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Growth, Yield and Nutrient Concentrations of Tomato as Affected by Soil Textures and Nitrogen

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ABSTRACT

Sand, loam and clay are three main textural classes of soil. However, they differ in their nutrient and water holding capacities. A greenhouse experiment was conducted to determine the effect of five rates of N fertilizer (0, 30, 60, 90, 120 kg N ha^{-1}) grown in 3 different textural classes (sand, loam and clay) of soil on growth, yield and nutrient composition of tomato. Effects of N on all the parameters determined were significant ($p \leq 0.05$) except plant height at 2 and 4 Weeks after Planting (WAP). The highest plant height at harvest (12 WAP), mean fruit weight, fruit yield and dry matter yield were obtained at 90 kg N ha^{-1}. Tissue nutrient (NPK) concentrations increased as the rate of N increased. Loam soil produced the highest value of all the parameters determined except tissue N concentration. Tomato growth and yield were significantly influenced by soil texture and N applications; loam soil at 90 kg N ha^{-1} proved superior to other treatments, in this study.

Key words: Nitrogen, soil texture, nutrient concentration, tomato

INTRODUCTION

Tomato crop is very important in terms of diet and economy in Nigeria. Large production is grown in Northern Guinea Savanna (NGS) of Nigeria both during the rainy season (rainfed) and dry season (using irrigation facilities). Nitrogen is the most limiting nutrient in the NGS zone (Enwezor *et al.*, 1990; Aduayi *et al.*, 2002). The soils of the zone are low in organic matter, poorly buffered and are made up of Low Activity Clay (LAC) with kaolinite as dominant clay fraction, therefore cations and water retention capacities are low (Ojanuga, 1979; Enwezor *et al.*, 1990; Odunze, 2006). Application of N as fertilizer to soils in the Savanna is therefore essential in order to achieve high crop yields of good quality (Upendra *et al.*, 2003).

Nitrogen has a pronounced effect on growth and development of tomato. It promotes both vegetative and reproductive growth and impacts the characteristic deep green colour of leaves. Application of optimum N-fertilizer to the soil produces high tomato fruit yield and improves fruit quality (Adams *et al.*, 1978) whereas, excessive application leads to luxuriant development of vegetative parts of the plant at the expense of reproductive growth (Tisdale *et al.*, 2003). It has been reported that tomato can grow on a variety of soils except worst soils such as gravelly soils and water-logged soils (Simons and Sobulo, 1974) but better yields were obtained from some soil types than others even with the same management practices and environmental conditions (Pettygrove *et al.*, 1999).

Soil texture which is the proportion of soil particles in different size ranges influences several components of soil fertility, such as the amount of nutrient reserves and their proportion to the plant available nutrient fraction (Brady and Weil, 2004; Mengel and Kirkby, 2001).

Sandy soils are low in organic matter and water holding capacity. They are well drained and are generally poor in nutrient reserves but they provide favourable conditions for root growth and soil aeration; whereas loamy soils have better moisture and nutrient holding capacity than sandy soils. Clay soils are sticky when wet but extremely hard and cloddy when dry; they can however retain water and nutrients.

The effects of nitrogen on growth and yield of tomato has been widely investigated and well documented (Sobulo, 1975; Adams *et al*., 1978; Erinle, 1989). However, there is little evidence on how N fertilizer and soil texture affect the yield of tomato. It is possible to make broad generalizations regarding nutrient requirements of crops, quite often soil texture is one of the factors that influence crop growth and yield, tissue nutrient concentrations and crop response to treatments (Vandamme, 1978; Tisdale *et al*., 2003; Mengel and Kirkby, 2001).

The study was undertaken to determine the (i) best soil texture (sand, loam and clay) for growth and yield of tomatoes, (ii) optimum N rate for the yield of tomatoes and (iii) tissue nutrient concentration of tomato plants.

MATERIALS AND METHODS

The experiment was conducted in a greenhouse at Institute for Agricultural Research, Faculty of Agriculture, Ahmadu Bello University, Samaru, Zaria, Nigeria. The soil samples-sand, loam and clay soils collected from three sites (representing the three different textural classes) at the Institute for Agricultural Research farm, ABU Zaria, were air-dried, crushed and sieved. Some of the sieved samples were used for soil analysis while the remaining one was used for greenhouse study.

