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Optimizing tomato (*Solanum lycopersicum* L.) growth, yield and soil quality with inorganic n and farmyard manure in Sudan Savanna of Nigeria

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ABSTRACT

Field study was carried out in 2019/2020 and 2020/2021 dry seasons at the Nigeria Institute of Horticultural Research Sub-station Bagauda, Kano State, of Nigeria to evaluate the impact of integrated nutrient management (INM) on tomato growth, yield and soil properties under irrigated conditions. Treatments consisted of combination of Nitrogen (N) urea + Farmyard manure (FYM) as follows: T^1 = Control, T^2 = 50% N (60 kg N ha^{-1}) T^3 = 100% N (120 kg N ha^{-1}), T^4 = 5 t ha^{-1} FYM, T^5 = 10 t ha^{-1} FYM, T^6 = 25% N + 7.5 t ha^{-1} FYM, T^7 = 50% N + 5 t ha^{-1} FYM, T^8 = 75% N + 2.5 t ha^{-1} FYM and T^9 = 100%N +10 t ha FYM. A basal application of 60 kg P_2O_5 and 60 kg K_2O at land preparation in all plots and nitrogen was applied in two splits at 2 and 6 weeks after transplant (WAT) while FYM was applied two weeks before transplanting (on air dry matter basis). The experiment was laid out in a randomized complete block design and replicated four (4) times with the experimental plots (basins) measuring 3 × 3 m. Data were collected on some growth and yield parameters, and soil quality attributes after the experiment on each treatment plot. The result revealed that the application of 50% N + 5 t ha^{-1} of FYM significantly ($p<0.05$) improved soil organic carbon, total soil N and narrowed the C:N ratio. Crop growth response was significantly influenced by application of 10 t ha^{-1} FYM + 100% N when compared to control. However, yield and yield components of tomato significantly responded to combined application of 50% N + 5 t ha^{-1} FYM beyond which addition of N or FYM did not produced any significant increase in yield and yield components. It is concluded that combined application of 50% N + 5 t ha^{-1} FYM was found adequate for tomato productivity and improvement of soil organic status.

Keywords: Soil quality; Nutrient management; soil health Agroecology

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is the most popular vegetable crop in Nigeria and around the world due to its wider adaptability and multifarious uses. Tomato is known to be

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a heavy feeder and exhaustive among vegetable crops that requires large quantities of inorganic and organic nutrients.

Soil depletion is one of most threatening factors among others in agricultural and tomato productivity in Nigeria. The application of minerals like Urea (46%) is used as common source of nitrogen for maintaining soil fertility without adequately supplying organic manures. The excessive or indiscriminate use of nitrogenous fertilizer is not judicial for soil health and crop production. However, application of organic manure in judicious combination to chemical fertilizers facilitates profitable and sustainable crop production along with maintenance soil fertility (Singh and Sinsinwar, 2006).

Despite Nigeria being among the leading producer of tomato (3.6 MT per annum), the production per hectare is very low (4.4 t ha^{-1}) when compared to what is obtained by other producing countries (FAOSTAT, 2020). This decline in yield is linked to sub-optimal crop management, which could include poor fertilization and irrigation, and to abiotic constraints (e.g., pedoclimatic variations and land degradation.) (Ullah *et al.*, 2021; Ferrante and Mariani, 2018). The fundamental cause is the degradation of land followed by their loss of fertility (physical, chemical, and biological fertility).

The use of organic manure has been reported to improve biological, chemical, and physical properties of the soil and invariably increase plant growth and yield because of its high organic matter content due to high microbial activity (Mitran *et al.*, 2018). Farmyard manure (FYM) is widely used in soil amendment for improving physicochemical properties and biological activities of agricultural soils and for improving crop yield. FYM is rich in organic matter that can be used for tomato production.

