The effect of different types of tillage on soil's physical, mechanical, and biological properties

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Abstract: In this research the effect of different types of tillage on soil's physical, mechanical, and biological properties was investigated. The soil texture was silt-clay. The mechanical impedance of soil in non-ploughed state and also ploughed states with moldboard and chisel ploughs was determined by means of a penetrologger and then the soil samples were obtained from 10 to 20 cm depths in order to determine the apparent special mass and microbial respiration. The soil tilled by moldboard plough showed 3% and 14% less penetration impedance rather than chisel ploughed and no-plough soils, respectively. In no till soil, the apparent density is higher than soil tilled with moldboard and chisel ploughs. The moldboard plough caused more microbial respiration in soil due to its better soil flipping and mixing of wheat residues with soil and consequently placing more organic materials inside sampled soil and or applying larger contact surface for microorganisms with plant residues. Soil inversion percentage measurements for both tested ploughs showed that moldboard plough had the highest soil inversion with 79%. By measuring tractor slippage it was indicated that chisel plough causes less slippage due to lower draft resistance and therefore favors lower energy consumption rather than moldboard plough.
[Bahram Hosseinzadeh, Alireza Shirneshan, Hemad Zareiforoush. **The effect of different types of tillage on soil's physical, mechanical, and biological properties.** Researcher. 2011;3(7):25-29]. (ISSN: 1553-9865). http://www.sciencepub.net.

Key words: Soil, Tillage, Plough, Chisel, Moldboard

1. Introduction

One of the most important stages of producing crops is the soil preparation stage after harvest and before next planting stage. Different tools and practices leave different effects on physical, mechanical, and biological properties of soil. After normal tilling, the activity of microorganisms in soil increases, which by increasing their amount it is signified that this increase is due to destruction of soil particles, improvement of air conditioning, and exposure of the soluble solids' area (Asgharzadeh,1997). Lubwayi et al (1998 and 1999) observed that tillage effects on microbial properties of soil is more than previous crops' in rotation and also tillage increases CO_2 progressively and the increase of CO_2 is a better index than residues decomposition.

According to the effect of soil's impedance on seed germination, root establishment and development, plant development, and the most important of all, the product performance, its measurement on field is necessary. For measuring mechanical impedance of soil through stationery method, for each measurement the penetrometer must penetrate in soil and should be extracted after the measurement is done. The penetrometers are devices have being used for several years to measure the soil's penetration impedance.

The increasing application of cone penetrometers is due to: 1) this device is fast, easy, and economical; 2) their data are easily analyzed (Adamchuk et al 2001, Alihamsyah et al 1990, Andrade at al 2003); 3) they have wide range of applications. They also have several usages in agriculture and could be used to obtain information about different soils and their impedance (Ddesbiolers et al 1999), evaluating soil compaction due to movement of vehicles (Ddesbiolers et al 1999), predicting the traction performance of non-road vehicles by means of mean penetration impedance at 0 -15 cm of soil layer (Ddesbiolers et al 1999), and applying special penetrometers for determining soil's mechanical impedance against root growth and seed germination (Ddesbiolers et al 1999). In this investigation by using two different ploughs, moldboard and chisel, some of soil's post-tillage physical, mechanical, and microbial respiration properties were determined.

2. Materials and Methods

The experiment was carried out after harvesting products in a farm located in Saman, ChaharMahal and Bakhtiari province, Iran, longitude and latitude 50°57'48", as a factorial design in form of a complete random block design test in five replications. The soil texture was silt-clay. In this experiment the mechanical impedance of soil in non-ploughed state and also ploughed states with moldboard and chisel ploughs was determined by means of a penetrologger and then the soil samples were obtained from 10 to

20cm depths in order to determine the apparent special mass and microbial respiration.

Soil mechanical impedance determination method

In order to measure the soil's mechanical impedance, a penetrologger made by Eijkelkamp Company was used. This device was able to present integrated data from time of penetration. Also by connecting to a PC all data were presented through relative software. This device is consisted of electronic penetrologger, cone, link rod, and depth reflective screen. In this experiment 1 meter distances were used for sampling and 5 samples were obtained from each plot. The penetrologger indicated the soil penetration impedance in mega Pacal (MPa). The device's penetration speed in soil was chosen to be 30 mm/s.

Soil apparent special mass measurement

To measure the soil apparent special mass, the sampling was performed in different spots of each plot by penetrating a sampling cylinder with 60mm diameter and 40mm height, in expected depths of intact soil, and after drying the soil in an oven, the soil's apparent special mass was calculated (ASAE Standards 2001).

