SOIL PHYSICAL PROPERTIES AFFECTED BY SOIL PLANKING AND ROOT GROWTH OF COTTON (*GOSSYPIUM HIRSUTUM* L.)

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Abstract. In the South East Anatolia region of Turkey as well as in many parts of world, soil planker is used to level and firm the soil prior to planting of cotton (*Gossypium hirsutum* L.) at least four times. However, excessive soil compaction due to using of planker can increase soil strength and hamper root growth. This study aimed to investigate the effects of soil planking on soil physical properties, the root growth of cotton and the density of weed species. In this purpose, a field experiment was carried out at different pass numbers of a planker by using a randomized block design with three replications in 2018. The results showed that penetration resistance was increased by the pass number of the planker at 0-15 cm soil depths. While soil planking increased the soil moisture content at 15 cm soil depth, it reduced the soil temperature. Multiple passes of planker decreased the root length and dry root weight of cotton. Soil planking levels differently influenced the density of weed species. Consequently, it can be said that the planking of soil before cotton seeding may influence the root growth and the density of weed species due to changing the physical properties of soil.

Keywords: *soil packing, penetration resistance, moisture content, root length, root weight, weed density*

Introduction

The main condition for a successful cotton production is early stand of uniform seedlings that are rapidly emerging and developing. One of the key factors to accomplish this goal is a well-prepared, smoothened and firmed seedbed. The smoothening of seedbed is required for proper operation of sowing machines. Also, a firm seedbed is considered desirable for increasing emergence and seedling growth of cotton because the close contact between the soil particles and between soil and seed results in faster germination and allow more effective use of existing soil moisture (Berti et al., 2008; Tong et al., 2015). Therefore, planker are commonly used before seeding in cotton production in the South East Anatolia region of Turkey as well as in many parts of world because the using of planker can create appropriate soil condition for planted seeds by compacting soil particles to a suitable density, providing better soil-seed contact and encouraging capillary rise of water from subsoil (Tong et al., 2015; Zuo et al., 2017). However, excessive soil compaction due to using of planker can hamper root growth and decrease soil aeration, and consequently affect yield of crops. Also, it decreases infiltration rate and hydraulic conductivity by increasing bulk density and penetration resistance of soil (Nawaz et al., 2013; Singh et al., 2015).

There have been contradictory findings reported in the literature about the effects of the change of soil physical properties due to compaction on plant root growth and yield.

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The effect of the same compaction degree on root growth and plant yield depends on the crop grown, soil type, and weather conditions (Dias et al., 2015). Baker (2014) reported that the effect of soil compaction was different under dry and wet conditions. He stated that although slight compaction is beneficial but too much is detrimental to yield under dry conditions, any amount of compaction can decrease yields as a result of inhibiting root respiration due to reduced soil aeration under wet conditions.

Using of a planker before seeding results in important changes in the movement and content of heat, air, water and nutrients in the seedbed. These changes within soil significantly affect plant root growth, which has an important role in the nutrient uptake and plant growth. Although several researchers (e.g. Lipiec and Hatano, 2003; Botta et al., 2010; Sivarajan et al., 2018) determined the axle load on some soil properties and yield, most of them did not investigate the correlation between the soil physical properties caused by compaction and plant growth. Also, there is little research on using of the planker before seeding in the literature. It is important to know how much the amount of packing is necessary for smoothening of seed bed and allowing more effective use of soil moisture without hampering root growth. The work by Johnston et al. (2003) showed that a packing force of 333 N per press wheel provided adequate emergence and grain yield across varied environmental conditions. They found that the higher packing force influenced emergence in canola, and not yield. Planking level of a particular soil is affected by many factors such as moisture content, type of soil, contact pressure, number of planker passes, and working speed of planker. In South-East Anatolia region of Turkey, farmers usually pass the planker at least four times before cotton seeding. An understanding of how the planking pressure and the passes number of a planker before seeding influence the soil properties and root growth would help producers apply the optimum number of passes for given type of planker in their farm and soil conditions.

The objective of this study is to investigate the effects of different pass numbers of a planker on soil physical properties (moisture content, temperature, penetration resistance), the root growth of cotton (root length, root thickness, root dry weight) and the density of weed species. Also, the relationship between the soil physical properties caused by compaction, and soil physical properties and root growth parameters will be evaluated by correlation analysis.