Five kilograms of sieved soil was weighed into each pot of 10 liter capacity, perforated under for free drainage. Tomato seedlings (Roma VF variety) which were raised in a nursery, were transplanted at four Weeks after Planting (WAP) at the rate of four seedlings per pot. At 2 Weeks After Transplanting (WAT), the seedlings were thinned down to two seedlings per pot. Treatments consisted of five levels of N fertilizer (0, 30, 60, 90 and 120 kg N ha^{-1}) and three soils textures (sand, loam and clay). The design used was randomized block design with three replicates. Nitrogen fertilizer was applied as urea in two split doses-at 2 and 6 WAT; uniform rates of 45 kg P_2O_5 and 45 kg K_2O ha^{-1} were applied into the pots at 2 WAT. Plants were sprayed fortnightly for the control of fungi diseases.

Parameters determined were plant height (taken fortnightly), weight of fruits and fruit weight per pot. The plants were harvested at 12 WAT by cutting the above ground portion, washed thoroughly in distilled water and oven-dried at 70°C to constant weight. The dried plants were weighed, ground and store in polythene bags for plant tissue analysis.

Laboratory analysis

Soil analysis: Soil pH in water and $CaCl_2$ were determined in 1:2.5 soil/water suspensions using glass electrode pH meter while Organic Carbon (OC) was determined by the wet oxidation method of Walkley and Black (1934). Total N was determined by the Kjeldahl method, available P was extracted by the Bray-1 method and P in solution was determined colorimetrically. The particle size distribution was determined by the hydrometer method. Exchangeable bases (Ca, Mg, K and Na) were brought into solution by repeated extraction procedure with neutral 1M NH_4OAc solution at pH 7. Ca and Mg concentrations were determined with atomic absorption spectrophotometer; while

K and Na were determined with flame emission photometer. Cation exchange capacity was determined by the NH_4OAc saturation method. Micronutrients (Cu, Zn, Mn and Fe) were extracted using 1M HCl solution and the micronutrients in solution were read using Atomic absorption spectrophotometer (Juo, 1979).

Plant analysis: Ground plant samples were digested in a mixture of perchloric, nitric and sulphuric acids. The concentration of P in the digest was determined with spectrophotometer while flame photometer was used to determine K in the digest. Total N in the plant samples were determined by the Kjeldahl method (Juo, 1979).

Statistical analysis: Data collected from the study were subjected to analysis of variance (ANOVA) to test for differences among treatments; the means that showed significance F-test were separated using Duncan Multiple Range Test. MSTAT was used to rank the interaction between N and soil types that showed significance.

RESULTS AND DISCUSSION

Soil analysis: The results of the soil analysis are presented in Table 1. The soils are slightly acidic with pH (water) ranging from 4.0 to 4.5. The soils were low in Organic Carbon (OC), total N and available P. The concentrations of exchangeable bases were generally low while Ca dominated the exchange sites. The concentrations of these nutrients are below the recommended critical values of the nutrients in the soil of the zone (NGS). These characteristics are typical of savanna soils of Nigeria (Jones and Wild, 1975; Enwezor *et al*., 1990; Aduayi *et al*., 2002). It could be inferred from these results that the soils are of low fertility levels, justifying the need for additional fertilizer input to boost crop yield.

Table 1: Physiochemical properties of soils

Characteristics	Sand	Loam	Clay
pH (water)	4.00	4.50	4.20
pH ($CaCl_2$)	3.80	4.20	3.70
Organic carbon (g kg^{-1})	2.20	7.20	7.90
Total N (g kg^{-1})	0.14	0.42	0.56
Available P (mg kg^{-1})	3.24	4.50	5.40
Exchangeable bases (cmol kg^{-1})			
Ca	0.96	0.6	2.10
Mg	0.62	0.43	1.30
K	0.42	0.43	0.60
Na	0.27	0.23	0.40
CEC	5.10	4.60	7.60
Micronutrients (mg kg^{-1})			
Cu	1.8	2.5	4.0
Zn	3.4	5.6	4.4
Mn	10	12	24
Fe	38	62	90
Mechanical analysis (g kg^{-1})			
Sand	880	400	280
Silt	100	360	240
Clay	20	240	480

Table 2: Effect of N levels and soil types on plant height of tomato

Treatments	Plant height (cm)					
N-levels	2 WAT	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT
0	9.30^{b}	10.2^{c}	15.9^{c}	16.6^{c}	17.1^{c}	17.6^{d}
30	9.90^{ab}	11.3^{b}	17.1^{b}	21.9^{b}	25.4^{b}	30.1^{c}
60	10.4^{a}	12.0^{b}	17.2^{b}	22.8^{ab}	27.0^{ab}	32.6^{b}
90	10.8^{a}	13.3^{a}	19.0^{a}	23.1^{ab}	28.7^{a}	35.0^{a}
120	11.0^{a}	14.0^{a}	20.0^{a}	23.4^{a}	28.1^{a}	32.2^{bc}
Soil types						
Sand	10.0	12.1	16.5^{b}	19.6^{b}	23.1^{b}	26.5^{c}
Loam	10.3	12.0	18.8^{a}	22.9^{a}	27.1^{a}	32.4^{b}
Clay	10.6	12.3	18.2^{a}	22.1^{a}	25.6^{a}	30.0^{a}
Interaction						
NL×ST	NS	NS	NS	NS	1.3	1.25

