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Effects of Tillage Methods on the Physical Properties of Sandy Loam Soil, Growth and Yield of Water Melon (*Citrullus Vulgaris*) in Maiduguri Borno State

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Abstract: *An appropriate tillage method is necessary to create an optimum seed bed condition for optimum crop growth and yield. A one-year field experiment will be conducted 2020-2021 to investigate the effect of different tillage methods on the physical properties of sandy -loam soil, growth and yield of water melon (Citrullus Vulgaris) in Maiduguri. The Tillage treatments were disc ploughing plus disc harrowing (DP+DH), double disc ploughing (DDP), double disc harrowing (DDH), disc ploughing (DP) and disc harrowing (DH) as minimum tillage (MT) and zero tillage (ZT) as direct drilling method (control). The experiments will be laid out in a randomized complete block design (RCBD) having four replications. A wide range of tillage methods are being used in Nigeria without evaluating their effects on soil physical properties and crop yield. There is need to adopt suitable methods of tillage systems so as to boost our food production and for a good health of people through consuming natural juices obtained from water melon. On the other hand, poor soil management can result in decrease in arable farm lands and increase in the demand for melon production. Many modern tillage methods are being reviewed to improve and minimize soil and water loss. But information for decision making related to tillage and watermelon production is limited in this study area. It is therefore against this background that the study on the effects of tillage practices on melon production was initiated. This research will cost about ₦742,000.00 and it will affect the livelihood of the people in such a way that the low crop yield and growth, rate of water melon recorded due to inadequate tillage system has stimulated the interest of researchers in Nigeria and world over. It will provide suggestion to farmers on the appropriate tillage system combine with crop growth and yield for growing of water melon in the semi-arid region of Nigeria. Water melon is an excellent source of Vitamin C and a very good source of Vitamin A, notably through its concentration of beta-carotene. Water melon is one of the leading crops produced in North Eastern region of Nigeria and a major source of vitamins A and C. The choice of appropriate tillage system for growing this crop in this area is very important for continuous management of soil for sustainable productivity.*

Key words: *Water melon, Treatment, Tillage method, Growth and yield.*

1.0 Introduction

Water melon (*Citrullus vulgaris)* is one of the most important vegetable crops in Nigeria, and is well adapted to most soils and climatic conditions (Nkakino *et al*., 2008). Water melon ranks second in cultivated area and production after tomatoes at Varamin in Iran (Rashidi and Keshavarzpour, 2007). The average production of water melon had been 3.2 million tons during the last two (2) years at Iran. In Nigeria, though there are no official figures recorded for its production, the crop has a wide distribution as a garden crop, while as a commercial vegetable production; its cultivation is confined to the drier savannah region of Nigeria (Anon, 2006). Although, the use of improved varieties and fertilizers has increased the production of water melon, the full potential of the crops production has not yet been achieved (Statistical Year Book, 2005). Soil tillage is among the important factors affecting soil physical properties and crop yield. Among the crop production factors, tillage contribute up to 20% of crop production factor (Khurshid *et al.,* (2006). Tillage method affects the sustainable use of soil resources through its influence on soil properties (Hammel, 1989). 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 of the soil caused by conventional tillage produce a finer and loose soil structure as compared to conservation and no tillage methods that leave the soil intact (Rashidi and Keshavarzpour, 2007). 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 also controls erosion, runoff and crop performance (Khan *et al.,* 2001). Many modern tillage methods are being reviewed to improve and minimize soil and water loss. But information for decision making related to tillage and watermelon production is limited in this study area. It is therefore; against this background that the study on the effects of tillage practices on melon production was initiated. The main aim of the study is to evaluate the effectiveness of common tillage practices in improving soil physical conditions and on growth and yield of water melon (*citrullus vulgaris*) in a semi-arid environment.

2.0 Materials and Methods

2.1 Experimental Site:

This study was carried out at the Department of Agricultural Engineering Research Farm of Ramat Polytechnic Maiduguri, under irrigated farming. The farm is located between latitude 11^{o} 15’ North and longitude 10^{o} 25’ East. Borno state is located in the North Eastern sub-region of Nigeria. The soil of the research farm had earlier been classified as Typic upstisanment (Rayar, 1984) with Aeolian sand formation and weakly aggregated. The soil has a sandy loam texture and made up of 6% silt, 17% clay and 77% sand (Ohu *et al*., 1989).

