Effects of Four Different Crops Harvest Processes on Soils Compaction

Hamza NEGİŞ*, İlknur GÜMÜŞ, Cevdet ŞEKER

Selcuk University, Faculty of Agriculture, Dept. of Soil Science and Plant Nutrition, Konya, Turkey
*Corresponding author: hnegis@selcuk.edu.tr

Geliş Tarihi (Received): 01.03.2017 Kabul Tarihi (Accepted): 15.04.2017

The rapid population growth in the developing world in order to meet the food demands, agricultural land is exposed to high traffic in the year. The composed traffic influences negatively the physical properties of the soil. As a result of unconsciously processing the soil; the loss of organic matter increases, the compaction occurs at the top and bottom of soils, the structure breaks down and thereby, soil degradation begins. Because of the degradation, there is a significant decline in productivity. Water storage property of the soil in Konya plain, where it is located in the arid and semi-arid climate zone, has great important. The connection between soil particle array and pore structures is important in terms of soil water holding capacity. In this study, the effects of agricultural machinery on the soils, which are under different cultures (corn, sugar beet, sunflower and wheat), was examined at the pre-harvest and post-harvest stage. Bulk density and soil compaction were measured in the clay soils. The bulk density values showed an alteration between 1.21-1.46. Showed significant differences between pre and post-harvest the bulk density values. In the measurements of penetration resistance values of 0-20 and 20-40 cm, the values measured before harvest were observed to increase after harvest.

Keywords: Penetration resistance, bulk density, Konya plain

Introduction

Productivity should be increased for humans to be able to be nourished balanced and with higher quality. The mechanization operations made in the agricultural lands within the period increase gradually and machines became bigger and heavier (Bennett et al. 2017). Mechanizing the agriculture increased productivity of the crop production. On the other hand, the axle load of farm machines increased over the last decades so much that questions regarding the long-term detrimental effects of soil compaction were revealed. Agricultural production techniques on the industrialized countries within the period of the last decades changed dramatically. Growing economic crops, makes machine power, vehicle weight and implementation size to increase continuously. For example, the rate of tractors bigger than 50 hp which are registered in Turkey increased from 50% to 90% between 1988 and 2015 (TÜİK. 2015). During the recent years, the number of tractors in Turkey increased 32% and became a total of 1,260358. Continuous increase of the heaviness of agricultural machines and the need of using heavy machines in inappropriate ground conditions increased the compaction in soils. Soil compaction was found to have detrimental effects on lots of soil characteristics regarding the soil cultivation, drainage, crop growth and environment. For example, the subsoil compaction blocked the infiltration and increased the runoff and erosion (Fullen. 1985).

The degree of soil compaction depends on soil texture, soil moisture, organic substance content as well as the axle loads, tyre pressure and contact area of the vehicle to the soil (Alakukku et al. 2003; Bygdén et al. 2003; Jansson & Johansson. 1998). The harvesters cause superficial or substratum soil compaction. The highest mechanization operation occurs within the harvest period. The fact that the harvesters are too heavy and their maximum loads show an increase between 5-10 tons with the harvest cause burdens on the lands. As the soil compaction increases, an increase occurs on the bulk density values (Bertrand & Kohnke. 1957; Phillips & Kirkham. 1962). With the increasing bulk density values, the aggregates were broken up and porosity, ventilation and infiltration decreases (Kozlowski. 1999). For this reason, depending on the soil compaction on the lands, soil compaction also affects the nitrogen content and uptake of crops (Bertrand & Kohnke. 1957; Lowery & Schuler. 1991; Phillips & Kirkham. 1962).

In this study, the changes in the physical characteristics of lands under different plant growth were examined as a result of field traffic during the harvest period. The harvesters were compared to determine in which plant pattern the soil compaction affects the soil within the superficial or substratum.