Materials and methods

Experiment site description and experimental design

An experiment was conducted in a farmer's field in Diyarbakır, Turkey during cotton growing season in 2018. Experimental field (latitude: 37°55’36”N, longitude: 40°13’49’E, altitude: 630 m above sea level) is located at South-East Anatolia region of Turkey. The region is characterized by a semi-arid climate (humid winters and dry summers). The annual rainfall, based on the long-term average (1929-2017) is 483.5 mm, about 80% of which occurs from November to May. Monthly rainfalls and temperature records during the experimental year and over the long term are shown in *Figure 1*. The rainfall at experimental growing season was significantly higher than long-term average at May after cotton planting. There was no much difference between mean monthly air temperatures of long-term years and 2018. Post-planting rainfall and air temperature may be expected to influence seedling emergence and plant growth by affecting the oxygen content and temperature of soil (Berti et al., 2008).

The soil (0-20 cm) of the experimental field was clay loam with pH of 8.03, organic matter content of 15.8 g kg^{-1}, total salt of 0.08% and $CaCO_3$ of 60.8 g kg^{-1}. Average values of soil moisture content, temperature, penetration resistance at different soil depths before the application of treatments are listed in *Table 1*. The moisture content (dry basis) of soil at 10 cm depth was 10.87%. This moisture content is suitable for planking operations on a clay loam soil. The values of soil temperature and penetration resistance were within the appropriate limits for cotton emergence and seedling root growth.

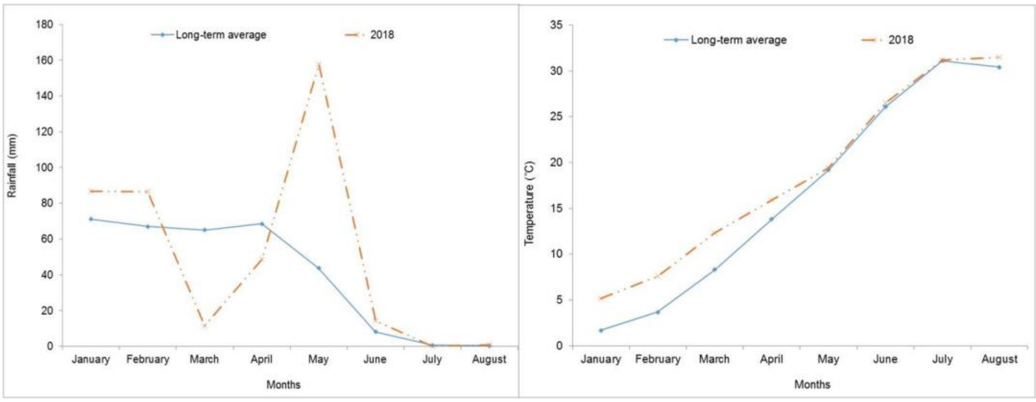

Figure 1. *Total monthly rainfall and mean temperature during experiment year*

Table 1. *Initial soil physical properties at 0-30 cm soil depths before the application of the treatments*

Soil parameters	**10 cm**		**20 cm**		**30 cm**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Moisture content (%)	10.87	2.96	44.96	2.42	74.53	10.18
Temperature (°C)	21.30	0.8	20.85	0.45	20.40	0.20
Penetration resistance (kPa)	76.33	44.64	510.60	204.60	1007.20	146.84

The previous crop at the experimental site was cotton. The seed bed preparation included chopping the post-harvest cotton stalk, an autumn moldboard plowing (20 cm) followed by cultivator to 10 cm in April after broadcasting the fertilizer (20-20-0%, N-P_2O_5-K_2O for supplying 60 kg N plus 60 kg P_2O_5 ha^{-1}). The different pass numbers of a planker (200 kg m^{-1}) were tested by using a randomized block design with three replications. Treatments included the pass numbers of planker as untreated control (planking0), soil planking by planker in one (planking1), two (planking2), three (planking3) and four (planking4) passes. Plot size was 84 m^2 (30 m x 2.8 m). The first passing of planker was applied on 15 April 2018, and other passing was applied two days after the first passing of planker. DP-499, standard cotton cultivar for the region, was planted at seed rate of 20 seeds m^{-2} by using a pneumatic precision seed drill on 18 April 2018. The sowing depth of drill was adjusted as approximately 5 cm. First hoeing was done at about 15-20 days after sowing (DAS), second and third hoeings were done at about 30 and 45 DAS to loose, aerate the soil and control the weeds two times. Also, a lister was used to apply the top-dress fertilizer (100 kg ha^{-1} ammonium nitrate) and make the furrow before the first irrigation. The first irrigation was applied by furrow irrigation methods 60 days DAS. The latter furrow irrigations were applied by 7 times at approximately 11-13 days intervals during growing season, with nearly 150 mm at each irrigation. For a given irrigation, all plots received the same amount of water.

Description of planker

The planker tested was a metal rectangular with length of 600 cm and width of 20 cm, attached to a carriage frame (*Fig. 2*). Total weight of the planker was 1200 kg, calculating the weight per meter as 200 kg m^{-1}. The calculated contact pressure of the planker was 9.81 kPa. The tractor, New Holland T6600 with 4-wheel-drive developing 119 kW, was operated at 5.4 km h^{-1} for pulling the planker.

