Soil Tillage Effect in Cotton Crop

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ABSTRACT

An experiment to study the impact of five methods of tillage on soil physical aspects and cotton growth was established in Thessaly Greece in 1996 in order to reduce inputs in the cotton crop. The methods included conventional tillage with ploughing at 25cm, reduced tillage with heavy cultivator at 20 cm, reduced with rotary cultivator at 15cm, reduced with disc harrow at 8 cm and no-tillage. Soil in reduced tilled plots had a higher bulk density, shear strength and resistance to penetration. Cotton plants grown under reduced methods of tillage had delayed emergence, reduced growth, less bolls and lower yields. At harvest, conventional tillage gave the best yield with 4 t/ha of seed cotton followed by heavy cultivator with 3.8 t/ha. The methods of rotary cultivator and disk harrow yielded much less, with 3.2 t/ha. The no-tillage plots gave 2.8 t/ha of seed cotton and were last of all.

Introduction

Cotton is the most important industrial crop in Greece, with about 400.000 ha per year. However, farmers are facing a reduced gross income due to rising production costs and static lint prices. The transition to less intensive methods of soil tillage, broadly referred as conservation tillage, is expected to reduce energy consumption and machinery costs.

Ploughing is considered the most effective technique for weed control (Porterfield and Davidson, 1974). Long-term no-tillage causes increased organic matter in the upper layer of soil and reduced soil pH, with adverse results in the activity of residual herbicides such as fluometron (Brown *et al.*, 1994). Increased rates of herbicide are required to maintain weed control comparable to conventional tillage (Brown *et al.*, 1987). Post-emergence directed foliar herbicides might be effective (Brown and Whitwell, 1985).

Cotton growth and lint yields were similar with conservation and conventional tillage in irrigated crops with satisfactory weed control (Denton and Tyler, 1997) but yields might increase in dryland crops (Wiese *et al.*, 1992) and in periods with limited rainfall (Vacek and Mutocha, 1997). Reduced tillage in Greece caused early maturity with reduced seed-cotton production (Maletos *et al.*, 1996). However, in years when quick seedbed preparation is important, rotary cultivators proved effective in producing an adequate seedbed with one pass. Conservation tillage can reduce production costs even though herbicide costs are greater with no-tillage since long-term profits are higher than with conventional tillage because of increased yield and lower machinery depreciation costs (Harman *et al.*, 1989). Apart from the economic benefits, there are long term profits associated with soil conservation. Crop residues protect soil surface from erosion (Yoo *et al.*, 1988, Denton and Tyler, 1997) while increasing the organic matter in the upper layer of the soil. Increased organic matter improves soil structure and water holding capacity while preventing soil compaction (Helms *et al.* 1997, Harman *et al.*, 1989).

Materials and methods

A randomized complete block design was used with four replicates in two sites, a silty clay field (sand 9.7%, silt 41.1%, clay 49.2%, O.M. 1.26%) and a clay field (sand 20.1%, silt 32.7%, clay 47.1%, O.M. 1.08%). Plots were 10 m in length by 6 rows at 1 m in width. Five methods of soil tillage were tested:

1. Conventional tillage. Ploughing at 25 cm, in late Autumn and two passes with a disk harrow in Spring before planting the crop.
2. Reduced tillage with heavy cultivator. One heavy cultivator pass at 20 cm in Autumn and two pre-planting disk harrow passes in Spring
3. Reduced tillage with a rotary cultivator. One rotary cultivator pass at 15 cm in Autumn and two pre-planting disk harrow passes in Spring.
4. Reduced tillage with a disk harrow. One or two disk harrow passes at 8 cm in Autumn and two pre-planting passes in Spring.
5. No-tillage. A pre-planting herbicide and direct planting over the destroyed vegetation with a conventional planting machine.