Soil transition and inversion amounts measurements

In order to determine the amount of soil inversion, a 1-meter frame was placed randomly in different parts of the farm and the amount of weeds inside the frame was weighed. By assuming that the weeds were distributed uniformly along the farm, the average weight of the weeds inside the frame was measured. After tilling and secondary measurements, the average sample weeds weights for different ploughs was determined. The percentage of soil inversion was calculated by equation (1) (Alihamsyah et al 1990):

$$F = \frac{W_P - W_E}{W_P} \times 100 \qquad (1)$$

Where,

F = the percentage of soil inversion;

W_p= weeds weight before tillage;

W_E = weeds weight after tillage.

In order to measure the amount soil transition, small wood pieces were scattered along the movement direction of one plough, and after tilling, the distance between the farthest wood pieces and the second plough furrow's wall was measured. The tractor slippage was determined by measuring the distances that the tractor moved in loaded and unloaded states. Therefore, the distance travelled in five rotation of tractor's wheel in both states, while tilling and not tilling, was measured and repeated 5 times for each plough.

Determining the microbial respiration

The microbial activity of the soil was measured by CO_2 emission method. In order to measure the microbial respiration about 110g dry air soil was accurately weighed and was placed inside a 1 liter jar. Then 40cc of distilled water was added to each jar to regulate the soil moisture content at 70 percent of field capacity (required for maximum microbial activity). Then about 10cc normal 0.5 NaOH was poured inside a 20cc plastic plate and was placed above the soil surface. The jars containing soil were placed inside an incubator at 25±1 °C. At last the amount of CO_2 emission from microbial respiration (C_t) was calculated from equation 2 in kg/mg:

$$C_t = \frac{(B - S) \times N \times E \times 1000}{W} \qquad (2)$$

Where,

B = ml of consumed acid without sample

S = ml of consumed acid with sample

N = acid normality

E = Equivalent weight

W = oven dried soil weight

And 1000 is the coefficient to convert soil grams to kilograms.

3. Results and Discussion

Figure 1 indicates significant differences for three treatments at level of 5% for mechanical impedance of soil. The soil tilled by moldboard plough showed 3% and 14% less penetration impedance rather than chisel ploughed and no-plough soils, respectively. This is due to soil flipping and consequently more soil disturbance at 30cm depth by moldboard plough, rather than chisel plough and no-tillage practices. The same results were reported by Bayat et la (2006).

By increasing depth because of more soil compaction in no-till soil and lesser impacts of tillage machineries, the soil's penetration impedance decreases (figure 2). While by increasing depth from 10cm to 20 and 30cm, the penetration impedance increases by 6.7 and 17 percent, respectively. The same results were reported by Hosseinzadeh et al (2008).

Figure 3 shows the variations in penetration impedance for tested treatments. In no till soil, the apparent density is higher than soil tilled with moldboard and chisel ploughs. Since in tilled soils the soil compaction decreases, therefore this causes the soil density to decrease. Other researches show same results (Bayat, 2006).

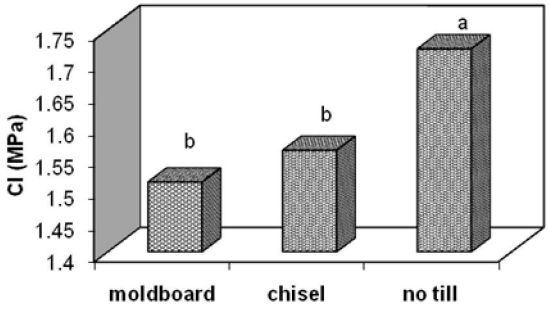

Figure 1 – the average penetration impedance in no-till soil, and tilled by chisel and moldboard ploughs