2.2 Treatments and Experimental Design:

The experimental treatments consisted of six tillages were namely zero tillage (ZT)(control), Disc Harrow (DH), Disc Plough (DP), Double Disc Harrow (DDH), Double Disc Ploughing (DDP) and Disc Ploughing Plus Disc Harrowing (DP/DH), laid in a Randomized Complete Block Design (RCBD), with four (4) replications. A Massey Ferguson (MF 375) tractor with 31.0kpa contact pressure was used for the tillage operations. A total of 24 plots were used in the study. The experimental field was 85m x 55m (4675) m^2, divided into 24 plots of 10m x 10m with alleys of 5m between the plots

2.3 Land Preparation

The field was cleared and laid out before the treatments were applied. Disc ploughing was done at an average depth of 30cm with a 3-furrow mounted disc plough having 65cm disc diameter. Harrowing was done with an offset disc harrow at an average depth of 15cm with 55cm diameter discs. Zero tillage involves planting on bare land with no soil disturbance, whereas the other treatments were carried out by ploughing followed by harrowing using the above implements. Watermelon seeds of Sisico variety (Khan *et al*., 2001) were planted in the month of October, 2020 following a heavy rainfall the preceding day. Planting was done manually by placing three (3) seeds per hole at an interval of 1.5m along the rows and 50cm between the rows at an average depth of 5cm. Weeding were carried out manually at 3,7 and 12 weeks after planting (WAP).

2.4 Field Experimentation

2.4.1 Moisture Content: Soil moisture content was determined gravimetrically, following the samples. as shown in equation 1 (ASAE Standards, 1965).

$$MC\% = \frac{\text{weight of wet soil (g) - weight of dry soil (g)}}{\text{Weight of dry soil (g)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

2.4.2 Bulk Density: Soil dry bulk density was determined on undisturbed core samples using the core sampling method as modified by Blake & Hartge (1986). Core samples were taken for bulk density determinations before treatment applications and different stages of plants growth, that is, at initiation, developmental and mid-season or late season.

2.4.3 Penetration Resistance: Standard cone penetrometer having a cone base diameter of 15mm and cone angle of 60^0 operating at $1829mm^{-1}$ (ASAE, 1984) was used to measure penetration resistance of the soil at the depth of 30cm. Four penetrometer readings were also taken in each plot.

2.5.0 Determination of Growth and Yield Parameters

Days to 50% germination, the number of days to 50% germination was determined by counting, when 50% of the plants have germinated in each plot. Similarly, Plant length was measured using a meter rule from the ground level to the tip of the longest leaf during vegetative growth from each plot at 3, 6, 9, and 12WAP. And also, the Leaf area index was measured from lengths and widths of (10) selected leaves on each branch was measured using ordinary tailor's tape to obtain the leaf area. The leaf areas were multiplied by factor 0.76 to arrive at the leaf area index, as detailed in Chen and Black (1992). Mathematical expression of leaf area index (LAI) = one half the total leaf area per unit ground surface area is being used (Chen and Black, 1992). LAI = 1.1x N (32.5). However, number of days to 50% flowering was determined when 50% of the plants have started flowering, at least one another in each plot. This was done by regular observation of the growth parameter at least once in a week until when the flowering is 50%, based on the known number of plants. Furthermore, the number of days to physiological maturity was determined when

50% of the fruit has reached maturity size. This was determined at per plot basis. Water melon usually matures in about 90 – 100 days depending on variety of the fruit and if the female flower is pollinated and weather conditions. When it was observed that fruit tendrils were brown, the fruits become pale yellow at the spot close to the ground and when the sound of the fruit when thumbed with a knock gives a soft hollow sound instead of metallic ringing sound. Conversely, fruit length was measured from the (10) sampled plants in mm from the basal node of the fruit to the tip (Khurshid, *et al*.2006) and the number of fruits per plant from the sampled plants was counted and average recorded. Finally, the harvested fruits per plot were weighed and the value obtained was converted to kg/ha.

2.6 Statistical Analysis:

All data collected were subjected to Analysis of variance (ANOVA) using statistical software statistics version (SPSS) 16.0 to compare the significance of the differences between the treatment means. Mean separation was done using (DMRT). Regression analysis was also carried out.

