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Assessment of Growth and Yield of Watermelon and Soil Physical Properties in Response to Different Tillage Methods

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Authors' contributions

This research work was carried out in collaboration among all authors. Authors AJB, HKD and KA designed the study. Authors KA, AJB and IB wrote the first draft. Authors BYO, KK and HKD managed the analysis of the study. Field observation and data taken was carried out by all authors as well as the final draft and approval. The final manuscript was read and approved by all authors.

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ABSTRACT

Field experiment was conducted to investigate the response of soil physical properties, crop growth, yield and yield components of watermelon to different tillage methods in the transitional zone of Ghana in a two year period. The tillage treatments used in the study were plough and harrowed (PH), minimum tillage (MT) and no tillage (NT) which was laid out in a Randomized Complete Block design (RCBD) with 3 three replications. The two field experiments were undertaken at the experimental site of the University of Education, College of Agriculture, Mampong-Ashanti, (7°08' N, 1°24' W)located within the transitional agro-ecological zone between the forest and Guinea Savannah zones characterized with two rainfall regimes with an annual

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rainfall of 1094.2 mm with 30°C temperature. The soil belongs to the Bediase series with ochrosol type formed from voltain sandstone and a pH between 5.5 to 6. The statistical analysis revealed that, tillage methods significantly affected soil physical properties particularly, total porosity, volumetric water content and bulk density. Also, tillage methods influenced crop growth, (number of leaves and vine length), yield and yield components of watermelon in the order of Plough and harrowed > Minimum tillage > No-Tillage in almost all the treatments. Accordingly, the ploughed and harrowed (PH) was found to be more appropriate and profitable tillage method to improving soil physical properties, crop growth, yield and yield components of watermelon in the forest-transitional of Ghana.

Keywords: Citrillus vulgaris; bulk density; tillage; total porosity; volumetric water content; yield.

1. INTRODUCTION

Watermelon (*Citrillus vulgaris*) which belongs to the family cucurbitaceae is originated in tropical Africa and it is regarded as one of the important fruit vegetables in Ghana [1]. The crop does well relatively in most parts of the country and is regarded as one of the valuable crops for some tribes in Ghana apart from being used as fruits. The “Ga” tribe in Ghana for example, use it for their annual “Homowo” festival [2]. It requires relatively stable and relatively high temperature of about 25°C to 32°C but high humidity and precipitation leads to foliar diseases [1] thus why the crop does well in both northern and southern part of the country.

There has been an increase demand and use of watermelon in many Ghanaian homes due to its nutritional benefits. Most homes will normally squeeze the juice and use as drinks not to talk about the increasing demand by marketers and juice factories for drinks. Due to this demand, total production in Ghana needs to increase in order to meet the demand of the fruit in the country. Cultivation of watermelon with appropriate tillage method would therefore help increase production since most resource poor vegetable farmers do not resort to scientific methods of cultivation to maximize production to meet the current demand.

Soil tillage is one of the factors that affect the physical properties of soil and crop yield. According to Khurshid et al. [3], soil tillage contributes up to 20% of crop yield. Proper use of tillage normally improve soil related constraints but improper tillage most of the time causes a range of undesirable processes such as destruction of soil structure, depletion of organic matter, accelerated erosion, disruption of water cycle and plant nutrient availability [4]. Bad tillage operations normally leads to destruction and causes harm to the soil. In view of this, there has been a paradigm shift to conservation to control erosion and other soil factors [5].

Dauda and Maina [6], observed that, watermelon plant length was affected bythe tillage methods employed in planting. Steiner [7] reported that among the functions andreason why farmers invest labour and money in tillage was to increase water infiltrationto enhance soil moisture storage and reduce run-off and to control insect pests in soil. Keshavarzpour and Rashidi [8] observed that tillage methods significantly affected crop yield, fruit weight, vine length and fruit length of water melon.

Conventional tillage method has been found to modify the soil physical properties particularly, bulk density, penetration resistance and moisture content. Again, this method loosens and improves percolation while conservation and no-tillage leaves the soil intact [9] because the soil is not disturbed. Khan et al. [10] observed that conventional tillage method produces a favourable environment for crop growth and nutrient use. Again, Rashidi and Keshavarzpour [11] reported 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.