Figure 2. *The packer tested in the experiment*

Measurements

Soil moisture content and temperature was measured by Aquaterr - Model T300 - Moisture Measurement Instrument (*Fig. 3a*). The measuring range of this Instrument was 0% d.b.–100% d.b., and the precision was ±1.5 F.S. Measurements was taken at 15 cm soil depth before the application of treatments and 5 days DAS. Soil penetration resistance were measured using a digital cone penetrometer FieldScout SC 900 (Spectrum Technologies, Aurora, IL) recording the pressure applied in Pascals every 2.5 cm, to a depth of 45 cm at the same time when soil moisture content and temperatures were measured (*Fig. 3b*). All the measurements were conducted at three random locations in each plot and the average value was taken as the result.

Figure 3. *Soil moisture and temperature measurement instrument (a) and soil penetrometer (b)*

Root samples were obtained by digging out plant roots to a depth of 30 cm at the early flowering period. A cylindrical soil corer with a 130 mm inner diameter was used to dig out the roots (*Fig. 4a*). Five plants were randomly selected in each plot to determine the root length, root thickness and root dry weight. Root thickness was recorded with a digital vernier caliper (Mitutoyo UK Ltd., Hampshire, UK) on the collar and root length was measured with a meter ruler (*Fig. 4b*). To determine dry root weight, roots was cut on collar from plant and thoroughly washed with water for devoid of soil particles. Then, roots samples were oven-dried to a constant weight at 65 °C for 72 h and weighed to determine the root weight (g).

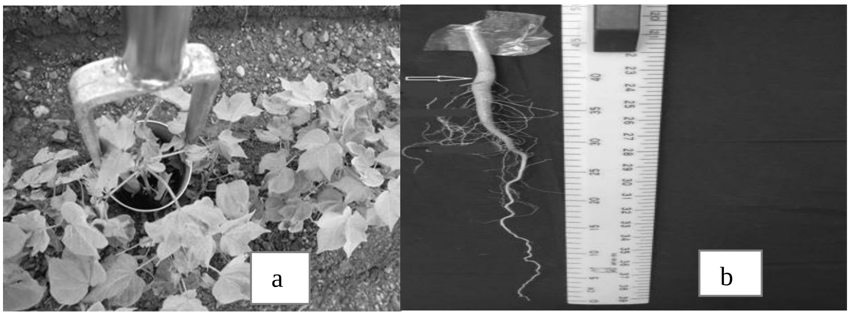

Figure 4. *The soil corer for taking root sample (a) and measurement of root length and the measurement point of root thickness (b)*

Weed species and their densities were determined by counting their numbers in 1 m^2 quadrats which were located randomly in each plot before cotton harvest. The density of weed species was calculated by taking the arithmetical mean of plots for each treatment and classified according to A-E scale used by Uremis (2005). In this scale,
a represents weed density $\geq$ 3 weeds m^{-2}
b represents 2 weeds $m^{-2} \leq$ weed density < 3 weeds m^{-2}
c represents 1 weeds $m^{-2} \leq$ weed density < 2 weeds m^{-2}
d represents 0.1 weeds $m^{-2} \leq$ weed density < 1 weeds m^{-2}
e represents weed density < 0.1 weeds m^{-2}.

Statistical analysis

Analysis of variance (ANOVA) was performed on all the measured soil properties and root growth variables using the JMP statistical software package (SAS, 2002, Cary, NC, USA). The means between treatments were compared using LSD's multiple range tests at the significance level of 0.05. Simple correlation coefficients between the soil properties and root growth in the study were calculated using correlation analysis.

Results and discussion

Soil physical properties

Soil moisture content and temperature

Figure 5 shows that the soil moisture content was affected by the passing numbers of planker five DAS. Using the planker significantly increased the soil moisture content at 15 cm soil depth. However, there was no significant difference among the pass numbers of planker. Unlike the soil moisture content, the soil temperature was the highest in the untreated plots that planker was not used. As their effects on soil moisture content, the difference among the pass numbers of planker was not statistically significant (*Fig. 5*). Soil moisture and temperature are two important soil parameters which have significantly influenced crop growth by affecting many physical and biological processes such as soil N-mineralization within the soil (Wang et al., 2006). Therefore, it is very important to know how planking practices affected the soil moisture content and temperature. Soil planking decreases air pockets in which evaporation occurs. Therefore, soil drying and heating slow down as the result of soil compaction. Also, soil compaction encourage capillary rise of water from subsoil to topsoil (Tong et al., 2015).

