Effects of Secondary Tillage Implement on Some Properties of Soil and Yield of Sunflower

B. Kayişoğlu **Y. Bayhan** **L. Taşeri**

Department of Agricultural Machinery, Agricultural Faculty, University of Namık Kemal, Tekirdag-Turkey.

In this study, field cultivator (FC), disk harrow (HD), combination of cultivator with spring teeth and rotary harrow (CS+RH) were used as secondary tillage equipment in spring. Physical properties of soil such as bulk density, porosity, mean weight diameter and aggregate stability were determined before and after tillage. Moreover, effect of different seedbed preparation techniques on yield of sunflower was also investigated.

In the result of the study, differentiations among the secondary tillage equipment were observed due to bulk density and porosity. Small sized aggregates (1-5mm) were highly in tillage with combination of cultivator with spring teeth and rotary harrow. While the mean weight diameter, which shows the durability of aggregates to water, was 2.83 mm before tillage, it was 3.96 mm in tillage with DH, 1.80 mm in tillage with FC and 2.50 mm in tillage with combination equipment. Although the mean weight diameter in tillage with DH increased, decreased in tillage with FC. The best aggregate stability obtained from seedbed preparation by disc harrow. On the other hand field cultivator is the most affective soil embossing tool while the cultivator with spring teeth rotary harrow combination is smashing.

The yield values were found 2.002 Mg ha^{-1} with DH, 2.106 Mg ha^{-1} with FC, 2.175 Mg ha^{-1} with CS+RH.

Keywords: Secondary tillage, bulk density, aggregate stability, sunflower yield

İkinci Sınıf Toprak İşleme Aletlerinin Toprağın Bazı Fiziksel Özellikleri ve Ayçiçeği Verimini Üzerine Etkileri

Bu çalışmada, ayçiçeği tarımında tohum yatağı hazırlamak amacıyla tarla kültivatörü, döner ve yaylı ayaklara sahip kombine tırmık ve diskaro kullanılmıştır. Bu ikinci sınıf toprak işleme aletlerinin toprağın fiziksel özelliklerine olan etkisini ortaya koymak amacıyla toprağın hacim ağırlığı, porozitesi, ortalama ağırlıklı çapı ve agregat stabilitesi değerler ölçülmüştür. Bu işlemler toprak işleme öncesi ve sonrası yapılmıştır. Ayrıca, farklı tohum yatağı hazırlama tekniklerinin ayçiçeği verimi üzerindeki etkileri de araştırılmıştır.

Araştırma sonucunda, toprak işleme aletlerinin toprağın hacim ağırlığı ve yoğunluğu üzerinde farklı etkiler yaptığı gözlenmiştir. Kombine tırmıkla işlenen topraklarda küçük boyutlu agregatların (1-5 mm) dağılımı oldukça yüksek bulunmuştur. Agregatların suya dayanımının ölçüsü olan ortalama ağırlıklı çap, toprak işlemeden önce 2.83 mm iken, bu değer diskaro ile işlemeden sonra 3.90 mm, tarla kültivatörü ile 1.80 mm ve kombine tırmıkla 2.50 mm olmuştur. Diskaro ile işlemeden sonra ortalama ağırlıklı çap artarken tarla kültivatörü ile işlemeden sonra bu değer azalmıştır. En iyi agregat stabilitesi diskaro ile işlemeden sonra elde edilmiştir. Diğer yandan tarla kültivatörü en etkili kabartma işlemini yaparken, parçalama ekinliği de kombine tırmıkta daha fazla olmuştur.

Farklı tohum yatağı hazırlama yöntemlerinde ayçiçeği verimi, diskaro ile 2.002 Mg/ha, tarla kültivatörü ile 2.106 Mg/ha ve kombine tırmıkla 2.175 Mg/ha olarak gerçekleşmiştir.

Anahtar Kelimeler: İkinci sınıf toprak işleme, hacim ağırlığı, agregat stabilitesi, ayçiceği verimi.

Introduction

Maintenance of soil structure is an important feature of sustainable agro ecosystems because of its role in many biological and physical soil processes. Good soil structure promotes favorable water relations, root environment, and build-up of organic matter and reduces the susceptibility to erosion. Therefore, understanding the processes of aggregate formation and degradation will aid in making management decisions to maintain a good soil structure (Bossuyt et al., 2001).

