Asian Journal of Plant Sciences

ISSN 1682-3974

Asian Journal of Plant Sciences 7 (2): 223-227, 2008
ISSN 1682-3974

Yield of Silage Maize as Affected by Compaction Treatments at the Planting Time

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Abstract: In this study, effects of the different soil compaction treatments and tire-soil contact pressures on soil and plant properties and dry matter yield of second crop silage maize were investigated. Soil compaction was applied in the forms of the following treatments; Compaction on Furrow Surface (CFS), Compaction on Furrow Bottom (CFB), Compaction on Inter Rows (CIR) and non-compaction as a Control (C). The tire-soil contact pressures were selected as 0.025, 0.051 and 0.076 MPa control treatment was 0.0085 MPa. After planting and before harvesting; soil penetration resistance and soil bulk density were determined as soil properties at different soil compaction treatments stated above. Before and after harvesting period, as generative growth, plant stalk diameter, plant height, single plant dry weight, percentage of corncob, harvesting index and dry matter yield were determined. Soil penetration resistance values changed in the soil depth of 0-10 cm from the 0.23 to 0.45 MPa after planting and from the 0.64 to 1.15 MPa before harvesting. Also values changed 0.32 to 0.83 MPa in the soil depth of 10-20 cm after planting and from 0.95 to 1.33 MPa before harvesting. C treatment gave low mean values of soil penetration resistance in the soil depth of 0-20 cm. The lowest mean dry matter yield was obtained in CIR treatment as 8.39 Mg ha^{-1}. The highest values obtained at C and CFS treatments as 9.98 and 9.28 Mg ha^{-1}, respectively. Compaction treatments caused by press wheel increased soil bulk density and penetration resistance. Dry matter yield of maize was affected by compaction treatments.

Key words: Silage maize, soil compaction, tire-soil contact pressure, soil properties

INTRODUCTION

For solving animal feed problems and improving the animal breeding in Turkey; special importance is given to corn, soybean and silage maize production as a second crop. Soil compaction is one of the most important physical factors affects the seed germination, growth and yield. Increasing the soil compaction and decreasing the air penetration into the soil not only cause to prevent the root growth but also increase the microbiology activities. Yield response to soil compaction appears to be strongly influenced by these factors; inconvenient soil structure tends to alleviate the plant growth and yield. In order to study the level of different tire-soil contact pressures on silage maize yield this study was carried out. Shallow, near-surface soil compaction is attributed to tire-soil contact pressures, the number of field passes and soil moisture content at the time of tire traffic (Raghavan *et al*., 1977; Bicki and Siemens, 1991). Tire-soil contact pressures from 0.035 to 0.076 MPa caused decreasing the germination in sugar beat, maize and bean. The best seed germination was obtained on non-surface soil compaction treatments into the convenient soil moisture (Stout *et al*., 1961). Not only the physical soil properties into the planting depth and also the convenient conditions of sub planting the planting depth might be affected on the root growth (Tacket and Pearson, 1964). A limited amount of surface compaction promotes better seed-soil contact and rapid germination and reduces the rate at which soil dries. Elsewhere excessive compaction can hamper root growth, limit nutrient uptake and cause moisture stress; all of which result in decreased yields. Gee-Clough *et al*. (1990) reported that the soil compaction treatments before and after planting caused reduction on maize yield by 1.5 to 41%. Siemens and Peterson (1997) reported that corn in tractor tracks had an average yield reduction of 13% when compared to untrafficked. Erbach (1987) reported that soil compaction applications by roller after the planting tend to increase the seed germination in wheat. Increasing seed germination might be 19% in the insufficient rainfall years. Also Lindemann *et al*. (1982) reported that the soybean yield increased by the soil compaction in the rainy year according to non-compacted plots. Bayhan *et al*. (2002) reported that wheel traffic applied on rows and entire area after sunflower planting caused reduction in yield as it negatively affected the vegetative growth of plant. Wheel traffic applied on inter-rows after planting did not affect the yield negatively. Altuntas *et al*. (2005) reported that

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compaction treatments caused by tractor wheel traffic in tillage systems increased soil bulk density and penetration resistance.

Objectives of this study were to investigate the effects of different soil compaction treatments and tire-soil contact pressures on soil and plant properties and yield in second crop silage maize.

