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Performance of watermelon (Citrullus lanatus L.) in response to organic and NPK fertilizers

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Abstract. The soil of North-Central Nigeria is home to many plant products that are used as industrial raw materials, and after processing their waste are often left in drainage channels, which ultimately find their way into rivers and streams where they pollute these water bodies, and sometimes some of these materials are burnt, which further aggravates global warming. In addition, the soil of the region is characterized by low organic matter content because of annual bush burnings, which reduce the low humus content of soils. Watermelon requires a fertile soil, which is high in organic matter content, while infertile soils yield an increased production of male flowers at the expense of female flowers, which results in low fruit set. Therefore, a study was carried out at the University of Ilorin Teaching and Research Farm, Ilorin, North-Central Nigeria, during the rainy seasons of 2013 and 2014 to assess the effect of different organic materials on the growth and yield of watermelon. The factors imposed were a control, NPK fertilizer and five organic materials (neem seed cake (NSC), jatropha seed cake (JSC), poultry manure (PM), compost manure (CM), and cow dung (CD)). The experiment was a randomized complete block design (RCBD) replicated thrice. Data collected on soil physico-chemical properties were: organic matter content, soil pH, organic carbon, total N, P, K, Ca, and Mg, bulk density (BD), micro porosity (MIP), macro porosity (MAP), and saturated hydraulic conductivity (K_S). Plant parameters evaluated include growth (vine length and number of leaves) and yield (number of fruits per plant, fruit weight per plant, and yield ha^{-1}). Results indicated that the organic matter content increased after the first year's cropping and declined at the end of the study. The amended plots showed significantly higher values ($P < 0.05$) with respect to most soil physical properties (MIP), (MAP), and (K_S), except the BD, where the values were lower. The bulk density particularly deteriorated on soils that were not organically amended. In addition, the soil chemical properties examined increased following the first year's cropping, and thereafter declined at the end of the second-year cropping season. The response of watermelon showed that the two years' yield data ranged between 334 and 402 t/ha, 306 and 390 t/ha, and 38.25 and 59.20 t/ha for NPK, poultry manure, and control treatments respectively. From the results, it was observed that the organic amendments were environmentally more friendly compared to the inorganic amendment (NPK fertilizer) in terms of positive effects on soil structural properties.

Keywords: watermelon, inorganic, organic materials, growth and yield

1. Introduction

Watermelon (Citrullus lanatus [Thunb.] Matsum. and Nakai), a member of the Cucurbitaceae family, is cultivated for its fruit and vegetative parts [1] and accounts for 6.8% of the global vegetable production [2]. The fruit is an important source of carotenoids and a precursor of vitamin A [3]. It ranks among the top five most frequently purchased and cultivated fruits globally with a per capita annual consumption of 7 kg [4]. The fruit can be served fresh in fruit salads, cooked and used as confectionary, and is becoming an everyday fruit like bananas, apples, and oranges [5]. Its seed is also considered an important dietary item [6] and contains a high amount of minerals and other nutrients [7, 6]. Lycopene in watermelon is an anti-carcinogenic compound found in red-fleshed cultivars [5]. In 2008, watermelon accounted for about 5.4% of the total area of land devoted to the cultivation of vegetables in Africa, and this contributed to about 4.6% of the world production of watermelon [8]. Most soils of North-Central Nigeria are inherently low in fertility [9] and soils used for the cultivation of watermelon should be well drained and rich in organic matter content [10]. In general, high-nitrogen fertilizer and high temperature promote the production of male flowers and lower the number of female or perfect flowers, resulting in low fruit set [11].

The major constraint to crop growth and yield is soil fertility, and peasant farmers in the north central zone of Nigeria depend on inorganic fertilizer for the restoration of lost nutrients, but its continuous use can lead to soil acidity. The long-term use of NPK fertilizer has a depressing effect on yield, and this can cause a decline in fruit number and delay in fruit setting, which subsequently delays ripening, and leads to the proliferation of vegetative parts [12]. Due to the use of NPK fertilizer, the identified production constraints can be ameliorated by the application of nutrient-rich organic amendments. Soil amendments are important in North-Central Nigerian soils because of its low organic matter content due to constant bush burnings and subsequent erosions. Harnessing the nutrient energy from biological wastes is very important in crop production. When these wastes are recycled as manure and utilized for agriculture, it reduces the pollution of streams and rivers [13].

