

## **Effect of Soil Compaction (Plough Pan) on Soybean Yield at Samsun Conditions**

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**Abstract:** In this study, the effect of soil compaction on plant growth and yield in soybean that is a strategically important plant in Turkey and especially the Samsun Region was investigated. Macon type soybean which was recommended by Karadeniz Agricultural Research Institute was used. Plant yield was recorded during two years and in addition to this interested parameters such as plant length, height of the first pod, the number of pods per plant, thousand seed mass, seed yield, and the number of secondary branches on the main stem were measured. This research plan was setup in approximately 0.05 ha for two different area with five repetitions for completely randomized design on Karadeniz Agricultural Research Institute in Samsun-Turkey for two years. Subsoiling application was accomplished only one of the areas. The penetration resistance was measured with a soil penetrometer. The results show that the effect of subsoiling application was found statistically significant at  $p < 0.05$  on thousand seed mass, the number of secondary branch on the main stem, the number of pods per plant, and seed yield. Year factor was found statistically significant at  $p < 0.05$  on the height of the first pod, the number of secondary branches on the main stem and the number of pods per plant. As a result, the subsoiling application increased the all the interested parameters for both years.

**Key words:** Soil Compaction, Plow Pan, Cone-Index, Soybean.

### **INTRODUCTION and LITERATURE REVIEW**

One of the main nutriment elements for the human being is oil which is originated from plant and livestock.

The most portion of the worldwide oil production (80-85 %) is supplied from the plant because of the limited production and excessive cost of the livestock's oils (Aroğlu, 2000). Cultivated areas and oil crop production of oil plants in the world was given in Table 1.

It seems that soybean is located at first place in the world, otherwise in Turkey; soybean follows cotton, sunflower, olive and peanut etc. respectively.

According to FAO database in 2005, it is apparent that soybean is cultivated in 10 000 ha limited areas. At the same time, Turkey is situated between insufficient countries in terms of oil plant production and substantially imports for the purpose of meeting the deficit oil plant production. Mainly imported oil plant seed of Turkey are showed in Table 2.

Table 2 showed that Turkey imported approximately 226 million dollars of soybean seed in 2004.

Along with agricultural consolidation for cultivating more yields, the essential aim is to obtain the highest yield per unit area. From this point of view, it should be aimed to increase yield by determining the appropriate soil cultivate system based on special crop with considering local soil and climate condition.

Especially, in the some areas which has got an excessive precipitation level over the average precipitation per  $m^2$  of Turkey as well as The Black Sea Region, while trying to accomplish the same existing problems via soil tillage treatments after the applied methods can cause another problem.

Even though the soil is turned over particularly the surface which is buried downwards and thus ventilated in this sense but, the compaction is still not avoided under the processed part of the soil as a layer, which can cause the formation of very tough and nontransparent layer that decreases the pores in the soil and exposes it to vertical loads by the mass of the plough itself. Finally, the compaction of the soil in this area will become unavoidable (Korucu, 2003)

**Table 1. Cultivated area and oil plant production in the world . (FAO 2005)**

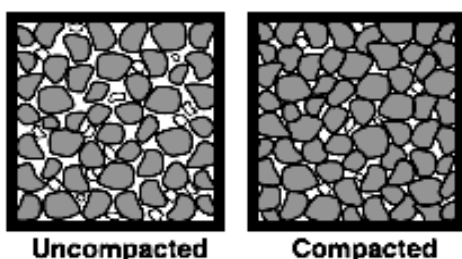
Oil Plants (2005)	TURKEY		WORLD	
	Cultivated area (ha)	Production (ha)	Cultivated area (ha)	Production (ha)
Soybean	10.000	30.000	91.386.621	209.531.558
Peanut	26.000	80.000	25.217.201	36.492.147
Olive	649.350	850.000	7.455.049	14.511.779
Sunflower	480.000	950.000	23.416.311	30.674.534
Rape	500	1.150	27.050.925	45.329.763
Aspir	165	150	812.687	773.427
Sesame	43.000	23.000	7.554.200	3.321.453
Poppy	99.431	16.000	174.581	60.135
Cotton	600.000	2.290.000	3.146.438	41.132.246
Hemp	650	80	24.793	31.680