In another breadth, conservation tillage leads to increased soil strength and results in stable aggregates [12,13]. Conventional tillage has some setbacks which includes decreased pore network and sometimes disruption of soil organisms which burrows through the soil [14] but overall, general positive effects is advantageous since favourable environment is created for crop growth and efficient nutrient usage [10].

No-tillage on the other hand, shows some contradiction to other tillage methods [5]. No-tillage was reported in arid regions as improving moisture preservation and there was an increase in income of about 13% more in no-tillage than other methods [15]. Since no-tillage consists of killing weeds on a field or planting cover crops with the main crop in trash of mulch, soil nutrients is improved and therefore there is a continuous addition of organic matter which provides nutrients for crop growth, development and yield [16].

Again, minimum tillage and hoe tillage is practiced in Ghana in some areas to improve soil physical properties and onward yield of crops. Due to these methods that are available and relevant to the improvement of melon production, there is the need to investigate into different tillage methods to ascertain their influence on soil physical properties, crop growth and yield. The objective of this study was to evaluate the effect of three land preparation methods on physical properties of soil, growth, development and yield of water melon in the forest transitional zone of Ghana.

2. MATERIALS AND METHODS

2.1 Description of Experimental Site

Two field experiments were undertaken at the experimental site (Nursery) of the University of Education, College of Agriculture, Mampong-Ashanti. Mampong –Ashanti (7°08′N, 1°24′W) [17] (Mampong –Ashanti Meteorological Station, 2003). The site is situated within the transitional agro-ecological zone that is between the forest and Guinea Savannah zones.

This region has two rainfall regimes – the major season which occurs from April to July and minor one also occurs from August to October. The mean daily temperature is about 30°C with monthly mean rainfall of 91.2 mm. The total annual mean rainfall is estimated to be 1094.2 mm. The soils of the Mampong –Ashanti belongs to the Bediase series and is deep sandy-loam, free from stones and red in colour and is of forest ochrosol type which was formed from voltain sandstone with pH between 5.5 to 6.5 [18].

2.2 Experimental Design and Treatments

The field experimental design used was Randomised Complete Block design (RCBD) with 3 three replications. Three (3) land preparation methods were used, namely;

- No Tillage (NT).
- Conventional Tillage with ploughing and harrowing (CT)
- Minimum tillage with hand hoeing (MT)

2.3 Field Lay-Out

Total field used for the experiment was 576 m^2 (32 m x 18 m). Each plot size measured 4.5 m × 2.25 m. There were four (4) rows and each row had nine hills.

2.4 Soil Physical Properties

The bulk density was determined by using the core method [19]. The samples of soil were taken diagonally making six sites and were bulked together using the core sampler at the depth of 15cm. The samples were weighed before and after drying in an oven at a temperature of 105°C for 24 hours. The dry bulk density was determined as follows:

$$\text{Bulk density (g cm}^{-3}) = \frac{W_1}{V_1}$$

where W_1 is the weight of the undisturbed oven-dried soil sample and V_1 is the volume of the soil which is equal to the volume of the core sampler.

The volumetric moisture content was calculated using the formula by [20].

$$\theta v = (\theta)g \times BD/Dw$$

where θ g is soil gravimetric moisture, BD is bulk density and Dw is density of water.

Soil porosity was determined using the formula [20].

$$f = (1\text{-}BD/PD) \times 100$$

where;

f = Total porosity
BD = bulk density
PD = particle density = 2.65 g/cm^3 [20].

2.5 Management Practices

Land preparations involved spraying with Glyphosate 41% SL herbicide for zero tillage plots. The other plots conventional tillage (ploughing and harrowing) as well as hand

hoeing (minimum tillage) were done at different dates in such a way that the weeds on the sprayed plot could die down to coincide with the other land preparations. For the conventional tillage, a tractor was used to plough the land and was later harrowed in order to break the lumps/clogs of soil and levelled to make the soil loose and fine textured. For zero tillage, a hoe was used to turn the top soil so that the weeds at the top will remain just beneath. The hoe does not go deep into the soil. Demarcation and pegging of plots were also carried out.