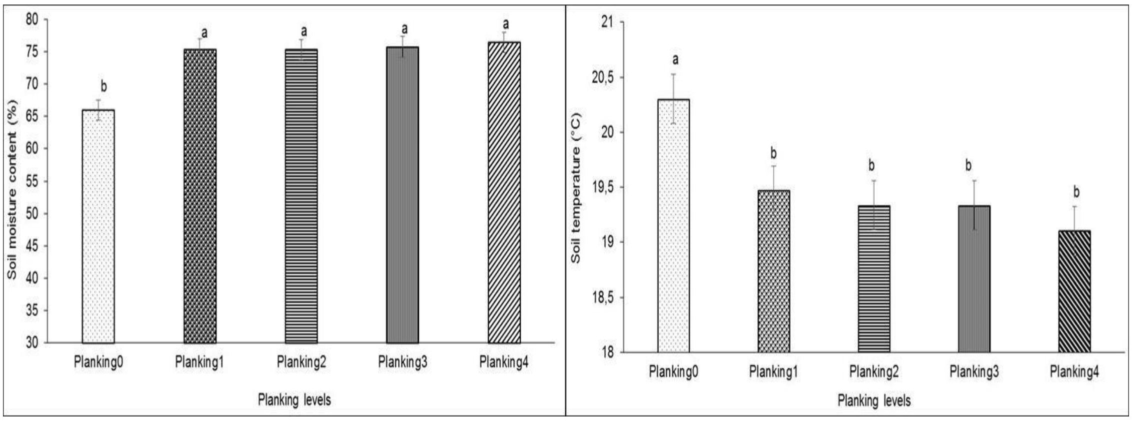

Figure 5. *The effect of different pass numbers of planker on soil moisture content and temperature at 15 cm depth. Means followed by different letters are significantly different according to LSD's multiple range test at the significance level of 0.05. Planking0: untreated control; Planking1: soil planking by planker in one pass; Planking2: soil planking by planker in two passes; Planking3: soil planking by planker in three passes; Planking4: soil planking by planker in four passes*

Soil penetration resistance

Mean values of penetration resistance at different planking levels and different soil depths are presented in *Figure 6*. While the pass number of planker significantly influenced the penetration resistance at the soil surface (~0 to 15 cm depth), there was no significant difference between treatments at subsurface layers (20-30 cm soil depths). Using the planker significantly increased the penetration resistance at the soil layers of 0-15 cm depth. The soil planking by planker in four passes (Planking4) resulted in a significantly higher soil penetration resistance which was the highest (1356.67 kPa) at 5 cm depth. There was no significant different between planking3 and planking4 at 0-10 cm soil depth. In general, it can be said that penetration resistance was linearly increased by the pass number of the planker at all soil depths of surface layer (~0 to 15 cm). However, the peak values of penetration resistance for all the pass numbers of planker were commonly obtained at 5 cm soil depth. In all treatments, the values of the penetration resistance at all soil depths were below critical compaction (2000 kPa) reported by Hamza and Anderson (2005).

Root growth parameters

Root growth is a critical component in overall plant performance during production. Main root growth parameters include: root length, root thickness, root weight, root volume, root:shoot ratio, specific root length, branching pattern, horizontal distribution, root hair density, root uptake ability, root hydraulic conductance, and root viability

(Judd et al., 2015). In this study, we could determine only root length, root thickness and root dry weight at the early flowering period.

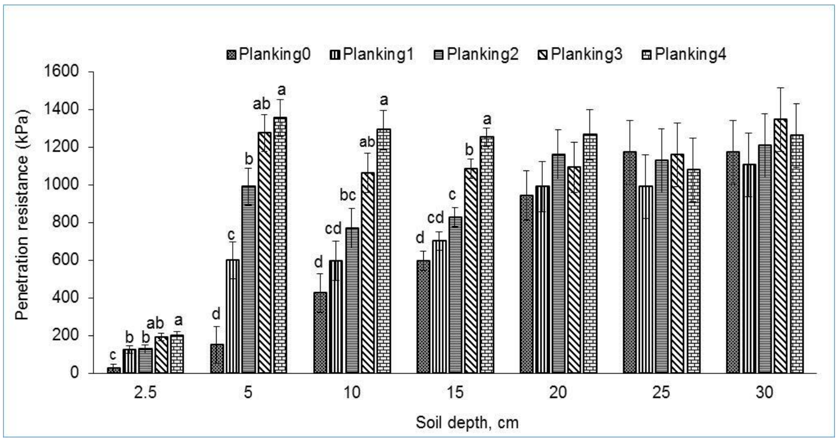

Figure 6. *The effect of different pass numbers of planker on soil penetrometer resistance at different depths. Means followed by different letters are significantly different according to LSD's multiple range test at the significance level of 0.05. Planking0: untreated control; Planking1: soil planking by planker in one pass; Planking2: soil planking by planker in two passes; Planking3: soil planking by planker in three passes; Planking4: soil planking by planker in four passes*