3.0 RESULT AND DISCUSSION

3.1 Bulk Density

The result on the effect of different tillages used as treatments had significantly affected soil bulk density during both years of study (Table1). The highest soil bulk density of 1.79 and 2.20 mg/m^3 was found in plots with disc plough/disc harrow (DP/DH) treatments and lowest soil bulk density of (1.38 and 1.41mg/m^3) was found in plots with zero tillage (ZT) for the year 2013 and 2014. This is in line with Osunbitan *et al*. (2005); Rashidi and Kashavarzpour (2007, 2008); Sharma *et al* (2009);

Table 1: Effects of different tillage methods on bulk density (mg/m^3) of sandy loam soil

Treatments	Bulk density (mg/m3)
Zero tillage (ZT)	1.41^e
Disc harrow (DH)	1.52^d
Disc plough (DP)	1.58^d
Double disc harrow (DDH)	1.67^c
Double disc plough (DDP)	1.72^b
Disc plough + disc harrow (DP/DH)	1.79^a

3.2 Penetration Resistance:

As illustrated in Table 2. A significant effect of different tillage treatments on soil penetration resistance was also found during the years of study (Table 3.4). The highest soil penetration resistances of 2.20Mpa were obtained for the zero tillage (ZT) treatment and lowest 0.61 Mpa for the disc plough + disc harrow treatment (Table 3.4). The difference in penetration resistance observed could be due to amount of moisture retention. These results are in agreement with those of Khan *et al*. (2001) who concluded that (DP/DH) conventional tillage (CT) has lower penetration resistance than that of the zero tillage (ZT) treatment whereas, DH (1.73 Mpa), DP (2.08Mpa), while DDH has 1.45Mpa and lastly DDP has 1.96Mpa . Greater soil penetration resistance of reduced tillage (RT), manual tillage (MT) and no-till (NT) treatments may also be due to lower soil moisture contents. This is in line with the results reported by Ghuman and Lal (1984) that penetration resistance decreased with increase in soil moisture content and vice versa. The kind of results reported is expected because after load application from tractor traffics, ploughing which is primary tillage operation will break the soil that will result in larger clods since the soil had been compacted. It is expected that the depression of the penetrometer probe into the soil will be affected by over-burden pressure from the soil which will lead to high penetration values. Harrowing as secondary tillage is expected to produce better tilth than ploughing and hence the reduction in penetration resistance compared to ploughing leading to lower penetration resistance. However, the bulk density and penetration resistance values was plot against different tillage's experimented for more clarification see Fig 1.

Table 2: Effects of different tillage methods on penetrating resistance (Mpa) of sandy loam soil

Treatment	Penetrating Resistance (Mpa)
Zero tillage (ZT)	2.20a
Disc harrow (DH)	1.73b
Disc plough (DP)	2.08a
Double disc harrow (DDH)	1.45c
Double disc plough (DDP)	1.96b
Disc plough + disc harrow (DP/DH)	0.61d