2.6 Watermelon Sowing

Watermelon was sown on 9th October, 2010for the first year of the experiment and 29th August 2011 for the second year. In each case two seeds per hill were sown at the planting depth of 3-4 cm and were later thinned to one. One variety of watermelon was used thus Technisem (KAOLACK) treated with Thiram from Reiss and Co. Ltd.

There were four rows with nine (9) plants on each plot. Out of the four rows in each plot, the two (2) middle rows, six (6) plants were tagged for data collection. On the average, over 90% of the sown seeds germinated in five (5) days after sowing (5 DAS).

2.7 Weed Control

In both experiments, weeds were controlled by hoeing and hand pulling. The dominated weeds were *Cynodon plectostachys* (Giant star grass), *Euphorbia heterophylla* (milk weed) and Cyperus *rotundus* (Sedge).Weeds were controlled four times before harvesting. The first weed control was carried out in two weeks after sowing (14DAS). The rest of the weeding were carried out fortnightly till the fruits were ready for harvesting thus 2nd, 4th, 6th and 8th weeks respectively.

Earthing-up was done after every weed control to give plants extra support and also to expose any insect pest to be killed. The soil was frequently stirred to ensure free soil gas exchange and to increase infiltration rate after watering.

2.8 Fertilizer Application

During both the first and second experiments, there were two regimes of fertilizer application on the watermelon plants. The first application was two weeks after sowing using 50 kg of N.P.K. 15:15:15 and 30 kg of P_2O_5 per hectare as indicated by Yayock et al. [21].

9.72 kg N.P.K. was applied on a total experimental area (972 plants) on the 3rd week that is, each plant taking 7 g of N.P.K. At fruiting thus around 6th week after planting, 14.58 kg of Ammonium sulphate was applied on a total area at a rate of 15 $gplant^{-1}$ to a stand as reported by [22].

2.9 Diseaseand Pest Control

Effective disease control measures adopted in each of the experiment was the use of Diahane M-45 conti-zeb “5” 80% WP which was applied at the rate of 80 g in 15 litres of water in a knapsack sprayer on the (14DAS) and repeated three (3) times between 7-10 days of each application. Dosage of 500-1000 litres of water per hectare was recommended to check leaf spot and Downy mildew Bright.

Pest of watermelon mostly found were Grasshoppers, Crickets and fruit fly and were controlled by spraying with Cymethoate Super E.C using 100 mls of the chemical for 15litres of knapsack with the recommended rate of 1-1.5 litre per ha. Four spraying were carried out on the 2nd, 4th, 6th and 8th weeks after planting.

2.10 Harvesting

Developing fruits were protected from soils insects by being raised on pads of grass. When the curly tendril on the leaf near the stem dried up which became brown, indicated maturity. Splittstoesser [23], indicated that a sharp metallic sound shows that watermelon fruit is not matured but a dully sound indicates maturity. Watermelon harvest for the first season was done on the 23rd of December 2010 whereas the second harvest was done on November 17th. After harvesting, all fruits from each plot (six plants) were weighed and the average recorded. Total number of fruits from each plot was also recorded.

2.11 Data Collection

2.11.1 Vegetative growth of watermelon

Among the vegetative growth parameters that were taken are plant length and number of leaves which has been described below.

2.11.2 Plant length

Plant length was measured from the soil level to the terminal bud using ruler. Recordings were taken on the 14 DAS, 28 DAS, 42 DAS and 56 DAS. As the plants were growing, metre-rule andtape measure were used to take readings. All recording were in centimetres (cm) and mean values for the data were also determined.

2.11.3 Number of leaves

The number of leaves within the harvestable or tagged plants was counted fortnightly from 14 DAS, 28 DAS, 42 DAS and 56 DAS. Average for the recordings wastaken.

2.11.4 Yield and yield components of watermelon

2.11.4.1 Number of fruits of watermelon

Total number of fruits from the selected plants of each plant was counted and the number recorded as the number of fruits per plot.

2.11.4.2 Mean weight of watermelon

Weight of individual crops on each treatment was weighed and the mean values taken in kilogrammes (kg).

2.11.4.3 Circumference of the fruits

Individual fruit from the tagged plants were measured using tape measure in centimetres (cm).

2.11.4.4 Yield of watermelon fruits

Yield of fruits harvested from the selected rows were countered and weighed to measure the yield.