MATERIALS AND METHODS

The research was conducted on field conditions with clay-silt soil and planed in randomised block design with three replications. Blocks were 8 m long and 6 m wide. Compaction treatments were applied to the plots randomly. The soils in the plots were found to statistically the same texture. After the seedbed preparation just before the planting applications, soil moisture contents were determined as 13% at the 0-10 cm soil depth, 15% at the 10-20 soil depth. Corn variety TTM-813 was drilled in rows spaced 67.5 cm apart at a rate of 76 920 seeds ha^{-1}. Standard tractor and the pneumatic precision planter weights are 2324 and 644 kgf, respectively. The planter with vacuum pressure, holed disk and 4 rows was used in the experiments. Planting depth was arranged to 8 cm and working speed was 6.02 km h^{-1} during the experiments. Planting and harvesting dates were 20 July 2001 and 10 October 2001, respectively. Soil compaction pressures were used to obtain the different tire-soil contact pressures by compaction tires loaded with additional weights. Tire-soil contact pressures applied to the plots were 0.025, 0.051, 0.076 and 0.0085 MPa (control). Soil compaction was applied in the forms of the following treatments;

CFS : Compaction on furrow surface,
CIR : Compaction on inter rows,
CFB : Compaction on furrow bottom,
C : Non-compaction (Control).

In the CFS treatment; surfaces of rows were compacted by compaction tires with additional weights. In the CFB treatment, some constructional changes made at the planter. Seeds flow were blocked and furrows were opened by the shoe coulters of the planter. Afterwards opened furrows were compacted by additional weighted compaction tires. Then seeds were placed into by bottom of furrow and covered by soil. In the CIR treatments; inter rows were compacted by the additional weighted compaction tires after the standard planting application. Planting applications in control treatment were performed by the same planter with compaction tires without additional weights.

In the research, the soil penetration resistance and bulk density were determined after planting and before harvesting. The firm soil samples which were taken at 0-10 and 10-20 cm soil depth were used for determine of the soil moisture content and soil bulk density. Soil penetration resistance was evaluated with an Eijelkamp cone penetrometer (Asae, 1997). Bulk density was determined according to the core method. Soil moisture content was gravimetrically determined from bulk density samples. The cores were dried at 105°C to determined soil dry bulk density. In the research; stalk diameter, plant height and single plant dry weight were determined within the 10 plants were taken randomly from each plots. To determine the percentage of corncob and harvesting index; two samples for each plot were taken and dried out 48 hours into the oven at 70°C. Then dried grains in corncob were weighted. The weighted grains were divided by single plant weight to determine the harvesting index. Percentage of corncob and harvesting index were determined as Graybill *et al*. (1991). Silage maize dry matter yields were estimated by harvesting in all eight rows in each plot. Wet weight maize yields were obtained for each plot. Chopped maize sub-samples were hand collected, dried at 65°C to estimate dry matter yields (Carter *et al*., 2002).

RESULTS AND DISCUSSION

Soil physical properties: Moisture contents were determined as 12.46 and 13.39% in the soil depth of 0-10 and 10-20 cm, respectively before the harvesting. The effects of different soil compaction treatments and tire-soil contact pressures on soil physical properties such as bulk density and soil penetration resistance mean values after planting and before harvesting (Table 1).

The effects of soil compaction treatment and tire-soil contact pressures on soil bulk density and penetration resistance at the 0-10 and 10-20 cm soil depth were found statistically significant (Table 1). The minimum and maximum penetration resistance values were obtained in C and CFS treatments respectively in the soil depth of 0-10 cm. CFS treatment gave higher value (0.40 MPa) than the CFB treatment because of the compaction under the planting depth in CFB. The minimum and maximum penetration resistance values were obtained in C and CFB treatments in the soil depth of 10-20 cm. The lowest mean soil bulk density value obtained in the soil depth of 0-10 cm in CFB treatment as 1.23 g cm^{-3} and the same treatment gave the highest mean value as 1.48 g cm^{-3} in the soil depth of 10-20 cm after planting because of the compaction under the planting depth. The lowest mean soil bulk density value obtained in the soil depth of

Table 1: Effects of the soil compaction treatments and tire-soil contact pressures on soil properties after planting and before harvesting