The most common wastes which abound in the north central zone of Nigeria are jatropha (Jatropha curcas) and neem (Azadirachta indica) seed cakes, which are residues obtained after the extraction of oil from their seeds. [14] stated that the nutrient composition of jatropha is N (4.44%), P (2.09%), and K (1.68%). [15] also reported a high nutrient status of jatropha seed cake in soils, which led to a 179% and a 120% increase in the yield of maize and millet respectively. Neem seed cake, on the other hand, contains (2–5%) nitrogen, (0.5–1.0%) phosphorus, (0.5–3%) calcium, (0.3–1%), magnesium, and (1–2%) potassium [16], and it has pesticidal properties, especially in soils prone to nematode infestation [17]. The compost, which is a rich source of plant nutrients, is a mixture of decomposed organic materials, kitchen wastes, etc. The use of compost can reduce over-dependence on chemical fertilizers. The hazardous environmental consequences and the high cost of inorganic fertilizers make them not only undesirable but also uneconomical and beyond the reach of peasant farmers, who still dominate the Nigerian agricultural sector. The addition of compost improves the structure, texture, and tilth of the soil [18]. A good soil should have an organic matter content of more than 3%. The application of compost provides an alternative to the current methods of waste disposal and reduces the quantity of water and fertilizer applied to crops [19]. Poultry manure is rich in nitrogen and phosphorus, which can promote a good growth of plants [20]. [21] has earlier reported the use of organic materials such as rice hull, wood shavings, and kola husks as soil amendment in maize. The use of organic manures has been reported to have a comparatively higher advantage over inorganic fertilizers [22]. Many traditional farmers who cannot afford commercial fertilizers have resorted to the use of organic materials. Besides increasing soil fertility status, organic materials also help to improve physical condition, which in the long run increases crop productivity. The study was therefore aimed at determining the effect of different organic and inorganic material sources on the performance of watermelon.

2. Materials and methods

Experimental site

The study was conducted in the Teaching and Research Farm of the University of Ilorin, Ilorin – Nigeria (Latitude 8o 291 North, Longitude 4o 351 East and 307 metres above sea level), during the 2013 and 2014 cropping seasons. Ilorin is characterized by an annual rainfall of 1,186 mm, while mean annual temperature and relative humidity are 29ºC and 85% respectively. The soil is well drained, and the soil order is Alfisols belonging to the Tanke series [23]. The experimental site has been under fallow for two years before the commencement of this study.

Land preparation

The soil was ploughed, harrowed, and flat seedbeds measuring 6 m × 4 m were made. Each plot was separated from the other by a one-metre alley.

Soil sampling and analysis

Top soil (0–30cm) samples were collected in a 4 × 10 m^2 grid, bulked, and a composite sample was collected for physico-chemical characterization. Soil pH was determined (soil: water ratio 1: 2.5) using a glass electrode [24]; total N content was determined by micro-Kjeldahl method [25]; available phosphorus was determined following Bray No 1 method [26]; organic carbon was determined according to the Walkley–Black method [27]; exchangeable bases: calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na) were extracted with 1N ammonium acetate. Calcium and magnesium in the extract were analysed using Atomic Absorption Spectrophotometer (AAS), whereas K and Na were determined by flame photometry. Saturated hydraulic conductivity was determined by using a constant head permeameter [28] and the transposed Darcy's equation for vertical flows of liquid was used to calculate saturated hydraulic conductivity (Ks); thus, Ks = Q/At × L/H, where Q is the steady state volume of flow (cm^3). The cross-sectional area of core sample (cm^2) is A, the time elapsed (hr.) is t, the length of core sample (cm) is L, and the change in hydraulic head (cm) is H. Pore size distribution: the macro- and micropores were the two types of pores measured. Macroporosity (Map) was calculated thus: MaP = volume of water drained at 60 cm tension/volume of bulk soil, while microporosity (MiP) was determined after oven-drying the sample to constant weight at 1,050°C; MiP = volume of water retained at 60 cm tension divided by the volume of bulk soil. Total porosity was calculated as the sum of macro- and microporosities. Bulk density was analysed according to the method of [29]. Mean weight diameter of water-stable aggregates was estimated by the wet-sieving technique described by [30].

