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The Effects of Soil Tillage on Stem Development of Pepper plant

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Abstract: The research was conducted at clay loam in an unheated greenhouse (glass) located at GOP University, Horticulture Department, Tokat, Turkey. The effects of soil tillage method on penetration resistance and on development of the pepper stem grown inside a greenhouse were investigated. The pepper stem was studied under four tillage systems with three replication. Tillage managements were Y1 ploughing, Y2 ploughing and rotary tillage, Y3 rotary tillage and, Control or no tillage. The pepper seedlings were grown in torf multi pot then transferred in the greenhouse when pepper plant have been 6 or 7 leaves at May 6. Stem and total plant length, stem diameter, leaves number and stem weight were determined at five measurement. The effect of tillage method on penetration resistance and on stem development were significant ($p<0.01$). Primary tillage and fallowing secondary tillage using a rotary tillage supplied lower penetration resistance. Therefore, better stem growth in stem diameter, stem and leaves fresh weight and leaves number were obtained under this tillage method.

Key words: Pepper stem, soil tillage, stem length, stem diameter, penetration resistance

INTRODUCTION

Alleviation of soil compaction is a reason to till soil. However, tillage equipment also causes compaction. Machinery application for greenhouse grown agricultural production has been advanced for decades. Consequently, soil under cultivation for agricultural production exposed to soil compaction which is defined as increasing in bulk density due to increasing equipment pass. Ideal bulk density for silty clay loam, loam, silt, clay loam and sandy loam soil is less than 1.40 g cm^{-3}. Bulk density higher than 1.60 g cm^{-3} may affect root growth and bulk density higher than 1.75 g cm^{-3} may restrict root growth (USDA NACS soil quality test kid guide). Threshold level at which soil strength hinders root elongation varies with plant species, but usually ranges between 2000 and 3000 kPa and the peak value is 1800 kPa (Chen *et al*., 2004). Increased soil bulk density reduce the air filled porosity, the air diffusivity and the air permeability as well as the hydraulic conductivity. Lipiec and Stepniewski (1995) expressed that evidence is presented to indicate interactive relationships between the amount of soil compaction, root growth, soil water and soil aeration status and nutrient supply and uptake by plants. Nutrients and organic matter accumulate near the soil surface after ploughless tillage and in the long run the soil PH decline (Rasmussen, 1999).

Studies on influence of seed bed condition on the emergence and development of pepper seedlings revealed that seed bed compaction delayed and reduced seedling emergence. High soil moisture content and high nutrient content reduce the severity of soil compaction on seedling root and shoot development. Chartzoulakis and Klapaki (2000) observed a significant reduction in pepper seedling growth with salinities higher than 10 μm. Plant growth parameters such as plant height, total leaf area and dry weight were significantly ($p<0.05$) reduced at salinities higher than 25 μm NaCl both hybrids. Roots had the highest Na+ concentration compared to leaves, which increased with increasing salinity, while Cl- in leaves was much higher than Na+ potassium concentration of plant tissues was less affected than Na+ and Cl- by salinity increase. Leskovar *et al.* (1990) observed that an increase in root growth over 56 days was linear for transplants while in direct seeded pepper plant root growth had a lag phase of approximately 14 days, with a sharp increase thereafter. The coordination of growth between root and shoot changed after fruit set only in transplants, which indicates that transplants exhibited a greater fruit sink demand and fruit production than seeded plants. Shumin *et al.* (2000) indicate that a photo selective film with a R : FR ratio of 2.2 (which corresponds to 75% light transmission) caused about 20% height reduction in chrysanthemum and 30% height reduction in bell pepper after 4 weeks of treatment. Non- destructive mechanical

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measurements on leaves and fruit in sweet pepper in greenhouse were investigated. In two experiments, plant growth was not affected by mechanical measurements. In a third experiment, the use of mechanical measurement reduced stem elongation, leaf area and yield. Retardion of stem growth was accompanied by increased dry matter content and changed nutrient content of stems. Obviously, thigmomorphogenetic effects of mechanical measurements are difficult to predict (Kläring, 1999). Nielsen and Veierskov (1988) found that a close relationship between growth of roots and vegetative top parts indicated that a functional equilibrium between root and top exists in pepper plants. This relationships changed as plants entered the generative growth phase. However, the change was independent of the development of fruits.