Figure 7 shows a picture of the characteristic growth patterns of individual roots under different soil planking levels. As seen in picture, the direction of the root growth change from vertical to horizontal immediately above the restricting layer with increasing the pass number of the planking because roots are physically restricted by a dense layer containing few pores suitable for root penetration. Several researchers (e.g. Goss and Russell, 1980; Tsegaye and Mullins, 1994) reported that soil compaction cause the root tip exert a force to deform the soil due to pores much smaller than the root diameter. They stated that this process may considerably decrease root elongation rates, increase the root diameter and change the pattern of lateral root initiation.

The root length was the highest in the Planking0 (untreated control) treatment and the difference between the Planking0 and Planking1 was not statistically significant. Increasing the pass number of planker from one to two significantly decreased cotton root length and there was no significant difference among Planking2, Planking3, Planking4 treatments (*Fig. 8*). Our results are consistent with general results from the previous researches. For example, in a recent review, Bengough et al. (2011) reported that root elongation significantly slowed in soils with penetrometer resistances in the range 800-2000 kPa. Similarly, Logsdon et al. (1987) determined that the root length of corn (Zea mays L.) seedlings decreased with increased mechanical impedance in a fine-textured soil. In our study, multiple passes of the planker significantly increased the penetration resistance at 0-15 cm soil depths as seen in *Figure 6*. This increase in penetration might decrease the root elongation. Geisler-Lee et al. (2010) reported that the higher ethylene production in roots due to a lack of oxygen in compacted soils is associated with the inhibition of elongation. Also, the decreased root elongation in compacted soil might be resulted from a decreased rate of cell division in the meristem together with a decrease in cell elongation (Bengough and Mullins, 1990).

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Figure 7. *The characteristic growth patterns of individual roots under different soil planking levels at the early flowering period. Planking0: untreated control; Planking1: soil planking by planker in one pass; Planking2: soil planking by planker in two passes; Planking3: soil planking by planker in three passes; Planking4: soil planking by planker in four passes*

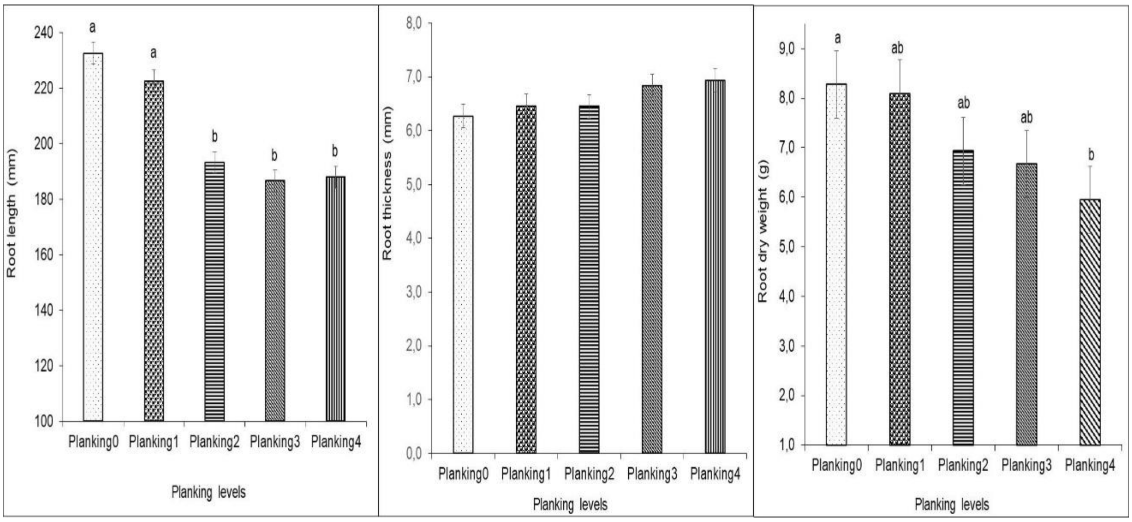

Figure 8. *The effect of different pass numbers of planker on some root growth parameters (root length, root thickness, root dry weight) at the early flowering period. Means followed by different letters are significantly different according to LSD's multiple range test at the significance level of 0.05. Planking0: untreated control; Planking1: soil planking by planker in one pass; Planking2: soil planking by planker in two passes; Planking3: soil planking by planker in three passes; Planking4: soil planking by planker in four passes*