The stability of aggregates at the immediate soil surface greatly influences the susceptibility of soil to erosion. Raindrop impact on exposed soil causes breakdown of surface aggregates. This breakdown affects infiltration, surface sealing, soil detachment, and finally soil erodibility. Stability of soil aggregates is probably the single most important soil property governing soil erodibility. Therefore, soil physical, chemical, mineralogical, and microbiological properties that influence aggregate stability indirectly influence soil erodibility (Reichert et al., 2001). Aggregate formation and stabilization are affected by several factors. One of these factors is the type of tillage implement.

Tillage has an important role in controlling weeds and managing crop residue, but the primary purpose of tillage is to change soil structure (Raney and Zinng, 1957), to create conditions favoring germination of seed, emergence of seedlings, and growth of crops, while maintaining aggregate strength to make the soil less susceptible to erosion (Francis and Cruse, 1983; Adam and Erbach, 1992).

In Turkey 17,85 million ha area is used for crop production. In winter, cereals are planted in approx. 78.5% of this area. In spring, the balance pulse to industrial crops, oil seed and tuber crops. During soil tillage, different secondary tillage implements are used. Some of these implements cause the formation of a surface crust and erosion because of the fragmented topsoil on the other hand, some implements leave large clods. Surface crust and large clods, which are the results of different tillage, have negative effects on seed germination and seedling emergence.

The aim of this study is to examine the effects of arranged secondary tillage implements (field cultivator, disk harrow, combination of cultivator with spring teeth and rotary harrow) on size distribution of clods, an aggregate stability and on the seedling emergence of sunflower.

Materials and methods

Experiment site description

The experimental site was established in April 2000 at experimental area of Tekirdag Agricultural Faculty (27^{o} 34´E and 40^{o} 59´N). The soil is loam clay with a texture of 37 % sand, 25% silt and 38% clay. The organic matter and pH of the soil were 1.24% and 7.2 respectively. Average moisture content was 17.2% in the depth range of 0-10 cm, 19.3% in the depth range of 10-20 cm and 23.7 % in the depth range of 20-30 cm. The climate of Tekirdag is characterized by Mediterranean type with mild and rainy winters and hot and dry summer at the coast while continental type prevails inside. The 64 year (1939 between 2002) mean annual temperature, relative humidity and total annual precipitation are 13.8 ^{o}C, 75% and 580.8 mm, respectively. In 2000, the averages of annual temperature, relative humidity and total annual precipitation are 14.4 ^{o}C, 78.5% and 410.1 mm, respectively. Average monthly rainfall, temperature, relative humidity during the vegetation period of sunflower, was 50.9 and 48.5 mm for March, 7.2 and 14.0 ^{o}C, 81.2 and 84.57% for April respectively (Anonymous, 2002).

The experimental area comprised of two adjacent sites used for wheat and sunflower rotation for several years. This area was tilled by chisel plough after harvesting of wheat and removing of straw in summer, by moldboard plough in autumn and by chisel plough again early spring. Finally, seed-bed was prepared by three different secondary tillage equipment in spring.

Experimental design

The experimental design was a complete randomized plot with three replicates of each treatment. A plot was 20 m long by 6 m wide and contained eight rows of sunflower on 70 cm row spacing. There were three secondary tillage implements, viz disc harrow, field cultivator and combination of cultivator with spring teeth and rotary harrow (referred to as DH, FC and CS+RH, respectively).

Secondary tillage implements

Disc harrow (DH): Mounted and offset type with 16 discs.

Field Cultivator (FC): Rigid tines, four in the front and five in the back.

Combination of cultivator with spring teeth and rotary harrow (CS+RH): Spring teeth, in four rows (5, 5, 5 and 6) and a tandem rotary harrow.

Measurements

In order to measure soil penetration resistance, an Eijelkamp Stiboka mechanical penetrometer was used. The penetration values were determined according to ASAE standard S313.2 (Anonymous, 1994).

The soil samples were randomly taken from A horizons (0-10 cm) from each plot. The size distribution of clods, bulk density, porosity and aggregate stability were determined before and after secondary tillage.

Size distribution of clods: After and before tillage, soil samples (approx. 4kg) were collected from each plot with three replications. The soil samples were dried by air in the laboratory and then sieved into five size categories by using an oscillating sieve shaker. The shaker was run at a rotation speed of 540 rev/min for 30 seconds (Chepil and Bisal, 1943). The aggregate size classes were; weight 19-, weight 8-, weight 4.75-, and weight 2 mm. The weight percentage of each category was calculated.

