EFFECTS OF SURFACE RESIDUE LEVELS ON PLANT AVAILABLE SOIL MOISTURE IN MONOCULTURE WHEAT PRODUCTION IN OKLAHOMA

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PREFACE

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CHAPTER I

INTRODUCTION

In crop production, soil water content is an important factor relating to yields. Where water stress is a yield limiting factor, conservation of soil water is vitally important during both the fallow period and the growing season of winter wheat (Triticum aestivum L.). We are interested in the effect of tillage practices, or levels of surface residue on soil water, and the effect these tillage systems have on soil characteristics such as bulk density and soil structure, which influence the availability of soil water.

Soil water can be evaluated on either a total water, or a plant available water basis. Since not all water in the soil is available to plants, the use of plant available water or water held in the soil at a tension of less than 1.5 megapascals is best in evaluating the influence of tillage practices, or surface residue levels on soil moisture.

Research has shown that tillage practices may affect soil bulk density, which in turn influences the availability of water in the soil profile. Therefore, proper characterization of soil bulk density is essential for an accurate interpretation of experimental results dealing with plant available soil water. Although many studies of tillage effects on gravimetric soil water content have been conducted, whether or not plant available soil water is significantly affected by various tillage practices is still unclear.

Therefore the objectives of this research are:

A. To evaluate soil bulk density as influenced by four tillage systems (plow, disk, V-blade, and no-till).

B. To determine the effect of crop residue management treatments (buried, mixed with surface 100 mm, slight mixing but most on surface, and no mixing), as achieved through tillage, on plant available soil water.

CHAPTER II

PREVIOUS WORK AND LITERATURE REVIEW

Smika et al. (1969), reported that in simiarid conditions, soil water is a predominant factor that influences grain yields. Numerous studies have been conducted concerning water storage and physical aspects of the soil, and how they are influenced by tillage practices.

A four year study conducted by Davidson and Santelman (1973), showed no significant tillage effect upon bulk density in the top 220 mm of the soil profile. Also, Bhatnagar et al. (1983), reported that a tillage treatment of disk plowing and disk harrowing did not cause significant changes in soil properties. However, several studies have shown resulting bulk density differences between tillage treatments. Tanchandropongs and Davidson (1970), showed that aggregate stability, organic matter content, and bulk density were significantly better in the top 300 mm of the soil profile after 11 years of stubble mulching in wheat, compared to plow or clean till procedures.

Power et al. (1984), stated that bulk density is often greater with no tillage than with tillage.

Gantzer and Blake (1978), found that soil under no-till had significantly greater bulk density both in spring and fall as judged from samples taken from the surface 300 mm in comparison to those of conventional tillage.

Although reports indicate that differences are apparent only in the surface 300 mm and bulk density differences due to tillage generally converge at depths greater than 300 mm (Gantzer and Blake, 1978), bulk density readings should be taken to a greater depth to eliminate variations in bulk density due to differences in soil texture when reporting plant available water content on a volumetric basis (Cassel and Nelson, 1985).

Several researchers have reported significant increases in water storage with increasing amounts of straw on the soil surface. Greb et al. (1970), reported a progressive increase in soil water storage with increased application rates of straw mulch regardless of the quantity of precipitation during the fallow period. However, Unger (1976) showed that little improvement in water storage could be expected from applying surface residues, even at relatively high rates, when precipitation amounts are small.

Cochran et al. (1982) reported that surface crop residues significantly improved water storage during seasons with major runoff events, however, had no effect when soil profiles were filled by spring. Also, they reported that considerably more soil water was stored in the no-till treatments than in either the tilled or stubble burned treatments. Water left in the profile after harvest was not significantly different among treatments, which indicated that the plants were able to extract the additional water.

Unger and Parker (1975), indicated that growing season water storage was greater (about 40-50% as compared with 20%), and that crops utilized more of the growing season precipitation for growth and grain production on residue covered, no-till seeded areas than on bare soil. Also, direct drilling of sorghum into cereal residues increased water storage during a season with lower than normal precipitation.

Studies concerning evaporation of stored soil water have shown a reduction in evaporation losses with an increase in straw mulch. Good and Smika (1978), reported that a disc tillage operation reduces residue by as much as 75 percent per operation, and that water loss in the top 127 mm of the soil was much greater after the disc operation than when the stubble was present.

Smika (1983), stated that wind was the dominant factor influencing soil water loss, and that wind velocity at the soil surface was greatly reduced by standing straw. Research in the Great Plains has indicated that a 50:50 mix of standing and flat straw may be the most effective residue combination to minimize soil water losses (Smika, 1983; Fenster and Peterson, 1979). Smika (1976), stated that soil water storage during fallow periods from 1967 to 1970 was greater where V-blade tillage was conducted (not all stubble standing) than no-till (all stubble standing). Good and Smika (1978), reported that standing residue offset soil water losses better than either flat residue or bare ground. Van Doren and Allmaras (1977), reported that with residues left on the soil surface, maintenance of both infiltration and surface storage will be dependent on residue distribution and orientation. If residues are standing, they present a smaller interception area for vertically falling raindrops, and may be less effective in intercepting raindrops than flat residues, depending upon actual incident angle of interception. Also, residues that are completely incorporated into the soil will have little or no direct effect on infiltration or surface storage capacity. Van Doren and Allmaras (1977), also reported that evaporation from soils which develop shrinkage cracks will be reduced less by the presence of crop residues than will soils which do not crack.

Low residue amounts have not been very effective in increasing amounts of stored water in many previous studies in the dryland area. For example, Wiese, et al. (1967), suggested that residue production by dryland crops in the Southern Great Plains generally is low and inadequate for significantly increasing water storage in soil during fallow over that obtained for bare soil. Also, Bond and Willis (1971), required in excess of 9,000 kg/ha straw mulch to significantly reduce cumulative evaporation beyond 30 days in the absence of rain. However, Greb et al. (1970) found that precipitation stored as soil water ranged from 16 to 26% with no residues to 31 to 37% with 6,720 kg/ha of wheat straw on the soil surface.

Unger and Parker (1968), showed in a greenhouse study that a layer of residues just below the soil surface can reduce evaporation to some extent (by 19% compared with residues mixed uniformly in the soil), but this did not compare very favorably with the 57% reduction from leaving the same 11,000 kg/ha of wheat straw on the soil surface.

Tanaka (1985), reported that large quantities of surface residue reduce soil water evaporation rates but the constant rate evaporation time is appreciably lengthened. With continued drying, cumulative evaporation for bare and residue-covered surfaces eventually become equal (Bond and Willis, 1969). For chemical fallow to effectively store more soil water than stubble-mulch fallow, frequent precipitation during low potential evaporation periods is necessary (Tanaka, 1985).

There is a large amount of published literature dealing with the influence of tillage practices and residue management of winter wheat on soil water content. Most of this literature deals with a wheat-fallow rotation, where there is an 11 to 15 month fallow period, and does not consider monoculture yearly wheat production systems. Soil water analyses have frequently been reported on a gravimetric basis, and the conditions are not representative of bulk densities that exist in the field at the time of sampling. In many cases this may lead to improper interpretation of experimental results (Doran and Mielke, 1984), since higher bulk densities would result in a larger amount of water on a volumetric basis. Variations in soil texture and bulk density can have a large effect on availability of water in the soil profile. Therefore, this research takes into account the existing bulk densities and evaluates the effects of crop residue management on plant available soil water in an annual wheat production environment.

CHAPTER III

MATERIALS AND METHODS

The study was conducted on a Pulaski course-loamy, mixed, thermic Typic Ustifluvent (fine sandy loam 0-2 percent slope) soil at the Oklahoma State University North Agronomy Research Farm, Stillwater, Oklahoma. The study was initiated immediately following wheat harvest in 1982, and data were collected over four growing seasons, 1982-1985. All plots were in wheat the year prior to the beginning of the study.

A randomized complete block design was used in the study, with four replications. Each replication had four treatments consisting of moldboard plowing in the minimal surface residue plots, disking the low surface residue plots, using a 2.5 m wide V-blade in the intermediate surface residue plots, and no-till (all residue left on surface) in the maximum surface residue plots. The no-till treatment was duplicated in each replication. The plot size was 15 meters by 38 meters.

Tillage operations were conducted as soon after harvest as soil conditions would allow (Table I, Appendix A). Tillage in the minimal surface residue plots consisted of moldboard plowing to a depth of 200 mm following harvest. These plots were then disked as needed for weed control. The low surface residue plots were disked following harvest, and weed control was accomplished as needed by disking. Intermediate surface residue plots were swept at a depth of 120 mm with a 2.5 meter V-blade following harvest, and weed control after the V-blade operation was accomplished with herbicides only, so 75 percent of the residue would be retained on the soil surface. Weed control in the no-till plots was accomplished through the use of various herbicides. Uniform herbicide applications were sprayed across all treatments (Table I, Appendix A).

Percent ground cover (the percent of the soil surface covered by the previous years crop residue) was determined by the point count system as described by Owensby (1973) immediately after planting for the 1983, 1984, and 1985 crop years.

In 1982 planting was performed using a modified John Deere hoe drill. In 1983, 1984, and 1985, a Crustbuster double disk opener no-till drill with 250 mm row spacing was utilized. Planting dates, and seeding rates varied for each year of the study (Table II, Appendix A).

Soil water content in the plots was monitored through the use of a neutron probe moisture gauge (Troxler Model 3233). Two, 38 mm inside diameter, thin wall electrical conduit tubes were used for neutron probe access in each plot. Readings were taken at 150 mm intervals from 0.22 to 1.57 m below the surface on a bi-weekly basis during the 1982 and 1983 cropping seasons, and on a monthly basis during the 1984 and 1985 cropping seasons. The last reading each crop year was taken on the day of harvest. Access tubes were removed from all plots, with the exception of the no-till plots, immediately after harvest to allow for tillage operations. The tubes were then replaced and moisture readings began for the next crop year after the initial tillage was performed.

Soil samples for measurement of soil bulk density were taken at 150 mm intervals from 75 mm to a depth of 1.6 m using a 66.4 mm diameter probe, mounted on a truck. Samples were taken at two sites in each plot, approximately 3 m away from the access tubes. Bulk densities were determined as outlined by Black (1965).

After the bulk density of the samples had been determined, each sample was ground, sieved through a 2-mm round hole sieve, and mixed thoroughly. The amount of water remaining in the soil at the theoretical permanent wilting point of 1.5 megapascals (MPa) was determined using a pressure-membrane apparatus. A subsample from each sample was taken, and placed on the pressure membrane apparatus. Soil samples on the membrane were contained in rings of approximately 10 mm height and 50 mm diameter which held approximately 25 grams of soil. The rubber rings were used on acetate membranes. The samples were saturated with water, and a pressure of 1.5 MPa, was applied to the samples for a 24 hour period, at which time liquid water outflow had ceased from all samples on the membrane. Water content of the samples was then determined as described by Black (1965).

Volumetric water content of the soil at a tension of 1.5 MPa was calculated by multiplying the the percent water held in the soil at a tension of 1.5 MPa of each soil interval by the soil bulk density of that interval. Plant available water contained in each interval was calculated by subtracting the volumetric water content of the soil interval at a tension of 1.5 MPa from the total water in that interval.

Particle size analysis was conducted on 8 soil samples from various locations and depths within the study. Particular samples were selected based upon minus 1.5 megapascal values assuming this would result in the range of textures in the site. Organic matter was oxidized from 40 gram soil samples using 30% hydrogen peroxide and distilled water. The samples were then centrifuged for 30 minutes at 6000 rpm. Following the centrifuge process, the pellet was removed from the solution and 50 ml Calgon solution containing sodium hexametaphosphate was added as a dispersing agent. The samples were shaken for 12 hours, transferred to 1 liter graduated cylinders, and distilled water was added to total 1 liter. Samples were mixed for 30 seconds, and hydrometer readings were taken at 30 second intervals for the first 5 minutes, then again at 6 minutes, 7 hours, 8 hours, 9 hours, and 24 hours. Soil textural class was then determined as outlined by Black (1965).