Experimental design

The design of the experiment was a randomized complete block (RCBD) replicated thrice. Treatments comprised control, NPK fertilizer, neem seed cake, jatropha seed cake, poultry manure, cow dung, and compost manure

Field layout

The organic manure was incorporated 14 days before planting at the rate of 15 t ha-1 and NPK fertilizer applied at the rate of 300 kg ha-1 at 21 days after planting, using the side-band placement method. Three seeds (Sugar baby cv.) were sown per stand at a spacing of 0.75 m by 0.75 m on 16 July 2013 and on 16 July 2014, which were later thinned to two seedlings per stand at 21 days after sowing. Weed control had been done manually using a traditional hoe at biweekly intervals before total ground cover was attained to ensure an adequate weed control. The crops were sprayed three times with lamdocyahalothrin as karate (2 litres per hectare) at 21, 35, and 49 days after planting to protect the plants from insect attacks.

Growth parameters

The growth parameters recorded were vine length and number of leaves per plant at 28, 42, 56, and 70 days after planting. Vine length was taken by measuring from the base of the plant at the soil level to the terminal bud with the aid of a measuring tape. The number of leaves was estimated by counting the green leaves.

Yield and yield component

Harvesting of the fruits commenced at 70 days after planting, when the fruits turned deep green in colour. Harvesting was done by carefully pulling off the matured fruits from the vine. After harvesting, the yield components were assessed [fruit diameter, number of fruit(s) per plant, and the weight of fresh fruits per plant at harvest]. Fruit circumference was measured with a flexible tape and fruit weight was measured by using a weighing balance.

Data analysis

The collected data were analysed via Analysis of Variance (ANOVA) using “GENSTAT” 17 statistical software package. Significant means were separated at 5% probability level (LSD 0.05).

3. Results and discussions

The pre-planting soil data (*Table 1*) indicated that in 2013 the soil was moderately acidic but decreased to slight acidity at the end of the first cropping season. There was, however, no change in soil acidity at the end of the second cropping season. The total organic carbon was moderate before and after the experiment in 2013, but it was very low at the end of the study in 2014. The total N content before and after the study was very low. The level of potassium and magnesium in the soil was low at the beginning and remained low at the end of the experiment in the second cropping season.

Table 1. Physical and chemical status of the soil before and after the experiment

Year	Soil pH	% org. Carbon	Org. Matter (%)	Total N (%)	P (ppm)	K (cmol/kg)	Ca (cmol/kg)	Mg (cmol/kg)
2013a	5.9	1.02	1.76	0.03	1.63	0.12	2.15	0.9
2013b	6.1	1.12	1.94	0.05	0.76	0.6	9	1.8
2014	6.2	0.3	0.52	0.04	0.75	0.2	5	0.97

a. Prior to planting, b. After harvesting

Bulk density did not significantly respond to manure types in 2013, whereas the soil amendment (organic and NPK fertilizer) led to significant changes in the bulk density of treated soils in 2014 (*Table 2*).

Table 2. Effects of organic and inorganic materials on the physical properties of soil

Treatments	2013				2014			
	Bulk Density	Micro-porosity	Macro-porosity	Hydraulic Conductivity	Bulk Density	Micro-porosity	Macro-porosity	Hydraulic Conductivity
Control	1.31	15.82	1.90	34.29	1.47	12.29	2.06	38.00
NPK	1.40	12.07	2.29	32.15	1.42	14.39	2.47	40.05
Neem cake	1.36	15.87	2.93	38.44	1.29	16.43	3.11	48.56
Compost	1.37	13.13	2.35	42.14	1.33	14.56	2.99	41.29
Jatropha	1.36	15.61	3.41	44.67	1.33	15.56	4.24	49.47
Cow dung	1.35	14.51	3.34	35.55	1.35	15.36	4.06	51.30
Poultry ma	1.38	14.43	4.95	46.43	1.32	15.02	5.23	53.49
Mean	1.37	14.49	3.02	39.09	1.36	14.93	3.46	46.02
LSD (0.05)	Ns	0.146	0.090	0.373	0.042	ns	0.236	1.713

