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Effect of Different Tillage Methods on Soil Physical Properties and Crop Yield of Watermelon

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Abstract: A two-year field experiment was conducted to investigate the effect of different tillage methods on soil physical properties and crop yield of watermelon. Tillage treatments in the study were moldboard plow + two passes of disk harrow as conventional tillage (CT), two passes of disk harrow as reduced tillage (RT), one pass of disk harrow as minimum tillage (MT) and no-tillage (NT) as direct drilling method. The statistical results of the study indicated that tillage method significantly ($P \leq 0.05$) affected crop yield, fruit weight, fruit length, fruit diameter and total soluble solids, but there were no significant differences in other components such as number of plants per hectare, number of fruits per plant, root length and root dry matter. The maximum value of crop yield (21.11 t ha^{-1}), number of plants per hectare (2730), fruit weight (5.15 kg), fruit diameter (20.3 cm), root length (42.0 cm) and root dry matter (54.1%) was observed in case of CT treatment, while maximum value of number of fruits per plant (1.56), fruit length (23.0 cm) and total soluble solids (7.8%) was noted in case of RT treatment. On the other hand, the minimum value of crop yield (12.26 t ha^{-1}), number of plants per hectare (2590), number of fruits per plant (1.40), fruit weight (3.38 kg), fruit length (20.7 cm), fruit diameter (17.9 cm), root length (37.1 cm) and root dry matter (46.5%) was obtained in case of NT treatment, while the minimum value of total soluble solids (6.6%) was noted in case of MT treatment. The statistical results of the study also indicated that tillage method significantly affected soil physical properties. The soil of the CT treatment had consistently the highest moisture contents (19.6%) and the lowest bulk density (1.41 g) and penetration resistance (560 kPa); while the soil of the NT treatment had the lowest moisture contents (16.8%) and the highest bulk density (1.52 g) and penetration resistance (1250 kPa). Accordingly, moldboard plow followed by two passes of disk harrow was found to be more appropriate and profitable tillage method in improving soil physical properties and crop yield of watermelon.

Key words: Tillage methods · Watermelon · Yield · Yield components · Soil physical properties

INTRODUCTION

Watermelon (*Citrullus vulgaris*) is one of the most important vegetable crops of Iran and is well adapted to its soil and climatic condition. Watermelon ranks second in cultivated area and production after tomato. The average production of watermelon has been 3.2 million tones during the last two years. Although the use of improved varieties and fertilizers has increased watermelon production to much extent, the full potential of crop production has not yet been achieved.

Soil tillage is among the important factors affecting soil physical properties and crop yield. Among the crop production factors, tillage contributes up to 20% [11]. Tillage method affects the sustainable use of soil resources through its influence on soil properties [4]. The proper use of tillage can improve soil related constrains, while improper tillage may cause a range of undesirable processes, e.g. destruction of soil structure, accelerated erosion, depletion of organic matter and fertility and disruption in cycles of water, organic carbon and plant nutrient [12]. Use of excessive and unnecessary

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tillage operations is often harmful to soil. Therefore, currently there is a significance interest and emphasis on the shift to the conservation and no-tillage methods for the purpose of controlling erosion process [8].

Conventional tillage practices modify soil structure by changing its physical properties such as soil bulk density, soil penetration resistance and soil moisture content. Annual disturbance and pulverizing caused by conventional tillage produce a finer and loose soil structure as compared to conservation and no-tillage method which leaves the soil intact [13]. This difference results in a change of number, shape, continuity and size distribution of the pores network, which controls the ability of soil to store and transmit air, water and agricultural chemicals. This in turn controls erosion, runoff and crop performance [10].

On the other hand, conservation tillage methods often result in decreased pore space [6], increased soil strength [1] and stable aggregates [7]. The pore network in conservationally tilled soil is usually more continues because of earthworms, root channels and vertical cracks [2]. Therefore, conservation tillage may reduce disruption of continues pores. Whereas, conventional tillage decreases soil penetration resistance and soil bulk density [9]. This also improves porosity and water holding capacity of the soil. Continuity of pore network is also interrupted by conventional tillage, which increases the tortuosity of soil. This all leads to a favorable environment for crop growth and nutrient use [10]. However, the results of no-tillage are contradictory [8]. No-tillage methods in arid regions of Iran had an adverse effect on crop yields [5]; while Ghuman and Lal [3] comparing conventional tillage method to no-tillage method concluded that higher moisture preservation and 13% more income was obtained in case of no-tillage.

At this time, a wide range of tillage methods is being used in Iran without evaluating their effects on soil physical properties and crop yield. Therefore, the present investigation was planned to determine the effect of different tillage methods on soil physical properties and crop yield of watermelon in the arid lands of Iran.