Analyses of variance were run in order to test for differences in tillage effects on bulk density for each 150 mm soil layer from 0.1 m below the soil surface to a depth of 1.6 m. Analyses of variance were also run to test for statistically significant residue level effects on total water, plant available water in the 1.6 m profile, 1.0 m profile, .38 m profile, and for each 305 mm soil layer below .38 m to a depth of 1.6 m.

CHAPTER IV

RESULTS AND DISCUSSION

Significant differences in soil bulk density owing to tillage treatment was limited to the surface 225 mm of the profile. Bulk density in the bottom plow treatment was significantly lower than all other tillage treatments (Table III, Appendix A). These findings are consistent with the findings of Gantzer and Blake (1978), and Power et al. (1984) in that bulk density was greater in the no-till treatment than in the bottom plow treatment, however, the bulk densities between the disk tillage treatment and the no-till treatment were not significantly different. This could have been due to the length of time between the tillage operation and the time of sampling (239 days), or to the fact that the disk cultivation was limited to the surface 130 mm while sampling depth was from 75 to 225 mm.

The percent water held in the soil at a tension of 1.5 MPa (minus 1.5 MPa reading), varied substantially both by location and by depth within a location. Particle size analyses were run for random samples with low, medium, and high water contents at a tension of 1.5 MPa. Textural analysis revealed that samples having low minus 1.5 MPa readings were sands or sandy loams, the medium readings were sandy loams or loams, and the high minus 1.5 MPa samples were loams or clay loams (Table IV, Appendix A) .

Tillage treatments did affect surface residue levels as desired. A wide range of residue levels remained when counts were taken immediately after planting each year for the 1983 - 1985 crop years (Table V, Appendix A).

Plant available water contents of the 1.6 m soil profile were not statistically different (P = .05) between treatments at the beginning of this study. Evaluating soil water content on a plant available basis resulted in statistical differences (P = .05) between tillage treatments on several moisture sampling dates which were not statistically different in total water content. Although throughout the four years of the study, the V-blade treatment consistently contained a greater amount of plant available soil water in the surface 1.6 m, significant differences (P = .05) between treatments were recorded on only 10 of the 66 sampling dates (Figures 1-4, Appendix B). When total water in the 1.6 m profile was analyzed, statistical differences between treatments were observed on only 3 of the 66 dates that soil water was monitored (Figure 5-8, Appendix B).

Statistical analysis of the surface 380 mm soil layer, and each 305 mm interval below 380 mm revealed that differences in total water present in each zone were contained mainly in the surface 380 mm (Tables VI-IX, Appendix A), and differences in plant available water in each zone were contained in the upper 1 m profile (Tables X-XIII, Appendix A). Also, no statistical differences in either total water or plant available water in each 305 mm interval existed below the 1 m depth at any date. Although significant differences in plant available soil water were not observed in intervals below the 1 m profile, soil water extraction by roots was apparent during dry down periods in the 1982-1983, and the 1983-1984 cropping years (Figures 9-10, Appendix B). However, fluctuations in plant available water due to removal by wheat plants, evaporation, and infiltration, were far greater in the surface 1 m than in the 1 - 1.6 m profile, thus leading to the greater number of significant differences in plant available water between treatments in the surface 1 m profile as compared to the surface 1.6 m profile. Therefore, water contents in the surface 1 m will be covered in greater detail in the remainder of the discussion.

In 1982, surface residue levels showed no effect on total water in the surface 1 m until 299 days after the beginning of the study. However, the V-blade treatment consistently contained a slightly greater amount of total water in the 1 m profile than all other treatments on almost all reading dates in the 1982 cropping year (Figure 11, Appendix B). Total water content in the V-blade treatments remained higher than all other treatments during the following 3 cropping years, which is consistent with the findings of Smika (1976), who reported greater water storage in V-blade plots than in no-till plots, however in this study, only 6 of the reading dates showed significant differences in total water contained in the surface 1 m profile due to surface residue amounts (Figure 12-14, Appendix B).

Plant available soil water in the surface 1 m showed statistically significant differences (P = .05) due to tillage at 284 days after the beginning of the study, at which time a greater amount of plant available water was observed in the V-blade treatment than all other treatments with the exception of one no-till treatment (Figure 15, Appendix B). Earlier in the growing season, at approximately 190 days after July 1, 1982, the V-blade treatment began showing a slightly greater amount of plant available water in the profile than other treatments. Differences in plant available water present in the soil between the V-blade treatment and other treatments gradually increased over time prior to the date of the first statistical difference. Plant available water remained statistically higher (P = .05) in the V-blade treatments than all other treatments for the remainder of the 1982-1983 growing season with the exception of a 13 day period in May following a major rainfall event, when there were no statistical differences between treatments in plant available water in the 1 m profile.

The higher plant available water content contained in the 1 m profile of the V-blade treatment as compared with the other treatments in the study, carried over into the 1983-1984 cropping year, and was significantly higher for 14 of the 21 dates that soil water was monitored throughout the growing season (Figure 16, Appendix B).

In the 1984-1985 cropping year, again the V-blade treatment had a statistically greater (P = .05) amount of plant available water in the 1 m profile, and the plow treatment contained the least amount of plant available water on all reading dates showing significant differences in plant available water (Figure 17, Appendix B). During both the 1983-1984 and the 1984-1985 crop years, even when statistically significant differences were not present the V-blade treatment always had the highest measured plant available water content.

Crop failure due to herbicide in the no-till plots during the 1985-1986 cropping year, allowed for a greater amount of plant available water to accumulate in the 1 m profile of these treatments than other treatments late in the growing season (Figure 18, Appendix B).

Significant differences in plant available soil water between treatments in the surface 1 m profile occurred following major rainfall events, but occurred more often during dry down periods. This would suggest that decreased evaporation was a larger factor resulting in the greater amount of plant available soil water present in the V-blade treatment than was increased infiltration.

In contrast to the findings of Greb et al. (1970), who observed a greater amount of water storage in no-till treatments than in V-blade treatments, over the four years of this study, treatments with surface residues slightly mixed in the top soil or V-blade treatments, were able to capture and store a greater amount of plant available water than all other treatments. The greater amount of plant available water present in the V-blade treatments than in the no-till treatments could have been due to tillage disrupting capillary movement of water to the soil surface, thus reducing evaporative losses. Also, since greater amounts of plant available water were observed in the V-blade plots than in the no-till plots, perhaps the amount of residue left on the soil surface as discussed by Greb et al. (1970) influenced infiltration and evaporation of soil water to a lesser degree than did orientation of the residue left on the soil surface as observed by Van Doren and Allmaras (1977), or perhaps, the increased water content in the V-blade treatments as compared with the no-till treatments was a result of tillage allowing more water infiltration.

Treatments with residue slightly mixed in the soil (V-blade treatments), initially accumulated a greater amount of plant available water during a period of heavy rainfall, and appeared to maintain the greater amount of available water through dry down periods. The initial statistical difference (P = .05) between treatments occurred late in the growing season when surface residue levels should have little effect on the capture of rainfall due to the wheat canopy. The V-blade treatments did however, contain a slightly greater amount of plant available water prior to the first series of major rainfall events which led to the first statistical difference in plant available water due to surface residue levels.

Tillage treatments utilized in this study did show an affect on soil bulk density. Bulk density of soils where moldboard plow treatments had been utilized were significantly lower than soils where either disk, V-blade, or no-till treatments were used however, these differences were observed only to a depth of 225 mm.

Crop residue management treatments or surface residue levels, as achieved through tillage, had a significant affect on the presence of plant available soil water present in the profile. Soils where V-blade treatments had been utilized, leaving residue slightly mixed in the soil, but mostly on the surface, were able to capture and store plant available soil water in the 1 m profile more effectively than either moldboard plow, disk, or no-till treatments.

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APPENDIX A

TILLAGE DATES, FIELD CONDITIONS, AND RESULTS

TABLE I

SUMMARY OF HERBICIDE APPLIED, DATE OF APPLICATION, AND RATE OF APPLICATION

Cropping Season	Date	Chemical Applied	Rate kg ha^{-1} (ai)
1982–1983			
	9–13	Glyphosate	2.24
	12–17	Brominal Plus	0.56
1983–1984			
	7– 7	Glyphosate	2.02
	8–29	Glyphosate	0.56
	9–27	Glyphosate	0.56
1984–1985			
	7–10	Glyphosate	1.12
	8–28	Glyphosate	1.12
	10– 8	Glyphosate	0.28
	11– 8	Tycor	1.12
	3–14	Sencor	0.42
1985–1986			
	6–28	Landmaster	
		Glyphosate	0.42
		2,4–D	0.75
		Surfactant	0.75
	8– 2	Glyphosate	1.12
		2,4–D	1.12
	9– 3	Glyphosate	0.28
	10–28	Glyphosate	0.28
	3– 3	Sencor	0.42

TABLE II

SUMMARY OF INITIAL TILLAGE DATES, PLANTING DATES, SEEDING RATES, AND HARVEST DATES

Cropping Season	Tillage Date	Planting Date	Seeding Rate	Harvest Date
			kg ha^{-1}	
1982-1983	8- 1	9-13	65.0	6-24
Replanted:		9-27	65.0	
1983-1984	7- 7	9-28	61.6	6-16
1984-1985	7-17	10- 8	67.2	6-12
1985-1986	7-18	10-28	78.5	6-14

TABLE III

EFFECT OF TILLAGE TREATMENT ON SOIL BULK DENSITY FOR 75-225 mm DEPTH

Treatment	Mean	Observations
Moldboard plow	1.6128	8
Disk	1.7274	8
V-Blade	1.6978	8
No-till	1.7476	8
No-till	1.6873	8

LSD (5%) = 0.074
CV = 4.00 %

TABLE IV

WATER HELD IN SOIL AT A TENSION OF 1.5 MPa FOR VARIOUS SOIL CLASSES IN THE STUDY

Water Content at −1.5 MPa	Sand	Silt	Clay	Soil Class
%	%	%	%	
2.023	92.9	2.1	5.0	Sand
2.789	85.5	9.5	5.0	Loamy Sand
2.841	75.4	13.7	10.9	Sandy Loam
5.513	56.1	26.7	17.2	Sandy Loam
5.620	45.5	36.0	18.5	Loam
13.158	51.6	31.2	17.2	Loam
13.343	28.4	44.6	27.0	Clay Loam
14.373	32.9	32.3	34.8	Clay Loam

TABLE V

PERCENT GROUND COVER AFTER PLANTING AS AFFECTED BY TILLAGE

Crop year Tillage	1983	1984	1985
		%	
Moldboard Plow	8	4	1
Disk	22	31	6
V-blade	68	75	89
No-till	89	97	99

TABLE VI

STATISTICAL EVALUATION AND RANKING OF TREATMENTS IN TOTAL SOIL WATER CONTENT FOR EACH DEPTH AND DATE

Days after July 1	DEPTH 0 - 38 cm.	38 - 68.5 cm.	68.5 - 99 cm.	99 - 129.5 cm.	129.5 - 160 cm.
1982					
20	2 3 4 5 1*	NS**	NS	NS	NS
35	3 2 5 4 1	NS	NS	NS	NS
56	3 2 5 4 1	NS	NS	NS	NS
82	NS	NS	NS	NS	NS
92	NS	NS	NS	NS	NS
111	NS	NS	NS	NS	NS
125	NS	NS	NS	NS	NS
137	3 4 5 2 1	NS	NS	NS	NS
152	NS	NS	NS	NS	NS
168	NS	NS	NS	NS	NS
190	NS	NS	NS	NS	NS
232	NS	NS	NS	NS	NS
256	NS	NS	NS	NS	NS
263	NS	NS	NS	NS	NS
284	NS	NS	NS	NS	NS
293	3 5 4 1 2	NS	NS	NS	NS
299	3 5 4 1 2	NS	NS	NS	NS
305	3 5 4 1 2	NS	NS	NS	NS
312	3 5 4 2 1	NS	NS	NS	NS
323	NS	NS	NS	NS	NS
330	3 2 1 5 4	NS	NS	NS	NS
336	3 2 1 5 4	3 1 5 2 4	3 5 1 4 2	NS	NS
343	3 2 1 5 4	3 1 5 2 4	3 5 1 4 2	NS	NS
354	3 1 2 5 4	3 5 1 2 4	3 5 1 4 2	NS	NS

* Treatments: (1) Moldboard Plow, (2) Disk, (3) V-blade, (4) No-till, (5) No-till.