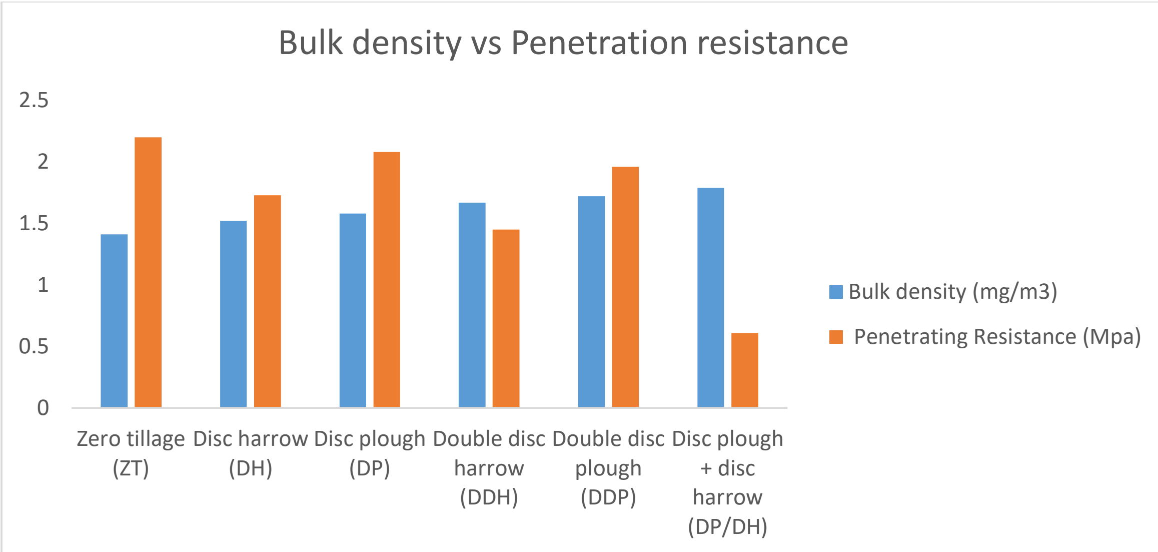

Figure 1: Plot of Bulk density, penetration resistance against tillage's

3.3 Plant length

The plant length (m) for 3-12 weeks for the study period is presented in Table 3. The results revealed that the plant length (m) for the period of 3-12 weeks increased with time. This was expected as the growing days increase, length of plant increases. There were significant variations in plant length among the different tillage methods in which DP/DH had the highest plant length and ZT lowest (DP/DH>DDH>DDP>DH>ZT). The reason could be due to the differences of compaction arising from the different tillage methods as reported by Ohu and Folorunso (1989). Statistically, there were significant multiple contribution of the plant length of 91% and the different tillage contribution of (ZT) 0.04, (DH) 0.007, (DP) 0.048, (DDH) 0.042, (DDP) 0.18 and (DP/DH) 0.14 respectively. This indicated that tillage treatment and irrigation received has effect on the plant length. The findings is in line with that of Ohu and Folorunso (1989) who reported that some amount of compaction is necessary for good crop growth in the same sandy loam soil. Table 3.7 shows DP/DH at 12 WAP to have the highest plant length followed by DDH, DDP, DP, DH and ZT respectively. This is expected because; ploughing favors more aeration and better soil moisture storage due to deeper cut of the plough into the soil. Disc ploughing/Disc harrowing followed by ploughing, and the secondary tillage operation harrowing is expected to produce better tilth. The soil being a light soil, more water is expected to evaporate from the soil after any rainfall. The nine (9) weeks plant length recorded for double disc harrowing was less than those of the double disc plough and disc plough less than disc harrowing. This was because, harrowing is a secondary tillage which is expected to result in smooth surface soil produced than ploughing and harrowing. The zero tillage (ZT) resulted into the least length at 12 WAP because the soil surface was naturally compacted, with poor water infiltrating into the soil for subsequent use by the plant.

Table 3: Plant Length (m) for 3 to 12 weeks

Weeks	3WAP	6WAP	9WAP	12WAP
ZT	7.1^{b}	11.4^{c}	12.5^{c}	15.2^{a}
DH	9.0^{b}	13.5^{c}	14.6^{b}	17.2^{a}
DP	7.9^{b}	11.4^{c}	12.8^{c}	15.7^{a}
DDH	11.0^{a}	15.2^{a}	17.0^{a}	20.8^{a}
DDP	10.0^{a}	13.2^{c}	17.0^{a}	18.2^{a}
DP/DH	11.5^{d}	15.0^{c}	16.3^{b}	20.5^{a}

Values followed by the same letter in a column are not statistically different at 5% level using the Duncan Multiple Range Test (DMRT)

3.4 Number of fruits per plant (NFPP) kg/ha in

Table 4. Show the effect of different tillage treatments on number of fruits per plant (NFPP) was also found significant during the year of study (Table3.8). However, the highest numbers of fruits per plant were 16 for DP/DH treatment, and lowest 4 for the ZT treatment (Table 3.8). The differences observed in yield of water melon over the period of study could be attributed to the amount of water received over the period of the study (Table 3.1)

Table 4: Number of Fruits per plant (NFPP) kg/ha

Treatment	Number of fruit per plant
ZT	4^{d}
DH	5^{c}
DP	4^{c}
DDH	10^{c}
DDP	11^{b}
DP/DH	16^{a}

Values followed by the same letter in a column are not statistically different at 5% levels using the Duncan's Multiple Range Test (DMRT).