Generally, plots treated with organic amendments showed significantly lower bulk density values compared to the control and NPK-treated plots. Notably, there was an increase in the bulk density values in the control soil from 1.31 gcm^{-3} in 2013 to 1.47 gcm^{-3} in 2014, which translated to about 12% increment. In soils amended with inorganic manure (N.P.K.), the corresponding bulk density values ranged from 1.40 gcm^{-3} to 1.42 gcm^{-3}, translating to less than 2% increase. With bulk density values increasing at this rate in the control soil (unamended), the germination of most arable crops may be threatened in about six years of continuous cultivation, while it may probably take about 25 years for the same observation in soils amended with N.P.K. The results also indicated that although the microporosity of the treated soils significantly ($P < 0.05$) differed among treatments in the first year (2013) and showed no difference in the second year (2014), there was generally no established trend. There was a significant difference ($P < 0.05$) between the organic-amended and non-organic-amended plots in terms of macroporosity (MaP) and saturated hydraulic conductivity (K_s). Poultry manure consistently yielded significantly higher MaP and K_s on treated soils with values ranging from 4.95 to 5.23% and from 46.43 to 53.49 cmh^{-1} respectively, whereas the lowest values were generally obtained in control plots. It was generally observed that organic materials of animal origin significantly improved the measured soil physical properties more, when compared to observations made in soils amended with plant-based organic materials.

The data on rainfall, temperature, and relative humidity are presented (*Table 3*). The data in 2013 and 2014 indicated that the month of September had recorded peak rainfall. This rainfall comes in torrents, but sometimes for a short duration; temperatures and relative humidity were high. The meteorological data for the two years clearly indicated that the highest monthly rainfall and maximum temperature were experienced during the cultivating seasons for the two years (August–October).

Table 3. Meteorological data of the experimental site in 2013 and 2014

Months	Rainfall (mm)		Temperature ºC (2013)		Temperature ºC (2014)		Relative Humidity (%)	
	2013	**2014**	**Min.**	**Max.**	**Min.**	**Max.**	**2013**	**2014**
January	0.5	6.3	19.4	34.2	20.6	34.5	81	81
February	39.2	34.2	22.7	34.8	20.7	35.3	81	82
March	39.0	71.0	24.2	35.6	23.8	34.8	81	81
April	181.8	321.4	23.6	32.3	22.5	32.7	81	81
May	81.8	163.8	22.7	31.5	22.7	39.6	81	81
June	132.9	154.4	20.9	34.2	21.9	30.4	80	81
July	107.3	82.1	21.8	28.0	21.9	29.6	80	81
August	**17.7**	**94.9**	**21.4**	**27.8**	**21.3**	**27.5**	**80**	**80**
September	**202.5**	**391.6**	**21.5**	**29.2**	**21.2**	**28.5**	**80**	**80**
October	**154.3**	**259.4**	**21.7**	**31.0**	**21.7**	**31.6**	**80**	**81**
November	**0.0**	**0.0**	**23.4**	**31.5**	**22.7**	**32.5**	**83**	**81**
December	11.4	0.0	19.4	33.5	19.4	33.2	82	82
Mean	**969.0**	**1579.4**	**21.9**	**32.0**	**21.7**	**32.5**	**81**	**81**

The data on the vine length of watermelon in 2013 and 2014 is presented in *Table 4*. In 2013, NPK-fertilizer-treated plots produced plants with the longest vines, whereas the control plots produced the shortest vines. However, in 2014, the NPK- and poultry-manure-amended plots produced plants with vines that were on a par with each other but significantly longer than the other treatments.

Table 4. Effects of organic and inorganic materials on the vine length of watermelon in 2013 and 2014 at 28, 42, 56, and 70 days after planting (DAP).