Mt: Megaton 1000 t ha: hectar 10000m<sup>2</sup>

**Table 2. Oil seed import of Turkey. (FAO 2004)**

Turkey	Import (t)	Import (1000\$)
Soybean	681.964	226.828
Sunflower	481.703	157.376
Cotton	83.814	19.576
Susame	79.190	59.037

Soil compaction is basically the reduction in volume of a given mass of soil. It is commonly defined as an increase in soil bulk density, closer packing of solid particles, and decreased porosity, especially the proportion of large pores. (Kirişçi, 1999; Canillas and Salokhe, 2002; Korucu, et al. 2003; Selvi, 2003). During compaction soil aggregates and soil particles are crushed and packed closer together, squeezing out pore space (Figure 1). (Anonymous 1)



White: Air      Dark gray: Soil      Light gray: Moisture  
**Figure 1. Effect of compaction on pore space.**

In compacted layer, water, nutrients and airflow towards the plant roots are also restricted. These restrictions may reduce the crop growth and yield. Soil compaction plagues many parts of the world and affects many different crops. In fields where soil

compaction is a problem, subsoiling (also called ripping, chiseling and aerating) has been found to help alleviate it. Subsoiling severely compacted soil reduces the soil resistance and provides increased rooting depth that helps the plants withstand short-term drought conditions (Akıncı et al. 2004).

Mainly, there are four different compaction types:

- Soil crust,
- Surface compaction,
- Plough pan (hard pan ) and
- Deep soil compaction.

Soil crust; Crusts are relatively thin (0.5 – 1.5 cm thick), massive, and composed of somewhat continuous layers on the soil surface. These layers restrict water movement, oxygen diffusion, and seedling emergence, especially of non-grasses. (Stiegler 2008)

When the axle load becomes higher than the 5 tons for each axle, surface compaction occurs and its effects appear on the 10 cm layer thickness of the soil surface generally.

Every soil tillage implements may cause compaction in specific level. Plough pan, hard pan or soil pan; It is an impermeable compacted layer several cm thickness (5-10 cm) beneath normal tillage depth (20-25 cm) which is occurred by using primary tillage implements especially mouldboard plough and discharrow etc. trough long years in general. (Selvi, 2003).

Several studies have been reported on soil compaction effects on soil physical properties and

crop performance, and relationship between soil-machine-plant interactions.

Adawi and Reeder (1996) investigated the effect of annual compaction (1987–1989) of 9 and 18Mg axle loads and subsoiling for a corn/soybean rotation on a Hoytville silty-clay loam soil. They determined that 9 and 18Mg loads significantly reduced yields between 1992 and 1994, respectively. Measured in 1995, soil cone index, dry density and total porosity were still affected by the compaction. Subsoiling applications removed the compaction effect, and increased yields of soybean and corn crops substantially.

In a study on Cotton response to deep tillage with controlled traffic on clay compaction and subsoiling effects, Smith, L.A. 1995 studied the control traffic and deep tillage effects on cotton yield on the two different experimental plots in the clay soils through 4 years successively which is impending irrigated and non-irrigated. They compared the subsoiling and disc harrow application effects on the yields. They measured that while the subsoiling effects increased 14.7 % the cotton yield in the non-irrigated and 8.2 % irrigated plots according to the disc harrow application respectively. Finally, they explained that subsoil applications were effected the yield affirmatively in suitable soil moisture content.

Isaac et al. (2002) studied the using cone index data to explain yield variation within a in non-irrigated field near Manhattan, Kansas. They found that of the CI derived soil measurements, the mean CI throughout the 76.2 cm (30 in.) profile best explained yield variation ( $R^2=0.70$ ) along the transect. The maximum CI also correlated with yield, but to a lesser extent than the mean CI. Since they had only one CI reading above 2 MPa (300 psi), they could not determine if maximum CI readings at or above 2 MPa (300 psi) corresponded with reduced yields. Finally they recommend that this method of CI data analysis be conducted on a field with a substantial number of maximum CI readings exceeding 2 MPa (300 psi).