Materials and Methods

The research was carried out in the application farm of Selcuk University agricultural faculty. In this study made in 2015, samplings and measurements were implemented on the lands where planting of different plant species (corn, sugar beet, sunflower and wheat) were executed. In order to determine some physical and chemical characteristics of the soils, 0-20 cm disturbed soil samples were taken from the lands. In order to determine the pre-harvest and post-harvest situation in the lands, the penetration measurements were made in 2 periods with 10 repetitions from each land. Undisturbed soil samples were also taken with 4 repetitions at the same time with the penetration measurements. Moisture adjusting should be made in order to compare the penetration resistance values measured in different periods (Şeker. 1999). For this reason, the function developed by Busscher and Bauer (2003), was used.

The samples' textures were found according to the Bouyoucos hydrometer method (Gee & Bauder. 1986); the field capacity (FC) was determined using a pressure plate at 33 kPa (FC) pressure (Klute. 1986), as a percentage of moisture retained in the weight of soil; the wilting point (WP), using a pressure plate at 1500 kPa pressure, as the percentage of moisture retained in the weight of soil (Klute. 1986); available water capacity (AWC) was found, by subtracting the PWP value from the FC values. Penetration resistance (PR) measurements were made by using a penetrologger produced by Eijkelkamp, where the device is inserted into the soil by pushing with hands. Bulk density (Pb) was measured by the core sampling method (Blake & Hartge. 1986). Organic matter contents were measured by "Smith-Weldon" (Nelson & Sommers. 1982).

Results and Discussion

Some physical characteristics of the research subject soils are given in Table 1. The soils contain clay between 53.25-58.85 %, silt between 32.70-36.60 % and sand between 8.45-10.32 %. All of the soils take place in the class of clay. The FC and WP values show a change between 33.25-34.67 % and 15.84-17.28 % respectively. The AWC were found to be between 17.36-18.38 %. When the OM content is examined, all of the soils take place in the middle class organic substance (Ülgen & Yurtsever. 1974). The soil characteristics are observed to be compatible with the previous studies.

Table 1. Soil physical and chemical properties at different plants samples.

Soil properties		Sunflower	Corn	Sugar beet	Wheat
Sand (%)		10.15	8.88	8.45	10.32
Clay (%)		53.25	55.35	58.85	53.85
Silt (%)		36.60	35.77	32.70	35.83
Texture class		Clay	Clay	Clay	Clay
FC ($g\ g^{-1}$)		34.10	34.65	33.25	34.67
WP ($g\ g^{-1}$)		15.84	17.28	15.89	16.29
AWC ($g\ g^{-1}$)		18.26	17.37	17.36	18.38
OM (%)		2.36	2.74	2.95	2.55
Moisture (%)	0-10 cm	12.44	9.74	18.39	9.17
	10-20 cm	15.22	11.87	20.55	13.14
	20-30 cm	17.35	12.19	20.85	15.49

FC: field capacity; WP: wilting point; AWC: available water capacity; OM: organic matter

Pre-harvest and post-harvest Pb values within the soils of study area are given in Table 2. The comparisons in each plant species were made in the pre-harvest and post-harvest same depths. When the sunflower plant is examined, no differences are observed to occur cyclically in the depths. Since the plant was left to dry in the sunflower harvest, the mechanization operation for the harvest was carried out on dry soil and did not generate differences statistically on Pb values ($P>0,05$). When the Pb values of corn were examined and pre-harvest and post-harvest values in the same depths were compared, an increase was observed on the post-harvest values. Significant differences occurred statistically in all of the values ($P<0.01$). Even though the land conditions in the corn harvest were dry, this increase is considered to occur from the high-weight harvesters. The weight of harvester used is 14400 kg and its carrying capacity is 7600 liters. When the Pb values of the sugar beet plant were examined, statistically significant differences were found between the values ($P<0.01$). When the Pb values were examined, the highest increase was observed to occur in the sugar beet agriculture. When all of the depths were examined, an average increase of 13% was observed to occur. The increase of Pb value in the sugar beet agriculture was originated from the harvest works made in high moisture content. When the wheat was examined, no significant differences were observed statistically in 0-10 and 10-20 cm within the Pb values (p>0.05) while statistically significant difference was found in 20-30 cm (p<0.01).

Table 2. The values of bulk density before and after harvesting of different plants.

