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Short communication

Evaluation of tomato growth and soil properties under methods of seedling bed preparation in an alfisol in the rainforest zone of Southwest Nigeria

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Abstract

Tillage is expected to influence growth, yield and nutrient status of tomato (*Lycopersicon esculentum*, Mill.) plant, but there is scarcity of research to investigate the relationship between tillage and performance parameters of tomato. Hence the variation in soil physical and chemical properties, tomato growth, plant nutrient contents and fruit yield in response to different tillage methods and seedling bed types and positions, were investigated on an alfisol (Ferric Luvisol) at Akure in the rainforest zone of Nigeria. Different bed types for transplanted tomato seedlings were created using herbicide-based zero tillage, manual clearing (a form of zero tillage), top, side and base positions of ridges and mounds for planting seedlings of early and late season tomato crops. The soil at the top, side and base positions of ridges and mounds had lower bulk densities that was associated with greater root length, plant height, number of stems, branches and number of leaves and weight of tomato fruits, and leaf nutrient contents compared with zero tillage and manually cleared soils. Planting on ridge or mound positions increased the number of fruits and fruit weight by 200 and 100%, respectively, compared with planting on untilled soils. Soil bulk density was negatively correlated with root growth and leaf nutrient content. Tomato requires tillage for optimum productivity.

Keywords: Tillage; Soil properties; Tomato; Nutrients; Nigeria

1. Introduction

In the humid tropics where most of the farmers are smallholders and chemical fertiliser is scarce and expensive, soil working and tillage methods can be a suitable alternative to enhance nutrient availability to crops. The farmers grow crops such as tomato (*Lycopersicon esculentum*) in multiple cropping systems and planting of seedlings may be done at any position on manually constructed mounds or ridges or in untilled manually cleared soil.

Although the normal practice is to grow tomato on manually tilled soils, repetitive tillage is known to affect the soil properties adversely. Hence there is need to examine the potential of growing tomato using zero and reduced tillage methods and the effects of tillage on nutrient uptake and performance of tomato. Information is scarce on the response of tomato to tillage methods, and the effect of seedling bed type on soil nutrient accumulation and nutrient uptake. The influence of zero tillage, manual tillage and tractorised ploughing on soil physical properties and yield of

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tomato was studied in the guinea savanna zone of Nigeria (Adeoti and Olarewaju, 1990). Manual and tractorised ploughing significantly reduced soil bulk density, and the fruit yield in the manually tilled and ploughed soils were 67 and 157%, respectively, higher compared with yield for the untilled soil.

The present work carried out in the rainforest zone of Nigeria investigates the response of tomato yield components and nutrients contents to the physical and chemical soil conditions at the top, side, base positions of ridges and mounds, in untilled manually cleared soils, and in untilled, herbicide treated soils. The hypothesis is that loose soil in positions of ridges and mounds would enhance root growth and nutrient uptake by tomato thereby increasing its yield. It is expected that information would be generated on suitable soil preparation method for enhancing nutrients uptake and yield of tomato.

2. Materials and methods

2.1. Soil preparation methods

Various soil working methods were used in experiments conducted in the early and late cropping seasons of 1998 at Akure (7°15′N, 5°15′E) in the rainforest zone of Southwest Nigeria. The soil at Akure is an alfisol classified as clayey skeletal Kaolinitic isohyperthermic Oxic Paleustalf or Ferric Luvisol (FAO). The surface soil is sandy loam with 441, 254 and 305 g kg^{-1} sand, silt and clay, respectively. The values for organic matter, available P, exchangeable K, Ca, Mg and pH ($CaCl_2$) were 3.6 g 100 g^{-1}, 11 mg kg^{-1}, 0.18 mmol kg^{-1}, 1.4 mmol kg^{-1}, 0.25 mmol kg^{-1} and 6.6, respectively. The land was cleared manually from 2 years fallow dominated by weeds such as *Chromolaena odorata* (L.) King and Robinson, *Digitaria horizontalis* Wild and *Pennisetum purpurium* Schum. The eight soil working methods evaluated for tomato were as follows:

1. Zero tillage in which paraquat at 5 kg a.i. ha^{-1} was sprayed 2 weeks before transplanting.
2. Manual clearing with cutlass and transplanting on flat.
3. Manual ridging with hoe after clearing and transplanting on ridge top.
4. Manual ridging with hoe after clearing and transplanting at ridge side.
5. Manual ridging with hoe after clearing and transplanting at ridge base.
6. Manual mound construction with hoe after clearing and transplanting on mound top.
7. Manual mound construction with hoe after clearing and transplanting at mound base.
8. Manual mound construction with hoe after clearing and transplanting at mound base.

Treatments 2–8 are seedling bed types used by farmers in Nigeria. They were compared with the introduced zero tillage.