**MATERIAL and METHOD**

**Material**

Experimental area is located in 2004 and 2005 on C-4 blocs which is belonging to Karadeniz Agricultural Research Institute, Samsun, Turkey.

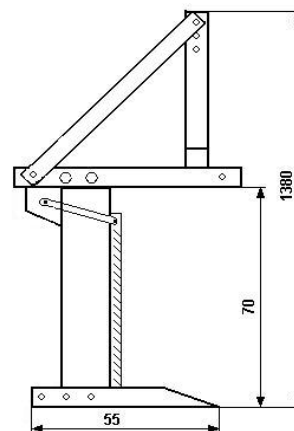
Macon type soybean was used which is developed in 1995 by the Illinois Agricultural Experiment Station at the University of Illinois in experiments. Plant has white flowers, tawny pubescence, and brown pod color at maturity, and dull yellow seeds with black hila.

The soil texture of experimental site is classified as a Vertic Luvisol according to the FAO soil classification. The clay, silt and sand contents of the main plots are summarized in Table 3.

**Table.3 Soil texture class of experimental plots**

Plots	Soil texture class (%)			Soil classify according to the FAO
	Sand	Silt	Clay	
Subsoiling	4.75	18.30	76.95	Vertic Luvisol
Control	8.61	12.64	78.75	Vertic Luvisol

General view of fixed leg subsoiler which is used for the purpose of eliminate (removed) plough pan in experimental plots was given in Figure 2. Some specifications belonging to this implement are given Table 4.



**Figure 2. The view of fixed leg subsoiler**

**Table.4 Fixed leg subsoiler specifications**

Specifications	Fixed leg subsoiler
Type and Hitches	Pull type, three-point hitch
General dim. (mm)	
a.Total lenght	740
b.Total width	658
c.Toplam height	1380
Number of legs	1
Leg dim. (mm)	1000*3200*340
Weight (kN)	5.70
Working depth (m)	Adjustable blade depth, max. 0.55m

Penetration resistance was measured using the Eijelkamp hand held penetrometer, with 16.60 mm in diameter, 30° in angle cone.

## Method

### Experimental Design

The experimental area (0.05 ha) was divided two different main plots 20 × 25 m in size. The plots were regularly sampled every harvest time for the crops in 14 m<sup>2</sup>, (5 × 2.8 m) subplots (Figure 3). The plots layout consisted of a completely randomized design with five repetitions.

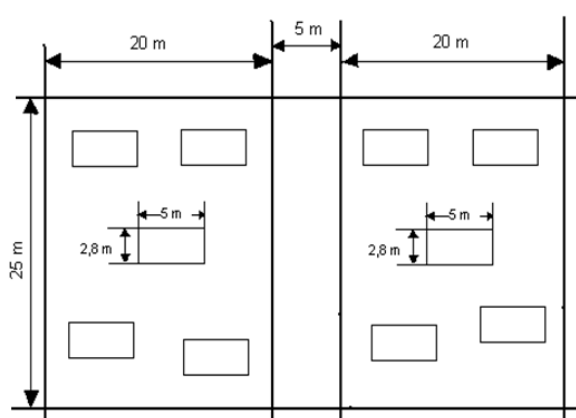


Figure 3. Design of experimental plots.

### Plant sampling and measurements

Soybean was grown in 2004 and 2005. Seeds were sown at a depth of 0.05 m and a row spacing of 0.70 m together with linurex (200cc/da) for herbicide control. Subsoiling was (one-pass ) applied only to one part of main plot before sowing time after silage corn harvest in 2004 for comparing control plot.

All other field operations (soil tillage, irrigation etc.) were conventionally done for both main plots except harvesting on a regular schedule as permitted by weather conditions.

Each subplot harvested with hand and mechanically thrashed to separate seeds from the vegetative portion of the samples.

Height of plant (cm) is obtained with the measuring the distance between soil surface and last mature pod which is randomly selected 10 plants from each row in the plots.