Extensive use of inorganic fertilizer has a depressing effect on yield, by causing a reduction in number of fruits, and delays and reduces fruit setting, which consequently delays ripening and leads to heavy vegetative growth (Aliyu *et al.*, 2003). Many other authors (Wu *et al.*, 2020; Ayeni and Ezeh, 2017; Islam *et al.*, 2017) mentioned the positive effect of the combination of organo-mineral fertilizers on tomato productivity. Also, the beneficial effect of combined organic manure with bio-fertilizer on availability of nutrients was reported by Youssef and Eissa (2017) and Fernandes and Bhalerao (2015).

Integrated soil fertility management plays a critical role in both short-term nutrient availability and longer-term maintenance of soil organic matter and sustainability of crop productivity in most smallholder farming systems in the tropics. The objective of the research is to proffer solutions for improving soil fertility and increasing tomato productivity through combining the inorganic N and farmyard manure.

MATERIALS AND METHODS

Study Area

Field study was carried out in 2019 and 2020 at the National Horticultural Research Institute substation Bagauda, Kano State in the Sudan Savanna of Nigeria under irrigated conditions (Latitude 11^0 23' N, Longitude 8^0.23' E) with an elevation of 159 m. The raining season takes effect from the month of May with average number of two raining days at 18.3mm and continues till June (7 rain days, 83.9 mm) and September (5 rain days, 55.2 mm), August (19 rain days, 258.9 mm) and September (5 rain days, 55.2 mm) only. It is mostly hot all the year round with temperatures ranging from16.4^0 - 40^0C hereby exhibiting great potentials of accommodating wide arrays of crops which are temperate and tropical in nature.

Treatments, Experimental Design/Cultural Practices

The treatment consisted of combination of nitrogen urea 46% N + Farmyard manure (FYM) as presented in Table 1. A basal application of 60 kg P_2O_5 and 60 kg K_2O at land preparation in all plots while nitrogen was applied in two splits at 2 and 6 weeks after transplant (WAT) while FYM was measured according to treatment and applied 2 weeks before transplanting (on air dry matter basis). The experiment was laid out in a randomized complete block design (RCBD) and replicated four (4) times with the experimental plots (basins) measuring 3 × 3 m. The test crop was Roma VF which was raised in the nursery for four weeks before transplanting. Cultural practices such as weed control was done manually with hoe at 2 WAT and subsequently as at when due, fertilizer application as per treatments and pest & disease control was observed as the need arises.

Data Collection

Data were collected on some growth (plant height, leaf area and number of branches per plant) and yield (fruit diameter, fruit weight, fruit weight per plant and total fruit yield per hectare) parameters of the crop and soil quality attributes (Soil organic carbon, soil nitrogen and C:N ratio) after the experiment on each treatment plot. Prior to the experiment, composite soil samples were collected from the field using a soil auger with diameter of 15 cm. At the end of the experiment soil samples were collected from each plot for soil organic matter determination as described by the procedures of Walkley and Black (1934).

Data Analysis

Data collected for 2019 and 2020 were averaged over the years and subjected to analysis of variance using general linear model (GLM) procedure with Statistical Analytic System software (SAS, 2009) and treatment means were compared using LSD ($P<0.05$).

Table 1: Treatments description

Treatments	Description/Composition
T1	Control
T2	50% N (60 kg N ha^{-1})
T3	100% N (120 kg N ha^{-1})
T4	5 t ha^{-1} FYM
T5	10 t ha^{-1} FYM
T6	25% N + 7.5 t ha^{-1} FYM
T7	50% N + 5 t ha^{-1} FYM
T8	75% N + 2.5 t ha^{-1} FYM
T9	100%N +10 t ha FYM

RESULTS AND DISCUSSION

Soil Characteristics

The incorporation of FYM showed significant improvement on the soil quality parameters (Table 2). The level of organic carbon ranges between 0.40-1.79% and standard soil N range 0.04-0.71% (0.5-5g/100g). Where the C:N ratio is <10 it is likely to break down very rapidly and C:N ratio is >20) also locks up nitrogen as it decomposes. Soil plots treated with FYM significantly increased soil organic carbon when compared with control treatment and plots treated with inorganic N fertilizer alone.