The treatments were laid out in a completely randomised block design with three replicates. Each plot was of 9 m^2 and there were 12 plants per plot. Each mound or ridge was approximately 1 m at the base and about 0.75 m high. The plants were spaced at 1.0×0.75 m^2. The top of the mounds and ridges were separated by 1.0 m. Three weeks old local variety of tomato seedlings were transplanted to the field in 9 April and 24 September for the early season and late season, respectively. The rainfall during April, May, June, July, August, September, October, November and December 1998, which covered the two cropping seasons, was 142, 162, 192, 188, 115, 120, 179, 55 and 23 mm, respectively. The equivalent values for air temperature were 30, 29, 27, 27, 26, 27, 27, 26 and 25 °C. One manual weeding was done for each experiment.

2.2. Determination of soil properties

For two seasons certain soil physical properties were evaluated on five occasions at 2 weeks interval after transplanting. Three steel core samples collected from 5 to 15 cm below each plot were used for the evaluation of bulk density, total porosity and gravimetric water content after placement of samples in oven set at 100 °C for 24 h. Total porosity was calculated using the particle density of 2.65 mg m^{-3}. Soil temperature at 9.00, 12.00 and 15.00 h was determined with a soil thermometer inserted to 10 cm depth and the mean value was computed.

Samples were obtained from 5 to 15 cm below each plot at 3 sites per plot at the beginning of harvest to determine soil chemical properties. The samples were composited, air-dried, and passed through a 2-mm sieve before making the determinations. The organic matter content was determined using dichromate oxidation method. Available phosphorus was determined colorimetrically after Bray-P1 extraction (Bray and Kurtz, 1945). Exchangeable calcium, potassium and magnesium were extracted with ammonium acetate and determined on flame photometer, and total N was determined by the Kjeldahl digestion method (Jackson, 1958).

2.3. Leaf analysis

At mid-flowering stage, leaf samples were collected randomly from each plot, dried in oven at 800 °C and were ground. Leaf N was determined by the Kjeldahl digestion method. Ground samples were digested with a nitric–perchloric–sulphuric acid mixture. (AOAC, 1990). Phosphorus was determined colorimetrically by vanadomolybdate method and K, Ca and Mg on flame photometer.

2.4. Determination of yield components

Five plants were selected per plot for biweekly determination of plant height and number of leaves. The number and weight of fruits were evaluated between 72 and 90 days after transplanting. The plants were excavated for the measurement of tap root length.

2.5. Statistical analysis

The mean values of soil properties, nutrient contents and growth and yield attributes of tomato were compared on treatment basis using LSD (0.05) (Steel and Torrie, 1960). The correlation coefficients between soil bulk density, root growth and leaf nutrients contents were determined.

3. Results and discussion

3.1. Soil chemical properties

There was no change in soil chemical properties due to different methods of seedling bed preparation for the early tomato crop (data not shown). However, zero tillage and manual clearing method resulted in the lowest values for soil organic matter and Ca contents for the late crop. The soil organic matter contents for zero tillage, manual clearing, ridge top, ridge side, ridge base, mound top, mound side and mound base were 2.1, 1.9, 2.2, 3.4, 2.5, 2.3, 3.2 and 2.4 g 100 g^{-1}, respectively (LSD = 0.60). The equivalent values for exchange Ca were 3.7, 3.4, 4.1, 5.1, 4.1, 4.0, 4.9 and 4.4 mmol kg^{-1} (LSD = 0.60).

3.2. Soil physical properties

The mean values of soil physical properties are shown in Table 1. The zero tillage and manually cleared soils had relatively high bulk density, lower total porosity, higher water content and lower day time temperature compared with soil located at different positions of a mound or ridge. The soils located at the base of a mound or ridge had higher bulk density, lower total porosity, higher water content and lower temperature compared with those of soils located at the top and side of a mound or ridge.

3.3. Performance of tomato

The tomato tap root lengths in zero tillage and manually cleared soils were less than those in soil located at positions of the mound or ridge (Table 2). Also the root lengths recorded for the base positions of a mound or ridge (with higher soil bulk densities) were less than those for the top and side of a mound or ridge. The reduced root growth recorded in the untilled (zero tillage and manually cleared) soils can be attributed to their higher bulk densities. The correlation coefficient (r) between root length and soil bulk density recorded for the early and late tomato crops were -0.99 ($P = 0.001$, $N = 7$) and -0.91 ($P = 0.01$, $N = 7$), respectively.

The early and late tomato crops on the untilled soils also had a lower leaf N, P, K, Ca and Mg status compared with crops on different positions of mound or ridge (data not shown). However, the effect of tillage on leaf nutrients contents was not statistically significant in case of early tomato crop ($P = 0.05$). Tillage and seedling bed type significantly affected the leaf P and Ca status of the late tomato crop. The leaf P contents recorded for zero tillage, manual clearing, ridge top, ridge side, ridge base, mound top, mound

Table 1
Effect of soil preparation method on soil physical properties (means for five determinations at 2 weeks interval)

