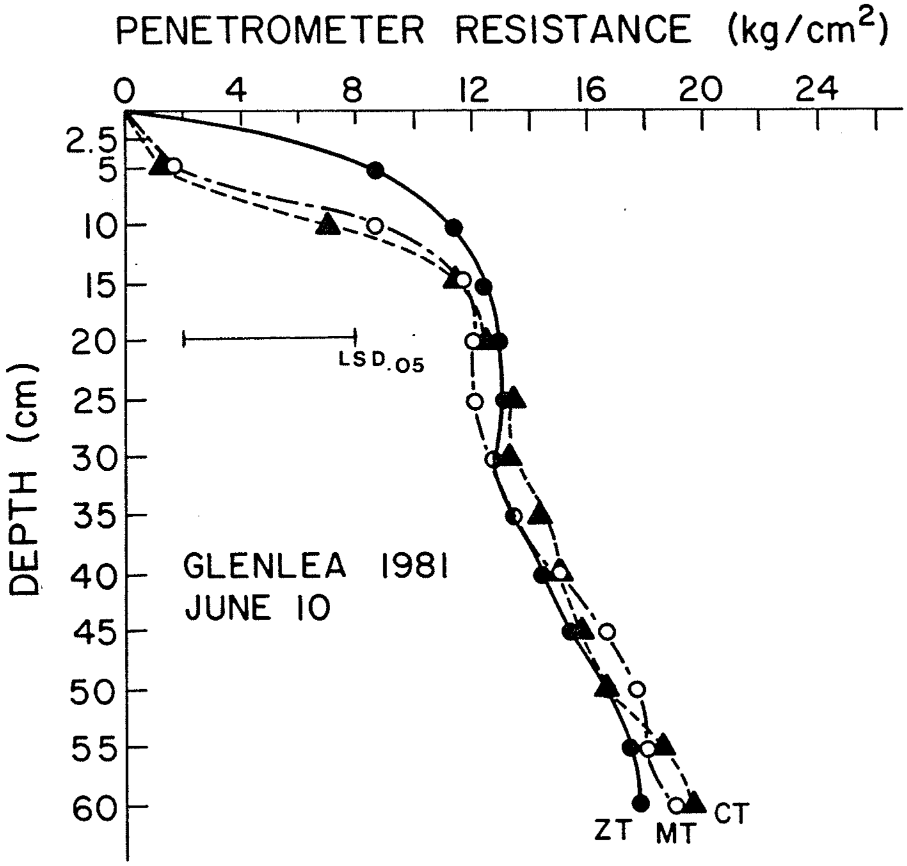

Figure 31 Penetrometer resistance vs. soil depth after an effective rainfall for zero (ZT), minimum (MT) and conventional (CT) tillage

Table 8

1981 Seasonal Means(1) of Penetrometer Resistance for Soils under Zero Tillage (ZT), Minimum Tillage (MT) and Conventional Tillage (CT)

Depth	Penetrometer Resistance(1)		
	ZT	MT	CT
		(kg/cm)	
2.5	18.7*	7.5	6.9
5.0	16.4*	10.3	9.5
10.0	15.0	13.7	12.7
15.0	15.3	14.7	14.3
20.0	16.0	15.6	15.6
25.0	16.8	16.1	16.8
30.0	17.5	16.9	17.6
35.0	18.5	17.5	18.5
40.0	19.0	18.2	19.0
45.0	20.5	18.6	20.1
50.0	21.2	19.8	21.7
55.0	22.2	20.7	23.3
60.0	23.3	21.5	25.3
LSD (.05)	6.1	6.1	6.1

(1) Each value represents the mean of 100 samples.

* Value is significantly different than the other tillage treatments.

the surface 5 cm (16.4 kg/cm^2) for the minimum (10.3 kg/cm^2) and conventional (9.5 kg/cm^2) tillage soils. Beyond the 20 cm depth resistance was similar to the 60 cm depth. The greater resistance to pentrometers found under zero tillage agrees with the findings of other researchers (Diebert _et_ _al_. 1980; Ellis _et_ _al_. 1979; Hodgson _et_ _al_. 1977), although the depth at which the differences occurred varied among these experiments. The increase in penetrometer resistance could possibly be due to increased bulk density and increased aggregate stability (Pidgeon and Soane, 1977; Hughes and Baker, 1977).