Means followed by the same letters are not significantly different at 5% level

Table 3: Interaction between N levels and soil types on tomato plant height at 12 WAT

	Soil types		
N levels	Sand	Loam	Clay
0	16.9	18.2	17.6
30	24.1	33.7	32.6
60	30.2	34.6	33.4
90	30.5	41.3	33.6
120	31.0	34.2	31.4
SE (0.05) = 1.25			

Effect of treatments on plant height: There were significant ($p \leq 0.05$) increases in tomato plant height with increase in N rates (Table 2) from 2-12 Weeks After Transplanting (WAT). At 2 WAT, plants treated with 120 kg N ha^{-1} gave the highest plant height but the results was similar to those of 30, 60 and 90 kg N ha^{-1}. Similarly, at 4 and 6WAT, 120 kg N ha^{-1} rate produced the tallest plants and the result was not significantly different with those at 90 kg N ha^{-1}. At 12 WAT, plants treated with 90 kg N ha^{-1} gave the tallest plants of 35 cm while there was no significant difference between the results obtained for plants treated with 60 and 120 kg N ha^{-1}; the least plant height was from the control (Table 2).

Effect of soil texture on plant height was only significant between 6-12 WAT. At 12 WAT, loam soil produced the tallest plants (32.4 cm) followed by clay (30 cm) and the least was from sand (26.5 cm). Plant height was significantly influenced by N rates and soil textures interactions only at 10 and 12 WAT (Table 2). The tallest plants (31 cm) produced by sand was at 120 kg N ha^{-1}, whereas that of loam (41.3 cm) was at 90 kg N ha^{-1}; similarly, clay soil produced the tallest plants (33.6 cm) at 90 kg N ha^{-1}. There were no significant differences between the results obtained for sand and clay at 30 and 60 kg N ha^{-1} (Table 3).

The significant response to N fertilizer recorded by plant height is because N is one of the limiting nutrients in savanna soils; this is evident in the result of the pre-planting soil analysis (Table 1). Nitrogen is necessary for photosynthesis, formation of chlorophyll and nucleic acids, its absence or deficiency causes stunted growth (Tisdale *et al*., 2003). However, positive response for plant height were up to 90 kg N ha^{-1} in loam and clay soils and 120 kg N ha^{-1} for sand, signifying that crop need was met at these rates.

Table 4: Effect of mean fruit weight, yield and plant tissue nutrient (NPK) concentration

Treatments	Mean fruit weight (g)	Fruit yield per pot (g)	Dry matter yield (g pot^{-1})	Tissue N conc. (g kg^{-1})	Tissue P conc. (g kg^{-1})	Tissue K conc. (g kg^{-1})
N levels (kg N ha^{-1})						
0	19.10^{e}	238.80^{d}	8.06^{d}	1.96^{c}	2.27^{c}	2.58^{c}
30	33.51^{d}	460.10^{c}	9.30^{c}	3.09^{b}	3.70^{a}	3.74^{bc}
60	39.80^{b}	728.40^{b}	10.40^{b}	3.10^{b}	3.90^{a}	4.51^{ab}
90	43.62^{a}	881.20^{a}	11.50^{a}	3.40^{ab}	4.10^{a}	4.76^{ab}
120	36.60^{c}	619.00^{b}	9.80^{c}	3.70^{a}	4.20^{a}	5.1^{a}
Soil Types (ST)						
Sand	31.64^{b}	502.10^{b}	9.20^{b}	2.70^{b}	3.31	3.81
Loam	36.90^{a}	642.30^{a}	10.70^{a}	3.10^{a}	3.90	4.90
Clay	35.10^{a}	611.70^{a}	9.60^{b}	3.40^{a}	3.64	4.13
Interaction						
NL×ST	**	*	**	NS	NS	NS

Means followed by the same letters are not significantly different at 5% level, * = Significant at 0.05 probability level, **= Significant at 0.01 probability level

Table 5: Interaction between N levels and soil types on tomato fruit yield per pot

	Soil types		
N levels	Sand	Loam	Clay
0	82.67	216.7	417
30	496	355	529
60	660	822	703
90	714	989	940
120	558	676	623
SE (0.05) = 67.3			

Effect of treatments in mean fruit weights: Effect of N rates on mean fruit weight was highly significant (Table 4). As the rate of N increased, there was increase in the weight of fruit up to 90 kg N ha^{-1}. The highest fruit weight of 43.62 g was obtained at 90 kg N ha^{-1}. Among the soil textures, loam soil produced the highest mean fruit weight of 37 g.