Tillage treatments are expected to affect soil response and crop yield (Comia *et al.*, 1994; Larney and Bullock, 1994; Shafiq *et al.*, 1994; Stewart and Vyn, 1994 and Tessier *et al.*, 1997). Erbach *et al.* (1992) evaluated the effect of the following tillage treatments: no-tillage, chisel plow, moldboard plow and para plow systems on three soils (poorly drained, medium and fine textured) in Iowa. Results showed that all tillage tools reduced bulk density and cone penetration resistance to the depth of tillage. However, after planting, only the soil tilled with the para plow remained less dense than before tillage.

Turkey known as an agricultural country has a variable climate and soil properties that allow growing a broad range of agricultural products. Recently, concerns about maintaining soil productivity and quality have forced researchers to search for alternative solutions to replace conventional moldboard plough based soil tillage systems. Soil management decisions are often aimed at improving and maintaining soil productivity. However, conventional tillage increases soil compaction and erosion. Tillage is well known to accelerate the loss of soil organic matter by increasing biological oxidation and often by increasing soil erosion. Erdem *et al.* (2006) studied the effect of tillage method on root development of pepper plant and reported that there was significant ($p<0.05$) effect of soil tillage method on the growth of primary root length and diameter, total root length and weight. Primary tillage using a moldboard plough and fallowing a secondary tillage using a rotary tillage supplied lower penetration resistance. Therefore, better root growth in terms of root distribution, primary root diameter and fresh root weight was obtained under this tillage method. There is limited information regarding the effect of tillage method on pepper plant growth in the dry land areas of Turkey. To investigate improved cropping practices of the dry regions of Turkey that exhibit a semi-arid climate pattern (Annual average rainfall ranging from 250 to 500 mm) a series of tillage systems were initiated. The objective of this study is to investigate the effect of soil tillage method on penetration resistance and stem development of pepper grown inside a greenhouse.

MATERIALS AND METHODS

Greenhouse: Experiments were conducted in an unheated greenhouse (glass) located at GOP University, Horticulture Department, Tokat, Turkey from May 16 through November 31, 2004. Total size of the 12 experimental plots used for this study was 58.8 m^{-2}. The size of the greenhouse was approximately 12 m wide and 35 m long with natural ventilation. The only plants growing in the greenhouse were 240 potted pepper seedlings used in the experiment.

Dry-bulb temperature and humidity of the greenhouse were measured at pre-determined period of time using a load heated cell and stored within a computer. The readings of temperature and humidity for each period were averaged. The average temperature was 24.91°C ranging from 14.49 to 39.22 °C and the average humidity was % 33.64 ranging from 22.4 to 78.5% inside the greenhouse in May. Average temperature was 24.55°C and maximum temperature was 46.4°C during the early growth period.

In the experimental field, the analyses of soil physical and chemical properties were carried out before the experiment (before soil tillage application) for each plot in order to characterize soil uniformity between the plots. Particle size analysis was done based on the hydrometer method (Gee and Bouder, 1986). Moisture content, bulk densities, penetration resistance for each plot were measured before the experiment. A 100 cm^{-3} cylindrical sampler was used to collect undisturbed soil samples. Soil samples were taken randomly for each plot from 0-10, 10-20 and 20-30 cm depths. Soil samples were used for both moisture content and bulk density determinations. Standard gravimetric method was used for moisture content determination.

