Effect of Plowing Depth and Soil Moisture Content on Reduced Secondary Tillage

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ABSTRACT

This study was carried out to investigate the effect of plowing depth and soil moisture content on reduced secondary tillage operation. Split plots were used for statistical analysis. The main plot was used for the percentage of soil moisture content and the sub-plot was used for investigation the effect of plowing depth (15-20 and 25-30 cm). Each treatment was replicated three times. For primary tillage and secondary tillage operations, moldboard plow and disk harrow were used, respectively. This research was done in two different land types; silty clay loam and loam soil. Based on this research, in the silty clay loam soil, clod mean weight diameter of soil was minimum with 15-18 % of soil moisture content regardless of plowing depth, and it was maximum with 10-13 % of soil moisture content. In the loam soil, clod mean weight diameter was minimum at 18-20 % of soil moisture content for 15-20 cm plowing depth and at 13-18 % of soil moisture content for 25-30 cm plowing depth. Results showed that, if primary tillage be performed in the optimal soil moisture content, we will have suitable seedbed with minimum secondary tillage operation. This can reduce the costs of secondary tillage operations.

Keywords: Secondary tillage, plowing depth, moisture content, soil, reduced tillage.

1. INTRODUCTION

For thousands of years of recorded history, humankind has been tilling the soil in order to increase the production of food. Soil tillage, in general, is one of the fundamental field operations in agriculture because of its influence on soil properties, environment, and crop production. To assure normal plant growth, the soil must be prepared in such conditions that roots can have enough air, water, and nutrients. (Gill and McCreery, 1960; Gill and Vandenberg, 1967; McKyes, 1985; Boydas and Turgut, 2007).

Using combined equipment and reducing number of passes is getting popularity due to its effect on time, efficiency and costs. Disk harrow is the most common equipment used for clod breaking rather than weed control or residue mixing after moldboard plow in Iran. Moldboard plow leaves cloddy and un-even surface, which need to use disk harrow several times in many regions. This operation could affect soil structure, create crust, increase risk of erosion and change operation cost and working time significantly (Javadi and Hajiahmad, 2006).

Tillage equipment should be capable to prepare a suitable seedbed with minimum expense (Kepner et al. 1978). According to the previous researches, about 60 % of total energy required for preparing the soil is used for tillage and preparing a good seedbed (Jacobs and Harrol, 1983). Therefore it is very important to know which parameters can reduce the cost of tillage and traffic in fields.

In order to efficiently handle the demand in agricultural food production, soil physical properties must be managed adequately. The main aspect of soil physics for plant productivity is to preserve suitable proportions between solid, liquid, and gaseous phases (Glinski and Lipiec, 1990). Soil physical properties are extremely vital to plant growth. The influence of tillage implements on soil physical properties is significant (Boydas and Turgut, 2007). Buschiazzo et al. (1998) determined that the soil physical properties, affected by soil tillage treatments, could influence the yield level of grown crops. Aggregate size, moisture content, penetration resistance, and bulk density are important soil physical properties.

Soil moisture content (SMC) is a very important parameter for cutting and milling the soil by moldboard plow. With low soil moisture content the cohesion force between particles of soil is very strong and a lot of energy is needed during tillage. Also after tillage there are big clods in the field. With the higher soil moisture content, tillage equipment cannot be used in the field. The plowing depth is also a very important and effective parameter. Increasing the plowing depth raise the clod mean weight diameter (MWD) (Yassen et al. 1992).

Most tillage experiment inconsistencies are due to the complexity of the changes in soil properties caused by tillage (Douglas and Mckyes (1983)). Chang and Lindwall (1990) indicated from a literature review that soil property changes due to tillage are related to several things. Those things include soil type, type of tillage equipment, tillage depth, soil conditions such as moisture content at the time of tillage and climatic conditions. Bauer and Kucera (1978) concluded inconsistencies in relative grain yield differences among tillage treatments over a period of years were, in part, associated with inconsistent differences in soil properties produced by given tillage treatments from one year to another. Inconsistencies were concluded to be likely associated with the presence of soil water at the time of tillage and climatic conditions - primary water supply, water distribution and temperature.