Primary tillage was on 17/12/96 and disk harrowing for seedbed preparation on 17/3/97. No-tillage plots were sprayed with 4-kg/ha glyphosate on 26/3/97. Fertilization, based on soil chemical analysis, was 90-100-350 kg of NPK on the silty clay field and 150-100-300 on the clay field. Planting with a pneumatic seeder on 18/4/97 set at 33 seeds/m of row at a depth of 5 cm. One week later, all plots were sprayed with 2kg/ha prometryne and 4kg/ha alachlor. Drip irrigation pipes

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were in every second row with stills at 1 m spacing, discharging 4 l\h.

The dry biomass of weeds was estimated on 16/1, 14/3 and 18/5, by collecting the surface mass on two random surfaces of 0.25 m_2 in each plot and oven drying for 48 hours at 72$_o$C. Soil samples were taken at two depths, 1.5-4 cm and 7.5-10 cm from each plot on 26/3, 20/4 and 8/5 and oven-dried at 105$_o$C for 48 hours for moisture determination. Samples of constant volume were taken on 20/4 for soil dry bulk density determination. The shear strength of soil was measured on each plot on 23/5 and 18/7 at depths of 5, 10 and 15 cm. The resistance of soil to penetration was assessed through three measurements taken on 17/6 and 20/7 in each plot, using a Bush soil penetrometer at 1cm intervals to a depth of 45 cm.

During emergence of the crop, the number of emerged plants was counted on 8/5, 10/5, 12/5, 16/5 and 20/5. A row of 1m length and three individual plants were marked in each plot. Measurements were made in these areas throughout the crop period. Plant height was measured on 10/6 and the number of buds and bolls on 17/7, 5/8 and 31/8. In the period from 16/7 until 5/8, the number of white flowers was registered every two days. Two hand harvests were mode on 22/9 and 18/10 in rows of 1 m of each plot. In each period, the number of harvested bolls and the weight of seed cotton and lint were measured. Seed cotton samples were analyzed for lint percent.

A multifactorial analysis of variance was applied to the data using the MSTATC statistic program.

Results and discussion

Before seedbed preparation, heavy cultivator and no-tillage plots had more weeds on 16/1 and 14/3 (Table 1). On 18/5, two months after seedbed preparation and spraying of the no-tillage plots with *glyphosate*, the differences were moderated. The reduced weed population in the conventionally tilled plots indicating the efficiency of this method to control. The most prevalent species were *Sonchus arvensis, Amaranthus retroflexus, Circium arvensis, Chenopodium album, Convolvulus arvensis, Silipum marianna, Fumaria officinalis, Veronica hederifolia, Sorgum halepense* and *Malva sp*.

Generally, soil water content was higher in the upper layer (0-4 cm) of reduced tillage plots. However, no-tillage plots were drier on 26/3, before weeds were destroyed but significant wetter at 20/4 and 8/5, after weed destruction (Table 1). Excessive of weed growth on 26/3 reduced soil water through transpiration. Surface evaporation was impeded by mulch formed when weeds were killed with herbicide on 20/4 and 8/5. Differences were not significant at greater depth (7.5-10 cm). Reduced tillage plots had higher bulk densities, greater shear strength (Table 1) and higher resistance to penetration (Fig. 1).

The conventional tillage plots had the earliest emergence and the highest final average population of 17.6 pl./m. The heavy cultivator plots came next with an average of 15 pl/m. Emergence in disk harrow and rotary cultivator plots was delayed with lower average population of 14 pl./m and 12.2 pl./m, respectively. The no-tillage came last with delayed emergence and a very poor average population of 11.6 pl./m (Table 1). One reason for this was that the surface mulch of the killed weeds impeded the operation of the common type of seeder. A high percentage of the seed was left uncovered in the planting furrow and did not emerge. Despite this, the population was close to the recommended population for Greek conditions at about 100-140.000 pl/ha.

During the vegetative stage on 10/6, plants in the conventionally tilled plots were taller followed by plants in heavy cultivator, disk harrow and rotary cultivator plots. No-tillage plots had significantly shorter plants, indicating that stress from more untilled soil had an adverse effect on their growth.