Penetration resistance measurements were taken with a hand pushing penetrometer (Eijelkamp, 1990) having maximum measurement range of 5 000 kPa. Points exceeded 5 000 kPa of PR were considered as missing data values in later depths. The penetrometer consists of a handle, a compression bar with a compression helical spring, a recording pen, a card controller, helix bar with its support and a conic penetration type. The handle is used to apply the proper penetration force for insertion. During penetration resistance measurement, the compression bar compresses the helical spring. The spring deflection under this force is also calibrated to obtain the cone indexes. At the same time, the helix bar rotates the card control roller with a constant rotation. The card control roller pulls the recording card that is tightened in the card support with a recording pen. Therefore, during the measurement process, recording pen records data on a scaled paper. The data for each 5 cm depth were compiled and individual values were averaged for each 10 cm depth increment to a depth of 30 cm. Data was converted in to the cone indexes using the calibration curve of the penetrometer. Values of penetration resistance of 0-10, 10-20 and 20-30 cm depths were averaged.

Pepper seedling dimensions were measured before the experiment. The measurements of 60 pepper seedlings were taken and average of 60 measurements of primary root length, secondary root length, total root length and primary root diameter were obtained (Table 1).

Moisture contents, bulk densities, penetration resistances, primary and secondary root lengths, total root lengths, primary root diameters and root weights of pepper plants for each plot were measured at five times during the growth period. The first measurements were done when first flower opened, which was 47 day after planting. The second measurements were done at first fruit harvesting, which was 76 day after planting. The other three measurements were taken at 109th day (the third measurements), 144th day (the fourth measurements) and 173rd day (the last measurements) after planting.

The pepper seedling was grown in a potted torf medium, then transferred inside a greenhouse when pepper plants had 6-7 leaves in May 6.8 kg da^{-1} DAP and 22 kg da^{-1} ammonium sulfate were applied based on the soil analysis results before the seedling drilling. Drip irrigation pipe was installed through each row with a 70 cm row space. The space of pepper in row was 35 cm. Two pepper roots from each plot were taken from soil by loosening the soil using a shovel for each measurement. For precise measurements of stem and total plant length and, stem diameter, a digital compass was used. The pepper stems were weighted by an electronic balance. Leaves were counted for each plant at each plot.

Soil tillage treatments: In the study, Y1 ploughing, Y2 ploughing + rotary tillage, Y3 rotary tillage and no tillage (control) were applied as soil tillage treatments (Table 2). Soil tillage methods were applied as complete randomized blocks design with three replications. Therefore, total 12 plots with dimension 1.4×3.5 m were included in the experiment. A two wheel 7.5 KW tractor which has a single axle was used as a power source of soil tillage.

Data analysis: Statistical analysis (ANOVA) was applied to penetration resistance and moisture content data in order to determine significance of difference between the plots. Same procedure was applied in order to figure out the effect of tillage method on penetration resistance and pepper growth. A randomized complete block design was applied with three replications. The statistical inferences were made at a 0.01 and 0.05 level of significance.

Table 1: Mean dimensions of pepper seedling

Measurements	Mean	Minimum	Maximum	SD[a]	CV[b]
Primary root length	33.89	25.18	41.82	3.06	9.02
Secondary root length	69.89	53.00	79.18	5.78	8.27
Total root length	103.78	92.00	119.00	4.38	4.22
Primary root diameter	2.06	1.06	3.00	0.23	10.95
Stem length	33.89	25.15	41.82	3.15	9.31
Total plant length	137.67	117.70	169.87	8.88	6.45

[a]Standard deviation, [b]Coefficient of variation

Table 2: Working depths of the tillage systems; Y1: Ploughing, Y2: Ploughing + Rotary tillage, Y3: Rotary tillage and Control: No-till

Treatment	Tillage equipment	Working depth (mm)
Y1	Moldboard Plough	125
Y2	Moldboard Plough+Rotary tillage	125
Y3	Rotary Cultivator	65
Control	No-till	-

RESULTS AND DISCUSSION

Preliminary field tests were conducted to characterize soil physical and chemical properties of experimental field. Soil analysis results (Table 3) suggested that field was silty clay loam.