Bulk density and porosity: Bulk density was calculated according to Blake and Hartge (1986) and porosity, Danielson and Sutherland (1986).

Mean weight diameter: A wet sieving method was used to determine the mean weight diameter (MWD) as an index of the water-stability of aggregates. The sieving method of Kemper and Rosenau (1986) was used with a set of sieves of 19, 8, 4.75, 2 and 1 mm diameters. After the soil samples were passed through an 8 mm sieve, approximately 50 g of soil put on the first sieve of the set and gently moistened to avoid a sudden rupture of aggregates. After the soil had been moistened, the set was sieved in distilled water at 30 oscillations per minute. After 10 min of oscillation, the soil remaining on each sieve was dried, and then sand and aggregates were separated (Gee and Bauder, 1986). The mean weight diameter was calculated as follows:

$$\text{MWD}= \sum_{i=1}^{n} X_i W_i$$

Where MWD is the mean weight diameter of water stable aggregates, X_i is the mean diameter of each fraction (mm) and W_i: is the proportion of the total sample mass in the corresponding size fraction after the mass of stone has been deducted (upon dispersion and passing through the same sieve).

Aggregates stability: The Kemper and Roseanau equation was used to calculate aggregate stability taking the results of wet sieving into account (Black, 1965).

Percent emergence was calculated by dividing the number of emerged plants counted by the number of seeds dropped by the planter in the 4.2 m row length predicted from the number of seeds dropped for a specific number of turns of the planter drive wheel. Plants were counted again at the 2-3 true leaf stage of growth to assess final emergence and plant stand (Smith et al., 2002).

By means of crop yield, four middle sunflower rows (2.8 X 15) were harvested and threshed by hand (Varsa et al., 1997).

Statistical analyses

In order determine the effects on soil physical properties and sunflower growth of secondary tillage implements; a linear model was used as below:

$$y_{ij} = \mu + STI_i + e_{ij}$$

Where:

y_{ij} = Observed value,

μ = estimated population mean,

STI_i = random secondary tillage implement effect,

e_{ij} = residual.

The analysis of variance (ANOVA-2) procedure was carried out to compare the effect of secondary tillage implements on the measured soil physical properties and sunflower growth (Freed et al., 1988). Mean separations were conducted using least significant difference (LSD) at *P< 0.05 test when ANOVA indicated a significant F-value (Steel and Torrie, 1980; Nyamangara et al., 2001).

Results and discussion

Penetration resistance

The effect of implements on soil penetration was given in Figure 1. The lowest penetration resistance of 0.158 MPa was observed between the soil depths 5-7.5 cm with implement of CS+RH while the highest value of 0.225 MPa was obtained with implement of DH. At 7.5-10 cm depth, the highest penetration resistance was found as with implements of DH and CS+RH. This was because the share of the tillage tools pressed the soil, which let to the formation of on hard layer below the seedbed. Implement of FC was the best tillage tool that loosens the soil profile between the depths 10 and 15 cm whereas the least one was implement of DH.

At 15 cm depth, the highest penetration resistance was found as 0.843 MPa with DH, and the lowest was 0.435 with FC. The highest resistance decrease due to tillage.

Size distribution of clods

The distribution of dried aggregate size was given Figure 2. After tillage,the most of aggregates in the DH were greater size than 19 mm (38%), and the least in soil tilled with CS+RH (28%). Size distribution of clods among 8-19 mm was the most in soil tilled with CS+RH (21%), the least in soil tilled with FC, 16%. Size distribution of clods between 4.74-8.00 was 11% in soil tilled with FC, 8% in soil tilled with CS+RH, and 9% in soil tilled with DH. Size distribution of clods between 2.0-4.75 mm was the most in soil tilled with FC (23%), and the least in soil tilled with DH (12%). Aggregates smaller than 2 mm was the highest in soil tilled with CS+RH (24%) and the lowest in soil tilled with FC (15%). When this criterion is taken into consideration during the seedbed preparation with CS+RH (43%) of total aggregate was formed with the aggregates having mean diameter in this interval. DH had the lowest value as 27% between these implements (Table-1).

Some tillage operations used for seedbed preparation, herbicide incorporation, and row crop cultivation may be structurally damaging to the soil. This damage may manifest itself as surface crust, large clods in the seedbed, poor seed germination, and delayed seedling emergence (Hamblin, 1987; Adam and Erbach, 1992). It is generally accepted that an aggregate size range of from 1 to 5 mm is required for a good seedbed (Russell, 1961; Adam and Erbach, 1992). However, this size range caused soil erosion (Reichert et al., 2001).