MATERIALS AND METHODS

A two-year field experiment was conducted to evaluate the effect of different tillage methods on soil physical properties and crop yield of watermelon during 2016 and 2017 growing seasons at Research Site of Varamin Agricultural Research Center, Iran. The site is located at latitude of 35°- 19' N and longitude of 51°- 39' E and is 1000 m above mean sea level, in arid climate in the center of Iran, where the summers are dry and hot while the winters are cool. The soil of the experimental site was a fine, mixed, thermic, Typic Haplacambids clay-loam soil. Details of soil physical and chemical characteristics are given in Table 1.

Table 1: Soil physical and chemical characteristics of the experimental site

Soil characteristics	Values
Texture	Clay-loam
Sand (%)	24.6
Silt (%)	38.0
Clay (%)	37.4
EC (dS m^{-1})	1.69
pH	7.50
Organic carbon (%)	0.95
Available P (mg kg^{-1})	40.4
Available K (mg kg^{-1})	460
Available Fe (mg kg^{-1})	2.84
Available Mn (mg kg^{-1})	12.9
Available Zn (mg kg^{-1})	1.5
Available Cu (mg kg^{-1})	1.13

The experiments were laid out in a randomized complete block design (RCBD) having three replications. The size of each plot was 10.0 m long and 6.0 m wide. A buffer zone of 5.0 m spacing was provided between plots. There were two furrows in each plot. The furrows had 10.0 m long, 75 cm wide and 50 cm depth and crop was sown manually on the both sides of each furrow by keeping row to row and plant to plant distance 3.0 m and 50 cm, respectively. The treatments were applied to the same plots during the 2 year (2016-2017) on farm study. Tillage treatments included one pass of moldboard plow followed two passes of disk harrow as conventional tillage (CT), two passes of disk harrow as reduced tillage (RT), one pass of disk harrow as minimum tillage (MT) and no-tillage (NT) as direct drilling method (Table 2).

In both growing season, one of the most commercial variety of watermelon cv. Crimson sweet was planted at the rate of 2 kg ha^{-1} on 25th April. The seed moisture and germination percentage were 15 and 95% respectively. Recommended levels of N (200 kg ha^{-1}), P (150 kg ha^{-1}) and K (100 kg ha^{-1}) were used as Urea, TSP and SOP, respectively. Pest and weed controls were performed according to general local practices and recommendations. All other necessary operations except those under study were kept normal and uniform for all the treatments.

Standard procedures were adopted for recording the data on various growth and yield parameters. Crop yield, number of plants per hectare, number of fruits per plant, fruit weight, fruit length, fruit diameter and total soluble

Table 2: Details of different tillage treatments

Treatment	Abbreviation	Description
Conventional tillage	CT	Moldboard plow + two passes of disk harrow
Reduced tillage	RT	Two passes of disk harrow
Minimum tillage	MT	One passes of disk harrow
No-tillage	NT	Direct drilling method

solids were determined by harvesting fruits of the two middle rows of each plot. Other parameters, i.e. root length and root dry matter, were determined from the 10 samples taken randomly from each plot. Soil bulk density, soil penetration resistance and soil moisture content was also determined at crop harvest. The soil bulk density on dry basis was determined for each treatment. For this test 10 undisturbed samples were taken from the plots by core sampler and dried 24 h at 105°C in an oven. Soil penetration resistance was measured by 10 insertions in each plot. A penetrometer (SP 1000) was used with 12.83 mm cone diameter and 30 degree angle based on ASAE standard S313.3 FEB04. Soil moisture content was also determined during cone index recording. The data collected were analyzed statistically using Completely Randomized Block Design (RCBD) as described by Steel and Torrie [14]. Duncan's Multiple Range test at 5% probability was performed to compare the means of different treatments by using the computer software SPSS 12.0.

RESULTS

Crop Yield: Different tillage treatments significantly affected crop yield during both the years of study (Table 3). The highest crop yield of 21.11 t ha^{-1} was obtained for the CT treatment and lowest (12.26 t ha^{-1}) for the NT treatment (Table 5).

Number of Plants per Hectare: A non-significant effect of different tillage treatments on number of plants per hectare was found during the study years (Table 3). However, the highest number of plants per hectare of 2730 was obtained for the CT treatment and lowest (2590) for the NT treatment (Table 5).

Number of Fruits per Plant: The effect of different tillage treatments on number of fruits per plant was also found non-significant during the years of study (Table 3). However, the highest number of fruits per plant of 1.56 was obtained for the RT treatment and lowest (1.40) for the NT treatment (Table 5).

Fruit Weight: Different tillage treatments significantly affected fruit weight during the study years (Table 3). The highest fruit weight 5.15 kg was obtained for the CT treatment and lowest (3.38 kg) for the NT treatment (Table 5).