Table 2: Effect of treatments on the soil characteristics (Averaged over 2 years)

Treatment	Organic carbon (%)	Total Soil N (g/kg)	C:N
T1	0.40b	0.04d	27.2a
T2	0.43b	0.56abc	11.0f
T3	0.44b	0.58abc	10.3f
T4	1.53a	0.25cd	20.7c
T5	1.74a	0.29bcd	25.4b
T6	1.63a	0.48a-d	17.4d
T7	1.68a	0.50a-d	14.0e
T8	1.58a	0.68a	16.1d
T9	1.79a	0.71a	12.7e
LSD (P=0.05)	0.891	0.371	1.43

T^1. Control, T^2. 50% N (60 kg N ha^{-1}) T^{3s}. 100% N (120 kg N ha^{-1}), T^4. 5 t ha^{-1} FYM, T^5. 10 t ha^{-1} FYM, T^6. 25% N + 7.5 t ha^{-1} FYM, T^7. 50% N + 5 t ha^{-1} FYM, T^8. 75% N + 2.5 t ha^{-1} FYM and T^9. 100%N +10 t ha FYM

Similarly, total N increased significantly ($p<0.05$) in plots treated with the addition of N doses at various percentages while the control treatment and different FYM rate significantly had lower total soil N. The use of N application significantly reduced C:N ratio when compared to control treatment that gave significant C:N (27.2) followed by plots treated with FYM of 4 (20.7) and 10 t ha^{-1} (25.4) accordingly.

The improvement of soil chemical properties and organic status is probably due to the quality of FYM that have been used. These results corroborate with the findings of Fairhurst (2012) who revealed that organic amendment that are rich in compounds with carbon and organic resources provide energy for soil microbes that drives soil biological process which enhance nutrient transformation. Similarly, according to Malugeta and Getahun (2020), who reported that organic amendment plays a positive role in chemical characteristics of soils, including increase in organic carbon (up to 58% with 120 t ha^{-1} when compared with unfertilized soil) and organic N up to 90% depending on the type and level applied. Also, the result of this research goes in line with the findings of Ayamba *et al*. (2021), Bashir *et al*. (2021) and Bergstrand (2020) reported that organic manure and their combinations with mineral fertilizers can be efficient to improve soil fertility and crop yield.

Crop Growth Attributes of Tomato

All the growth attributes like plant height, leaf area and number of branches were significantly influenced by N and FYM application (Table 3). Plant height increased significantly with corresponding increase in 100% N and 10 t ha^{-1} FYM application (82.8 cm) while shorter plants are recorded from control plot (47.8 cm). A similar trend was observed on leaf area which was significantly higher due to 100% N and FYM at 10 t ha^{-1} application (301.1 cm) over the control (133.3cm).

Table 3: Effect of treatments on the growth attribute of tomato (Averaged over 2 years)

Treatment	Plant height (cm)	Leaf area (cm^2)	Branch number $plant^{-1}$
T1	47.8e	133.3f	3.8c
T2	55.4de	144.7ef	5.6b
T3	69.3bc	189.6b	6.9ab
T4	56.5cde	181.0bc	5.8b
T5	75.8ab	163.8cde	6.9ab
T6	78.8ab	155.4de	6.1b
T7	66.7bcd	165.7cd	5.3bc
T8	78.9ab	189.0b	7.8a
T9	82.8a	301.1a	7.8a
LSD (P=0.05)	11.30	20.50	1.61

T^1. Control, T^2. 50% N (60 kg N ha^{-1}) T^3. 100% N (120 kg N ha^{-1}), T^4. 5 t ha^{-1} FYM, T^5. 10 t ha^{-1} FYM, T^6. 25% N + 7.5 t ha^{-1} FYM, T^7. 50% N + 5 t ha^{-1} FYM, T^8. 75% N + 2.5 t ha^{-1} FYM and T^9. 100%N +10 t ha FYM

Combined application of 100% N plus 10 t ha-1 FYM resulted to increased number of branches per plant but statistically at par with application of 50% N + 5 t ha^{-1} FYM and 75% N + 2.5 t ha^{-1} FYM while the control treatment gave the lowest number of branches.