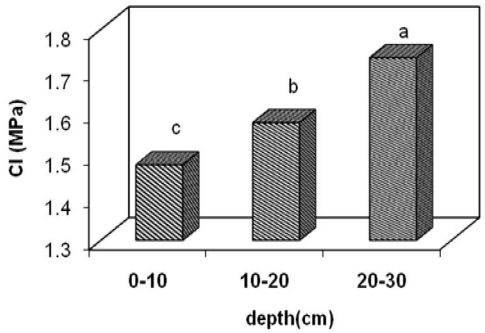

Figure 2 – average penetration impedance of soil in different depths

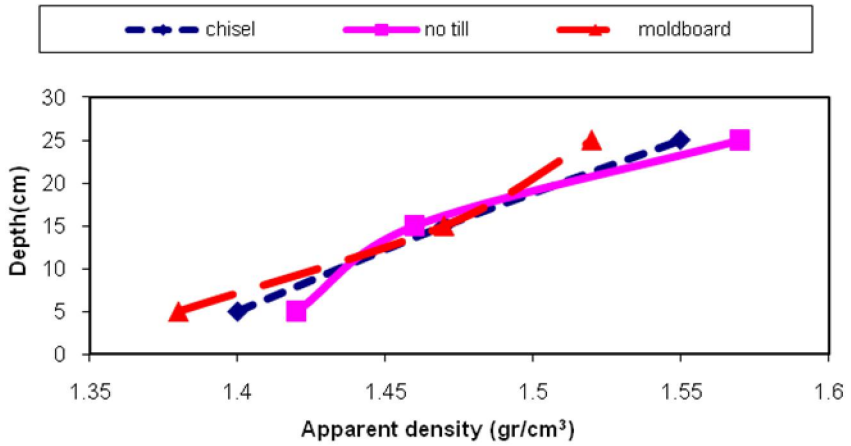

Figure 3 – apparent density variations at different depths

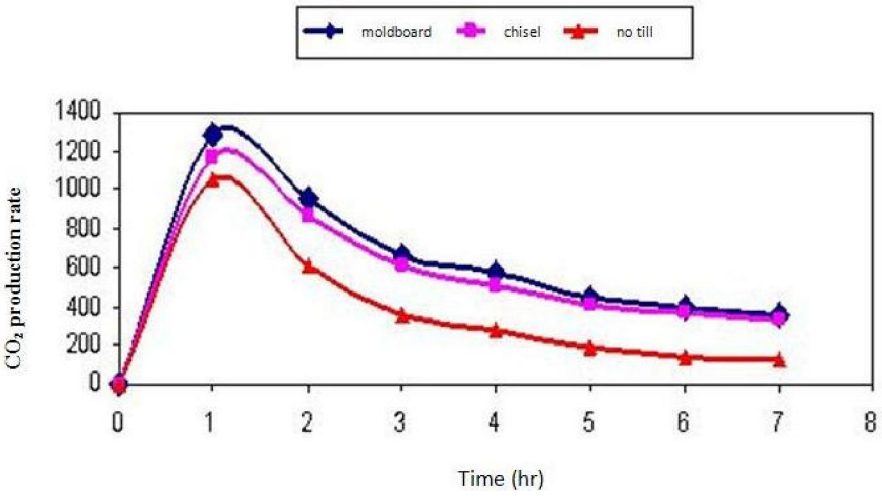

Figure 4 – CO_2 production rate for different tillage practices

It is indicated in figure 4 that at sampling depths, the moldboard plough caused more microbial respiration in soil due to its better soil flipping and mixing of wheat residues with soil and consequently placing more organic materials inside sampled soil and or applying larger contact surface for microorganisms with plant residues. This is quietly significant in first and second weeks. But as the time passes during next weeks, and by consumption of substrate, this difference between moldboard and chisel ploughs decreases. In no-till practice soil, since there is no mixing of residues and soil particles breakage, therefore shows less the respiration. Ghorbani et al also reported the effect of different tillage practices on soil microbial activities (Ghorbani, 2005).

The regression relationship between apparent special mass and soil penetration impedance with determination coefficient of 92%, shows a relationship between these two parameters by τ = 1.4427(1- e-1.9091m) equation (where m is apparent special mass and τ is mechanical resistance). In this equation the in apparent special mass with exponential function causes an increase in soil mechanical impedance. Same experiments have reported same results (Bayat, 2006). According to this, it is obvious that by decreasing mechanical impedance and apparent mass, the soil porosity and air condition will increase and therefore the microbial activity will increase.

Soil inversion percentage measurements for both tested ploughs showed that moldboard plough had the highest soil inversion with 79%, which is important from two aspects: first from mixing organic material and plants residues with soil that is positive for choosing this plough, and second from decreasing surface residues which increases the moisture loss rate and also soil erosion that is negative for choosing this plough (Table 1). By measuring tractor slippage it was indicated that chisel plough causes less slippage due to lower draft resistance and therefore favors lower energy consumption rather than moldboard plough. Also it was indicated that moldboard plough because of its performance width, displace soil more to the sides and causes soil erosion. Noorbakhsh et al (2004) reported same results.

4. Conclusions

Due to importance of tillage stage, different factors should be selected for determining various tillage machineries and practices. Using moldboard increases energy consumption but by decreasing mechanical impedance of soil, has a positive effect on germination and by disturbing the soil and increasing microorganisms' activity, is effective in improving crops' growth. However, it is worthy to mention that in no-till practice, decreasing soil erosion, moisture maintenance, and decreasing energy consumption are the main positive effects. Therefore, in order to choose a proper tillage practice, more study is needed.

Table 1 – some of plough properties for two different ploughs

	Moldboard	Chisel
Tractor wheel slippage	17.8%	13.1%
Soil displacement to performance width ratio	1.22	0.61
Inversion percentage	79%	28%

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6/9/2011