Fruit Length: A significant effect of different tillage treatments on fruit length was also found during both the years of study (Table 3). The highest fruit length of 23.0 cm was obtained for the RT treatment and lowest (20.7 cm) for the NT treatment (Table 5).

Fruit Diameter: Different tillage treatments significantly affected fruit diameter during the years of study (Table 3). The highest fruit diameter of 20.3 cm was obtained for the CT treatment and lowest (17.9 cm) for the NT treatment (Table 5).

Total Soluble Solids: A significant effect of different tillage treatments on total soluble solids was also found during the study years (Table 3). The highest total soluble solids of 7.8% was obtained for the RT treatment and lowest (6.6%) for the MT treatment (Table 5).

Root Length: The effect of different tillage treatments on root length was found non-significant during the years of study (Table 3). However, the highest root length of 42.0 cm was obtained for the CT treatment and lowest (37.1 cm) for the NT treatment (Table 5).

Root Dry Matter: A non-significant effect of different tillage treatments on root dry matter was also found during the study years (Table 3). However, the highest root dry matter of 54.1% was obtained for the CT treatment and lowest (46.5 %) for the NT treatment (Table 5).

Soil Bulk Density: Different tillage treatments significantly affected soil bulk density during both the years of study (Table 4). The highest soil bulk density of 1.52 g cm^{-3} was obtained for the NT treatment and lowest (1.41 g cm^{-3}) for the CT treatment (Table 6).

Table 3: Mean squares from the analysis of variance of crop yield and yield components of watermelon under different tillage treatments (mean of 2016 and 2017)

Source of variation	D.f.	Crop yield	Number of plants per hectare	Number of fruits per plant	Fruit weight	Fruit length	Fruit diameter	Total soluble solids	Root length	Root dry matter
Replications	2	332^{NS}	88541^{NS}	0.57^{NS}	0.03^{NS}	0.02^{NS}	0.04^{NS}	0.02^{NS}	209.1^{NS}	41.4^{NS}
Treatments	3	29.2^{*}	223958^{NS}	0.02^{NS}	0.85^{*}	1.99^{*}	3.56^{*}	0.76^{*}	58.9^{NS}	31.9^{NS}
Error	6	0.480	203125	0.09	0.008	0.003	0.015	0.019	24.6	92.0
C.V. (%)	---	7.6	5.9	8.2	6.3	8.7	7.1	8.3	6.8	9.5

* = Significant at 0.05 probability level

NS = Non-significant

Table 4: Mean squares from the analysis of variance of soil bulk density, soil penetration resistance and soil moisture content under different tillage treatments (mean of 2016 and 2017)

Source of variation	D.f.	Soil bulk density	Soil penetration resistance	Soil moisture content
Replications	2	0.022^{NS}	0.092^{NS}	0.252^{NS}
Treatments	3	0.028^{*}	8.084^{*}	1.019^{*}
Error	12	0.009	2.761	0.502
C.V.	---	10.95	14.05	8.18

* = Significant at 0.05 probability level

NS = Non-significant

Table 5: Effect of different tillage treatments on crop yield and yield components of watermelon (mean of 2016 and 2017)

Treatments	Crop yield (t ha^{-1})	Number of plants per hectare	Number of fruits per plant	Fruit weight (kg)	Fruit length (cm)	Fruit diameter (cm)	Total soluble solids (%)	Root length (cm)	Root dry matter (%)
CT	21.11^{a}	2730^{a}	1.50^{a}	5.15^{a}	22.5^{b}	20.3^{a}	7.1^{b}	42.0^{a}	54.1^{a}
RT	18.99^{b}	2685^{a}	1.56^{a}	4.53^{b}	23.0^{a}	18.5^{b}	7.8^{a}	39.7^{a}	50.7^{a}
MT	14.26^{c}	2650^{a}	1.43^{a}	3.76^{c}	21.4^{c}	18.0^{c}	6.6^{c}	38.3^{a}	48.4^{a}
NT	12.26^{d}	2590^{a}	1.40^{a}	3.38^{c}	20.7^{d}	17.9^{c}	6.8^{c}	37.1^{a}	46.5^{a}

Means in the same column with different letters differ significantly at 0.05 probability level according to Duncan's Multiple Range test

Table 6: Effect of different tillage treatments on soil physical properties (mean of 2016 and 2017)

Treatments	Soil bulk density (g cm^{-3})	Soil penetration resistance (kPa)	Soil moisture content (%)
CT	1.41^{c}	560^{c}	19.6^{a}
RT	1.47^{b}	815^{b}	18.4^{b}
MT	1.50^{ab}	1105^{a}	17.1^{c}
NT	1.52^{a}	1250^{a}	16.9^{c}

Means in the same column with different letters differ significantly at 0.05 probability level according to Duncan's Multiple Range test

Soil Penetration Resistance: A significant effect of different tillage treatments on soil penetration resistance was also found during the years of study (Table 4). The highest soil penetration resistance of 1250 kPa was obtained for the NT treatment and lowest (560 kPa) for the CT treatment (Table 6).