Measurement state	Soil properties	Soil depth (cm)	TSCP (MPa)	Compaction treatments CFS	CIR	CFB	C	Mean	LSD	Values
After planting	Bulk density (g cm^{-3})	0-10	0.025	1.327	1.267	1.217		1.270	Ct	(p<0.01) 7.541 e^{-02}
			0.051	1.353	1.277	1.226		1.285	TSCP	ns
			0.076	1.427	1.297	1.246		1.323	Ct×TSCP	ns
			Mean	1.369^a	1.280^b	1.230^b	1.270			
		10-20	0.025	1.385	1.284	1.430		1.366^b	Ct	(p<0.01) 7.541 e^{-02}
			0.051	1.394	1.351	1.461		1.402^{ab}	TSCP	(p<0.01) 7.541 e^{-02}
			0.076	1.461	1.356	1.547		1.455^a	Ct×TSCP	ns
			Mean	1.413^a	1.330^b	1.479^a	1.285			
Before harvesting	Bulk density (g cm^{-3})	0-10	0.025	1.356	1.321	1.357		1.345^b	Ct	(p<0.01) 4.354 e^{-02}
			0.051	1.357	1.361	1.457		1.392^a	TSCP	(p< 0.01) 4.354 e^{-02}
			0.076	1.405	1.375	1.469		1.416^a	Ct×TSCP	ns
			Mean	1.373^b	1.352^b	1.428^a	1.320			
		10-20	0.025	1.452	1.376	1.418		1.415^b	Ct	(p<0.05) 4.469 e^{-02}
			0.051	1.472	1.376	1.477		1.442^{ab}	TSCP	(p<0.05) 4.469 e^{-02}
			0.076	1.476	1.459	1.520		1.485^a	Ct×TSCP	ns
			Mean	1.467^a	1.404^b	1.472^a	1.365			
After planting	Penetration resistance (MPa)	0-10	0.025	0.33	0.23	0.27	0.277^c	Ct	(p<0.01) 4.354 e^{-02}	
			0.051	0.43	0.29	0.34		0.353^b	TSCP	(p<0.01) 4.354 e^{-02}
			0.076	0.45	0.35	0.40		0.400^a	Ct×TSCP	ns
			Mean	0.403^a	0.290^c	0.337^b	0.270			
		10-20	0.025	0.40	0.32	0.51		0.410^c	Ct	(p<0.01) 4.354 e^{-02}
			0.051	0.55	0.42	0.75		0.573^b	TSCP	(p<0.01) 4.354 e^{-02}
			0.076	0.71	0.46	0.83		0.667^a	Ct×TSCP	(p<0.01) 7.541 e^{-02}
			Mean	0.553^b	0.400^c	0.697^a	0.310			
Before harvesting	Penetration resistance (MPa)	0-10	0.025	1.02	0.71	1.02		0.918	Ct	(p<0.01) 0.230
			0.051	1.12	0.64	1.04		0.933	TSCP	ns
			0.076	1.15	0.77	1.12		1.013	Ct×TSCP	ns
			Mean	1.097^a	0.708^b	1.060^a	0.660			
		10-20	0.025	1.15	0.95	1.25		1.117	Ct	(p<0.01) 0.180
			0.051	1.26	1.02	1.27		1.183	TSCP	ns
			0.076	1.29	1.15	1.33		1.257	Ct×TSCP	ns
			Mean	1.233^a	1.040^b	1.283^a	1.020			

Ct: Compaction treatments, TSCP: Tire-soil contact pressures (MPa); Values with the same letter(s) in a row are not significantly different at p<0.05, ns: non significant

0-10 cm in C treatment as 1.32 g cm^{-3} and the CFB treatment gave the highest mean value as 1.47 g cm^{-3} in the soil depth of 10-20 cm before harvesting (Table 1).

The lowest mean soil penetration resistance value obtained in the soil depth of 0-10 cm in C treatment as 0.27 MPa and the CFB treatment gave the highest mean value as 0.70 MPa in the soil depth of 10-20 cm after planting. The lowest mean soil penetration resistance value obtained in the soil depth of 0-10 cm in C treatment as 0.66 MPa and the CFB treatment gave the highest mean value as 1.28 MPa in the soil depth of 10-20 cm at before harvesting (Table 1). The minimum and maximum values for soil bulk density and penetration resistance were obtained from each treatment by the 0.025 and 0.076 MPa tire-soil contact pressures. Soil bulk density and penetration resistance increased by increasing tire-soil contact pressures at each treatment.

Soil bulk density and soil penetration resistance values have increased by increasing tire-soil contact pressures and soil depth (Uppenkamp and Brinkmann, 1985). The lowest penetration resistance and bulk density values were measured at the lowest tire-soil contact pressure. Soil penetration resistance and bulk density values have increased on before harvesting measurements when compare to after planting measurements. Soil bulk density and penetration resistance values were affected by the agricultural operations applied during the growing season. Penetration resistance and bulk density values have also increased in compaction treatments when compared to control as in Erbach (1987).

Bicki and Siemens (1991) reported that the highest penetrometer resistance was generally found in compaction to entire plot at depth ranging from 15-23 cm. Bulk density measurements confirmed that compaction was greatest at a depth between 10 and 31 cm. Bayhan *et al.* (2002) reported that before and after the sunflower drilling, soil penetration resistance was found higher at entire field compaction treatments by wheel traffic applications than the pre-planting intra and inter rows compaction treatments. Ozgoz and Kasap (2007) reported that bulk density and penetration resistance values were affected by the agricultural operations applied during the growing season. They found that soil bulk density and penetration resistance values were higher in after harvest than the after tillage measurement time.