Site soil properties will affect how a tillage system changes the soil properties. Ojeniyi and Dexter (1979) indicated that there is optimum water content were tillage produces a maximum number of small soil particles and a minimum number of large voids. They also indicated that greatest total macro porosity was produced in the range of water contents 12.6 to 18.3 percent on an Urrbrae loam soil (17 % clay, 32 % silt and 51 % sand). Russell (1961) states researchers generally accept that a soil particle size range of 1 to 5 mm is required for seedbeds.

1.1 Objectives

Primary tillage operation often creates cloddy and un-even soil surface due to limited time and inappropriate moisture content in the most parts of Iran. Farmers therefore use disk harrows several times to overcome this problem, which affect soil properties, time and costs of operation significantly. The aim of this research was to investigate the effect of plowing depth and soil moisture content on reduced secondary tillage (ST).

2. MATERIALS AND METHODS

The following experiments were carried out under this study.

2.1 Experimental Procedure

In this research, the experiments were done in different soil moisture contents approximately 10-13, 13-15, 15-18, and 18-20 % and in two plowing depths, approximately 15-20, and 25-30 cm. After irrigation for each experiment, desired moisture contents were achieved when soil moisture was reached to the mentioned limits. Tillage depths were achieved using a depth control wheel.

Experimental fields were designed split plots according to the split-plot scheme and were used for statistical analysis. The main plot was the soil moisture content and the sub-plot was plowing depth. Four levels were considered for the main factor and two levels for the sub-plot. The area of main plot and sub-plot were 50* 100 m^2 and 8*40 m^2, respectively. The plots were selected randomly and clod mean weight diameter was measured in three points of each plot. Repetition for each treatment was three times. The experiments were done in two different soil types, one soil was silty clay loam soil (SCLS) and another soil was loam soil (LS). The soil properties of the soil layer 0-30 cm of the experimental site are shown in Table 1.

Table 1. Some soil properties of experimental site

Soil texture	**Silt (%)**	**Clay (%)**	**Sand (%)**	**Bulk density (Mg/m^3)**	**Particle density (Mg/m^3)**	**Organic matter content (%)**
Silty clay loam	62	32	6	1.43	2.85	2.17
Loam soil	82	17	46	1.24	2.62	2.23

Primary tillage was conducted in the third week of April 2006. A mounted moldboard plow (3 bottoms with a 30 cm working width) was used for primary tillage. The experiment area was left completely fallow from the third week of April to the first week of October. Secondary tillage was performed four times by a tandem disk harrow (20 disks with a 530 mm diameter, 5 each in 4 rows and working width of 1400 mm) with the same direction of plowing. At the high level of soil moisture contents, both moldboard and disk harrow were equipped with a series of mudguard in order to prevent adhesion of soil on the surface of these tillage implements. Operating speed used for primary and secondary tillage operation was 1.25 ms^{-1}. Tillage implements were pulled by a Massey Ferguson MF285 Model tractor. After plowing and each secondary tillage operation, soil samples from each plot were collected for determining the clod mean weight diameter, penetration resistance, and soil moisture content.

The results obtained were subjected to analysis of variance (ANOVA) and Duncan's test using SPSS 13 (SPSS Inc., USA).