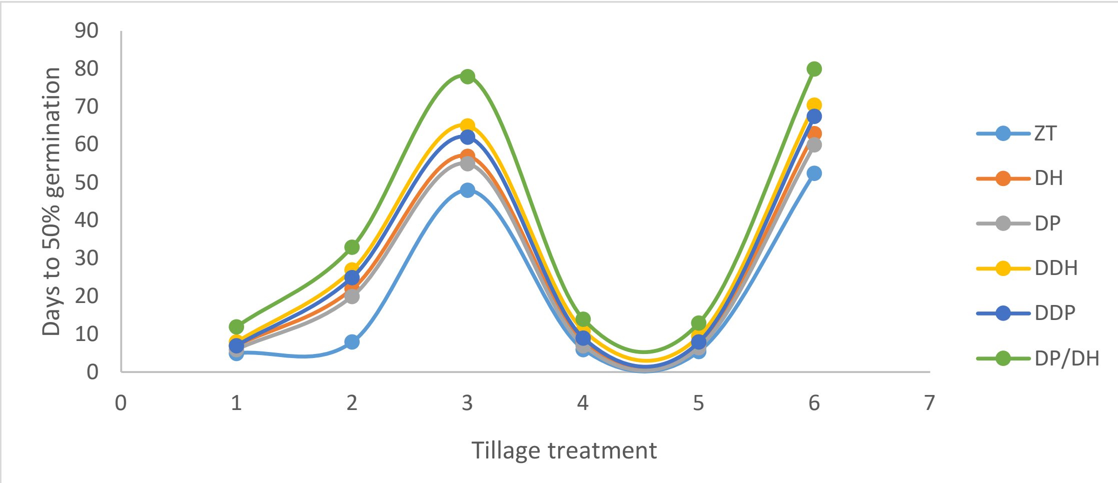

Fig 2: Shows plot of days to 50% germination of the crop.

3.5 Mathematical Model of Different Tillage Method on Plant Growth leaf Area Index

3.5.1 Model Development

This model development was based on the following assumptions:

Y = f (ø, Pg, LAI, NFPP, δd, Pr)…………………………………………. (1)

Where:

Y = fruits yield (kg/ha)

ø = moisture content (%)

Pg = Plant growth or plant length (cm)

δd = Bulk density (kg/m^3)

Pr = penetration resistance (Mpa)

LAI = Leaf Area Index (cm)

NFPP = Number of fruits per plant

The model was validated by using non-linear regression procedure in SPSS Version 16.0 for windows. This procedure minimizes the error inherent in the data using interactive steps. It usually required that initial values of coefficients be provided. The initial values of the coefficients in equation 12 as obtained using the non-linear regression procedure for the various types of tillage methods. The values of the yield predicted by the model and those obtained by the experiment are presented in Tables 2 and 3. The model was capable of adequately predicting the observed data. Figures2 and 3 show actual water melon in the study area while figure 4 and 3.4 show comparison between predicted and observed water melon. A good linear relationship ($r^2 = 0.99$ and $r^2 = 0.87$) were obtained between predicted and observed water melon with most of the data points either fit or are closely distributed. This implies that the relationship between the observed and predicted values of water melon exhibits a tendency towards a clear model that tracked with the observed data. However, the model could be said to yield its best performance in predicting water melon growth, weeks after planting (LAI) and yields on soil that was subjected to ploughing plus harrowing treatment.