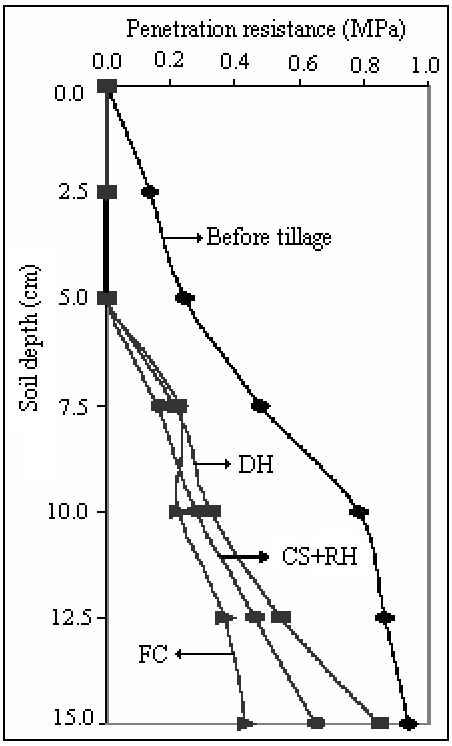

Figure 1. Penetration resistance as affect by secondary tillage tools

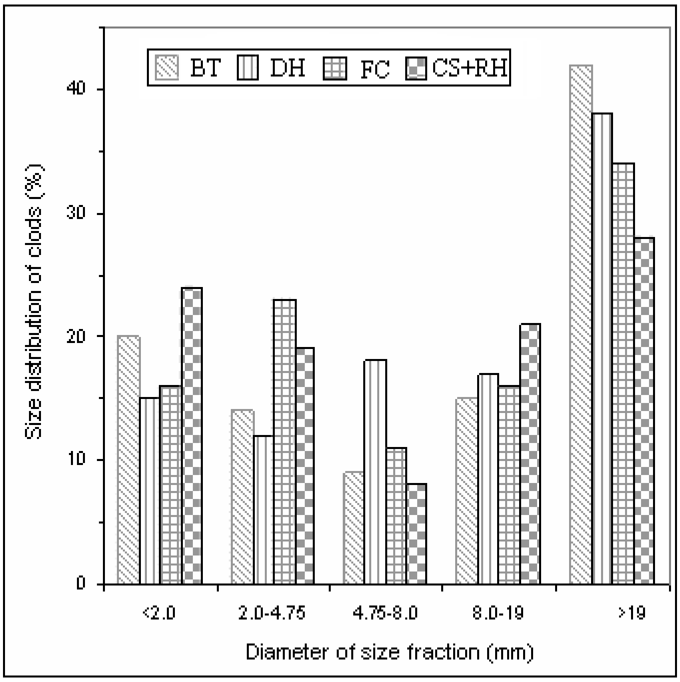

Figure 2. Dry soil aggregate as affected secondary tillage tools

Table 1. Effect of secondary tillage tools on size distribution of clods

Aggregate size distributions	Size distribution of clods (%)			Statistics of values			
	DH	FC	CS+RH	EMS	Fcal	LSD	CV%
<2.0 mm	15[b]	16[b]	25[a]	6.333	14.26*	5.70449	13.48
2.0-4.75 mm	12[b]	23[a]	19[ab]	9.944	9.20*	7.14865	17.41
4.75-8.0 mm	18[a]	11[ab]	8[a]	8.778	8.86*	6.71647	24.46
8.0-19.0 mm	17	16	21	7.111	3.25ns	--.--	14.91
19mm<	38[a]	34[b]	28[c]	2.278	35.76**	3.42153	4.54

Ns: Non-significant, * Significant, ** Highly significant, EMS: Error means squares. The means were taken P=0.05. Mean having the same letters are not significantly different at the probability of 5%

Bulk Density

The bulk density of soil in the field on the clods was found as before tillage 1.83 g cm^{-3} between 0 and 10 cm. After tillage there was a decrease in the bulk density of soil such as; 4.37% in DH, 2.19% in FC, 3.83% in CS+RH. The decrease in soil tillage implements bulk density was found high in soil tilled with DH and CS+RH. Although all the implements were significantly effective on bulk density, there was no significant difference among bulk density values of tillage implements according to statistical analyses (Table-2).