	2013 Days after planting				2014 Days after planting			
Treatments	28	42	56	70	28	42	56	70
Control	47.54	77.12	120.31	126.29	30.41	70.30	107.85	114.19
NPK	67.95	112.53	147.54	155.12	45.48	100.17	149.72	161.48
Neem cake	64.72	95.97	141.95	146.63	43.81	94.90	146.74	159.28
Compost	62.93	94.89	140.54	148.85	42.98	90.25	144.28	157.47
Jatropha cake	64.20	93.21	142.10	149.13	44.95	98.91	147.77	155.21
Cow dung	64.88	97.58	144.60	148.96	44.26	90.71	147.54	157.80
Poultry manure	65.55	105.23	146.99	152.80	48.59	100.18	149.50	161.14
Mean	62.54	96.65	140.58	146.83	42.93	90.92	141.91	152.38
LSD (0.05)	Ns	13.625	2.088	6.066	1.898	4.024	3.494	4.589

Generally, in 2013 and 2014 (*Table 5*), results indicated that plants in plots treated with NPK and poultry manure produced the same number of leaves, these numbers ranging from 9.00 to 47.33 for NPK-treated plots, while in poultry-manure-treated plots values ranged from 7.67 to 47.00 between the 28th and the 70th day after planting in 2013, whereas in 2014 they ranged from 8.00 to 52.00 for NPK and from 8.00 to 53.33 for poultry manure over the same period. It was also observed that plants in organic-manure-treated plots showed higher number of leaves compared to the control. Furthermore, the increment in the number of leaves was the highest between the 56th and the 70th day after planting. For instance, the number of leaves produced by NPK, which was the most effective, increased by 59%, 44%, and 129% in the periods of 28 to 42 days, 42 to 56 days, and 56 to 70 days, respectively, after planting in 2013. Similarly, in 2014, the number of leaves increased by 75%, 60%, and 133% in the periods of 28 to 42 days, 42 to 56 days, and 56 to 70 days respectively.

Table 5. Effects of organic and inorganic materials on the number of leaves of watermelon in 2013 and 2014 at 28, 42, 56, and 70 days after planting (DAP).

	2013 Days after planting				2014 Days after planting			
Treatments	28	42	56	70	28	42	56	70
Control	6.00	10.33	13.00	31.67	6.00	8.00	12.67	24.67
NPK	9.00	14.33	20.67	47.33	8.00	14.00	22.33	52.00
Neem cake	6.33	13.00	15.50	44.00	7.67	11.67	18.00	42.33
Compost	6.00	12.67	14.33	42.67	7.33	10.00	16.00	42.33
Jatropha cake	6.33	14.00	18.33	42.33	7.33	12.33	19.00	49.33
Cow dung	7.00	12.67	17.33	45.33	7.67	12.00	19.00	44.67
Poultry manure	7.67	15.00	19.00	47.00	8.00	13.33	21.33	53.33
Mean	6.90	13.14	16.88	42.90	7.43	11.62	18.33	44.10
LSD (0.05)	1.569	Ns	1.565	1.238	Ns	1.616	2.085	4.178

The organic and inorganic amendments enhanced yield and yield components to a great extent in both years (*Table 6*). Generally, the NPK fertilizer had the most pronounced effect, whilst compost had the least. For instance, NPK increased yield by 580% and 776% in 2013 and 2014 respectively. Even the least effective organic manure (compost) increased yield by 312% and 344% in 2013 and 2014 respectively.

Table 6. Effects of organic and inorganic materials on the yield and yield characters of watermelon in 2013 and 2014

	2013					2014				
Treatments	Fruit diameter (cm)	Ave. wt. of fruit	No of fruits/ plant	Fruit wt/ plant kg	Fruit wt. t/ha	Fruit diameter (cm)	Ave. wt. of fruit	No of fruits/ plant	Fruits/ plant (kg)	Fruit wt. t/ha
Control	12.65	1.13	5.13	5.92	59.20	12.40	0.93	4.05	3.83	38.25
NPK	15.01	4.20	9.67	40.27	402.67	15.33	4.10	8.17	33.49	334..93
Neem cake	14.24	3.49	8.00	27.91	279.13	15.17	3.50	5.74	20.08	200.83
Compost	13.71	3.47	7.00	24.33	243.73	13.43	2.97	5.72	16.96	169.65
Jatropha	13.75	3.37	8.50	28.47	285.67	14.43	3.40	6.25	21.23	212.45
Cow dung	14.65	3.73	8.50	31.75	317.50	14.64	3.27	7.41	24.23	242.30
Poultry manure	14.51	4.10	9.50	39.03	390.30	15.27	3.90	7.85	30.63	306.26
Mean	14.08	3.36	8.04	28.24	282.40	14.39	3.15	6.46	21.49	214.95
LSD (0.05)	0.729	0.638	1.515	5.82	58.23	0.933	0.648	0.272	4.15	41.61