**Non Significant (P = .05)

TABLE VII

STATISTICAL EVALUATION AND RANKING OF TREATMENTS IN TOTAL SOIL WATER CONTENT FOR EACH DEPTH AND DATE

	DEPTH				
Days after July 1	0 - 38 cm.	38 - 68.5 cm.	68.5 - 99 cm.	99 - 129.5 cm.	129.5 - 160 cm.
1983					
24	3 2 1 5 4*	NS**	NS	NS	NS
40	3 1 2 4 5	NS	NS	NS	NS
54	3 2 1 4 5	NS	NS	NS	NS
67	3 1 2 4 5	NS	NS	NS	NS
84	NS	NS	NS	NS	NS
104	NS	NS	NS	NS	NS
115	NS	NS	NS	NS	NS
132	3 1 2 5 4	NS	NS	NS	NS
144	3 2 1 5 4	NS	NS	NS	NS
160	3 1 2 5 4	NS	NS	NS	NS
213	NS	NS	NS	NS	NS
228	NS	NS	NS	NS	NS
244	3 5 4 1 2	NS	NS	NS	NS
265	3 5 4 2 1	NS	NS	NS	NS
279	NS	NS	NS	NS	NS
290	NS	NS	NS	NS	NS
313	3 2 5 4 1	NS	NS	NS	NS
321	3 2 5 1 4	NS	NS	NS	NS
328	3 2 5 1 4	NS	NS	NS	NS
334	3 2 5 1 4	NS	NS	NS	NS
353	3 2 5 4 1	NS	NS	NS	NS

* Treatments: (1) Moldboard Plow. (2) Disk, (3) V-blade, (4) No-till, (5) No-till.

** Non Significant (P = .05)

TABLE VIII

STATISTICAL EVALUATION AND RANKING OF TREATMENTS IN TOTAL SOIL WATER CONTENT FOR EACH DEPTH AND DATE

Days after July 1	DEPTH 0 - 38 cm.	38 - 68.5 cm.	68.5 - 99 cm.	99 - 129.5 cm.	129.5 - 160 cm.
1984					
25	NS**	NS	NS	NS	NS
197	NS	NS	NS	NS	NS
233	NS	NS	NS	NS	NS
256	NS	NS	NS	NS	NS
278	3 5 2 4 1*	NS	NS	NS	NS
285	3 5 2 4 1	NS	NS	NS	NS
291	3 5 2 4 1	NS	NS	NS	NS
298	5 3 2 4 1	NS	NS	NS	NS
306	5 3 1 2 4	NS	NS	NS	NS
313	3 5 2 4 1	NS	NS	NS	NS
319	5 3 4 2 1	NS	NS	NS	NS
346	NS	NS	NS	NS	NS

* Treatments: (1) Moldboard Plow, (2) Disk, (3) V-blade, (4) No-till, (5) No-till.

** Non Significant (P = .05)

TABLE IX

STATISTICAL EVALUATION AND RANKING OF TREATMENTS IN TOTAL SOIL WATER CONTENT FOR EACH DEPTH AND DATE

	DEPTH				
Days after July 1	0 - 38 cm.	38 - 68.5 cm.	68.5 - 99 cm.	99 - 129.5 cm.	129.5 - 160 cm.
1985					
39	NS**	NS	NS	NS	NS
52	NS	NS	NS	NS	NS
73	3 5 4 2 1*	NS	NS	NS	NS
115	NS	NS	NS	NS	NS
189	NS	NS	NS	NS	NS
252	NS	NS	NS	NS	NS
267	NS	NS	NS	NS	NS
309	5 4 2 3 1	NS	NS	NS	NS
351	NS	NS	NS	NS	NS

* Treatments: (1) Moldboard Plow, (2) Disk, (3) V-blade, (4) No-till, (5) No-till.

** Non Significant (P = .05)

TABLE X

STATISTICAL EVALUATION AND RANKING OF TREATMENTS IN PLANT AVAILABLE SOIL WATER CONTENT FOR EACH DEPTH AND DATE

	DEPTH				
Days after July 1	0 - 38 cm.	38 - 68.5 cm.	68.5 - 99 cm.	99 - 129.5 cm.	129.5 - 160 cm.
1982					
20	2 4 3 5 1*	NS**	NS	NS	NS
35	NS	2 3 4 5 1	NS	NS	NS
56	NS	2 3 4 5 1	NS	NS	NS
82	NS	NS	NS	NS	NS
92	NS	NS	NS	NS	NS
111	NS	NS	NS	NS	NS
125	NS	NS	NS	NS	NS
137	NS	NS	NS	NS	NS
152	NS	3 4 5 2 1	NS	NS	NS
168	NS	4 3 2 5 1	3 4 2 5 1	NS	NS
190	NS	NS	NS	NS	NS
232	NS	NS	NS	NS	NS
256	3 4 1 4 2	NS	NS	NS	NS
263	NS	NS	NS	NS	NS
284	NS	3 4 1 5 2	NS	NS	NS
293	NS	3 4 1 5 2	NS	NS	NS
299	3 4 5 1 2	3 4 5 1 2	NS	NS	NS
305	3 5 4 1 2	3 4 5 1 2	NS	NS	NS
312	NS	3 4 5 1 2	NS	NS	NS
323	NS	NS	NS	NS	NS
330	NS	NS	NS	NS	NS
336	NS	3 2 4 1 5	3 4 2 5 1	NS	NS
343	NS	3 4 2 1 5	3 4 5 1 2	NS	NS
354	3 1 2 4 5	3 4 2 5 1	3 4 5 1 2	NS	NS

*Treatments: (1) Moldboard Plow, (2) Disk, (3) V-blade, (4) No-till, (5) No-till.

**Non Significant (P = .05)

TABLE XI

STATISTICAL EVALUATION AND RANKING OF TREATMENTS IN PLANT AVAILABLE SOIL WATER CONTENT FOR EACH DEPTH AND DATE

	DEPTH				
Days after July 1	0 - 38 cm.	38 - 68.5 cm.	68.5 - 99 cm.	99 - 129.5 cm.	129.5 - 160 cm.
1983					
24	3 2 1 4 5*	NS**	NS	NS	NS
40	3 1 2 4 5	NS	NS	NS	NS
54	3 2 1 4 5	3 1 2 4 5	NS	NS	NS
67	3 1 2 4 5	3 1 2 4 5	NS	NS	NS
84	NS	NS	NS	NS	NS
104	NS	NS	NS	NS	NS
115	1 3 2 4 5	NS	2 3 1 4 5	NS	NS
132	3 1 2 4 5	NS	NS	NS	NS
144	3 2 1 4 5	NS	NS	NS	NS
160	3 2 4 1 5	3 4 2 1 5	NS	NS	NS
213	3 4 5 2 1	NS	NS	NS	NS
228	NS	NS	NS	NS	NS
244	3 4 5 1 2	NS	NS	NS	NS
265	3 4 5 2 1	4 3 5 2 1	NS	NS	NS
279	NS	NS	NS	NS	NS
290	3 1 2 4 5	3 2 4 1 5	NS	NS	NS
313	NS	NS	NS	NS	NS
321	3 2 5 4 1	NS	NS	NS	NS
328	3 2 4 1 5	3 4 2 1 5	NS	NS	NS
334	3 2 5 4 1	NS	NS	NS	NS
353	NS	NS	NS	NS	NS

* Treatments: (1) Moldboard Plow, (2) Disk, (3) V-blade, (4) No-till, (5) No-till.

** Non Significant (P = .05)

TABLE XII

STATISTICAL EVALUATION AND RANKING OF TREATMENTS IN PLANT AVAILABLE SOIL WATER CONTENT FOR EACH DEPTH AND DATE

Days after July 1	DEPTH 0 - 38 cm.	38 - 68.5 cm.	68.5 - 99 cm.	99 - 129.5 cm.	129.5 - 160 cm.
1984					
25	3 2 4 1 5*	NS**	NS	NS	NS
197	NS	NS	NS	NS	NS
233	3 2 1 4 5	NS	NS	NS	NS
256	NS	NS	NS	NS	NS
278	3 2 4 5 1	NS	NS	NS	NS
285	3 5 4 2 1	NS	NS	NS	NS
291	3 5 2 4 1	3 4 5 1 2	NS	NS	NS
298	5 3 4 2 1	3 5 4 1 2	NS	NS	NS
306	NS	NS	3 5 4 2 1	NS	NS
313	3 5 4 2 1	3 5 4 2 1	3 4 5 2 1	NS	NS
319	5 3 4 2 1	3 5 4 2 1	3 5 4 2 1	NS	NS
346	NS	NS	3 5 4 2 1	3 4 5 2 1	NS

* Treatments: (1) Moldboard Plow, (2) Disk, (3) V-blade, (4) No-till, (5) No-till.

** Non Significant (P = .05)

TABLE XIII

STATISTICAL EVALUATION AND RANKING OF TREATMENTS IN PLANT AVAILABLE SOIL WATER CONTENT FOR EACH DEPTH AND DATE

	DEPTH				
Days after July 1	0 - 38 cm.	38 - 68.5 cm.	68.5 - 99 cm.	99 - 129.5 cm.	129.5 - 160 cm.
1985					
39	NS**	NS	NS	NS	NS
52	NS	4 5 3 1 2*	NS	NS	NS
73	4 3 5 2 1	NS	NS	NS	NS
115	NS	NS	NS	NS	NS
189	NS	NS	NS	NS	NS
252	NS	NS	NS	NS	NS
267	NS	NS	NS	NS	NS
309	4 5 2 3 1	4 5 2 3 1	NS	NS	NS
351	4 3 5 2 1	4 5 3 2 1	NS	NS	NS

* Treatments: (1) Moldboard Plow, (2) Disk, (3) V-blade, (4) No-till, (5) No-till.