Porosity

Porosity, which is directly dependent on the bulk density, emphasizes the change of bulk emptiness in soil as a result of tillage. There is a contrary relation between the bulk density and porosity.

The porosity values were found 33.96% in the soil tilled with DH, 32.45% in the soil tilled with FC, and 33.58% in the soil tilled with CS+RH. Although we got the maximum value with DH, there was no significant difference between the porosity values of all implements (Table-2).

Table 2. Effect of secondary tillage tools on bulk density and porosity

	Tillage tools			Statistics of values			
	DH	FC	CS+RH	EMS	Fcal	LSD	CV%
Bulk density ($g\ cm^{-1}$)	1.75^b	1.79^a	1.76^b	0.0000759	13.18*	0.0197629	0.55
Porosity (%)	33.96	32.45	33.58	0.466	3.80^{ns}		2.05

The means were taken P=0.05. Mean having the same letters are not significantly different at the probability of 5%

Mean weight diameter

Mean weight diameter is used for making explanation about the water stability of aggregates. In the evaluation made according to the total of diameter groups, the value of soil tilled with DH increased after tillage. There was a big decrease in aggregate index of soil tilled with FC (Table-3).

Water stable aggregates increased with tillage by DH. The mean weight diameter of wet soil was greater than that before tillage and mean weight diameter increased. The mean weight diameter tilled with FC was less than before. There was no significant change in soil tillage with CS+RH (Figure-3).

Aggregate Stability

Aggregate stability was found 68% in the soils having 1-2 mm diameters before secondary tillage. In that diameter group water stable aggregates were found most in soil secondary tilled with DH as 63%, and the least in soil secondary tilled with CS+RH as 44%. Aggregate stability in 2-4.75 mm diameter group was highest with 16.26% in soil tilled with DH and the least in soil tilled with CS+RH as 8.16%. Aggregate stability in 4.75-8 mm diameter group was found the most with 5.89% in soil tilled with CS+RH and the least in soil tilled with DH as 2.23%. Aggregate stability in 8-19 mm diameter group was highest with 18.05% in soil tilled with DH and the least in soil tilled with FC as 5.09% (Table-4). The highest aggregate stability was found in tillage with DH. There wasn't any significant difference between FC and CS+RH considering the aggregate stability (Figure-4).

Table 3. Effect of secondary tillage tools on mean weight diameter

Aggregate size	MWD (mm)			Statistics of values			
distributions	DH	FC	CS+RH	EMS	Fcal	LSD	CV%
1.0-2.0 mm	0.90^a	0.71^b	0.56^c	0.001	82.46**	0.11887	4.53
2.0-4.75 mm	0.50^a	0.37^b	0.24^c	0.00016	314.96**	0.04476	3.44
4.75-8.0 mm	0.13^b	0.14^b	0.32^a	0.00016	303.7**	0.04857	5.42
8.0-19.0 mm	2.43^a	0.58^c	1.38^b	0.001	2047.14**	0.11887	2.43
Sum MWD	3.96^a	1.80^c	2.50^b	0.00034	10633.7**	0.06931	0.67

The means were taken P=0.01. Mean having the same letters are not significantly different at the probability of 1%