In addition to soil analysis, initial tests were conducted to determine moisture content and penetration resistance of each treatment (Table 4). There was no significant difference in moisture content between the treatments at all depths. Statistical analyses showed that while there was no significant difference at 10-20 cm and 20-30 cm depths, there was a significant difference ($p<0.05$) in penetration resistance between the treatments at 0-10 cm depth. The lowest mean penetration resistance was obtained as 0.756 MPa with control treatment while the highest penetration resistance was obtained with Y3 treatment at 0-10 cm depth.

The effect of soil tillage method on penetration resistance: To investigate the effects of different soil tillage method: Y1 ploughing, Y2 ploughing + rotary tillage, Y3 rotary tillage and no tillage (control) were applied with three replications as soil tillage treatments. The effects of soil tillage methods on penetration resistance were significant ($p<0.01$) at 0-10 cm depth while there were no significant effects of tillage methods at 10-20 cm and 20-30 cm depths. Each treatment fell in different group based on Duncan test (Table 5).

Table 3: Soil physical and chemical properties of the greenhouse

Parameter	Level (%)
Loam	38.25
Clay	28.42
Silt	33.33
Organic matter	1.3
Lime	12.9
Total saline	0.044
Total phosphorous	6.18
PH	7.94

Table 4: Mean moisture content and penetration resistance of the tillage systems; Y1: Ploughing, Y2: Ploughing + Rotary tillage, Y3: Rotary tillage and Control: No-till

Treatments	Soil profile (cm)	Moisture content (%)	Penetration resistance (Mpa)
Y1	0-10	4.02	1.256
	10-20	9.56	2.678
	20-30	11.86	3.022
Y2	0-10	3.34	1.589
	10-20	8.61	2.233
	20-30	11.96	2.711
Y3	0-10	3.27	1.722
	10-20	10.16	2.189
	20-30	11.79	2.633
Control	0-10	7.21	0.756
	10-20	9.73	2.667
	20-30	14.25	2.356

Based on LSD tests, all treatments fall in different group. These preliminary trials provided basis for the investigations

Table 5: Penetration resistance Duncan ($p<0.01$) of the tillage systems; Y1: Ploughing, Y2: Ploughing + Rotary tillage, Y3: Rotary tillage and Control: No-till (letters a, c, ab and bc represent the group categories of Duncan test)

	Soil profile (cm)		
Treatment	10	20	30
Y1	1.33^{bc}	2.26	2.48
Y2	1.09^{ab}	2.1	2.32
Y3	0.88^{a}	2.25	2.31
Control	1.43^{c}	1.8	2.11

Table 6: Penetration resistance measurements (1: before planting, 2: 47 days after, 3: 76 days after, 4: 109 days after, 5: 144 days after and 6: 173 days after planting) for the tillage systems; Y1: Ploughing, Y2: Ploughing + Rotary tillage, Y3: Rotary tillage and Control: No-till

	Mean penetration resistance (stdev), Mpa		
Measurement	Depth l (10 cm)	Depth ll (20 cm)	Depth lll (30 cm)
Y1			
1	1.25 (0.57)	2.68 (0.38)	3.02 (1.19)
2	2.19 (0.37)	3.33 (0.92)	3.15 (1.22)
3	1.01 (0.14)	2.02 (0.80)	2.71 (0.70)
4	1.63 (0.29)	2.37 (0.55)	2.34 (0.47)
5	0.46 (0.18)	1.23 (0.50)	1.42 (0.52)
6	0.91(0.54)	1.92 (0.42)	2.26 (0.66)
Y2			
1	1.59 (1.29)	2.23 (0.60)	2.71 (0.30)
2	2.40 (0.99)	2.68 (0.74)	2.87 (1.37)
3	0.99 (0.30)	2.18 (0.88)	2.61 (0.86)
4	0.47 (0.31)	1.45 (0.75)	1.73 (0.47)
5	1.04 (0.05)	1.81 (0.98)	2.10 (0.36)
6	1.17 (0.85)	2.24 (1.29)	1.90 (0.74)
Y3			
1	1.72 (0.76)	2.19 (0.30)	2.63 (0.89)
2	1.54 (0.32)	2.70 (0.75)	2.69 (1.03)
3	1.59 (0.66)	1.99 (0.73)	2.13 (0.12)
4	1.67 (0.43)	2.52 (0.46)	2.25 (0.37)
5	1.04 (0.52)	2.28 (1.15)	2.02 (0.95)
6	0.73 (0.10)	1.83 (0.52)	2.13 (0.47)
Control			
1	0.76 (0.22)	2.67 (0.38)	2.35 (0.40)
2	1.18 (0.43)	2.54 (0.55)	2.67 (1.02)
3	0.98 (0.44)	1.31 (0.31)	2.16 (0.93)
4	1.12 (0.48)	1.21 (0.17)	1.69 (0.54)
5	0.68 (0.13)	1.30 (0.20)	1.69 (0.51)
6	1.22 (0.54)	1.79 (0.47)	2.11 (0.51)