Decreases in penetrometer resistance as soil water content was increased has been well documented (Diebert _et_ _al_. 1980; Chancellor, 1977). This may be important under zero tillage soils in that root growth could extend to deeper soil zones even though bulk densities have increased under an untilled soil condition.

4.5 EFFICIENCY OF HERBICIDES FOR THE CONTROL OF ALFALFA

Initiating zero tillage cereal production on established forage land is similar to stubble land in that effective weed control practices are needed if this soil management practice is to succeed. Ineffective control of alfalfa, forage grasses and other established weeds increases the difficulty in establishing cereal crop Glyphosate, 2,4-D, and dicamba, alone and in combinations, were applied in the summer of 1980 to determine the effect the herbicides had on controlling alfalfa for cereal production in the following year.

Within 15 days after treatment, alfalfa leaf senescence had occurred on all herbicide treatmented plots. It appeared that a high level of alfalfa control was established so that the wheat establishment would not be impaired in the following spring.

In June 1981, the total weed frequency (dandelion, alfalfa) was determined on the seeded and unseeded area for each treatment. There was no significant interaction between the herbicide treatments and whether the plot was seeded or unseeded. There was a significant difference between the herbicide treatments for total weed frequency as shown by treatment means in Table 9.

As expected, on the two check plots, total weed frequency was high with weeds covering 76 and 66 percent of the plot area. No herbicide treated plot gave acceptable weed control. Total weed frequency in plots treated with glyphosate plus 2,4-D (1.12 + 2.25 a.i. kg/ha) was the lowest with 23 percent of the plot area covered with weeds. This treatment was only 70 percent better than the check.

Some interesting observations can be seen in this study. Herbicides applied alone, gave less control of alfalfa and dandelions than when they were in combination with each other (Table 9). Although none of the herbicides gave adequate control in general, the best control was obtained when herbicides were used at high rates.

The frequency of alfalfa (%) in the plot area can be seen in Table 9 and generally follows the same pattern as was seen for the total weed frequency (%). Herbicides applied alone were less effective in reducing the frequency of alfalfa occurring in the plot area than when herbicides were applied in combinations. The combination of 2,4-D (1.12 or 2.25 a.i. kg/ha) plus dicamba (0.42 a.i. kg/ha) was the most effective in reducing the frequency of alfalfa (75 percent less alfalfa occurrence than

Table 9

Total weed frequency, alfalfa frequency, mean dry matter accumulation plants and grain yield from treatments after application of dicamba, and 2,4-D alone or in combination

Treatment(1)	Rate	Total Weed(2) Frequency	Alfalfa(3) Frequency	Mean(4) Dry Weight	Grain(5) Yield
	Kg/Ha	%	%	g/m^2	g/m^2
Check	-	76.25	49.25	60.9	65.2
Check	-	66.37	40.50	33.1	54.4
Dicamba(6)	.28	61.87	38.37	50.0	69.0
Dicamba	.42	56.37	32.87	62.9	97.6
2,4-D(7)	1.12	61.25	36.37	60.9	110.2
2,4-D	2.25	42.87	30.87	41.1	127.8
Glyphosate(8)	1.12	56.50	31.50	55.7	135.3
Glyphosate	1.75	36.00	30.87	33.1	206.1
Glyphosate + Dicamba	1.12 + .28	47.62	32.50	86.3	136.2
Glyphosate + Dicamba	1.12 + .42	45.37	22.37	51.3	157.3
Glyphosate + Dicamba	1.75 + .28	35.25	23.15	56.0	205.8
Glyphosate + Dicamba	1.75 + .42	35.75	23.37	63.6	200.0
Glyphosate + 2,4-D	1.12 + 1.12	35.62	19.12	42.4	152.2
Glyphosate + 2,4-D	1.12 + 2.25	23.50	14.25	43.0	181.6
Glyphosate + 2,4-D	1.75 + 1.12	31.50	17.25	33.5	201.6
Glyphosate + 2,4-D	1.75 + 2.25	35.37	16.25	52.1	190.9
2,4-D + Dicamba	1.12 + .28	45.25	19.25	75.8	118.2
2,4-D + Dicamba	1.12 + .42	28.12	12.00	43.5	160.4
2,4-D + Dicamba	2.25 + .28	40.62	23.12	51.4	168.9
2,4-D + Dicamba	2.25 + .42	29.87	12.75	50.8	198.8
LSD(.05)		21.45	17.08	51.64	80.30