2.2 Clod mean weight diameter (MWD)

To determine the clod mean weight diameter, soil samples were randomly taken from the tilled plots, with three replications, using a special auger at the 0-30 cm depth soon after the primary and secondary tillage operation. The moist soil samples were allowed to air dry at room temperature for three months. After the primary and secondary tillage, the air dried soil sample was sieved using a set of sieves (mesh openings of 70, 63, 32, and 16 mm) with a shaking time of 30 s (Eghball et al., 1993). The clod mean weight diameter was calculated by using the formula below (Boydas and Turgut, 2007):

$$MWD = \sum_{i=1}^{n} \frac{w_i}{w} D_i \qquad (1)$$

where:
w_i = The weight of soil on each special sieve (kg)
w = The total weight of experimented soil (kg)
D_i = Net diameter of each sieve (cm)

2.3 Soil moisture content (SCM)
Special auger was used for measuring the soil moisture content for each depth between 0 and 30 cm. The weight of the wet soil samples was measured and then the soil sample was put in an oven at 105°C for 24 hr and then the weight of dry sample was measured. The following formula was used for calculating the soil moisture content (Javadi and Hajiahmad, 2006).

$$SMC = \frac{W_w - W_d}{W_d} 100 \qquad (2)$$

where:
SMC = Soil moisture content dry base
W_w = Weight of the wet soil (g)
W_d = Weight of the dry soil (g)

2.4 Soil penetration resistance
Penetration resistance was measured by three insertions in each plot after primary and secondary tillage operation. A penetrometer (SP 1000) was used with 12.83 mm cone diameter and 30 degree angle based on ASAE standard (ASAE, 1995). Penetrometer measurements were taken in depth in increments of 0 to 30 cm.

3. RESULTS AND DISCUSSION

3.1 Soil Moisture Content
According to the results (see Fig. 1), in the silty clay loam soil, the clod mean weight diameter of soil was lowest for both plowing depth (PD) at 15-18 % of soil moisture content after second or third secondary tillage, and it was highest for the same depth but with 10-13% of soil moisture content after first or second secondary tillage. The minimum value of clod mean weight diameter of soil after plowing for 15-20 and 25-30 plowing depth were gained at 10-13 and 15-18 % respectively, and the maximum value of clod mean weight diameter of soil for them were gained at 13-15 and 10-13 %, respectively.
Results (see Fig. 2) show that, in the loam soil, clod mean weight diameter was at the minimum for 15-20 cm plowing depth with 18-20 % of soil moisture content, and 25-30 cm plowing depth with 13-15 or 15-18 % of soil moisture content after second secondary tillage,

and it was at the maximum for both plowing depth with 10-13 % of soil moisture content after the first or second secondary tillage. The minimum and maximum value of clod mean weight diameter of soil after plowing for 15-20 cm plowing depth were gained at 15-18 and 10-13 %, respectively, and these values for 25-30 cm plowing depth were gained at 15-18 and 18-20 %, respectively.