Penetration resistances measured after soil tillage application and after planting at five times during the growth period were given in Table 6. The first measurements were done when first flower opened, which was 47 day after planting. The second measurements were done at first fruit harvesting, which was 76 day after planting. The other three measurements were taken at 109th day (the third measurements), 144 th day (the fourth measurements) and 173rd day (the last measurements) after planting.

Control treatment had the lowest mean penetration resistance for all treatments. After soil tillage, Y1 treatment had the lowest mean penetration resistance while the highest penetration resistance was obtained with Y3 treatment at 0-10 cm depth. After 47 days from planting, penetration resistance increased due to irrigation management, mechanical weed control and root growth for all treatment. Y1 treatment had the lowest penetration resistance at the third measurement. But the lowest penetration resistance was obtained with Y3 treatment (rotary tiller) and the highest penetration resistance was obtained with control treatment at 0-10 cm depth in last measurement.

The effect of soil tillage method on stem and total plant length development: Stem and total plant lengths of pepper plant for each treatment were measured at five times during the growth period. The first measurement was done when first flower opened, which was 47 day after planting. The second measurement was done at first fruit harvesting, which was 76 day after planting. The third, the fourth and the fifth measurements were taken 109 days after planting, 144 after planting and 173 days after planting, respectively. First flowering appeared 50 days after planting. The first fruit harvest was done 75 days after planting. Mean values of stem and total plant length measurements were shown in Fig. 1, 2.

The effect of tillage method on stem length was significant ($p<0.01$) at the first (first flowering) and the second measurements. However, there was no significant effect of tillage method at other measurements. Stem length was highest at the first measurement in Y3 treatment. The soil tillage method using only rotary

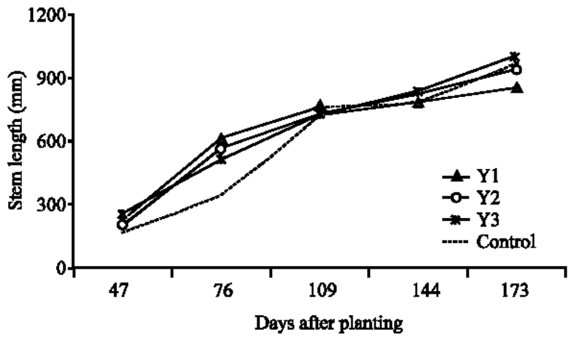

Fig. 1: Mean stem lengths for the tillage systems; Y1: Ploughing, Y2: Ploughing + Rotary tillage, Y3: Rotary tillage and control: No-till

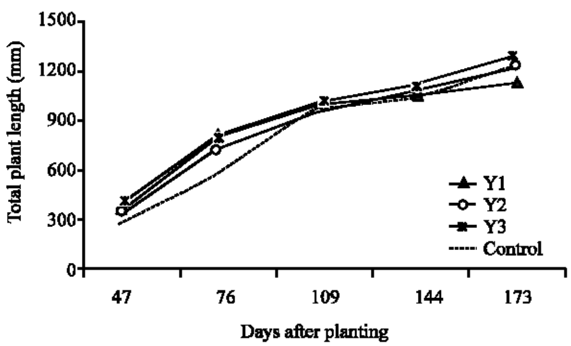

Fig. 2: Mean total plant lengths for the tillage systems; Y1: Ploughing, Y2: Ploughing + Rotary tillage, Y3: Rotary tillage and control: No-till