Crop pattern / Period	Deep (cm)					
	0-10		10-20		20-30	
	BH (g cm^{-3})	AH (g cm^{-3})	BH (g cm^{-3})	AH (g cm^{-3})	BH (g cm^{-3})	AH (g cm^{-3})
Sunflower	1.14±0.01	1.17±0.03	1.20±0.03	1.21±0.02	1.29±0.05	1.34±0.05
Corn	1.15±0.02^{b}	1.26±0.02^{a}	1.16±0.02^{b}	1.30±0.02^{a}	1.24±0.04^{b}	1.34±1.02^{a}
Sugar beet	1.17±0.02^{b}	1.31±0.04^{a}	1.22±0.01^{b}	1.38±0.02^{a}	1.24±0.01^{b}	1.42±0.03^{a}
Wheat	1.14±0.02	1.15±0.10	1.19±0.01	1.21±0.04	1.24±0.03^{b}	1.34±0.05^{a}

BH: before harvesting; AH: after harvesting. ^{a,b}: P<0.01.

The measurements of PR are usually being used as an indicator of the density of soil cultivation and field traffic (Salem et al. 2015; Soane & Van Ouwerkerk. 1994; Van Ouwerkerk & Soane. 1994). The values regarding the penetration measurements are given in Table 3. The comparison of the PR in the plant species was carried out in 3 different depths to examine the effect the post-harvest values make to the depths. When the penetration values of the sunflower plant were examined, it was not found statistically significant among the PR in 0-10 and 10-20 cm depth statistically (P>0,05). Its PR values have a positive relationship with its Pb values. When its Pb values were examined, no increases were observed in the 0-10 and 10-20 cm values. When its 20-40 cm PR values were examined, post-harvest values were observed to increase in comparison with pre-harvest values (P<0.01). When the PR values of corn, sugar beet and wheat samples were examined, statistically significant results were obtained in 0-10, 10-20 and 20-40 cm (P<0,01). In each 3 plant varieties, pre-harvest values were observed to be lower than post-harvest values. The PR values of wheat in the pre-harvest values were observed to be smaller than >3MPa, which is the value that will limit the plant root development. However, pre-harvest values for the sugar beet and the corn plants were observed to be bigger than >3 MPa in the 20-40 cm depth (Gugino et al., 2009). The fact that the field traffic which occurs in the development period of both plant species has effects on the PR is also indicated in the previous study (Negiş, 2014). Picture 1 is constituted for the PR values to be examined in terms of the soil profile in 0-40 cm. As is also understood from this, an increase is observed in the post-harvest penetration values in all of the plant samples.

Table 3. The values of penetration resistance before and after harvesting of different plants.

BH: before harvesting; AH: after harvesting; MPa: megapascal. a,b: P<0.01

Crop pattern / Period	Deep (cm)					
	0-10		10-20		20-40	
	BH (MPa)	AH (MPa)	BH (MPa)	AH (MPa)	BH (MPa)	AH (MPa)
Sunflower	1,40±0,55	1,98±0,61	2,71±0,37	2,96±0,22	3,71±0,43^{b}	4,26±0,42^{a}
Corn	0,94±0,53^{b}	2,31±0,94^{a}	2,60±0,22^{b}	3,60±0,22^{a}	3,95±0,56^{b}	4,43±0,45^{a}
Sugar beet	0,99±0,34^{b}	2,27±0,81^{a}	2,12±0,09^{b}	3,27±0,34^{a}	2,99±0,40^{b}	4,47±0,39^{a}
Wheat	0,85±0,37^{b}	2,15±0,45^{a}	1,88±0,17^{b}	2,56±0,07^{a}	2,24±0,11^{b}	2,86±0,08^{a}