By 17/7, the crop had entered the reproductive stage. Plants in conventional tillage and heavy cultivator plots had significant more flowers and were the first to form buds and bolls (Table 2). They also had a better growth rate with taller plants. No-tillage plots were worst of all with shorter plants and delayed and reduced production of flowers, buds and bolls. At 5/8, cotton plants had almost completed their vegetative stage and continued the reproductive stage. At this stage, conventional tillage still had taller plants with the most buds. However, plants in heavy cultivator plots had more bolls while plants in rotary cultivator plots had more buds. Disk harrow and no-tillage plots had shorter plants with fewer buds and bolls. At 31/8 the number of bolls were maximum in the conventional tillage plots, followed by heavy and rotary cultivator plots with disk harrow and no-tillage plots last (Table 2). Harvesting was in two picks. On heavy cultivator plots, a higher percentage of bolls were harvested in the first pick, indicating early maturity of the crop (Table 3). However, the final boll count and the yield of conventionally tilled plots came first. Rotary cultivator and disk harrow plots had less bolls and gave significant lower yields while the no-tillage plots had the fewest bolls and the lowest yield and a higher percentage of the crop in the second pick.

There were no differences between treatments in the mean weight of bolls but the heavy cultivator gave a significant higher lint percentage (Table 3).

Conclusions

It can be concluded from these results that:

1. Conventional tillage gave the highest yield with the least weed problems.

2. Heavy cultivator gave the second best yield but the machine was unable to destroy weeds.
3. Yield was much less with rotary cultivator and disk harrow that require much less energy.
4. No-tillage gave the worse results, probably because the planter was not the suitable.

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Table 1. Dry biomass of weeds, and physical properties of the soil.

	Dry biomass of weeds(gr/m2)			Soil moisture content (% wet base)						Dry bulk density(gr/cm3)		Shear strenght (N*m)		
Depth:	(cm)			1.5-4			7.5-10			1.5-4	7.5-10	5	10	15
Date:	16/1	14/3	18/5	26/3	20/4	8/5	26/3	20/4	8/5	20/4		20/4		
CO	8.0	16.1	9.2	21.9	15.7	16.0	24.0	19.7	19.1	1.05	1.33	2.2	5.9	5.6
HC	93.8	187.6	18.9	22.6	16.2	15.9	23.8	19.6	19.3	1.10	1.36	2.5	6.5	6.4
RC	28.1	56.3	34.1	23.5	16.9	16.6	23.1	18.8	19.0	1.18	1.40	2.9	6.9	6.8
DH	65.1	130.3	35.4	24.2	16.7	16.3	23.4	18.5	18.5	1.08	1.46	3.0	6.3	6.5
NT	144.7	289.4	67.3	22.1	17.7	18.8	22.5	18.7	18.6	1.30	1.47	3.7	7.0	6.8
$LSD_{0.05}$	34.3	68.6	11.2	1.7	1.2	1.1	-	-	-	0.12	0.08	0.9	-	-
CV%	48.9	48.9	32.9	7.0	6.7	6.1	5.0	5.1	4.8	10.05	5.47	31.7	21.6	19.4

CO = Conventional, HC = Heavy cultivator, RC = Rotary cultivator, DH = Disk harrow, NT = No-tillage.

Table 2. Emergence and development of the cotton crop.

	Emergence (pl./m)					Plants height (cm)				D.P.F.* (fl/m)	Bolls (bolls/m)		
Date	8/5	10/5	12/5	16/5	20/5	10/6	17/7	5/8	31/8		17/7	5/8	31/8
CO	10.8	13.7	15.2	16.1	17.6	15.8	78.7	88.8	95.1	3.3	24.5	81.0	96.2
HC	9.9	11.9	13.4	14.8	15.0	12.7	72.0	81.7	85.6	3.3	25.8	83.5	89.5
RC	7.1	8.9	10.1	11.3	12.3	11.3	63.8	76.4	83.4	2.2	17.3	68.7	86.2
DH	7.9	10.0	11.7	13.0	14.0	11.3	60.8	72.0	77.1	2.5	16.7	67.3	81.2
NT	5.9	7.8	8.8	9.1	11.6	10.0	53.0	69.4	77.6	1.7	9.2	56.7	75.5
$LSD_{0.05}$	1.5	1.5	1.7	2.0	1.8	2.4	5.4	6.6	6.9	0.35	3.8	10.4	12.9
CV%	17.7	14.1	14.1	14.8	12.2	18.9	8.0	8.2	8.0	13.1	19.6	14.2	14.6

CO = Conventional, HC = Heavy cultivator, RC = Rotary cultivator, DH = Disk harrow, NT = No-tillage.