Soil compaction can increase root thickness in order to reduce the risk of root buckling and the mechanical stress acting on the root during penetration (Kirby and Bengough, 2002; Colombi et al., 2017). Hettiaratchi et al. (1990) reported that a

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variable apex geometry's cyclic growth routine enabled plant roots to penetrate compact soil and this growth mode resulted in thickened roots. Also, Bengough and Mullins (1990) reported that soil mechanical impedance caused the increased root thickness due to increased thickness of the cortex and increases in the diameters of the outer cells as well as increases in the number of cells per unit length of root. *Figure 8* shows that the pass number of the planker did not statistically influence the root thickness. In this study, root thickness was determined on the root base near the soil surface not on root cap. No difference among treatments in terms of their effect on root thickness might be resulted from the measurement point of root thickness. Additionally, in our experiment, the highest soil penetration resistance was 1345 kPa. This resistance value might be apparently not high enough to modify root diameter. Rosolem and Foloni (2002) reported that the effect of soil compaction on root diameter depends largely on the level of penetration resistance.

The dry root weight was significantly reduced with the increased pass number of planker (*Fig. 8*). While untreated control treatment had the highest dry root biomass, the four passes of the planker resulted in the lowest dry root weight. There was significantly no difference among the other treatments. As seen in *Figure 6*, four passes of the planker significantly increased soil penetration resistance. This increase in soil penetration decreased the root length, consequently root dry weight (*Fig. 8*). Similarly to our results, several researchers found that the root dry weight was significantly reduced by soil compaction during growing of other crops including wheat (Rahman et al., 1999; Wu et al., 2018), alfalfa (Hakl et al., 2007), sugar beet and cotton (Gemtos and Lellis, 1997), soybean and common bean (Buttery et al., 1998). However, Sarto et al. (2018) determined that the root dry matter of safflower genotypes decreased as penetration resistance levels were increased from 200 to 1770 kPa. They stated that the effect of increased penetration resistance on root growth can change according to each plant species or genotype.

Correlations between soil properties and root growth parameters evaluated

The relation between the soil properties, and soil properties, seed cotton yield per plant and root growth parameters measured in the study was evaluated by Pairwise Correlation analysis. The results are shown in *Table 2*. The soil moisture content was positively correlated with the penetration resistance at 0-15 cm soil depths. This indicate that the increase in the penetration resistance due to planking significantly increase moisture content at 0-15 cm soil depth. However, these findings are contrary to the previous studies reported by several researches (e.g. Veronese et al., 2006; Van Quang et al., 2012; Lomeling and Möri Lasu, 2015) that show that penetration resistance is negatively correlated to soil moisture content. In this study, positive correlation between soil penetration resistance and moisture content can be attributed to the change in bulk density and macro pores caused by soil planking, prevention of the loss of soil moisture content and the capillary rise of water from subsoil to topsoil. The soil temperature was negatively correlated with both penetration resistance and moisture content. This indicates that the increase in soil moisture content and penetration resistance decreased the soil temperature. Lakshmi et al. (2003) reported that the changes in soil temperature affect soil moisture and vice versa. While the root thickness was positively correlated with penetration resistance at 10 cm soil depth, no significant correlations were found between the root thickness and penetration resistance at other soil depths. This indicates that increase in penetration resistance at 10 cm soil depth increased the root thickness.

Root length was positively correlated with soil temperature whereas it was negatively correlated with penetration resistances at 2.5, 5.0, 10, 15 cm soil depths and moisture content. This means that the increase in penetration resistance decreased the root length. Bengough and Mullins (1990) reported that mechanical impedance decreased the rate of root elongation because of both the decrease in the rate of cell division in the meristem, and the decrease in cell length. Negative correlation between soil moisture content and root length indicates that root length was increased with decrease in soil moisture content at 15 cm soil depth. This can be resulted from physiologically increasing root elongation to uptake available water in deeper soil zone (Serraj and Sinclair, 2002). Similarly, Malik et al. (1979) reported that the initial rate of root elongation after emergence was faster in the soil at low water content compared with that at high water content. There was no significant correlation between root length and thickness. While the root dry weight was positively correlated with soil temperature, it was not correlated with soil penetration resistance and moisture content. Besides, the root dry weight was positively correlated with the root length whereas no significant correlation was found between root dry weight and root thickness. This shows that while the root dry weight was affected by root length, effect of root thickness on root weight was not significant.