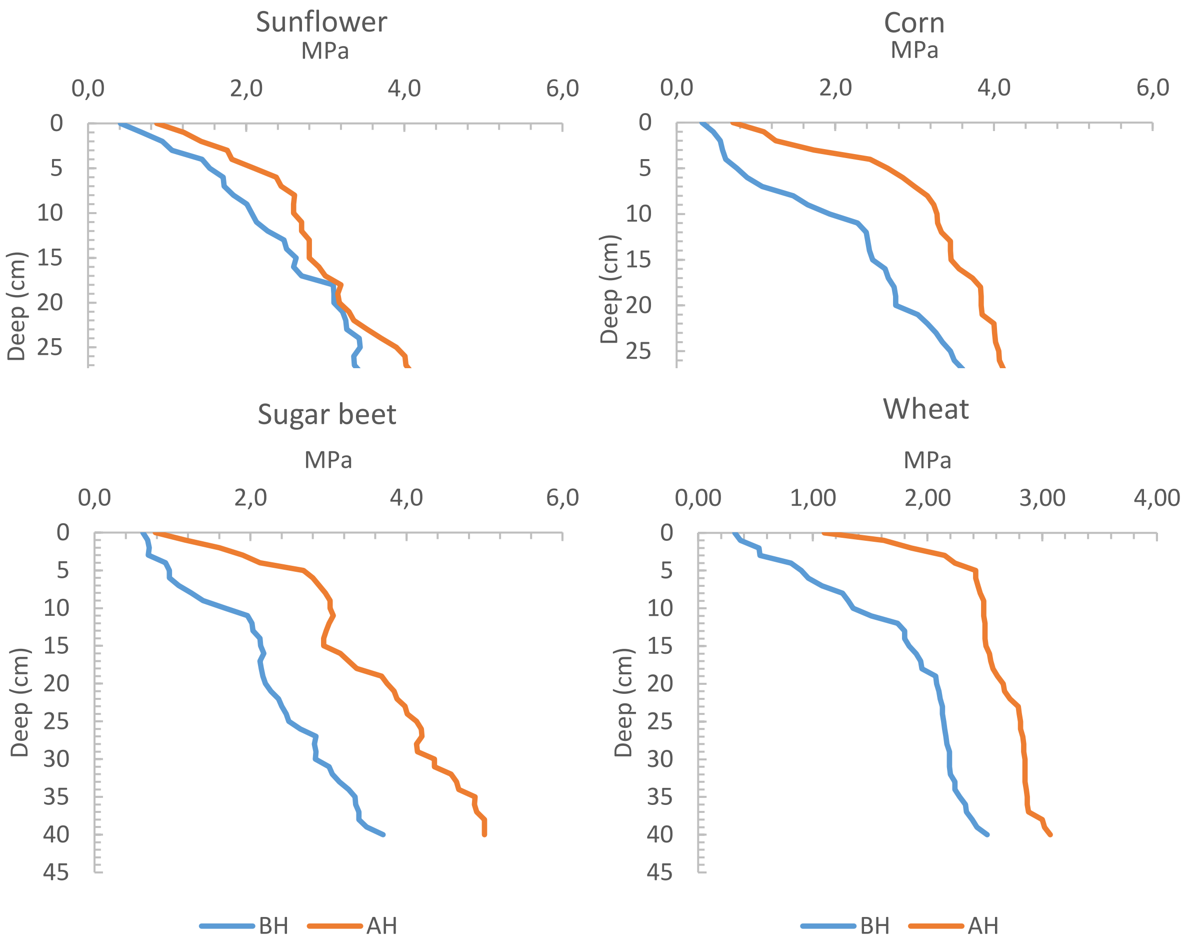

Figure 1. Before and after harvest under four different crops 0-40 cm depth penetration measurements

Conclusions

This study provided the assessment of effect of the compaction formed as a result of harvesting different plant species on the soil. In the post-harvest measurements, the harvesters were observed to leave the lands under too heavy loads. Our findings revealed that the physical soil characteristics were greatly influenced following the field traffic. The wetness of the soils decreases the carrying capacity of the soil.

The most serious sources for soil compaction are drives on heavy wheel loads implemented in soft ground conditions with high ground contact pressure. Machines and equipment's used in the field in critical conditions should be used after controlling their wheel loads and with low tire inflation pressures.

References

Alakukku, L., P. Weisskopf, W. Chamen, F. Tijink, J. Van der Linden, S. Pires, C. Sommer and G. Spoor, 2003. Prevention strategies for field traffic-induced subsoil compaction: a review: Part 1. Machine/soil interactions. Soil & Tillage Research, 73(1): 145-160.