** Non Significant (P = .05)

APPENDIX B

SOIL WATER CONTENT DATA

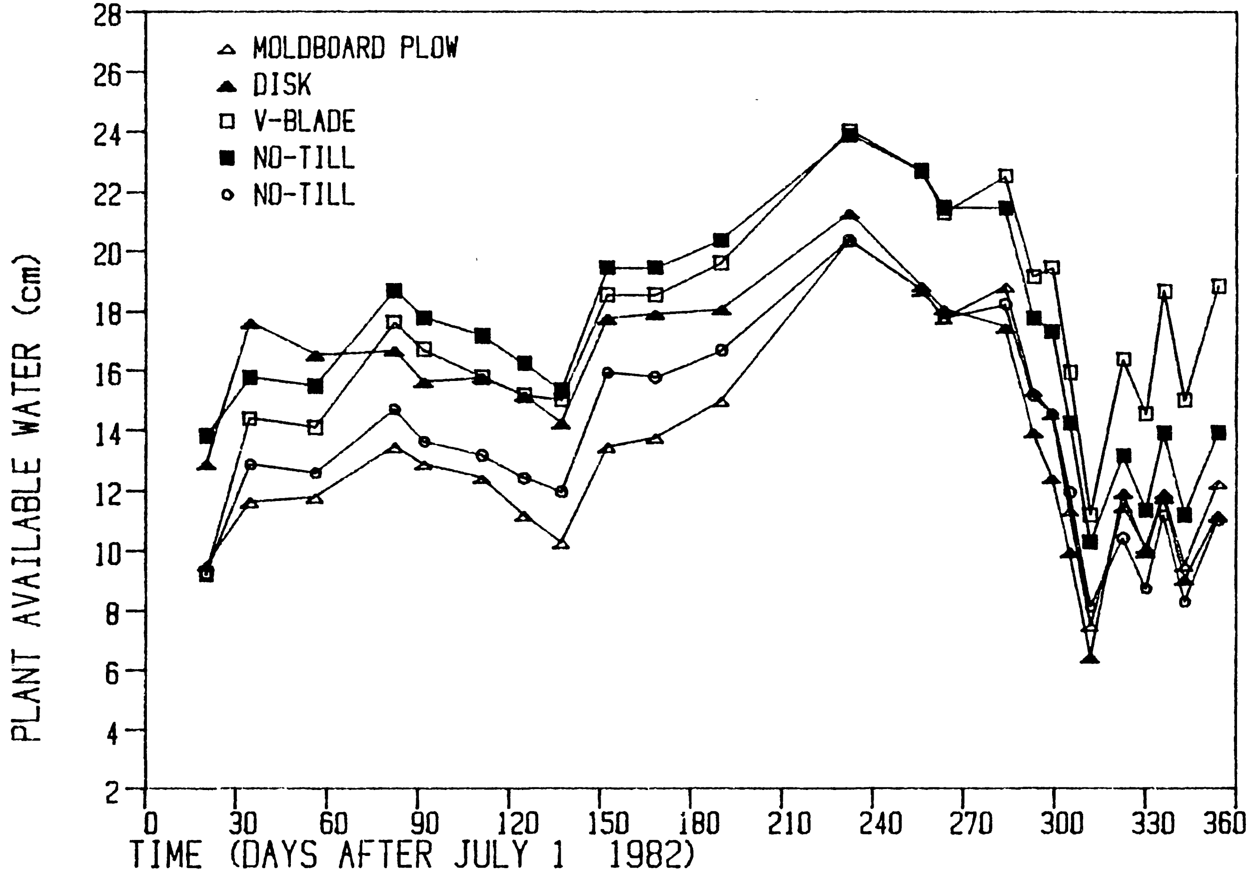

Figure 1. Plant Available Water Content of the 1.6 m Soil Profile

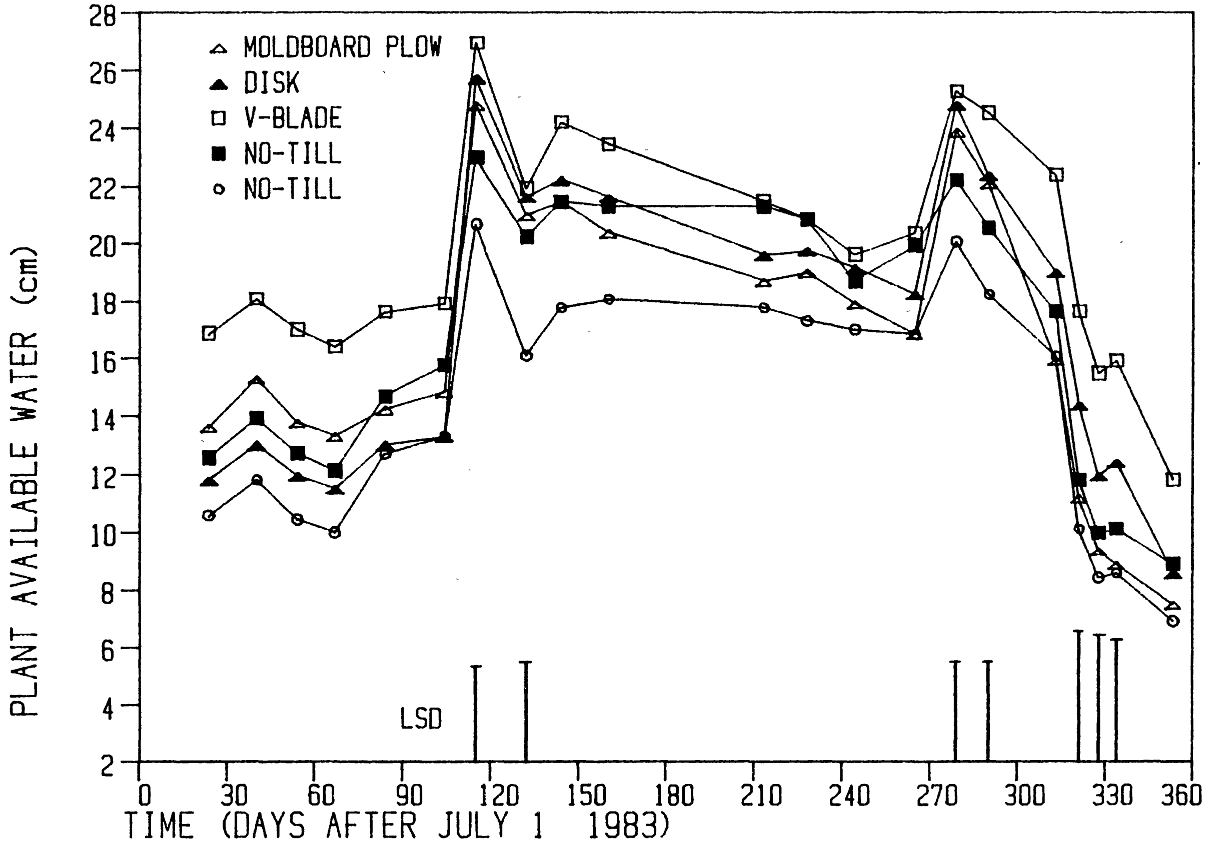

Figure 2. Plant Available Water Content of the 1.6 m Soil Profile

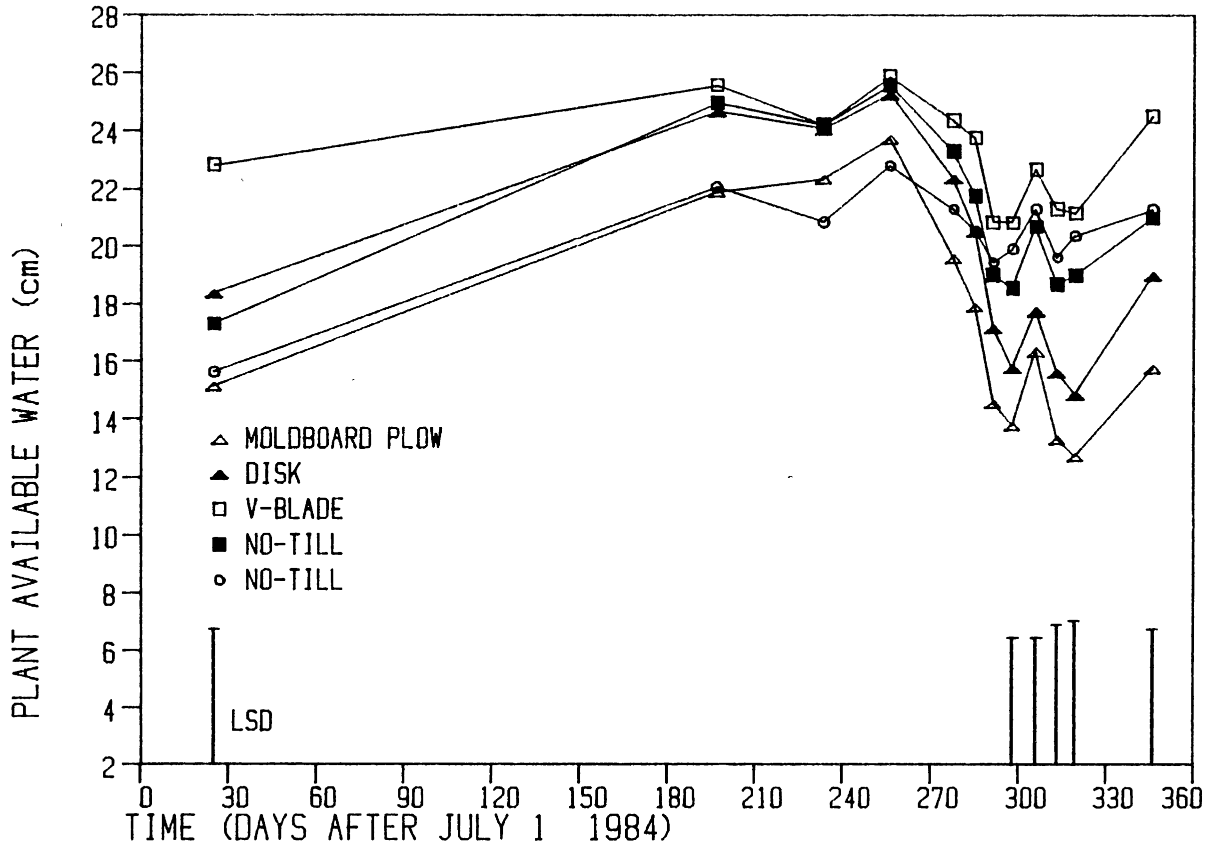

Figure 3. Plant Available Water Content of the 1.6 m Soil Profile

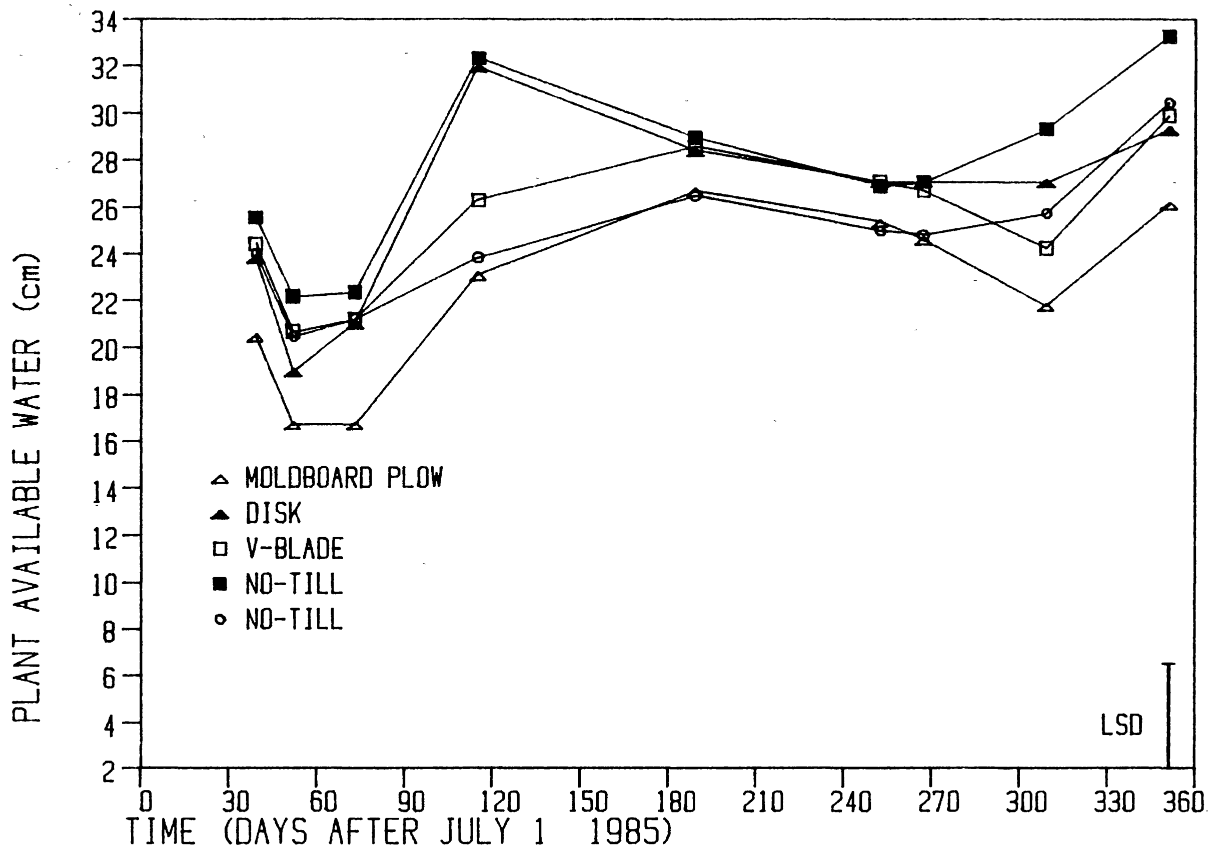