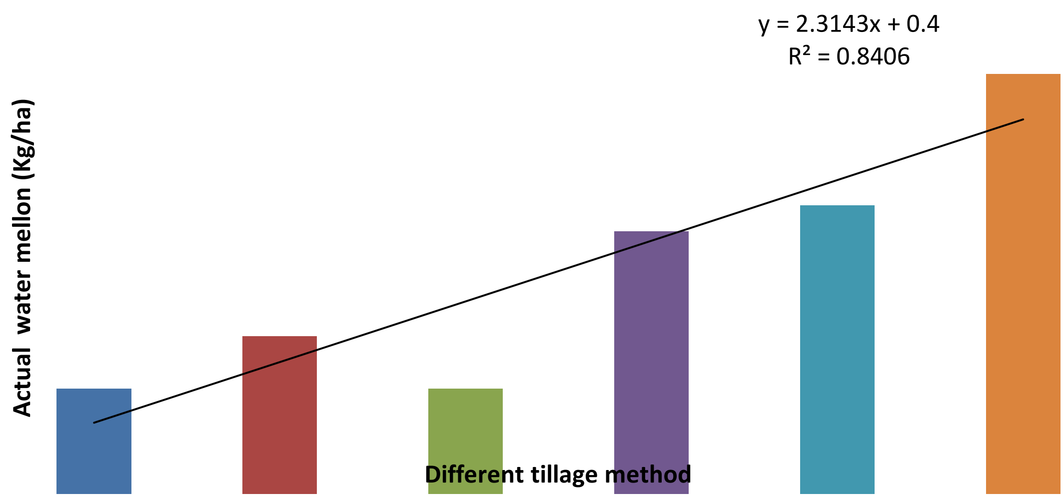

Fig. 3: Actual water melon yield(Kg/ha) Where the model equations for predicting water melon can be in the form: $Y = 2.314x + 0.4$; $R^2 = 0.840$; $Y = 3.914x + 1.133$ $R^2 = 0.961$

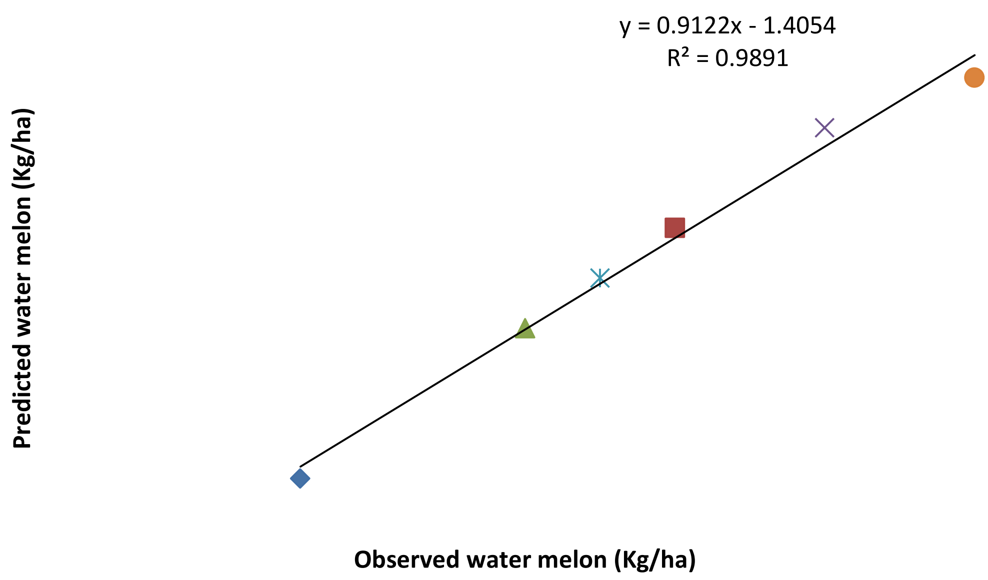

Fig:3 Predicted versus observed yield of water melon (Kg/ha)

3.6 Conclusion and recommendations

The outcome of the experiment showed that tillage treatments had significant influences on soil properties. The results showed the counteracting effects of tillage on soil bulk density and penetration resistance revealed that, soil parameter had significantly affected the yield. All the imposed tillage treatments significantly ($P<0.01$) improved all the soil physical properties over no till treatment (Zero Tillage). Generally, the optimum water melon growth and yield was obtained with Disc Ploughing Plus Disc Harrowing (DP/DH) treatment methods. Tillage method significantly affected crop yield of water melon in the order of DP/DH>DDH>DDP>DP>DH>ZT. The highest amount of crop yield obtained in the DP/DH method might be due to reduced soil penetration resistance and bulk density, increased soil moisture content, enhanced seed soil contact and suppressing weed growth. Where in case of DDH, DDP, DP, DH and ZT methods, the lower amounts of crop yield obtained may be due to significantly greater soil penetration resistance and bulk density and lower soil moisture content which adversely affect seed emergence and root growth and Number of Fruit Per Plant (NFPP) as reported by Khurshid *et al*. (2006). Accordingly, DP/DH was found to be more appropriate and profitable tillage method in improving soil physical properties and crop yield of water melon. Based on the research results, the Disc Plough plus Disc Harrow (DP/DH) was found to be the best tillage method to be used as cultivation practice for growing water melon in a light soil like sandy loam.

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