Bennett, J.M., S.D. Roberton, T.A. Jensen, D.L. Antille and J. Hall, 2017. A comparative study of conventional and controlled traffic in irrigated cotton: I. Heavy machinery impact on the soil resource. Soil & Tillage Research, 168, 143-154.

Bertrand, A. and H. Kohnke, 1957. Subsoil conditions and their effects on oxygen supply and the growth of corn roots. Soil Science Society of America Journal, 21(2): 135-140.

Blake, G. and K. Hartge, 1986. Bulk density. Methods of Soil Analysis: Part, 1, 363-375.

Busscher, W. and P. Bauer, 2003. Soil strength, cotton root growth and lint yield in a southeastern USA coastal loamy sand. Soil and Tillage Research, 74(2): 151-159.

Bygdén, G., L. Eliasson and I. Wästerlund, 2003. Rut depth, soil compaction and rolling resistance when using bogie tracks. Journal of Terramechanics, 40(3): 179-190.

Fullen, M.A. 1985. Compaction, hydrological processes and soil erosion on loamy sands in east Shropshire, England. Soil and Tillage Research, 6(1): 17-29.

Gee, G.W. and J.W. Bauder, 1986. Particle-size analysis. Methods of soil analysis: Part 1—Physical and mineralogical methods(methodsofsoilan1), 383-411.

Gugino, B.K., G.S. Abawi, O.J. Idowu, R.R. Schindelbeck, L.L. Smith, J.E. Thies, D.W.Wolfe and H.M. Van Es, 2009. Cornell soil health assessment training manual: Cornell University College of Agriculture and Life Sciences.

Jansson, K. and J. Johansson, 1998. Soil changes after traffic with a tracked and a wheeled forest machine: a case study on a silt loam in Sweden. Forestry, 71(1): 57-66.

Klute, A. 1986. Water retention: laboratory methods. Methods of soil analysis: Part 1—Physical and mineralogical methods(methodsofsoilan1), 635-662.

Kozlowski, T. 1999. Soil compaction and growth of woody plants. Scandinavian Journal of Forest Research, 14(6): 596-619.

Lowery, B. and R. Schuler, 1991. Temporal effects of subsoil compaction on soil strength and plant growth. Soil Science Society of America Journal, 55(1): 216-223.

Negiş, H. 2014. Şeker pancarı tarımında dönemsel toprak sıkışmasının belirlenmesi. Selçuk Üniversitesi Fen Bilimleri Enstitüsü.

Nelson, D. and L.E. Sommers, 1982. Total carbon, organic carbon, and organic matter. Methods of soil analysis. Part 2. Chemical and microbiological properties (methodsofsoilan2), 539-579.

Phillips, R. and D. Kirkham, 1962. Soil compaction in the field and corn growth. Agronomy journal, 54(1): 29-34.

Salem, H.M., C. Valero, M.Á. Muñoz, M.G. Rodríguez and L.L. Silva, 2015. Short-term effects of four tillage practices on soil physical properties, soil water potential, and maize yield. Geoderma, 237, 60-70.

Soane, B. and C. Van Ouwerkerk, 1994. Soil compaction problems in world agriculture. Soil compaction in crop production, 11, 1-2.

Şeker, C. 1999. Farklı toprakların penetrasyon dirençleri üzerine su içeriklerinin etkisi ve regresyon modelleri. Tr. J. of Agriculture and Forestry, 23, 467-471.

TÜİK, 2015. Tarım Alet ve Makine Sayıları. Türkiye İstatistik Kurumu Haber Bülteni. Retrieved from www.tuik.gov.tr/PreIstatistikTablo.do?istab_id=305

Ülgen, N. and N. Yurtsever, 1974. Türkiye gübreler ve gübreleme rehberi. Toprak ve Gübre Araştırma Enstitüsü Müdürlüğü, Teknik Yayınlar (28).

Van Ouwerkerk, C. and B. Soane, 1994. Conclusions and recommendations for further research on soil compaction in crop production. Soil compaction in crop production (Ed. Soane, BD-Van Ouwerkerk, C.), Elsevier Sci, 627-642.