Table 2: Effects of different soil compaction treatments and tire-soil contact pressures on some plant properties at silage maize

Plant properties	TSCP (MPa)	Compaction treatments CFS	CIR	CFB	C	Mean	LSD	Values
Stalk diameter (mm)	0.025	17.41	17.14	16.56		17.039	Ct	ns
	0.051	17.77	17.81	17.47		17.682	TSCP	ns
	0.076	17.56	16.90	17.18		17.212	Ct×TSCP	ns
	Mean	17.580	17.284	17.069	18.17			
Plant height (mm)	0.025	2176.00	2410.70	2032.00		2206.22	Ct	(p<0.01) 133.767
	0.051	2326.70	2136.00	2086.70		2183.11	TSCP	ns
	0.076	2290.00	2150.70	2160.00		2200.22	Ct×TSCP	(p<0.01) 231.743
	Mean	2264.20^a	2232.40^a	2092.90^b	2262.00			
Single plant weight (g)	0.025	134.13	128.51	129.84		130.826	Ct	(p<0.05) 9.262
	0.051	146.16	122.09	138.15		135.436	TSCP	ns
	0.076	137.21	126.57	146.16		136.648	Ct×TSCP	ns
	Mean	139.167^a	125.722^b	138.048^a	149.76			
Percentage corncob (%)	0.025	38.21	41.82	50.75		43.594	Ct	ns
	0.051	49.50	40.78	34.93		41.733	TSCP	ns
	0.076	46.52	43.80	30.83		40.386	Ct×TSCP	(p<0.01) 15.119
	Mean	44.742	42.134	38.837	43.12			
Harvesting index (%)	0.025	12.55	16.11	18.83		15.832	Ct	(p<0.01) 4.559
	0.051	24.19	12.63	15.73		17.516	TSCP	ns
	0.076	22.45	20.40	7.52		16.790	Ct×TSCP	(p<0.01) 7.897
	Mean	19.731^a	16.380^{ab}	14.037^a	20.60			
Dry matter yield (Mg ha^{-1})	0.025	8.942	8.572	8.656		8.723	Ct	(p<0.01) 0.852
	0.051	9.744	8.144	9.210		9.032	TSCP	ns
	0.076	9.148	8.438	9.744		9.110	Ct×TSCP	ns
	Mean	9.278^a	8.385^b	9.203^{ab}	9.984			

Ct: Compaction treatments, TSCP: Tire-soil contact pressures (MPa); Values with the same letter(s) in a row are not significantly different at p<0.05, ns: non significant

Plant properties and yield: The variance analysis table values on effects of different soil compaction treatments and tire-soil contact pressures on plant properties such as plant stalk diameter, plant height, single plant dry weight, percentage of corncob, harvesting index and dry matter yield mean values were shown in (Table 2).

The soil compaction treatments and (Ct×TSCP) intersection were found statistically significant on plant height, single plant weight harvesting, index percentage of corn and dry matter yield. Also, tire-soil contact pressures were not found statistically significant at each plant properties and dry matter yield in Table 2. For each plant properties the maximum mean values were obtained from C and CFS treatments. The mean lowest stalk diameter value was determined as 17.1 mm in CFB treatment, while it was found the maximum as 18.2 mm in C treatment. The lowest mean plant height value was determined as 2093 mm in CFB treatment, while it was found the maximum as 2264 mm in CFS treatment. The lowest mean single plant dry weight value was determined as 125.7 g in CIR treatment, while it was found maximum as 149.8 g for C treatment. The lower mean percentage of corncob value was determined as 38.8% in CFB treatment. The lowest mean harvesting index value was determined as 14.0% in CFB treatment, while it was found maximum as 20.6% for C treatment. The lowest mean dry matter yield was determined as 8.39 Mg ha^{-1} in CIR treatment while it was found maximum values in C and CFS as 9.98 and 9.28 Mg ha^{-1}, respectively.

Soil compaction treatments were found statistically significant on some plant properties such as plant height, single plant dry weight, harvesting index and dry matter yield. Tire-soil contact pressures were not found statistically significant at each of plant properties. Soil compaction treatments negatively affected dry matter yield and caused reduction on dry matter yield by 16% when compared to C treatment as in Gee-Clough *et al*. (1990). The lowest mean dry matter yield was obtained in CIR and the highest mean dry matter yield was obtained in C and CFS treatments.

Bayhan *et al*. (2006) reported that soil tillage and planting practices influenced the plant height and stem diameter in silage maize. Yalcın and Cakir (2006) reported that second silage maize was affected by soil tillage, planting and climatic conditions.

CONCLUSIONS

The effects of the different soil compaction treatments and tire-soil contact pressures on soil and plant properties and dry matter yield of second crop silage maize have been investigated in this study. In conclude, compaction treatment and tyre-soil contact pressures by press wheel increased soil bulk density and penetration resistance. Also, dry matter yield of silage maize was affected negatively by the press wheel compaction treatments.

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