2.12 Data Analysis

Data collected was analysed using analysis of variance (ANOVA) technique with SAS statistical package [24] and the means were separated using LSD at 0.05 (5%) probability level.

3. RESULTS AND DISCUSSION

3.1 Soil Physical Properties

Table 1 shows soil physical properties in 2010 and 2011 seasons. The results of the study in both seasons indicates that, tillage method significantly affected soil physical properties as they decreased soil bulk density, increased moisture content and total porosity for the two tillage treatments, conventional tillage (CT) and minimum tillage (MT) while the no tillage (NT) recorded higher bulk density with lower porosity and moisture content (Table 1). Soils of the CT and MT consistently showed superiority by having the highest volumetric water content (moisture) (23.28%, 25.23%), lower bulk density of 1.12 and 1.14 and a total porosity of 59.23% and 57.26% respectively in the two growing seasons (Table 1). Alternatively, the no tillage treatment recorded the lowest moisture (12.36%, 17.29%) and lower porosity of (54.84, 55.77) respectively and a higher bulk density of (1.20 and 1.19). The improvement in the CT treatment physical properties could be due to the effect of disrupting the soil structure which made the soil smooth and loose with fine textured which improved porosity and water holding capacity of the soil. Khurshid et al. [3] reported that different tillage practices normally increased soil moisture content and porosity with lower bulk density which has positive impact on crop growth and yield. The present study is in line with the observation made by Khurshid et al. [3]. There have been several studies which have revealed that soil moisture increases with soil depth which is function of degree of tillage. The present study is in line with the findings made by Ji et al. [25] who observed that moisture retention increases when deep tillage is applied which can simply mean that ploughing and harrowing (CT) can be combined to achieve good results on soils properties. It was clearly observed in the present study that as CT was done, the soil became fine textured which enabled the soil to contain more water than the zero tillage. This means that there was improved infiltration of water which invariably made nutrients available and accessible to the roots of plants of watermelon in the two growing seasons. Hulugale et al. [9] is of the view that tillage method loosens and improves percolation while conservation and no-tillage leaves the soil intact because the soil is not disturbed. Khan et al. [10] also observed that conventional tillage method produces a favourable environment for crop growth and nutrient use. This assertion is in line with the observation made in the present study.

3.2 Mean Vine Length (CM)

Table 2 below shows the mean vine length from 14 DAS, 28DAS, 42DAS and 56 DAS. For the

vine length, conventional tillage (CT) recorded the highest (193.81 cm) for 2010 and 230.47 cm for 2011 whereas the lowest vine length was recorded by minimum tillage (186.96 cm) for 2010 and 223.84 cm for 2011at the last sampling stage (56 DAS). There were significant differences among the tillage methods employed in the study. The highest plant vine length recorded by the CT treatment was influenced by the improvement in soil properties. Dauda and Maina [6] observed that, plant length was affected by the tillage methods employed in planting. The mean vine lengths obtained agrees with the assertion made by Messian [22] that watermelon plants grow from 1.5-5.0 m length.

3.3 Evaluation of Watermelon Number of Leaves

Table 3 shows the watermelon number of leaves recorded fortnightly on the plants from the treatment of the tillage methods.The treatment of the conventional tillage (CT) had the highest number of leaves (22.12) in the year 2010 and 26.13 in 2011 at the last sampling stage(56DAS). The lowest number of leaves was recorded by minimum tillage in both two growing seasons thus 21.16 and 25.41 for 2010 and 2011 respectively (Table 3). The highest number of leaves recorded by the CT might be due to the infiltration rate and ability of the soil to conserve moisture after the conventional tillage was done. This breaks the soil aggregates and increased porosity which improves water retention for plant growth. Claasen [26] on tillage methods suggested that soil moisture conserves best on how deep either the mouldboard or disc plough will cut into the soil. Again, [7] reported that among the functions and reason why farmers invest labour and money in tillage was to increase water infiltration to enhance soil moisture storage and to control insect pests in soil.