Soil Moisture Content: Different tillage treatments significantly affected soil moisture content during the study years (Table 4). The highest soil moisture content of 19.6% was obtained for the CT treatment and lowest (16.9%) for the NT treatment (Table 6).

DISCUSSION

In this study, effect of different tillage methods on soil physical properties and crop yield of watermelon was investigated. The salient components of crop yield such as number of plants per hectare, number of fruits per plant, fruit weight, fruit length, fruit diameter, total soluble solids, root length and root dry matter were studied to analyze the effect of different tillage methods on growth and yield of watermelon. Also, data regarding soil bulk density, soil penetration resistance and soil moisture content were studied to analyze the effect of different tillage methods on soil physical properties. Results showed a significant response in the growth and yield parameters of watermelon and physical properties of soil.

The statistical results of the study indicated that tillage method significantly ($P \leq 0.05$) affected crop yield, fruit weight, fruit length, fruit diameter and total soluble solids, but there were no significant differences in other yield components such as number of plants per hectare, number of fruits per plant, root length and root dry matter among the different tillage treatments during the study years (Table 3). The maximum value of crop yield (21.11 t ha^{-1}), number of plants per hectare (2730), fruit weight (5.15 kg), fruit diameter (20.3 cm), root length (42.0 cm) and root dry matter (54.1%) was observed in case of CT treatment, while maximum value of number of fruits per plant (1.56), fruit length (23.0 cm) and total soluble solids (7.8%) was noted in case of RT treatment (Table 5). These results are in agreement with those of Khan *et al.* [10], who concluded that conventional tillage method produces a favorable environment for crop growth and nutrient use. These results are also in line with the results reported by Rashidi and Keshavarzpour [13] that annual disturbance and pulverizing caused by conventional tillage method produce a finer and loose soil structure which in turn affect the seedling emergence, plant population density and consequently crop yield. On the other hand, the minimum value of crop yield (12.26 t ha^{-1}), number of plants per hectare (2590), number of fruits per plant (1.40), fruit weight (3.38 kg), fruit length (20.7 cm), fruit diameter (17.9 cm), root length (37.1 cm) and root dry matter (46.5%) was obtained in case of NT treatment, while the minimum value of total soluble solids (6.6%) was noted in case of MT treatment (Table 5). These results are in agreement with those of Hemmat and Taki [5], who concluded that no-tillage methods in arid regions had an adverse effect on crop yields. These results are also in line with the results reported by Iqbal *et al.* [8] that no-tillage method can not compensate the adverse effect of fine texture, very low organic matter and an overall initial weak structure of the soil.

The statistical results of the study also indicated that tillage method significantly affected soil physical properties as they increased soil moisture content while decreased soil bulk density and soil penetration resistance among the different tillage treatments during both the years of study (Table 4). The soil of the CT treatment had consistently the highest moisture contents of 19.6% and lowest bulk density and penetration resistance of 1.41 g cm^{-3} and 560 kPa, respectively (Table 6). Alternatively, the soil of the NT treatment had the lowest moisture contents of 16.8% and the highest bulk density and penetration resistance of 1.52 g cm^{-3} and 1250 kPa, respectively (Table 6). The soils of the MT and NT treatments had almost the same soil bulk density and moisture content. However, the soil of NT treatment reflected high penetration resistance and showed about 14% more resistance than the resistance offered by the soil of the MT treatment (Table 6). A significantly greater soil moisture content of the CT treatment than other treatments was considered to be due to effect of primary and secondary tillage implements used which improved porosity and water holding capacity of the soil. These results are in agreement with those of Khan *et al.* [9], who reported that conventional tillage method increased tortuosity of the soil. Furthermore, significant lower soil bulk density and penetration resistance of the CT treatment was judged to be due to soil loosening effect of primary and secondary tillage implements used. These results are in line with the results reported by Khurshid *et al.* [11] that soil of the conventional tillage treatment had higher moisture content and lower bulk density and penetration resistance than other treatments. Greater soil penetration resistance of RT, MT and NT treatments may also be due to lower soil moisture contents. This is in line with the results reported by Ghuman and Lal [3] that penetration resistance decreased with increase in soil moisture content and vice versa.

CONCLUSION

Moldboard plow followed by two passes of disk harrow was found to be more appropriate and profitable tillage method in improving soil physical properties and crop yield of watermelon.

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