Figure 4. Plant Available Water Content of the 1.6 m Soil Profile

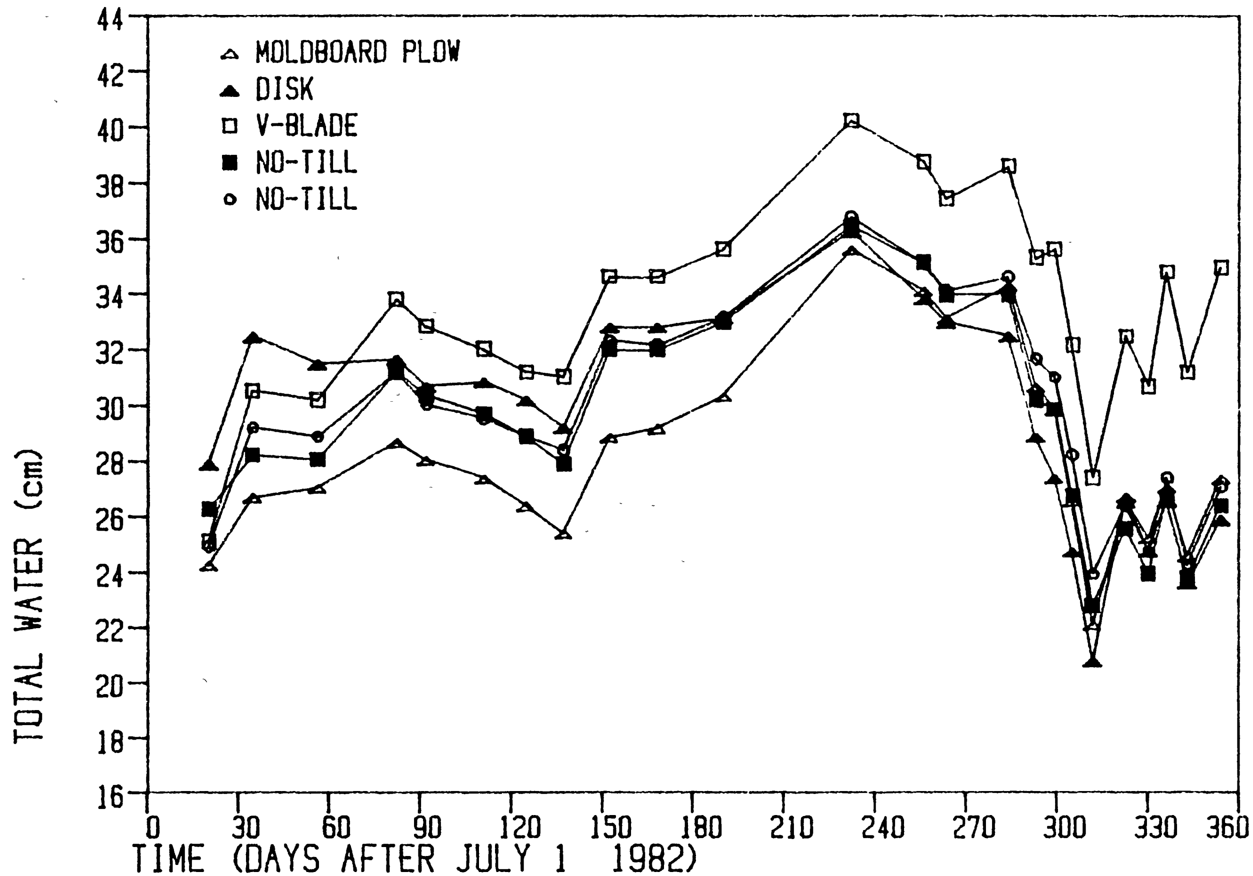

Figure 5. Total Water Content of the 1.6 m Soil Profile

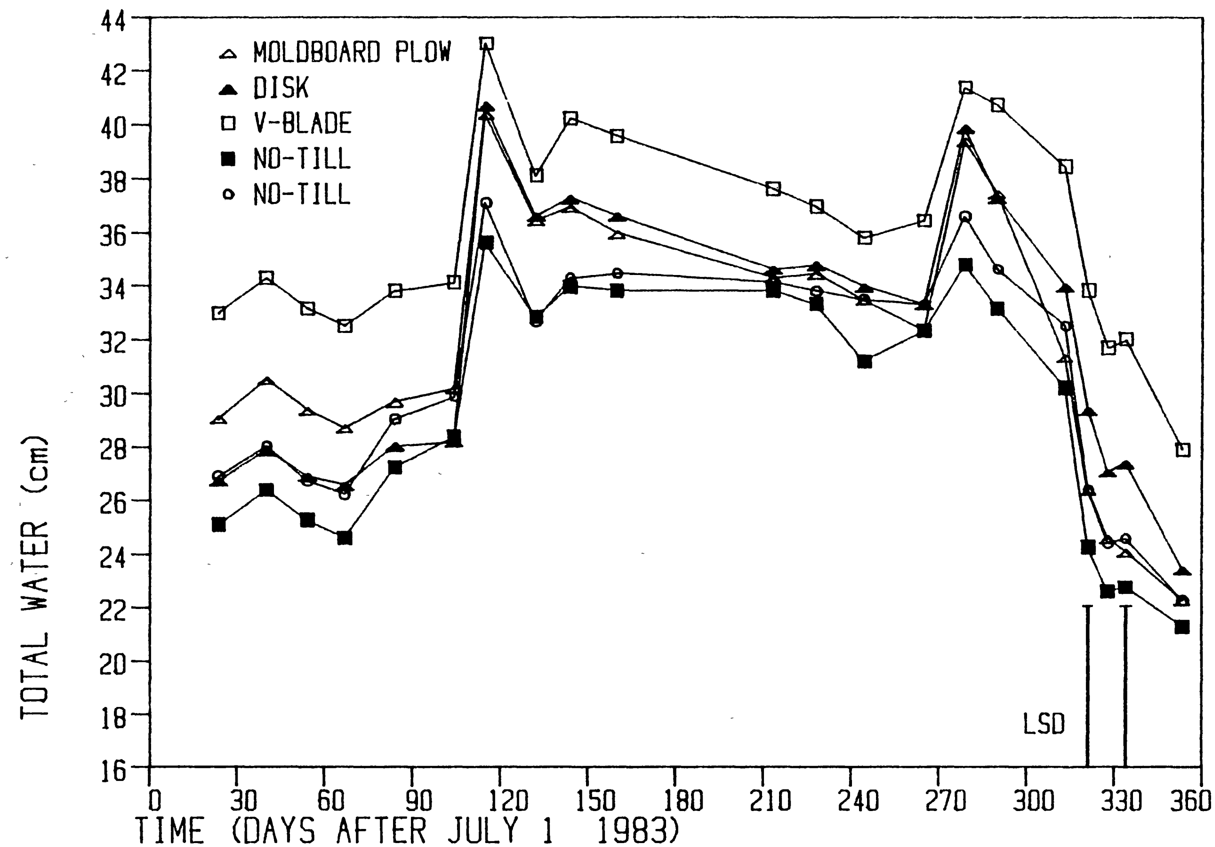

Figure 6. Total Water Content of the 1.6 m Soil Profile

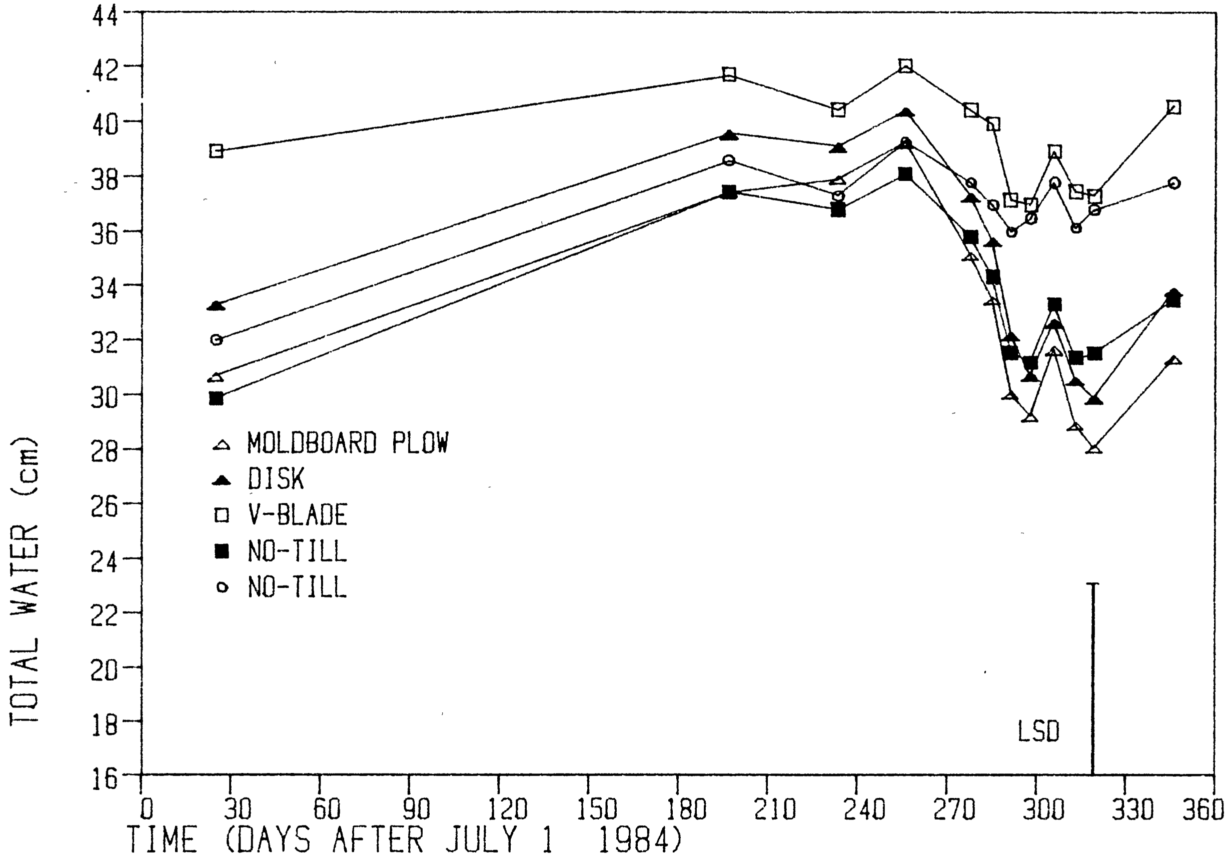

Figure 7. Total Water Content of the 1.6 m Soil Profile

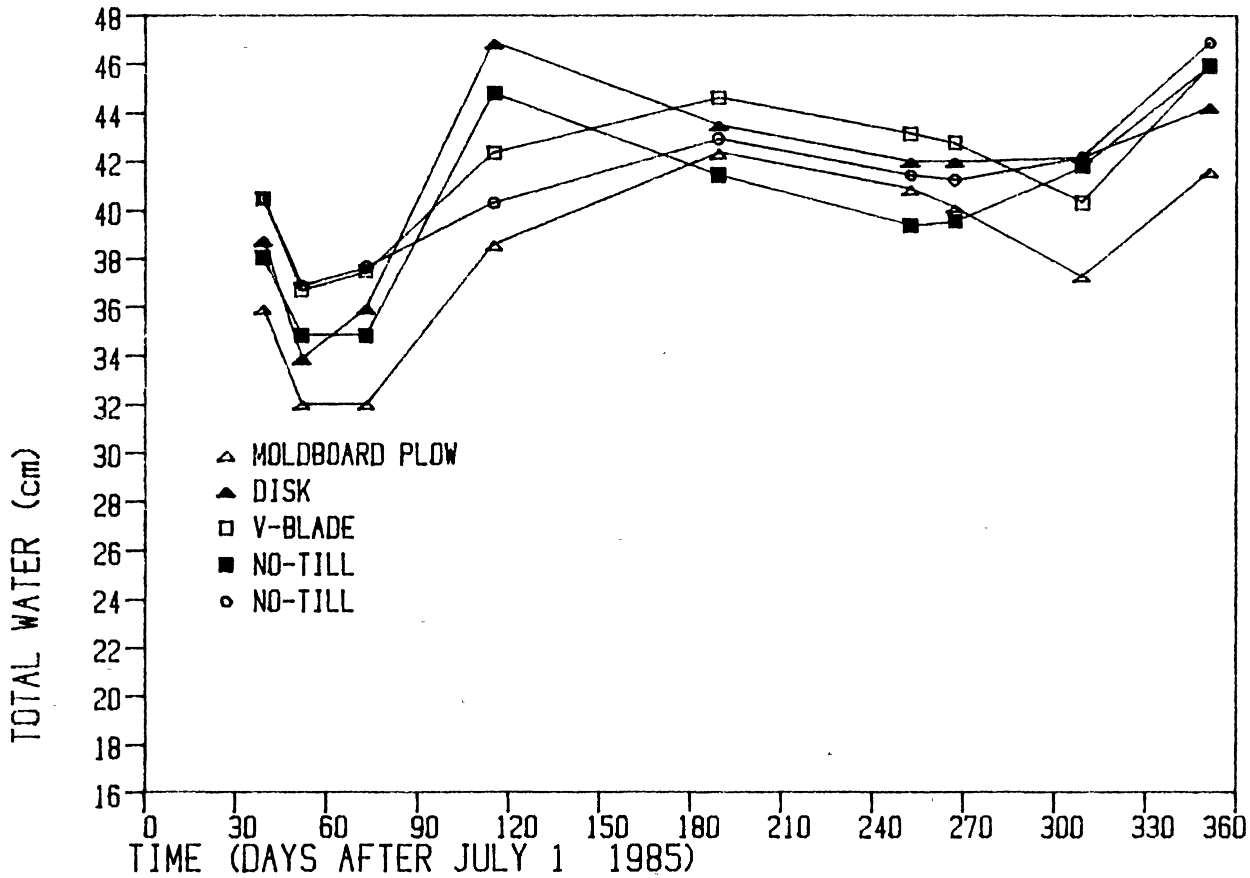