The low organic matter content of the experimental soil is characteristic of the soils in North-Central Nigeria (southern Guinea savannah) due to constant bush burnings and high temperatures leading to a high rate of organic matter decomposition. The low organic matter content invariably results in the fragility of soils in this environment. The foregoing necessitates organic amendment of soils in this area. Soil organic matter has been reported to improve soil microbial activities and soil-water-holding capacity, among other roles [31]. [32] had earlier reported organic matter content of 3% as the best for watermelon production in this area. The significant improvement observed in the physical properties, particularly in the bulk density of the organic-amended as against decline in NPK-amended and control soils over time, is indicative of the structural enhancement following soil organic amendment. Some researchers have reported either late emergence or complete germination failure as soil bulk density increased to 1.8 g/cm^3 in dry soil [33]. The comparative reduction of bulk density values in organic-manure-amended soils portrays its environmental friendliness, which is the reason for advocating its use for sustainable crop production [34, 31, 35]. The relatively higher improvement of soil physical properties observed with animal-based organic materials (poultry and cow dung) could probably be attributed to an advanced digestion/decomposition (bio-digestion) of the original materials in the digestive system of the animals and to the presence of faecal organisms. The released nutrients (including amino-acids) from the bio-digestion are likely to trigger off rapid multiplication of *in-situ* macro- and microorganisms in the soil pore spaces, which will subsequently increase soil total porosity. Furthermore, water and nutrient movement, rooting depth and density will be increased within the soil. In the same vein, improved water and nutrient absorption will ultimately translate to higher plant growth and yield. The soil pH of the experimental site was within the range for watermelon cultivation, which is 5.0–7.0 [36].

The increase in the vine length and number of leaves could be attributed to the presence of available nutrients in the poultry manure (15 tha^{-1}), which may be comparable to the one (300 $kgha^{-1}$) where NPK fertilizer was applied. The two weeks prior application of poultry manure with respect to planting may have resulted in fast mineralization and availability of the nutrients, which subsequently led to an increase in vine length and number of leaves comparable to those in the NPK-treated plots. The reason why the poultry-manure-treated plot outclassed the other organically amended plots may have been due to a comparatively faster decomposition rate and higher nutrient status. However, the vine length of watermelon in the two years of study was shorter and the number of leaves were less than what had been reported by [37] but similar to the findings of [38] using different rates of poultry manure in Asaba, Nigeria. The number of leaves produced were highest at 8 to 10 weeks; this period corresponded with the time of highest translocation of assimilates to the fruits.

The earlier reason adduced for the observation in the growth parameters may also have been responsible for that in the yield parameters. This is because the yield components followed a similar trend with the growth parameters. The number of fruits per plant obtained in this study is similar to that reported by [38] but lower than that of [39] using municipal wastes in Abakaliki, South-Eastern Nigeria. The yield experienced in this experiment was above what had been reported in a similar work by [40] (10–50t/ha) and [41], who reported a yield range of 10–20t/ha. [21] had reported yield increase in maize by using different agricultural wastes. The fruit weight per hectare using cow dung, poultry manure, and NPK fertilizer resulted in greater yield than the control plots in both years as compared to the plant-based manure components. Generally, animal-based manure produced superior growth and yield attributes than plant-based manure. This could be attributed to its ability to maintain more favourable physical conditions of the soil than discussed earlier.

Conclusion

It can be concluded from this study that the use of poultry manure at 15 tha^{-1} is equivalent to 300 $kgha^{-1}$ of NPK fertilizer in the cultivation of watermelon. However, NPK fertilizer is expensive and generally beyond the reach of peasant farmers. Therefore, the use of poultry manure is advocated, bearing in mind its beneficial effects on the soil.

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