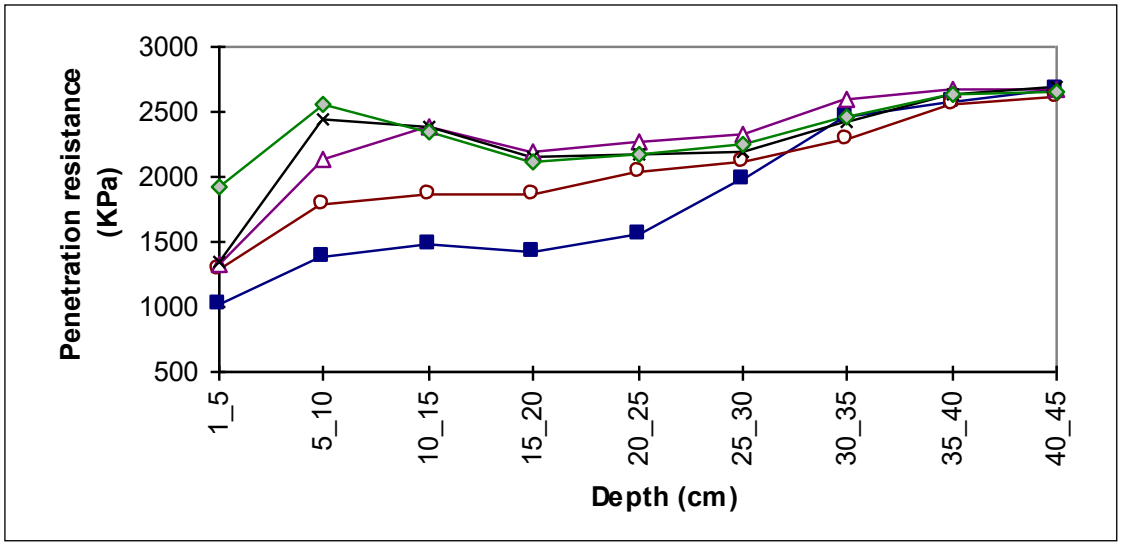
* D.P.F. = Mean daily productivity of white flowers in the period from 16/7 until 30/7.

Table 3. Yield characteristics of cotton.

	Number of harvested bolls bolls/m (% total)			Yield (t/ha)			Bolls mean weight	Lint percent
	1st hand	2nd hand	Total	1st hand	2nd hand	Total	(gr/ball)	(%)
CO	90.2(82.5)	18.6(17.5)	108.8	3.35	0.66	4.01	3.68	36.50
HC	84.8(85.9)	13.9(14)	98.7	3.30	0.50	3.80	3.86	39.47
RC	69.2(76.7)	21.1(23.3)	90.4	2.53	0.71	3.24	3.58	37.92
DH	62.13(71)	25.9(29)	88.0	2.39	0.88	3.27	3.72	38.09
NT	56.5(68.1)	26.4(31.9)	82.9	1.88	0.99	2.87	3.49	36.29
$LSD_{0.05}$	10.67	6.87	12.3	0.42	0.29	0.48	-	1.54
CV%	14.24	31.44	12.66	15.31	38.22	13.62	9.22	3.97

CO = Conventional, HC = Heavy cultivator, RC = Rotary cultivator, DH = Disk harrow, NT = No-tillage.

Figure 1. Soil penetration resistance at 17/6. Means for the five methods of tillage in the two fields.



■ - Conventional, -o- Heavy cultivator, -Δ- Rotary cultivator, -×- Disk harrow, -◊- No-tillage