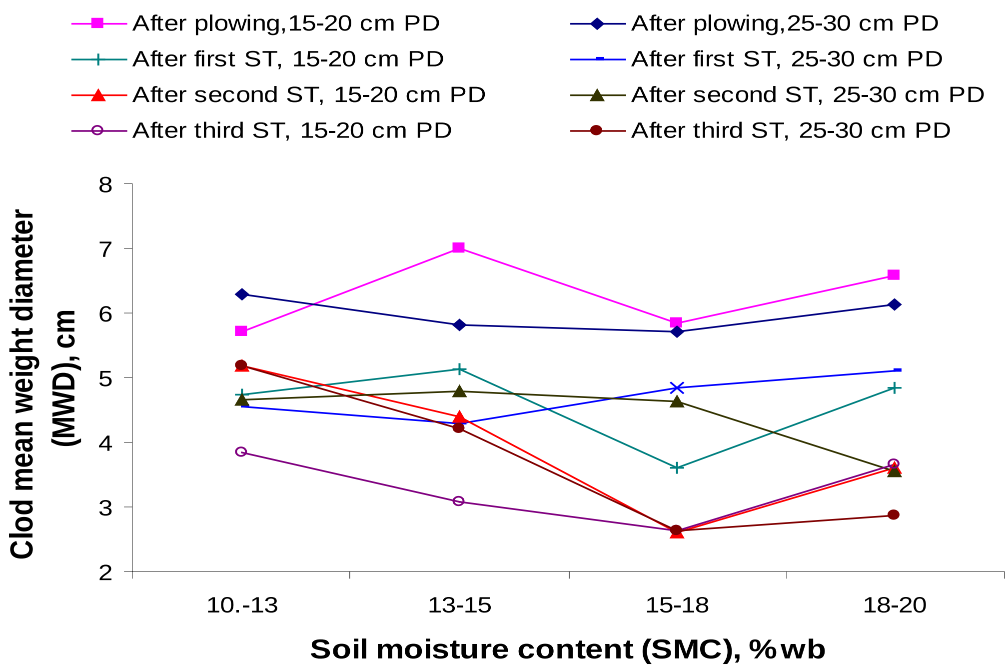

Figure 1. Clod mean weight diameter of silty clay loam soil in different soil moisture content, plowing depth, and number of secondary tillage

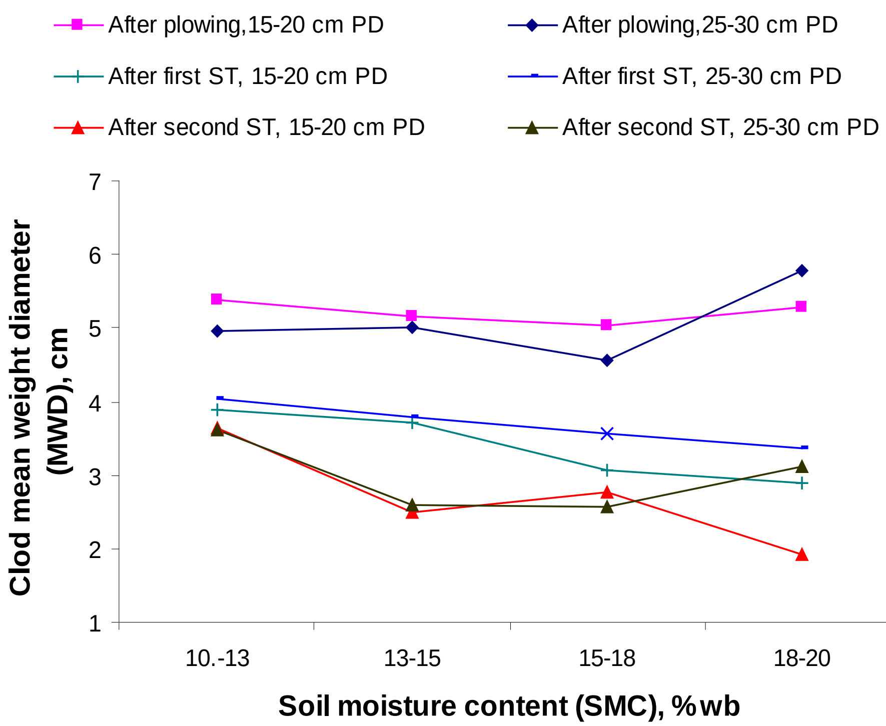

Figure 2. Clod mean weight diameter of loam soil in different soil moisture content, plowing depth, and number of secondary tillage

Tables 2 and 3 show the comparison of clod mean weight diameter against soil moisture content in the silty clay loam and loam soil, respectively. Results show that the percentage of soil moisture content has an effect on clod mean weight diameter.
According to the Table 2 in the silty clay loam soil, clod mean weight diameter is lowest at 15-18 % soil moisture content and is highest at 10-13% SMC.
In the loam soil, clod mean weight diameter was lowest at 15-18 and 13-15 % soil moisture content, respectively, and it was highest at 10-13% SMC (see Table 3).
Therefore, it can be concluded that in the silty clay loam soil the best soil moisture content for tillage is 15-18%, and in loam soil the best soil moisture content for tillage is 13-18%.