The growth parameters observed in this experiment were found to be higher in 100% N + 10 t ha^{-1} and this might be because high and continuous nutrient supply and availability from the combined nutrient source which ultimately resulted to increased crop growth. These results can be attributed to the fact that FYM combined with inorganic N can increase soil nutrient availability. High nutrient content and nutrient retention capacity lead to improved nutrient supply for plants and reduced nutrient losses through leaching (Glasser *et al.*, 2002).

Yield Attributes and Yield of Tomato

The yield attributes and yield of tomato where the fertility level is highly influenced by application inorganic N and combination with higher FYM is presented in (Table 4). Combined 100% N + 10 t ha^{-1} FYM application significantly increased fruit diameter (6.9 cm) which is not significantly different from applied 75% N + 2.5 t ha^{-1}. However, smaller fruit was obtained from the control treatment (4.5 cm).

Fruit weight increased significantly with addition of inorganic N up to maximum application of 100% N + 10 t ha^{-1} FYM that was statistically similar ($p>0.05$) to all other combined fertilization. However, the application of 50% N did not differ significantly with the control treatment that produced 60.9g weight (Table 4). Similarly, the application of 100% and 10 t ha^{-1} FYM alone did not improve fruit yield per plant and fruit yield per ha^{-1}. However, highest yield values were obtained from integrated application of 100% N + 10 t ha^{-1} FYM which was statistically at par with 75% N + 2,5 t ha^{-1} FYM and 50% N + 5 t ha^{-1} of FYM when compared to control treatment. The yield response from the integrated fertility might be attributed to readily available nutrients and good growing environment for plant growth.

Table 4: Effect of treatments on the yield attribute and yield of tomato (averaged over 2 years)

Treatment	Fruit diameter (cm)	Fruit weight (g)	Fruit yield plant^{-1} (kg)	Fruit yield (t ha^{-1})
T1	4.5c	60.9c	0.45d	5.1c
T2	5.4b	90.3bc	0.59cd	9.2b
T3	6.1ab	101.6ab	1.02b	9.8b
T4	5.6b	98.8ab	0.77cd	10.2b
T5	5.8b	96.5ab	0.89cd	9.4b
T6	5.8b	99.8ab	0.84cd	10.3ab
T7	5.7b	100.1ab	1.08ab	11.8a
T8	6.3ab	119.9ab	1.44ab	12.8a
T9	6.9a	120.8a	1.67a	13.2a
LSD (P=0.05)	0.90	30.30	0.491	1.50

T^1. Control, T^2. 50% N (60 kg N ha^{-1}) T^3. 100% N (120 kg N ha^{-1}), T^4. 5 t ha^{-1} FYM, T^5. 10 t ha^{-1} FYM, T^6. 25% N + 7.5 t ha^{-1} FYM, T^7. 50% N + 5 t ha^{-1} FYM, T^8. 75% N + 2.5 t ha^{-1} FYM and T^9. 100%N +10 t ha FYM

These results affirmed the findings of Wu *et al*. (2020) and Ayeni and Ezeh (2017) that combination of organic and inorganic fertilizer has positive effect on tomato productivity. The combination does not only improve the organic status of the soil but also increases inorganic fertilizer use efficiency. Additionally, Oyinlola *et al*. (2017) reported that combined use of organic and inorganic fertilization improved the soil properties and tomato yield. In the same vein, Naval *et al*. (2012) reported that application of 50% NPK + 10 t ha^{-1} FYM increased fruit yield of tomato.

CONCLUSION

From the results of this study, tomato productivity required important demand of nutrients. Therefore, combined application of 5 t ha^{-1} + 100% N had more advantage over organic and mineral fertilizer alone. At that combined rate it improved soil qualities and increased productivity of tomato in the area of study.

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