(1) Treatments applied August 30, 1980.
(2) Sampled June 4-5, 1981.
(3) Sampled June 4-5, 1981.
(4) Sampled July 17, 1981.
(5) Sampled August.
(6) Chemical name 3,6-dichloro-o-anisic acid.
(7) Chemical name (2,4-dichlorophenoxy) acetic acid.
(8) Chemical name N-(phosphonomethyl) glycine.

the control), although they were not significantly different than the glyphosate plus 2,4-D combinations or most of the other herbicide combinations (Table 9). The 2,4-D combinations appeared to be more effective than the dicamba in combinations with glyphosate. The level of herbicide effectiveness of the treatments on alfalfa was insufficient and unacceptable for crop production on a field scale.

Since alfalfa occurred in all the plots at an unacceptable level Dowco 290[6] (0.3 a.i. kg/ha) was applied on half of the plot area to reduce the competitiveness of alfalfa to the growing crop. Alfalfa dry matter production was sampled three weeks after the Dowco 290 was applied. There was no significant interaction between the primary herbicide treatment and whether or not the plot was sprayed with Dowco 290. The herbicide treatments were significantly different and mean alfalfa dry matter accumulation is shown in Table 9.

At the time of sampling, alfalfa plants had regrown considerably and generally covered the plots irrespective of treatment. The regrowth of alfalfa and dry matter accumulation does not reflect the frequencies of alfalfa observed earlier in the year. Most herbicide treatments were not different than the check plots (Table 9). The large number of alfalfa plants on the check plots had little growth with the dry matter accumulation consisting of many small alfalfa plants. On the other hand, treatments that had a low frequency of alfalfa, dry matter accumulation consisted of a few large plants. The degree of competition between the alfalfa plants determined the increase in growth seen on the plot area and resulted in few differences in the dry matter accumulation

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[6] Product of Dow Chemicals Canada. The trade name is Lontrel.

of alfalfa between the herbicide treatments (Table 9). This result is similar to findings by Waddington (1980) who showed that applications of 2,4-D (1.1 kg/ha) reduced alfalfa densities, however in a weed free environment alfalfa recovered to produce seed yields equal or better than where 2,4-D was not applied.

The results show that the level of control of alfalfa on established forage land was unacceptable with any of the treatments for field scale cereal production under zero tillage management. This result differs from Moomaw and Martin (1976) who showed that 2,4-D plus dicamba (1.12 + 0.28 kg/ha) provided effective control of alfalfa that was equivalent to ploughing, with spring treatments resulting in better control than fall treatments. Also, Sellick and Baird (1981) found that 1.7 kg/ha glyphosate controlled 86 percent of the alfalfa 28 days after treatment whereas 3.4 kg/ha glyphosate effectively killed 100 percent of the alfalfa 57 days after treatment. They did not report the percent of effective kill of alfalfa for a longer period than 28 days when 1.7 kg/ha glyphosate was applied. Siemens and Carder (1965) reported that one year old alfalfa was killed from 0.55 kg/ha dicamba, whereas in our study 0.42 kg/ha dicamba did not effectively control alfalfa. Differences in the level of effective alfalfa control may possibly be attributed to day time temperatures after applying herbicides, levels of light intensity, time of treatments, or stage of alfalfa development at the time of herbicide application.

Although alfalfa dry matter accumulation was not significantly different in most plots, visual observation showed that wheat density varied between the treatments. On herbicide treatments where the frequency of alfalfa was high, wheat plant density was low, plants were stunted and had no tillers and the heads were small. Where the frequency of alfalfa was relatively low the wheat plant density was high, the plants had tillers and the heads were large. The improved establishment of wheat under treatments with a low frequency of alfalfa was due to the considerably less competition from alfalfa at the time of seeding.