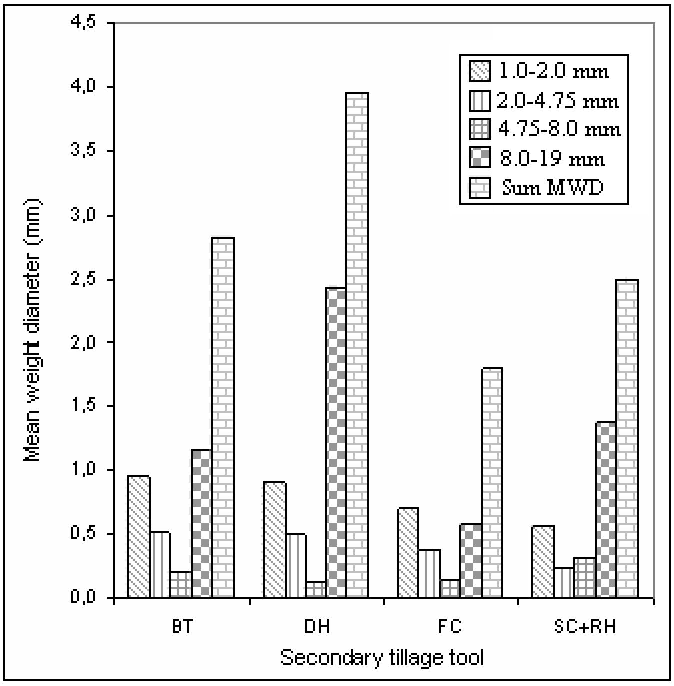

Figure 3. Mean weight diameter as affected secondary tillage tools

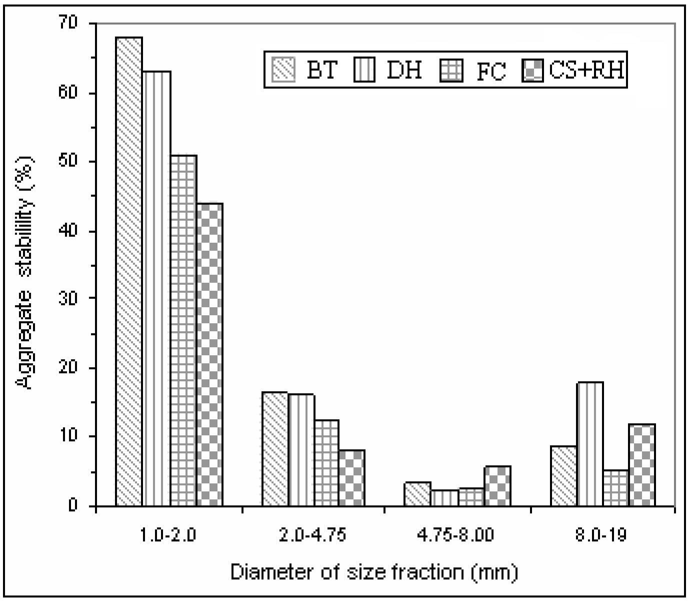

Figure 4. Soil aggregate stability as affected secondary tillage tools

Table 4. Effect of secondary tillage tools aggregation stability

Aggregate size distributions	Aggregate Stability (%)			Statistics of values			
	DH	FC	CS+RH	EMS	Fcal	LSD	CV%
1.0-2.0 mm	63.00[a]	51.00[b]	44.00[c]	0.510	543.14**	2.68462	1.36
2.0-4.75 mm	16.26[a]	12.47[b]	8.16[c]	0.073	671.04**	1.01568	2.20
4.75-8.0 mm	2.23[c]	2.47[b]	5.89[a]	0.003	4704.8**	0.20590	1.47
8.0-19.0 mm	18.05[a]	5.09[c]	11.81[b]	0.010	12694.21**	0.37592	0.86

The means were taken P=0.01. Mean having the same letters are not significantly different at probability of 1%

It was observed that smaller clods were more stability. In all soil tillage implements having 1-2 mm aggregate diameters, the aggregate stability decreased comparing to before secondary tillage. But as we consider the 8-19 mm soil clods, the water stable aggregates in soil secondary tilled with DH and CS+RH was higher compared to before secondary tillage. After secondary tillage, the water stability of aggregates was the best in DH, and the least in CS+RH.

Percentage of Emerged Seedling

There was no significant effect of secondary tillage implements on seedling emergence of sunflower. The percentage of emerged seedling was 80% with DH, 82% with FC, 85% with CS+RH. By smaller clods, seed germination was positively affected (Hamblin, 1987). The highest percentage of seed germination was in CS+RH as it had the best breaking up.

Sunflower Yield

Tillage implements had a magnificently effect on yield. The yield values were found 2.002 mg ha^{-1} in soil tilled with DH, 2.106 mg ha^{-1} in soil tilled with FC, and 2.175 mg ha^{-1} in soil tilled with CS+RH.

Conclusion

A hard soil layer under the level where seed is placed and aggregates in small diameters are desired during seeding. Based on this, the best results were obtained from tillage with CS+RH The lowest aggregate percentage in seedbed, on the other hand, was found for tillage with DC.

Aggregate percentage resistant to water, which is effective in reducing erosion caused by surface run-off was higher for tillage with DC.

In small aggregate diameter groups (between 1.0-4.75 mm) for all the methods, while the aggregate stability decreased after seedbed preparation, it was seen that there was an increase in the other groups in general.

As a result, it can be suggested that seedbed preparation can be done through a DC if there is a high risk of water erosion; otherwise, CS+RH can be used instead.

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