Plantain/Watermelon Intercropping Systems for Improved Food Security and Income Generation during the Late Cropping Season

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ABSTRACT

The application of poultry manure to plantain/watermelon intercrop was explored for improved yield, income generation and for sustainable production of plantain in drought prone areas for food security, poverty and hunger eradication in Nigeria. The mixture was established during the late cropping season in Southeastern Nigeria. The treatments consisted of three poultry manure rates (0, 10 and 20 t ha^{-1}) applied to plantain intercropped with four watermelon populations (0, 2500, 5000 and 10,000 t ha^{-1}) in September, 2010 and arranged in 3 x 4 factorial experiment in Randomized Block Complete Design. Sole plantain without poultry manure was the check. Application of 20 t ha^{-1} of poultry manure to plantain/watermelon intercrop resulted in rapid vegetal cover, high (96 %) plantain survivability, and effective weed suppression, and improved yields of plantain and watermelon compared to unmanured intercrops. Furthermore, the yield decline in plantain was low in manured plantain/watermelon intercrops. The application of 10 t ha^{-1} of poultry manure to plantain intercropped with 2500 stands ha^{-1} of watermelon population in the late cropping season was cost effective and had highest benefit cost ratio (6.68) and is therefore recommended to farmers for sustainable plantain production in drier zones.

Keywords: *Plantain, Watermelon, Intercropping, Poultry manure, Climate change, Food security.*

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Highlights of this paper

- The application of poultry manure to plantain/watermelon intercrop was explored for improved yield, income generation and for sustainable production of plantain in drought prone areas for food security, poverty and hunger eradication in Nigeria.
- The treatments consisted of three poultry manure rates (0, 10 and 20 t ha^{-1}) applied to plantain intercropped with four watermelon populations (0, 2500, 5000 and 10,000 t ha^{-1}) in September, 2010 and arranged in 3 x 4 factorial experiment in Randomized Block Complete Design.

1. INTRODUCTION

The rainforest agroecology of Southeastern Nigeria is characterized by two distinct eight (8) months rainy and four (4) months dry seasons. The bimodal rainfall pattern created the early and late cropping seasons. During the early cropping season, massive arable crop production dominates the agricultural activities. The demand for human labour is high. Soil erosion, pest and disease and weed infestation grossly reduce the productivity of crops. In the dry season, crop production is limited to the late season cropping of horticultural crops especially fruits and vegetables in FADAMAs and under irrigation systems. The late cropping season of the rainforest, though short, is suitable for plantain establishment and sustainable yields in the plantain off-season [1] and improved watermelon production and yield [2]. Recent agronomic manipulations including manorial practices [3] mulching [1] have improved late season plantain establishment and yield. In a rainfed crop production system, mulching the plantain during the late cropping season protects the soil from excessive moisture loss and sustain the plantain early growth phase during the four months dry season (November-February) in order to achieve plantain availability during the next rainy season when plantain is always scarce in the market. However, dry mulch is seasonal, expensive to source, transport and of limited availability. Live mulch is a promising alternative [3]. Watermelon is a profitable late season creeper [2] and unlikely to compete with late season plantain for growth resources when grown as a live mulch with plantains.

Thus, plantain (erectile) and watermelon (creeper) have biologically compatible growth patterns which may be advantageously exploited in properly synchronized plantain-watermelon intercropping systems for sustainable crop yields. To achieve the improved productivity of any crop mixture, optimum crop populations and adequate manure rates are critical. The adverse nitrogenous fertilizer effects on environmental and economic costs have necessitated research on the application of organic amendments to the ultisol [4]. Poultry manure is the most preferred organic manure for its multi-beneficial effects on the soil and improved crop growth, pest control and yields [5]. Watermelon is envisaged to serve as live mulch to ameliorate the adverse impacts of moisture stress. Intercropping mostly confers positive synergy on yields of the component crops and improvement in soil physic-chemical properties. Watermelon generates massive biomass and good yield within three months before any reasonable competition with plantains may occur. Watermelon shares the production operations of plantain [6].

Therefore, there is need for the assessment of late season plantain/watermelon intercropping and poultry manure application alternatives for sustainable productivity of plantain/watermelon intercropping system in southeastern Nigeria.