Figure 8. Total Water Content of the 1.6 m Soil Profile

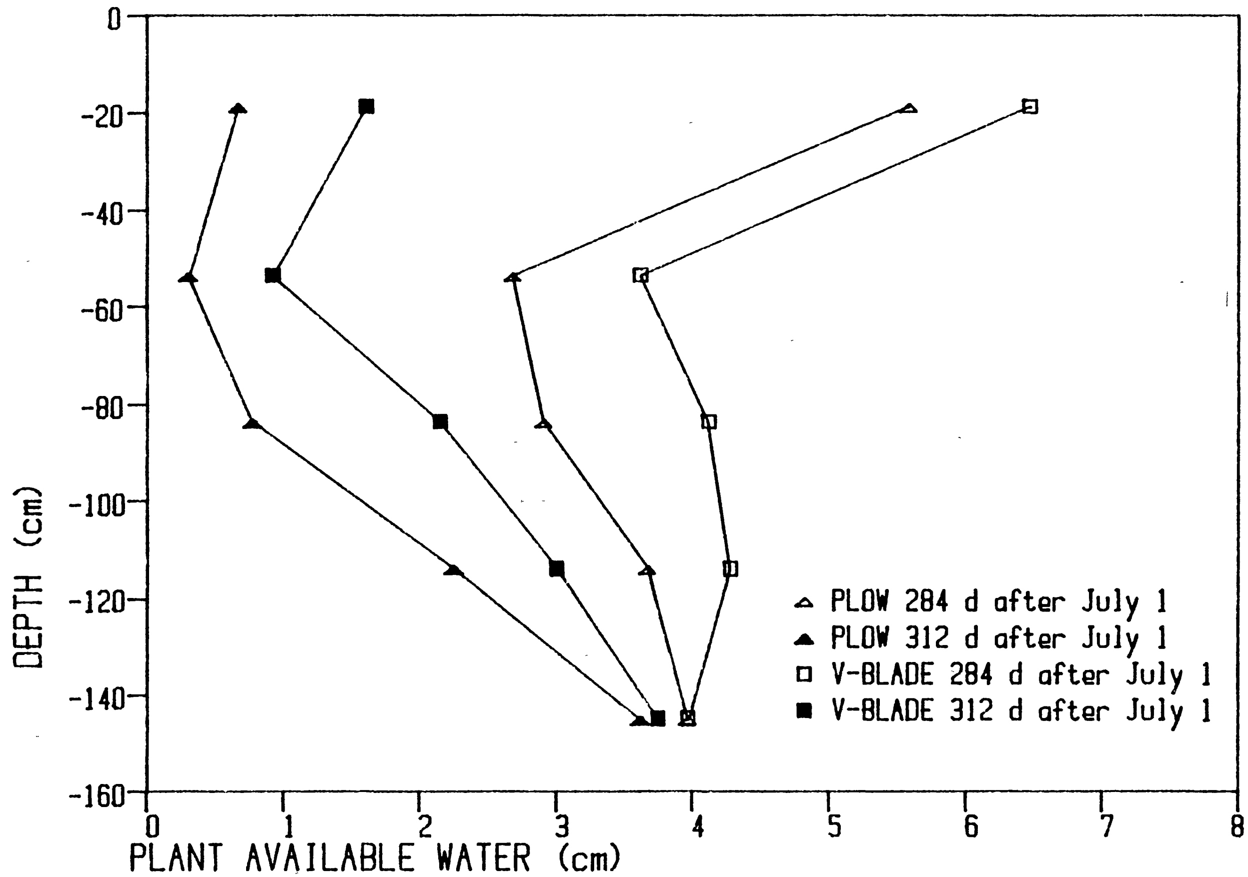

Figure 9. Changes in Plant Available Water for Moldboard Plow and V-blade Treatments by Depth over Time in 1982 between day 284 and day 312

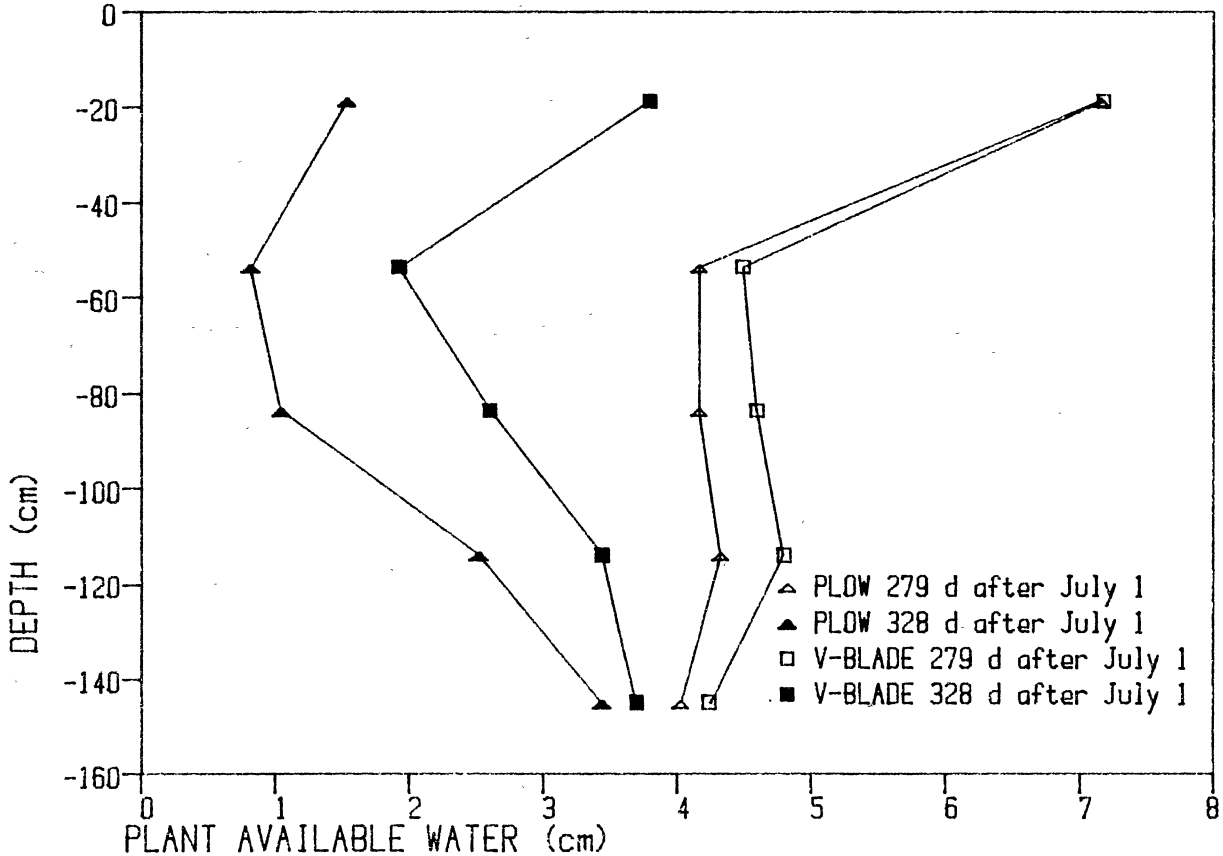

Figure 10. Changes in Plant Available Water for Moldboard Plow and V-blade Treatments by Depth over Time in 1983 between day 279 and day 328