The interaction between N rates and soil textures on mean weight of fruits was significant ($p<0.001$). Loam soil treated with 90 kg N ha^{-1} produced the highest mean fruit weight of 47 g. This result is in line with the report of Katerji *et al.* (1998) who reported a significant effect of soil texture on tomato fruit weight and also obtained a higher mean fruit weight in loam than clay soil.

Effect of treatments on fruit yield per pot: The results obtained for fruit yield per pot with the different rates of N fertilizer indicated a positive response to the fertilizer (Table 4). There was a steady increase in fruit yield with the fertilizer rates up to 90 kg N/ha; although the result obtained for 60 kg N ha^{-1} was higher than that of 120 kg ha^{-1}, there was no significant difference between the two results. The results obtained from this study have confirmed the critical role N plays in the nutrition of tomato (Upendra *et al.*, 2003). Samaila *et al.* (2011) who worked on the soil of the same zone obtained the highest tomato fruit yield at 90 kg N ha^{-1}.

Among the soil textures, loam produced the highest fruit yield per pot (642.3 g) while the least was from sand (Table 4). There was significant ($p<0.05$) interaction between N rates and soil textures (Table 5); loam soil treated with 90 kg N ha^{-1} gave the highest fruit yield per pot (989 g). The significant effect of texture on fruit yield of tomato agrees with the findings of Vandamme (1978), Katerji *et al.* (1998) and Pettygrove *et al.* (1999).

Effects of treatments on dry matter yield (DMY): Effect of nitrogen on DMY of tomato was highly significant ($p<0.001$). The highest DMY of 11.5 g pot^{-1} was obtained from 90 kg N ha^{-1}, whereas the least (8.06 g) was from the control (Table 4). The results obtained for 30 and 120 kg N ha^{-1} were similar. Loam soil produced the highest dry matter yield of 10.70 g and there was no significant difference in the result obtained for sand and clay soils. The significant interaction of N and soil textures on DMY could be due to the importance of N and soil textures for crop growth and development.

Effect of treatments on plant tissue nutrient (NPK) concentrations: Plant tissue N increased significantly ($p<0.001$) as N rates increased (Table 4). Tissue N concentration ranged from 1.96 to 3.7 g kg^{-1}. Although the highest rate of N (120 kg N ha^{-1}) have the highest amount of tissue N concentration (3.7 g kg^{-1}), there was no significant difference between the results and that of 90 kg N ha^{-1}. The control has the least (1.96 g kg^{-1}) tissue N concentration.

Soil textures have a significant ($p<0.001$) effect on tissue N concentration with clay soil having the highest value among the soil textures (Table 4). This is expected as the pre-planting soil analysis shows that clay soil have the highest N concentration (Table 1). There was a non-significant interaction between N rates and soil textures on tissue N concentration.

Effects of treatments on tissue P concentration was highly significant ($p<0.01$). There was no significant difference in the results obtained for the various rates of N except the control (Table 4). Plants treated with 120 kg N ha^{-1} gave the highest tissue P concentration (4.20 g kg^{-1}). Among the soil textures, loam produced the highest P concentration of 3.90 g kg^{-1}, despite that clay contained more available P in the pre-planting soil analysis (Table 1). This could be due to the fact that clay fixes more P than loam and sand soils. The interaction between N rates and soil textures on tissue P concentration was not significant.

Potassium concentration in the tomato plant tissue varied from 2.58-5.1 g kg^{-1} (Table 4). The application rate of 120 kg N ha^{-1} gave the highest tissue K concentration while the control gave the least. Effect of soil texture on tissue K concentration was not significant; however, loam soil produced the highest tissue K concentration (4.9 g kg^{-1}). Similarly, the interaction of N x soil textures was not significant. Plant tissue K did not respond to N application in the soils probably due to the inherent adequate K in the soils.

Nutrient status and behavior in soils depend on soil texture. Soil analysis of the soils used for this study (Table 1) shows that clay soil contains more nutrients than loam and sand soils but the highest growth and yield parameters obtained from this study were from loam soil. This signified that soil texture affects the amount of soil nutrient reserves and the available nutrient fraction to the crop.

CONCLUSION

The result of the soil analysis showed that clay soil contain more nutrients than sand and loam soils, as shown in the concentrations of the total N, available P and exchangeable bases. However, from the results obtained from plant growth and yield parameters studied loam soil showed superiority over others. Loam soil treated with N rate of 90 kg N ha^{-1} gave the highest result of growth and yield parameters. Clay soil produced the highest tissue N concentration, whereas loam produced the highest tissue P and K concentrations.

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