Table 2. Comparison of clod mean weight diameter against soil moisture content in silty clay loam soil- In each column the means with different letter have significant difference (Duncan 1%)

SMC (%)	MWD(cm)
10-13	5.06 b
13-15	4.83 b
15-18	4.06 a
18-20	4.55 ab

Table 3. Comparison of mean of clod mean weight diameter against soil moisture content in loam soil- In each column the means with different letter have significant difference (Duncan 1%)

SMC (%)	MWD(cm)
10-13	4.27 b
13-15	3.71 a
15-18	3.58 a
18-20	3.79 ab

3.2 Soil Cone Index (SCI)

Table 4 shows the relationship between soil cone index in the loam soil, soil moisture content, and plowing depth. According to this table, in the loam soil before and after tillage, the maximum soil cone index reduction about 40% occurred at soil moisture content 13-15% and at plowing depth 25-30 cm, and the minimum soil cone index reduction 4.9% occurred at soil moisture content 15-18% and at plowing depth 15-20 cm.

On the other hand, with an increase in plowing depth, the percentage of soil cone index reduction before and after tillage in different soil moisture content was increased, therefore for reducing the resistance penetration, the best soil moisture content and plowing depth are 13-15% and 25-30 cm, respectively.

Table 4. Relationship among soil cone index in the loam soil, soil moisture content, and plowing depth

SMC (%)	PD (cm)	SCI before tillage (kPa)	SCI after tillage (kPa)	Reduction of SCI (%)
18-20	15-20	1464	1160	20.7
18-20	25-30	1646	1009	38.7
15-18	15-20	1380	1312	4.9
15-18	25-30	1494	1039	30.4
13-15	15-20	1509	1138	24.6
13-15	25-30	1835	1100	40
10-13	15-20	1608	1305	18.9
10-13	25-30	1585	1221	23

3.3 Plowing Depth

According to the results of Figures 1 and 2, in the silty clay loam soil, we can see that the clod mean weight diameter is at minimum about 2.62 cm in plowing depth 15-20 cm after second secondary tillage and in plowing depth 25-30 cm after third secondary tillage, in the same soil moisture content 15-18 %. In the loam soil, the clod mean weight diameter is at minimum about 1.93 cm in plowing depth 15-20 cm after the second secondary tillage in soil moisture content 18-20 %.

3.4 Number of secondary tillage

Table 5 shows the comparison of clod mean weight diameter against operating tillage in the silty clay loam and loam soil. Results show that the number of secondary tillage is affected by clod mean weight diameter. Clod mean weight diameter was 3.51 cm in the silty clay loam and loam soil after third and first secondary tillage, respectively. For example the best clod mean weight diameter for planting potatoes is about 3.50 to 3.70 cm. Therefore in silty clay loam soil with 15-18 % soil moisture content and in loam soil with 18-20% soil moisture content, we can get optimal clod mean weight diameter after third and first secondary tillage, respectively.

Table 5. Comparison of clod mean weight diameter against operating tillage in the silty clay loam and loam soil- In each column the means with different letters has significant difference (Duncan 5%)

Name of operating tillage	MWD in SCLS (cm)	MWD in LS (cm)
After plowing	6.15 c	5.16 b
After one disk harrow	4.65 b	3.51 a
After two disk harrow	4.17 ab	2.85 a
After three disk harrow	3.51 a	-

4. CONCLUSIONS

In this research, it was found that soil moisture content and number of secondary tillage affect on the clod mean weight diameter. Two types of soil were investigated and results showed that in the silty clay loam soil and loam soil the best soil moisture content for tillage are 15-18 and 13-15%, respectively. In these soils moisture content, optimal clod mean weight diameter after minimum number of secondary tillage can be achieved. Also at these soils moisture content, primary tillage can be done at 15-20 cm plowing depth. Therefore it can reduce costs of secondary tillage.

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