Table 2. *Correlation coefficients among parameters considered in the study*

	PR2.5[1]	PR5[1]	PR10[1]	PR15[1]	PR20[1]	PR25[1]	PR30[1]	MC[2]	T[3]	RT[4]	RL[5]
PR5	0.9011***										
PR10	0.7565**	0.8147***									
PR15	0.8392***	0.9028***	0.8720***								
PR20	0.3559ns	0.4186ns	0.6609**	0.4414ns							
PR25	0.0306ns	0.025ns	0.2417ns	0.0503ns	0.5975*						
PR30	0.1420ns	0.2941ns	0.2991ns	0.1775ns	0.4140ns	0.4645ns					
MC	0.8245**	0.7268**	0.6674**	0.6602**	0.4846ns	0.0988ns	0.2157ns				
T	-0.5754*	-0.5370*	-0.4973*	-0.4996*	0.0197ns	0.2623ns	-0.1710ns	-0.6754**			
RT	0.4524ns	0.4969ns	0.6318**	0.3880ns	0.4230ns	0.3894ns	0.4090ns	0.3510ns	-0.2690ns		
RL	-0.6249*	-0.7114**	-0.5403*	-0.6027*	-0.0268ns	0.0521ns	-0.2324ns	-0.5170*	0.7098**	-0.4391ns	
RW[6]	-0.3389ns	-0.3406ns	-0.4288ns	-0.3697ns	0.0743ns	0.1448ns	-0.0489ns	-0.2819ns	0.7138**	-0.1327ns	0.5045*

[1]PR2.5…PR30: penetration resistance at 2.5…30 cm soil depths; [2]MC: moisture content at 15 cm soil depth; [3]T: temperature at 15 cm soil depth; [4]RT: root thickness; [5]RL: root length; [6]RW: root weight; *: significant effect at 0.05 level of probability; **: significant effect at 0.01 level of probability; ***: significant effect at 0.001 level of probability; n.s: non significant effect

The density of main weed species affected by planking levels

Soil firming by planker significantly affects the species richness, composition, and diversity of weed phytocenoses because it may change soil properties and weed seed emergence. The weed community in this experiment area was composed of 13 species including Cultivated licorice (*Glycyrrhiza glabra* L.), Common mallow (*Malva neglecta* Wallr.), Field bindweed (*Convolvulus arvensis* L.), Field Mallow (*Malvella sherardiana* (L.) Jaub. & Spach), Mexican Ground-cherry (*Physalis philadelphica* Lam.), Black nightshade (*Solanum nigrum* L.), Cocklebur (*Xanthium strumarium* L.), Redroot amaranth (*Amaranthus retroflexus* L.), Johnsongrass (*Sorghum halepense* (L.) Pers.), Giradol (*Chrozophora tinctoria* (L.) Raf.), Purple nutsedge (*Cyperus rotundus* L.), Common reed (*Phragmites australis* (Cav.) Trin. ex Steud.), Bermudagrass (*Cynodon dactylon* (L.) Pers.). The weed species observed in quadrats was Black nighshade (*Solanum nigrum* L.), Bermudagrass (*Cynodon dactylon* (L) Pers.), Mexican Groundcherry (*Physalis philadelphica* Lam.), Common reed

(*Phragmites australis* (Cav.) Trin ex. Steud), Purple nutsedge (*Cyperus rotundus* L.) and Field bindweed (*Convolvulus arvensis* L.).

Figure 9 shows the effect of soil planking levels on the density of those weed species. Considering the total density of weed species, while the highest weed density was observed in untreated control (17.21 weeds m^{-2}) and the four passes of the planker (16.99 weeds m^{-2}), planking1 treatment had the lowest (4.54 weeds m^{-2}). Total weed density was 10.32 weeds m^{-2} in Planking2 and Planking3 treatments. As seen in *Figure 9*, while the increase in the pass number of planker decreased the density of the Bermudagrass and Field bindweed species, it increased density of Common reed and Purple nutsedge. Planking1 treatment had the highest density of Black Nighshade among all treatments. While the density of the Bermudagrass was > 3 plant m^{-2} at untreated control plots, no plant was observed in in quadrats at other treatments (*Fig. 9*). The two passes of planker resulted in the highest density of Mexican Ground-cherry. Density of Common reed and Purple nutsedge was observed to be more than 3 plants m^{-2} when planker was passed four times. However, the density of Purple nutsedge was the highest at the Planking2 treatment as seen in *Figure 9*. The untreated control plots had the highest density of Field bindweed.