Height of the first pod (cm) is measured the distance between soil surface and first mature pod from the soil surface in the same way as the height of plant.

Number of pods per plant is counted the pods on randomly selected 10 plants from each plot and determined the average number of pods per plant.

The thousand seed mass; It is calculated from 100 seed with 4 replications from each plots.

Number of secondary branch on the main stem; it is obtained with the numbering of the secondary branch on the main stem as well as the same methodology of height of plants.

Seed yield; It is calculated with weighed the plants which are harvested from all experimental plots. (Arslan, 2007)

### Penetration resistance

Soil penetrations were measured by using Eijelkamp hand held penetrometer with 16.60 mm in diameter and 30° in angle cone during the experiments in 2004 to 2005. The measurements were made with 0.05 m increments to 0.45 m depth at each main plot before sowing and after harvesting time period with ten replications.

The penetration resistance (PR) in MPa was calculated by using the following equation (Korucu, 2002; Selvi, 2003);

$$PR = 0.0981 F/A \quad (1)$$

where; PR is the penetration resistance (MPa), F is recorded force value (kgf) and A is the base area of cone in cm<sup>2</sup> .

Massey Ferguson 385F – 4WD, 73.6 kW engine power was used to operate a conventional subsoiler with a depth of 0.70 m and width of 0.70 m in row.

Statistical analysis for crop parameters were performed with a standard analysis of variance and significant means separated by the DUNCAN test (P <0.05)

## RESEARCH RESULTS and DISCUSSION

### Soil resistance

Cone index values in experimental plots during the experiment years from 2004 to 2005, using with the soil penetration resistance as a function of soil depth and experiment years, was given in Figure 4.

A strong negative relationship was found between yield and the penetration resistance (it is called cone index, CI) rates.

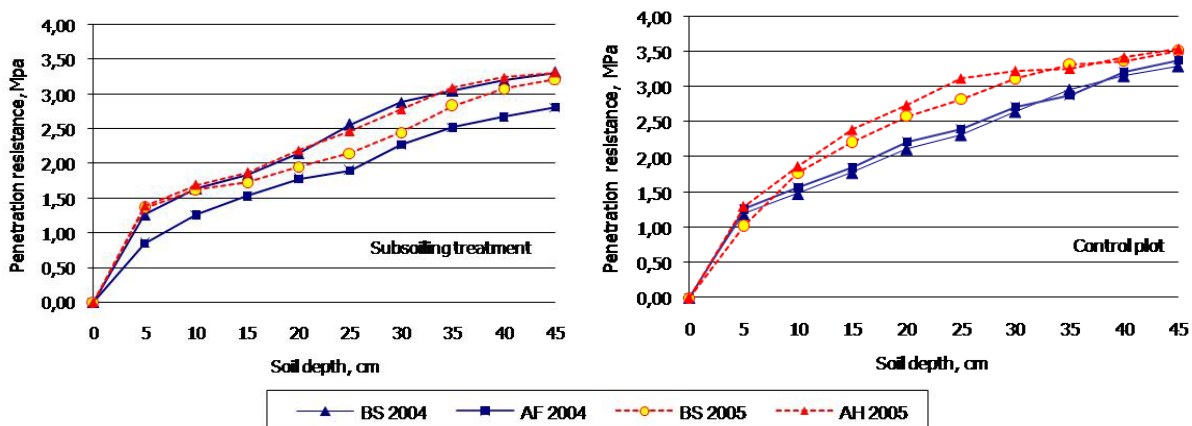


Figure 4. Changing the penetration resistance according to the soil depth

The soil compaction increases in all experimental areas throughout the years. Similar consequences were reported by Korucu and Kirişci (2003); Selvi et al. (2003); Akıncı et al. (2004).

2 MPa penetration force value is the accepted threshold value (Isaac et al. 2002) for vegetable production. This value was reached in the upper 17 cm of soil surface before sowing time period in the first experimental year. The same value was reached at 27 cm soil depth after subsoiling application. Otherwise both penetration values before sowing (BS) and after harvesting (AH) are shown to collaterally rise according to the first year experimental results.