cultivator supplied better soil condition at beginning for the first measurement. There was a rapid growth in stem length in Y1, Y2 and Y3 treatments at the first and the second measurement due to higher air temperature. The lowest penetration resistance was obtained with the control treatment both before and after soil tillage (Table 6). Stem length slowly increased in treatment comparing to other soil tillage method Fig. 1). Stem length in Y1 treatment rapidly increased at the second and the third measurement while the lowest penetration resistance value was obtained in Y1 treatment except control treatment at the first measurement. Y1 and control treatment was shown different trend at all measurements. Y1 and Y2 treatments supplied similar increasing stem length until the third measurement. Lower penetration resistance after soil tillage due to deeper tillage depth in Y1 and Y2 treatment supplied these results. The highest stem growth in stem length was observed in Y3 treatment at the last measurement. Arisli (2004) observed that there was a correlation between stem length and yield of pepper plant.

The effect of tillage method on total plant length was significant ($p<0.01$) at the first and the second measurement. There was a rapid growth in total plant length between the first (first flowering) and the second (first harvest) measurements in Y1, Y2 and Y3 treatments. There was a similar trend in Y2 and Y3 treatments at all measurements. However, the highest total plant growth was observed in Y3 treatment at the first, third, fourth and the fifth measurements. The highest penetration resistance at 0-10 cm soil depth was observed in Y3 treatment at the first measurement (right after soil tillage). There was a lower penetration resistance at 0-10 cm depth in Y3 treatment at the first measurement. Control treatment had the lowest total plant length at the first, the second and the fourth measurements. Total plant length was the lowest at the fifth measurement in Y1 treatment.

The effect of soil tillage method on development of stem diameter: The effect of tillage method was significant ($p<0.05$) on stem diameter at all measurements. Y3 treatment had the highest stem diameter at the first and the third measurements (Fig. 3). There was similar growth trend in Y3 and control treatment between the first and the third measurements while there was similar growth trend in Y2 and control treatment between the third and the fifth measurements. Stem diameter in Y1, Y2 and Y3 treatments showed similar growth trend at the second and the third measurements due to different soil tillage treatment. Control treatment supplied the lowest stem diameter at all measurements. The highest stem diameter in Y2 treatment was observed at the fourth and the fifth measurements.

The effect of soil tillage method on stem and leaves fresh weight: The Effect of tillage method was significant ($p<0.05$) on stem and leaves fresh weight between the second and the fifth measurements. After the second measurement (first fruit harvest), stem and leaves fresh weight rapidly increased in all treatments (Fig. 4). Fresh stem and leaves weight in Y1 and Y3 treatment showed similar trend between the first and the second measurements. However Y2 treatment showed approximately linear trend between the second and the fourth measurements.

The highest stem and leaves fresh weight was obtained in Y2 treatment at the fourth and the fifth measurements. Increasing fresh stem and leaves weight between the third and the fifth measurements was due to stem diameter. Control treatment supplied the smallest stem and leaves weight at the first, the second, the third and the fourth measurements however stem and leaves fresh weight at the last measurement (173 days after

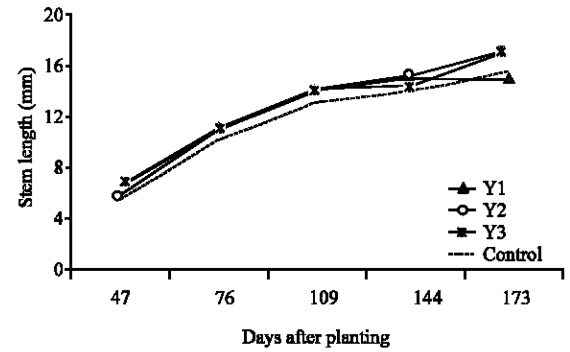

Fig. 3: Mean stem diameter for the tillage systems; Y1: Ploughing, Y2: Ploughing + Rotary tillage, Y3: Rotary tillage and Control: No-till