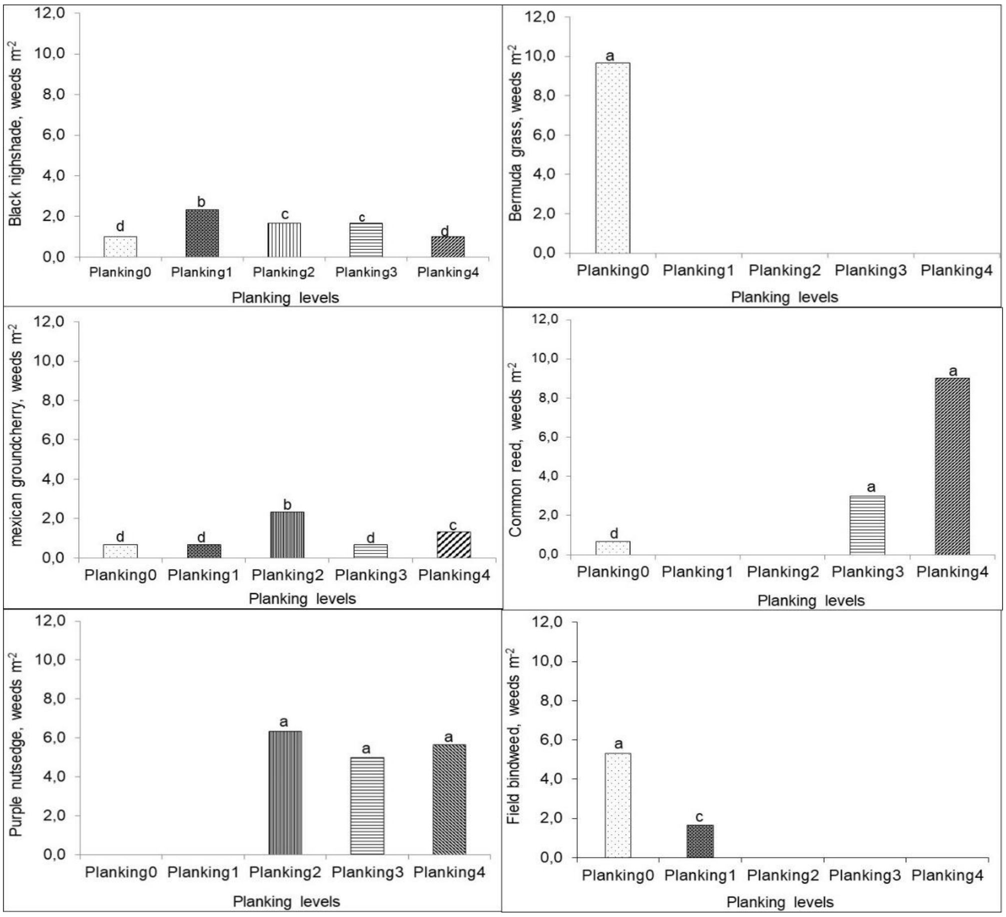

Figure 9. *The effect of different pass numbers of planker on the density of some weeds species. a:> 3 weeds m^{-2}; b: 2-3 weeds m^{-2}; c: 1-2 weeds m^{-2}; d: 0.1-1 weeds m^{-2}; e: <0.1 weeds m^{-2}. Planking0: untreated control; Planking1: soil planking by planker in one pass; Planking2: soil planking by planker in two passes; Planking3: soil planking by planker in three passes; Planking4: soil planking by planker in four passes*

The seedling emergence and growth of weed species can change in different soil conditions because of their genetic characteristics (Whitely and Dexter, 1984; Materachera et al., 1991). Therefore, the changes in soil physical and chemical properties due to soil planking may differently influence the seedling emergence and growth of weed species. Similarly, Lenssen (2009) determined that land rolling differently affected weed species after crop emergence and at harvest. Reintam and Kuht (2012) reported that the soil physical and chemical properties, and the position of weed seeds within the soil matrix play an important role in seedling emergence and seed survival.

Conclusions

In this study, the effects of soil planking levels on soil physical properties, the root growth of cotton and density of weed species was determined. The results of study revealed that the soil planking had an important effect on the root length and dry root weight of cotton for significantly changing the penetration resistance, moisture content and temperature of soil. Soil planking significantly increased the soil moisture content at 15 cm soil depth although there was no significant difference among the pass numbers of planker. Unlike moisture content, the soil temperature was the highest in the untreated plots and there was no significant difference among the pass numbers of planker. The penetration resistance was increased by the increased pass number of the planker at all soil depths of surface layer (0 to 15 cm) although soil planking had no significant effect on the penetration resistance at 20-30 cm soil depths. Multiple passes of planker significantly decreased cotton root length. Also, the dry root weight was significantly reduced with the increased pass number of planker. Correlation results indicated that while the increase in the penetration resistance due to planking significantly increased moisture content at 15 cm soil depth, it reduced soil temperature and root length. There was positive correlation between root thickness and penetration resistance at 10 cm soil depth but not other depths. Also, the density of weed species was affected by the pass number of planker. While the increase in the pass number of planker decreased the density of the Bermudagrass and Field bindweed species, it increased the density of Common reed and Purple nutsedge.

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