In the second year, 2 MPa penetration thresholds are occurred at 16 cm depth from the soil surface. AH, soil penetration values were showed similarly trend with BF values in comparison with first year's values.

When examining the results for the penetration resistance in both experimental years of the control plot is presented by different values according to the subsoiling treatment.

In the control plots, 2 MPa threshold point becomes fact at around 17 cm in a first year and 14 cm in a second year in the BS time period. These results were found 17 cm as the first year and 13 cm by years respectively.

### Crop yield

Subsoiling effects on the soybean yields in years of 2004 and 2005 were illustrated in Table. 5.

Subsoiling treatment had statistically significant effects on all measured parameters except plant height and height of the first pod. Year effect had statistically significant effect on all interested parameters except seed yield and 1000 seed mass. Interaction between subsoiling treatment and year

had statistically significant on the number of pods per plant and the number of secondary branch on the main stem and plant height. For seed yield parameter only subsoiling treatment had statistically significant effect ( $p < 0.01$ ), existence of subsoiling treatment increased the seed yield. The similar results were reported by Akıncı et al. (2004) for cotton, Busscher et al. (1995) for zea mays. These findings were valid for 1000 seed mass with  $p < 0.05$ .

When we examined the number of pods per plant, interaction term is statistically significant and in this situation main effects should not be interpreted as a statistical fundamental. The highest values for the number of pods per a plant were observed for subsoiling treatment within both years, and also, first year observations were higher than second year observations.

The number of secondary branch on the main stem was statistically affected by both factors and interaction term. The worst result observed for the treatment of a control plot was in the second year.

The others were not statistically significant, but Subsoiling treatment for both years resulted with higher values than control plot.

Plant height parameter had affected by mainly year effect and interaction effect. First year observations were higher than that in second year. Existence of subsoiling treatment manipulated the second year values. The height of the first pod parameter was affected statistically significant only by year effect. Results of the first year were higher than that in second year.

**Table.5. Subsoiling effects on the soybean yield and yields parameters.**

	Subsoiling		Control		Sig.		
	1. Yıl	2. Yıl	1. Yıl	2. Yıl	Subsoiling	Year	Int
Seed yield	6044.4 ± 259.5	6186 ± 846.1	5322.6 ± 446.9	4850 ± 471.9	**	-	-
1000 seed mass	216.2 ± 5.8	219 ± 8.15	209.6 ± 2.6	213.8 ± 5.4	*	-	-
Number of pods	120.7 ± 37 <sup>a</sup>	116.2 ± 43.3 <sup>ab</sup>	105.3 ± 36.7 <sup>b</sup>	76.3 ± 28.4 <sup>c</sup>	**	**	*
Number of secondary branch on the main stem	1.84 ± 0.65 <sup>a</sup>	1.74 ± 0.49 <sup>a</sup>	1.68 ± 0.59 <sup>a</sup>	1.22 ± 0.64 <sup>b</sup>	**	**	*
Height of the plant	98.64 ± 8.33 <sup>a</sup>	91.42 ± 7.3 <sup>b</sup>	100.48 ± 6.8 <sup>a</sup>	87.17 ± 9.7 <sup>c</sup>	-	**	**
Height of the first pod	14 ± 4	10.1 ± 3.4	15.4 ± 4.1	1.01 ± 3.7	-	*	-

<sup>a,b,c</sup>: different letters show the statistical difference for interaction term.

\*: statistically significant at  $p < 0.05$

\*\*: statistically significant at  $p < 0.01$

## CONCLUSION

The subsoiling period was decreased by the threshold of the soil compaction through experimental years. So, subsoiling should be applied at the high time to prevent the soil compaction occurring due to the intensive farming and heavy traffic in the field.

The measurements indicate that, subsoiling increases the soybean yield.

Based on this research, we recommend that, this application may allow to farmers to prevent their soil structure and increases their yield and profits

especially when the hardpan threshold is upper then the 2 MPa.

## ACKNOWLEDGEMENTS

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