Soil preparation method	Bulk density (mg m^{-3})		Total porosity (%, v/v)		Water content (g kg^{-1})		Temperature (°C)	
	E[a]	L[b]	E	L	E	L	E	L
Zero tillage	1.68	1.64	34.9	38.0	103	114	30.1	32.3
Manual clearing	1.68	1.68	35.0	35.7	103	112	30.2	32.6
Ridge top	1.45	1.44	43.3	45.7	66	98	33.9	34.8
Ridge side	1.50	1.49	42.3	43.9	65	100	32.5	34.1
Ridge base	1.50	1.54	41.9	41.9	69	103	31.5	33.5
Mound top	1.43	1.45	42.9	45.2	66	98	34.2	34.9
Mound side	1.48	1.50	41.8	43.2	66	100	32.3	34.1
Mound base	1.50	1.53	41.9	42.2	69	104	31.5	33.6
LSD (0.05)	0.08	0.08	3.0	3.0	9.0	NS	0.6	0.9

[a] Early tomato crop.
[b] Late tomato crop.

side, and mound base were 0.11, 0.12, 0.25, 0.30, 0.30, 0.23, 0.30 and 0.30 g P 100 g^{-1}, respectively (LSD, 0.05 = 0.07). The equivalent values for leaf Ca were 0.25, 0.24, 0.39, 0.47, 0.42, 0.40, 0.49 and 0.42 g Ca 100 g^{-1} (LSD, 0.05 = 0.15). Ojeniyi (1993) also found that surface hoeing increased uptake of N, P and K by maize. (*Zea mays* L.) in the humid zone of Nigeria. The lower nutrient content of tomato crops grown on untilled soil can also be related to the higher soil bulk densities that adversely affected root growth and nutrient uptake. Hence, negative correlations were recorded between soil bulk density and leaf nutrient content. The correlations (r) between soil bulk density and leaf, P, K and Ca of the early tomato crop were -0.67 ($P = 0.10, N = 7$), -0.85 ($P = 0.05, N = 7$), and -0.91 ($P = 0.01, N = 7$), respectively. The correlation of N and Ca in late tomato crop was -0.91 ($P = 0.01, N = 7$) and -0.85 ($P = 0.02, N = 7$), respectively.

Smaller mean values of growth parameters of tomato such as plant height, number of leaves and branches were recorded for untilled soils compared with soils located on a mound or ridge (Table 2). The overall mean number of leaves per plant for zero tillage, manual clearing, ridge top, ridge side, ridge base, mound top, mound side and mound base were 22, 15, 29, 31, 29, 30, 34 and 30, respectively. The equivalent values for number of branches were 5, 4, 7, 8, 8, 7, 8 and 7. The values of number and weight of fruits were also less for the untilled soils (Table 2). The overall mean number of fruits per plant for untilled soils (zero tilled and manually cleared) and

Table 2
Effect of soil preparation method on tomato yield components

Soil preparation method	Plant height (m)		Tap root length (m)		No. of fruit per plant		Fruit weight (g)	
	E[a]	L[b]	E	L	E	L	E	L
Zero tillage	0.39	0.36	0.16	0.08	9	5	272	82
Manual clearing	0.38	0.32	0.16	0.07	8	2	257	22
Ridge top	0.48	0.40	0.26	0.16	14	10	459	218
Ridge side	0.46	0.45	0.24	0.15	14	8	456	236
Ridge base	0.46	0.44	0.23	0.13	11	10	415	228
Mound top	0.48	0.41	0.26	0.20	14	8	461	206
Mound side	0.46	0.48	0.24	0.14	14	13	406	263
Mound base	0.46	0.43	0.24	0.13	13	7	423	226
LSD (0.05)	0.05	0.04	0.02	0.05	NS	4.0	124	84

[a] Early crop.
[b] Late crop.

positions on ridge or mound were 4 and 14, respectively (Table 2). The equivalent values for fruit weight were 159 and 329 g. There were no significant differences in yield of tomato crops grown at different positions of a mound or ridge. The lower performance of tomato on untilled soils is consistent with the lower leaf nutrient contents and associated high soil bulk density, which reduced root growth and nutrient uptake.

Differences in soil bulk density probably dictated differences in tomato growth, yield and nutrient status between untilled soils and soils located on mound and ridge. The mean bulk densities recorded for the untilled soil (1.54–1.68 Mg m^{-3}) were clearly above the optimum required for the growth and development of a number of important crops in the tropics (Obi and Nnabude, 1988).

Increase in soil bulk density is known to reduce root elongation at low water contents (Maurya and Lal, 1979). Although the untilled soils had a higher water content and lower temperature, these did not positively influence tomato growth and yield. Therefore, tomato grown on alfisols in the humid tropics requires tillage for reducing soil density and enhancing root growth, nutrient uptake and yields. Tillage and planting on a ridge or mound enhances availability of nutrients to a tomato crop.

4. Conclusions

Variation in soil bulk density between positions on the ridge and mound, and untilled soils induced variation in root growth, vegetative growth, nutrient status and yield of tomato. There were better growth, yield and nutrient status observed for tomato grown at different positions of a ridge or mound compared to untilled soils. It is concluded that tomato requires tillage for enhancement of root growth, nutrient uptake and yield on sandy alfisols commonly found in the humid tropics, and that tomato should be planted at positions on a ridge or mound for better performance.

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