3.4 Watermelon Yield Components (Number of fruits/plot, Wt. per Fruit (kg) and Circumference per Fruit (cm)

3.4.1 Number of fruits of watermelon per plot (2010 and 2011)

Number of fruits of watermelon are presented in Table 4. For 2010 season, the conventional tillage recorded the highest number of fruits (27.33) followed by the minimum tillage (24.33)

Table 1. Effect of different tillage on soil physical properties (2010 and 2011)

Treatment	Bulk density (g/cm)		Total porosity (%)		Volumetric water content (%)	
Tillage	2010	2011	2010	2011	2010	2011
No Tillage	1.20	1.19	54.84	55.77	12.36	17.29
Conventional Tillage	1.12	1.14	59.23	57.26	23.28	25.23
Minimum Tillage	1.13	1.18	57.77	56.76	19.74	22.94
LSD (0.05)	0.01	0.04	2.46	0.33	1.28	1.81
CV	0.40	1.00	1.60	0.10	3.20	4.10

Table 2. Effect of different tillage on vine length (cm) of watermelon (2010 and 2011)

Treatment	14 DAP		28 DAP		42 DAP		56 DAP	
Tillage	2010	2011	2010	2011	2010	2011	2010	2011
No Tillage	14.75	15.14	88.40	96.80	132.03	145.77	193.01	229.64
Conventional Tillage	15.90	17.10	89.70	98.61	132.13	146.17	193.81	230.47
Minimum Tillage	15.21	15.67	85.70	96.82	131.60	145.76	186.96	223.84
LSD (0.05)	0.68	0.01	0.46	0.02	0.07	0.02	0.001	0.002
CV	1.20	0.10	1.50	0.01	0.01	0.001	0.02	0.01

Table 3. Number of leaves (NLV) (2010 and 2011)

Treatment	14 DAP		28 DAP		42 DAP		56 DAP	
Tillage	2010	2011	2010	2011	2010	2011	2010	2011
No Tillage	6.09	6.35	9.02	11.74	16.44	17.73	21.18	25.64
Conventional Tillage	6.11	6.43	9.04	11.83	16.68	18.11	22.12	26.13
Minimum Tillage	6.25	6.69	9.15	11.95	16.68	17.72	21.16	25.41
LSD (0.05)	0.008	0.001	0.06	0.01	0.33	0.26	0.001	0.010
CV	0.20	0.20	0.10	0.10	0.50	0.30	0.00	0.00

with the no tillage recording the lowest (24.11). In 2011 season, same trend was recorded, the highest number of fruits was recorded by the plough (27.89) followed by the minimum tillage (27.00) with zero tillage again recording the lower number (26.22) of fruit (Table 4). There were significant differences among the treatments in all the seasons. Number of fruits and other components were influenced by the CT and MT applied to the soil before planting. Conventional tillage (CT) and minimum tillage (MT) methods improves physical properties of the soil which reduces penetration resistance and improves nutrient uptake and water movement and holding capacity which in turn favoured growth pattern and number of fruits. Keshavarzpour [27] observed that, tillage methods employed in water melon production produced more fruits than no tillage due to the influence it had on soil physical properties. These assertions influenced the results on the number of fruits obtained in the present study.

3.4.2 Fruit weight per plot of watermelon (kg)

For the mean weight per fruit, it was observed that in 2010 the conventional tillage (CT) recorded the highest (2.12 kg) and was followed by the minimum tillage (MT) (2.05 kg) with the lowest recorded by no tillage (NT) (1.96 kg). Similar ranking was found in 2011 growing season where CT recorded the highest weight per fruit of 5.03 kg and was followed by the MT (4.03 kg) whilst the no tillage recorded the lowest (3.59 kg) fruit weight. In 2010, no significant difference was obtained at probability (0.05), among the CT and MT but there was a significant difference between the CT and NT. However, in the 2011 season, there was a significant difference between the treatments at ($p > 0.05$) (Table 5). Keshavarzpour and Rashidi [8] reported that tillage methods significantly affected crop yield, fruit weight, vine length and fruit length of water melon. Their reports is in consonant with the present study which revealed that, fruit weight of CT was higher than the NT which is attributed to the soil preparation which improved nutrient uptake and infiltration rate of CT and MT than the NT where infiltration and nutrient movement would be limited due to undisturbed nature of the soil. Again, the present study confirms Rashidi and Keshavarzpour [28], work on the differences in fruit weight among the tillage methods. In 2010, of this study, the CT and the MT had the highest fruit weight than the NT but there were no significant differences between them and attributed the differences observed to tilth of the soils than the NT which influenced other soil physical properties.