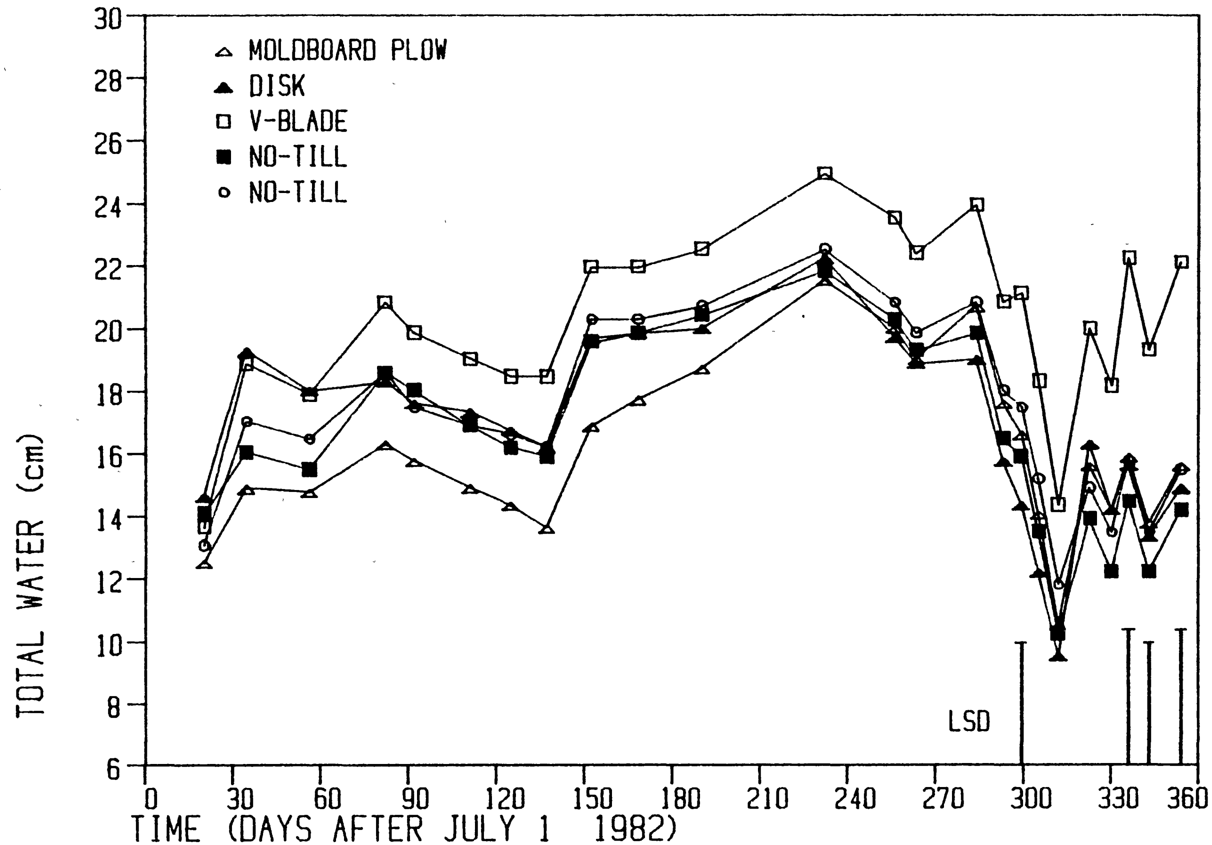

Figure 11. Total Water Content of the 1 m Soil Profile

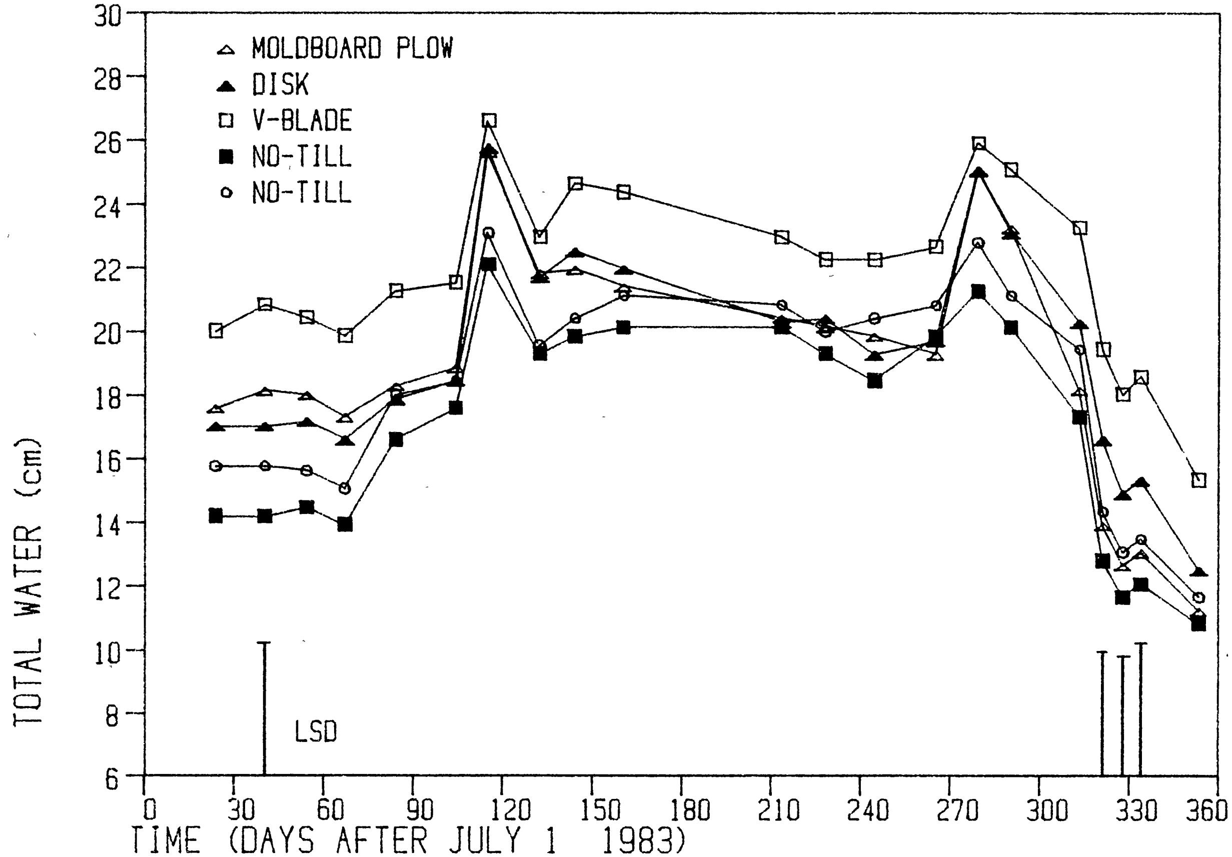

Figure 12. Total Water Content of the 1 m Soil Profile

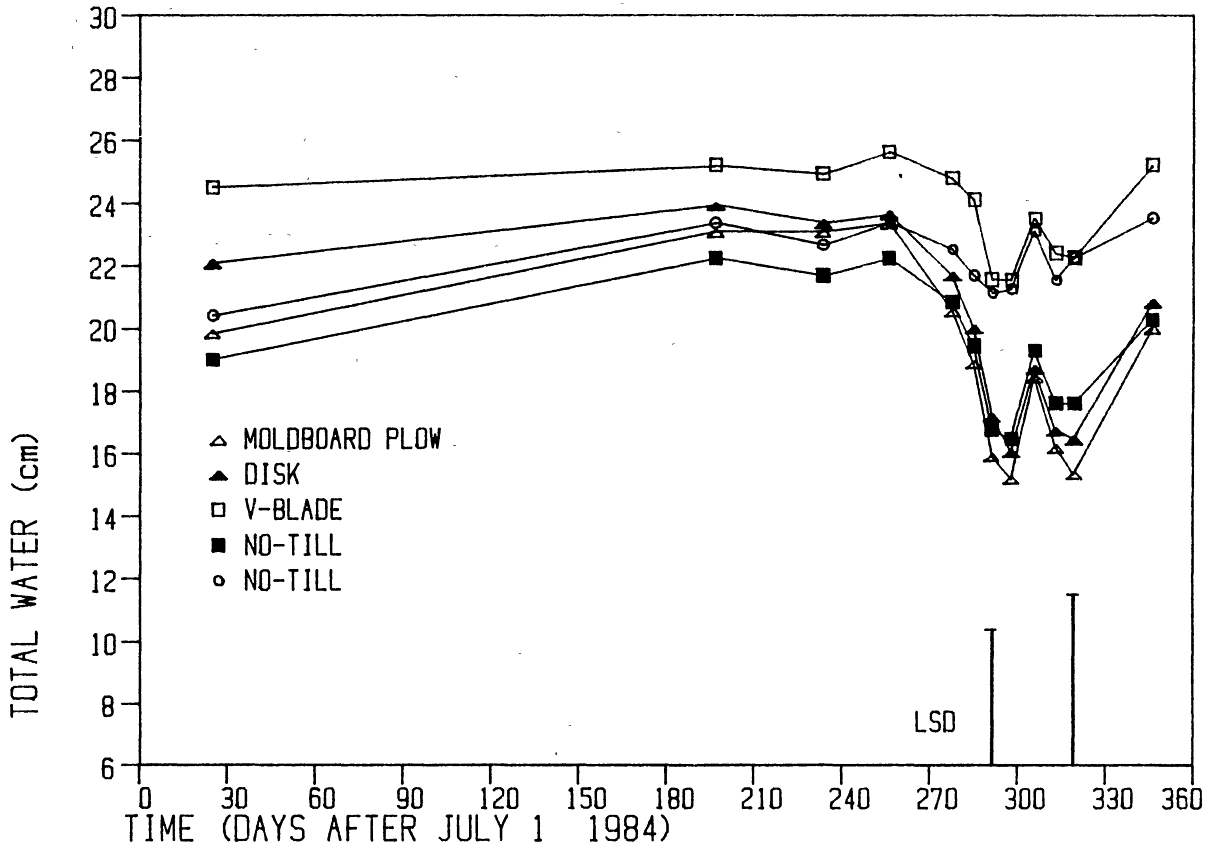

Figure 13. Total Water Content of the 1 m Soil Profile

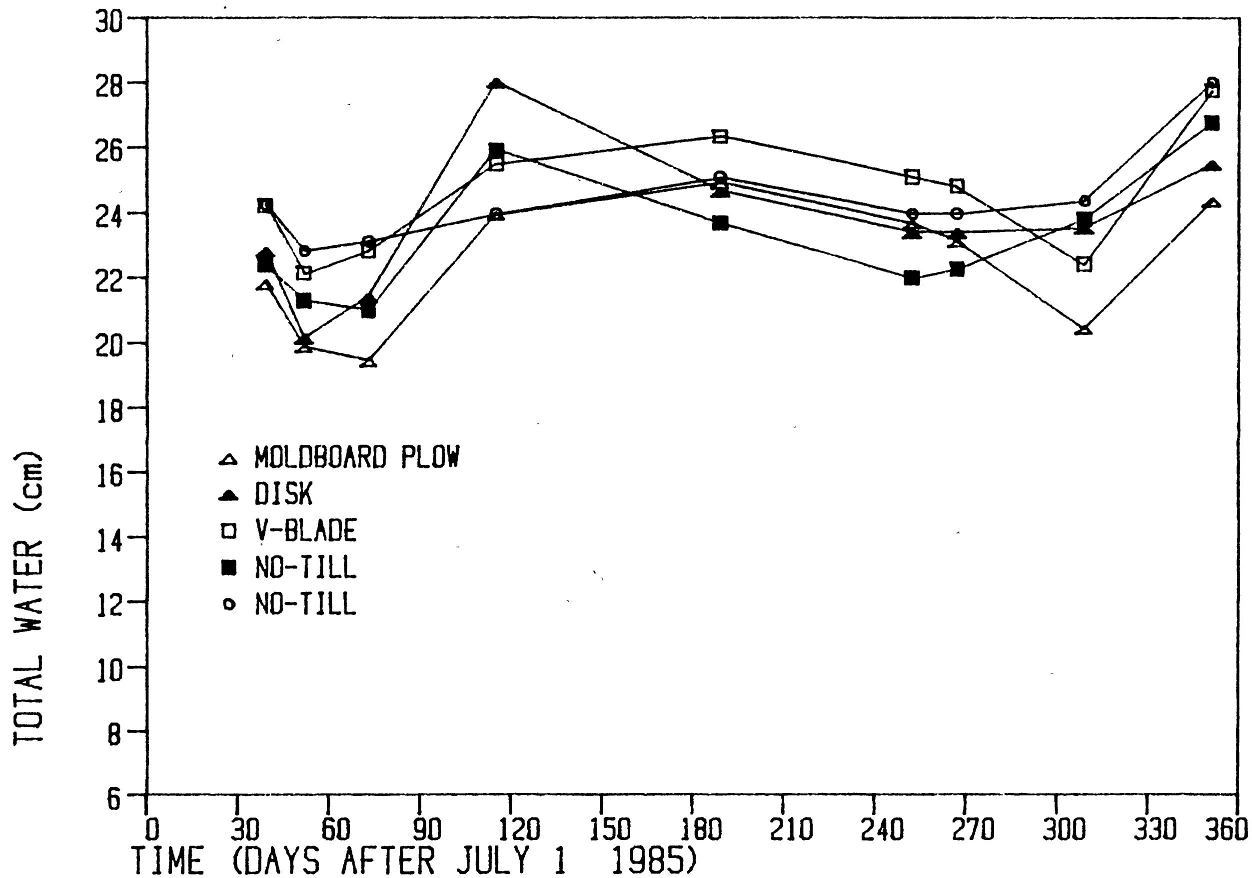

Figure 14. Total Water Content of the 1 m Soil Profile

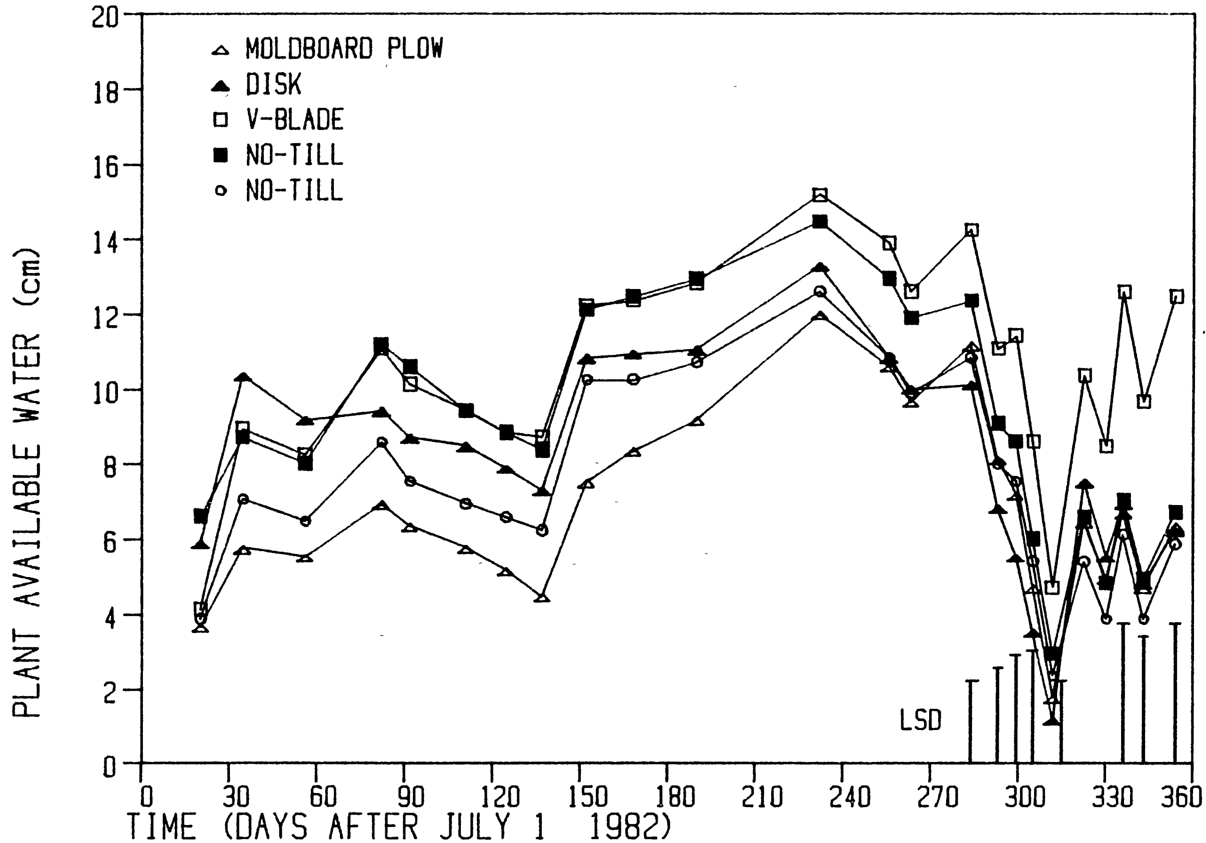