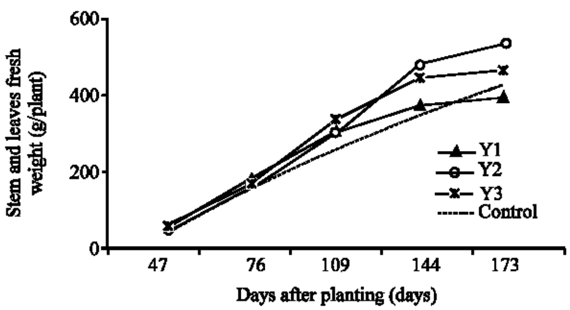

Fig. 4: Mean stem and leaves fresh weight for the tillage systems; Y1: Ploughing, Y2: Ploughing + Rotary tillage, Y3: Rotary tillage and Control: No-till

planting) was the lowest in Y1 treatment. Y1 treatment at the last measurement supplied the lowest stem length. There was a similar trend in plant growth for all treatments at the fourth and the fifth measurement.

The effect of soil tillage method on leaves number: The effect of tillage method was significant ($p<0.05$) on leaves number between the second and the fifth measurements. After the second measurement (first fruit harvest), leaves number rapidly increased in all treatments Fig. 5). Leaves number in Y1, Y2 and Y3 treatment showed similar trend between the second and the fourth measurements. The highest leaves number was obtained in Y3 treatment at the first and the third measurements. The highest leaves number was obtained in Y1 treatment at the second measurement. Y2 treatment supplied the highest leaves number at the fourth and the fifth measurements. Increasing leaves number in Y1, Y2 and Y3 treatment was due to stem and leaves fresh weight between the first and the fourth measurements. Control treatment supplied the

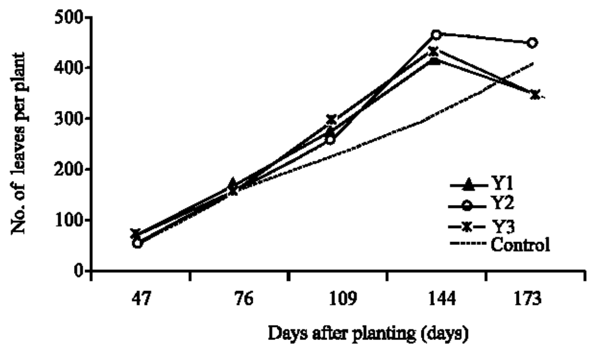

Fig. 5: Number of leaves per plant for the tillage systems; Y1: Ploughing, Y2: Ploughing + Rotary tillage, Y3: Rotary tillage and control: No-till

lowest leaves number at the first, the second, the third and the fourth measurements; however, leaves number at last measurement (173 days after planting) was the lowest in Y1 treatment.

Y1 treatment at last measurement supplied the lowest stem length and stem and leaves fresh weight. Vural *et al.* (2000) determined that lower light concentration causes more leaves and fruit yield was reduced due to reducing of flower buds growth. According to Jolliffe *et al.* (1995) the inverse of leaf weight ratio contributed significantly to row cover effects on yield variation.

The effects of soil tillage methods on plant growth were investigated at silty clay loam soil. In the investigation, Y1 ploughing, Y2 ploughing + rotary tillage, Y3 rotary tillage and no tillage (control) were applied as soil tillage treatments. Statistical results showed that the effect of tillage method on growth of stem length and total plant length ($p<0.01$) was significant at the first and the second measurements. Stem diameter was significant ($p<0.05$) at all measurements. Stem and leaves fresh weight and number of leaf were significant ($p<0.05$) between the second and the fifth measurements. Primary tillage and fallowing secondary tillage using a rotary tillage supplied lower penetration resistance. Therefore, better stem growth in stem diameter, stem and leaves fresh weight and leaves number were obtained under this tillage method. However better stem length and total plant length was observed in Y3 treatment used only rotary tillage.

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