3.4.3 Circumference of fruits (cm)

With regards to the circumference per fruit, the conventional tillage (CT) recorded the highest value of 26.44 cm followed by the minimum tillage (MT) of 25.44 cm and the least recorded by the no tillage (NT) with 24.66 cm. There was significant difference between the treatments. The 2011 cultivation witnessed the CT again recording the highest value of 66.11 cm followed by the MT with 61.22 cm and the least was recorded by NT with 58.44 cm. There were significant differences among the treatments (Table 6).

These differences among the tillage methods could be due to the fact that the CT and MT methods provided a favourable environment for the growth of the fruit and this is because, the disturbance and the pulverization of the soil made the soil loose and provided an avenue for root and plant growth and consequently fruit growth which resulted in the larger sizes and onward yield of the watermelon fruit. The current study agrees with Khan et al. [10], who observed that conventional tillage method produces a favourable environment for crop growth and nutrient use. Again, Rashidi and Keshavarzpour [11] reported 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.

Table 4. Number of fruits of watermelon per plot (2010 and 2011)

Treatment	2010	2011
Tillage		
No Tillage	24.11	26.22
Conventional Tillage	27.33	27.89
Minimum Tillage	24.33	27.00
LSD(0.05)	0.013	0.01
CV (%)	0.01	**0.02**

Table 5. Weight of fruit per plot of watermelon (kg) (2010 and 2011)

Treatment	2010	2011
Tillage		
No Tillage	1.96	3.59
Conventional Tillage	2.12	5.03
Minimum Tillage	2.05	4.03
LSD (0.05)	0.10	0.07
CV	0.50	0.60

Table 6. Fruit circumference (cm) of watermelon 2010 and 2011 seasons

Treatment	2010	2011
Tillage		
No Tillage	24.66	58.44
Conventional Tillage	26.44	66.11
Minimum Tillage	25.44	61.22
LSD(0.05)	0.001	0.10
CV (%)	0.01	**0.02**

Table 7. Yield of watermelon fruit in 2010 and 2011 seasons

Treatment	2010	2011
Tillage		
No Tillage	28210	55051
Conventional Tillage	43364	96157
Minimum Tillage	32531	65840
LSD(0.05)	8611	19306
CV (%)	17.92	13.66

3.4.4 Fruit yield of watermelon

For the yield of fruits per hectare, the following values were recorded for 2010 growing season; the conventional tillage (CT) yielded 43,364 kg/ha, minimum tillage (MT) was 32,531 kg/ha and no tillage (NT) with 28,210 kg/ha. The 2011 growing season also recorded the following; CT yielded 96,157 kg/ha, MT recorded 65,840 kg/ha and the NT yielded 55,051 kg/ha (Table 7). The differences in the yield of watermelon could be attributed to the tillage practices embarked on during the experiment. It is stated that, C Thad influence on the seed germination, growth and onward yield of watermelon. This is because, physical attributes of the soil are enhanced which also helps in nutrient uptake than undisturbed soils which are often hard and affects penetration of root, growth and yield. This observation has been made by Keshavarzpour and Rashidi [8] who stated that CT methods significantly affected crop yield, fruit weight, vine length and fruit length of water melon. Again, the current study is in line with Khan et al. [11], who observed that conventional tillage method produces a favourable environment for crop growth and nutrient use. Also, Khan et al. [11] reported that conventional tillage method produce a finer and loose soil structure which in turn affect the seedling emergence, plant population density and consequently crop yield.

4. CONCLUSION

Tillage method significantly affected soil physical properties thus total porosity, volumetric water content and bulk density. Also, tillage methods influenced crop growth, yield and yield components of watermelon in the order of Conventional tillage > Minimum tillage > No-Tillage. These observation made is mainly due to the favourable soil environment provided by the tilled land which improved soil physical abilities for improved growth and yield. It is recommended that for effective growth and yield of water melon in forest transitional zone, tillage practices such as conventional tillage (CT) and minimum tillage (MT) is better than the no-tillage (NT) method.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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