Figure 15. Plant Available Water Content of the 1 m Soil Profile

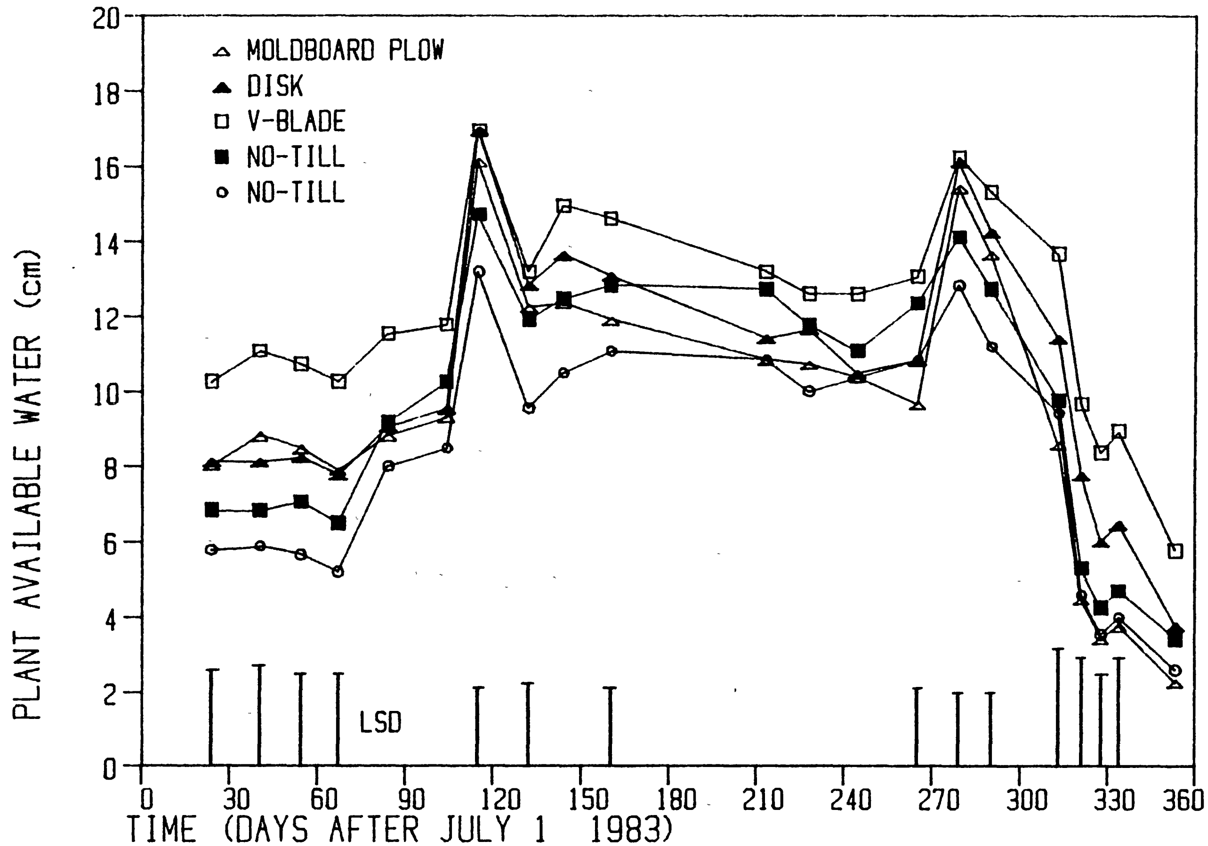

Figure 16. Plant Available Water Content of the 1 m Soil Profile

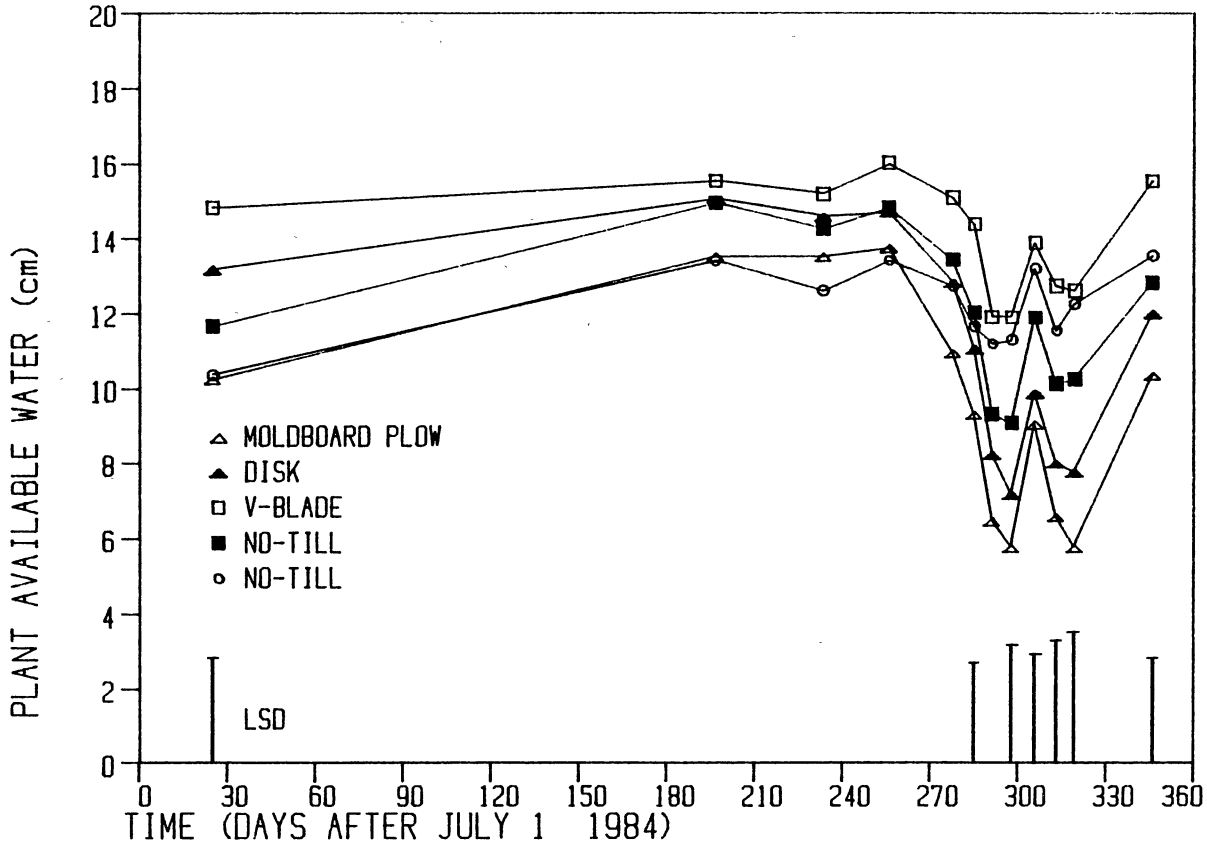

Figure 17. Plant Available Water Content of the 1 m Soil Profile

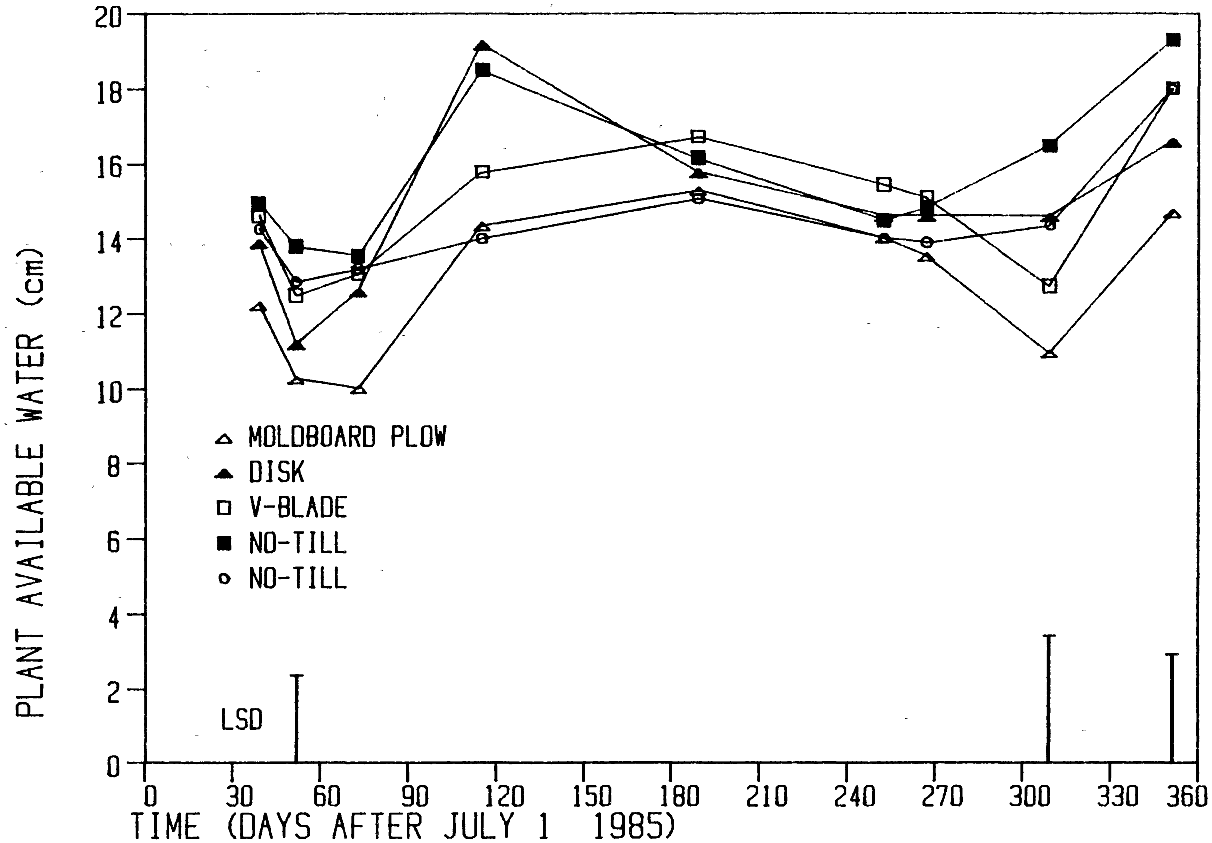

Figure 18. Plant Available Water Content of the 1 m Soil Profile

VITA

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