Grain yields were high on plots that had a low density of alfalfa (Table 9). The treatments that included the high rate of glyphosate (1.75 kg/ha) resulted in approximately 70 percent greater grain yields than the check plots. All the herbicide combination treatments had higher wheat yields than treatments where herbicides were applied alone with the exception of the glyphosate (1.75 kg/ha) treatment and the 2,4-D plus dicamba (1.12 + 0.28 kg/ha) treatment. Grain yields appeared to be higher from treatments that included the high rate of glyphosate (1.75 kg/ha) than when the low rate of glyphosate (1.12 kg/ha) was used. Grain yields were also generally higher from treatments that included the high rate of 2,4-D (2.25 kg/ha) than with the lower rate of 2,4-D (1.12 kg/ha).

Treatments with the highest rates of herbicide appeared to give the wheat time to become established prior to regrowth of alfalfa which was reflected in the grain yields. In general the low yields in this study were due to the competition from alfalfa.

Dandelions were a problem in the plot area but the population density was erratic between replications as well as within a replication making statistical analysis difficult.

Chapter V

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The surface soil conditions created by the tilled and untilled soils affected the amount of available water throughout the growing season. The zero tilled soil appeared to maintain a higher soil water content in the surface 20 cm than the tilled soils with the greatest differences occurring in the 10 cm horizon. The residue mulch from the chemically killed sod insulated the upper soil profile to reduce evaporation losses during the early stages of crop growth. Sod residue can prolong the constant rate evaporation for a short period of time. Without the benefit of recurring rains, cumulative evaporation from the surface soil with sod residues eventually equalled that of the conventional and minimum tillage. The soil management system had very little effect on soil water content below the 90 cm depth.

The infiltration rate was higher under zero tillage in 1980 despite a more compacted surface soil,probably due to pore continuity. Alfalfa, which was approximately 30 percent of the previous forage crop, left vertical channels from the decaying taproots in the undisturbed soil.

In 1981, greater infiltration under conventional till soils than zero till soils was attributed to reduced soil bulk density and increased soil porosity. Under zero tillage, lack of pore continuity due to the absence of alfalfa in the previous forage crop, high bulk density, and a reduction in pore size contributed to the decrease in the infiltration rate. Minimum till soils had the least amount of infiltration in both years, possibly due to lower porosity, reduced random roughness, reduced pore size or susceptibility to surface sealing.

Soil bulk density appeared to be higher on the untilled soil compared to the tilled soil in the surface 10 cm. Penetrometer resistance was higher in the surface 5 cm and appeared to be higher to a 20 cm depth under zero tillage. Soil compaction may have restricted root growth under zero tillage since water extraction by plant roots was lower in the untilled soil than the tilled soil in the 30-90 cm soil depth. Plant grown under conventional tillage extracted the most water at this depth.

Growth and development of spring wheat planted into a forage soil depended on good seed placement in the soil and adequate kill of the perennial forage species. In zero till soils, low seedling emergence caused by poor seed-soil contact and weed competition resulted in low grain yields. When conventional tillage did not control the bromegrass from the previous crop, yields were not different than on zero tillage. When tillage effectively killed the forage species, grain yields were highest on conventional tillage and intermediate on minimum tillage.

Water use efficiency of the tilled and untilled treatments was a general reflection of grain yield. When conventional tillage ineffectively controlled the bromegrass, water use efficiencies were no different than under zero tillage. When bromegrass was effectively controlled by tillage, water use efficiency was highest under conventional tillage and least under zero tillage with minimum tillage intermediate.

An inverse relationship between soil water loss and growing season precipitation occurred, hence, the wheat grown in 1981 was less dependent on stored soil water than the wheat grown in 1980.

The control of alfalfa by glyphosate, 2,4-D and dicamba applied alone, or in combination, was unacceptable.

5.2 RECOMMENDATIONS

1. Studies should be initiated to develop zero till drills which are more effective in sod seeding under a variety of soil moisture conditions.
2. Herbicides programs which include a broad spectrum of contact and residual herbicide mixtures, split applications, timing of treatment, and weed physiology are needed to evaluate herbicide efficiency of forage species.
3. In depth studies on how the changes in soil compaction and nutrient distribution in the surface soil expected under zero tillage effect the development of roots if the effects of reduced and conventional systems on crop yield are to be fully explained.
4. Under different tillage systems and soil types, knowledge on the effects of previous cropping on the physics of water movement across soil-air interfaces is necessary if hydrological benefits are to be understood in semi-arid climates.
5. Phytotoxicity of degrading sod residues on the growth and development of crops under zero tillage need to be developed under Manitoba conditions.

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