2. MATERIALS AND METHODOLOGY

The experiment was conducted at the Teaching and Research Farm, Federal University of Technology, Owerri, located at longitude 707' E, latitude 50 27' N and altitude 55.7m above sea level in the rainforest agroecological zone of Southeastern Nigeria. The four year fallow experimental site was cleared in debris packed out in July 2010 for late season planting of plantains. The suckers of false horn plantain CV Agbagba were harvested from the commercial plantain orchard of the university, pruned and planted in 60.0 x 60.0 x 60.0 cm holes at 3.0 x 2.0 m spacing. The viable watermelon seeds (*Citrullus lanatus*) were sourced from the university genetic resources unit. The poultry manure was sourced from the university livestock farm, cured and soil incorporated on treatment basis. The treatments consisted of three poultry manure rates (0, 10 and 20 t ha^{-1}) applied to plantain intercropped with four watermelon populations (0, 2500, 5000 and 10,000 plants ha^{-1}). Sole plantain without manure was the check. The experiment was a 3 x 4 Factorial experiment fitted into a Randomized Complete Block Design and replicated three times. Routine agronomic practices of plantain production were adopted. Pre and post core soil samples of the experimental sites were collected with the soil auger and analysed for physio-chemical at first ratoon plantain harvest while vegetal cover was established using quadrat. Growth and yield data of plantain and watermelon were statistically data were statistically analyzed using Genstat Release 4.24DE Version of 2005. Means were separated for significance with Fishers Least Significance Difference (FLSD) at 5 % probability level and reported.

2.1. Laboratory Analytical Methods

Five soil samples were collected randomly from the experimental site at 0 - 20 cm depth before planting and on per treatment basis after harvest. Samples were analyzed for physico-chemical properties. Soil pH was analyzed by the use of pH meter [7] organic carbon was determined by Nelson and Sommers [8] organic matter values were obtained by multiplying total carbon with 1.724 (Van Bemmelen's correlation factor) [8] available phosphorus was determined according to the procedure of Olsen and Sommers [9] total nitrogen was by microkjeldahl digestion technique [10] calcium and magnesium by Versenate titration method and potassium by flame photometer method. Poultry manure and palm bunch ash were analyzed for their nutrient status (pH, N, P, K, Al, C, Ca, Mg and Na) using the same procedures as for the soil analysis.

3. RESULTS

3.1. Characterization of Poultry Manure

Results revealed that the poultry manure used in the experiment contained 36.4 cmol kg^{-1} of calcium, 4.80 cmol kg^{-1} phosphorus, 15.50 cmol kg^{-1} potassium, 4.50 % of nitrogen and the pH was 8.12 Table 1.

3.2. Soil Status at Planting

The experimental soil was sandy-loamy soil Table 1. Percentage sand, silt and clay content of the soil were 89.20, 7.22 and 3.60 respectively. Soil pH was acidic (5.00).

Table-1. Physico-chemical properties of poultry manure and soil at planting during late cropping season.

Nutrient elements	Poultry manure	Soil
Aluminum (cmol kg^{-1})	1.38	0.12
Magnesium (cmol kg^{-1})	6.80	0.10
Calcium (cmol kg^{-1})	36.40	0.78
Potassium (cmol kg^{-1})	15.50	0.02
Phosphorus (cmol kg^{-1})	4.80	3.56
Organic Nitrogen (%)	4.50	0.04
Organic Carbon (%)	3.08	1.56
Organic matter (%)	53.10	2.25
pH in water	8.12	5.00
Sand	0.00	89.20
Clay	0.00	4.80
Silt	0.00	7.22
Textural class	0.00	Sandy loamy

The soil had low percentage nitrogen (0.02). The phosphorus, potassium, calcium and aluminum content of the soil were 3.56 cmol kg^{-1}, 0.02 cmol kg^{-1}, 0.78 cmol kg^{-1} and 0.12 cmol kg^{-1} respectively.

3.3. Climatic Data

Minimum and maximum temperatures increased from July to December 2010 and peaked in January 2011 and stabilize again in March 2011 Table 2. Rainfall dropped rapidly from November 2010 to zero rain in December 2010 and January 2011. Relative humidity in January and February dropped to the lowest in January and February (68.00 %).

3.4. Number of Live Leaves per Month

Unmanured sole plantain retained the least number of leaves from December 2010 to April 2011 Figure 1. Number of live leaves decreased as the volume of rainfall decreased from December 2010 to February 2011 and increased from March 2011 to April 2011. Plantain intercropped with watermelon and manure with 10 t ha^{-1} of poultry manure retained similar number of leaves as plantain intercropped with watermelon and manured with 20 t ha^{-1}.

Table-2. The climatic data of Owerri rainforest agroecology of southeastern Nigeria (average data of July 2010 – May 2011).

Month	Rainfall (mm)	Average Temperatures (°C) max.	min.	Average relative humidity (%)
July	286.00	31.90	27.50	74.40
August	305.00	31.20	27.80	74.80
September	330.00	31.50	27.50	74.60
October	398.50	32.00	19.00	75.00
November	108.00	32.50	26.00	78.70
December	0.00	32.00	26.50	79.00
January	0.00	33.00	29.50	68.00
February	40.50	32.50	28.50	68.00
March	122.20	30.62	29.00	73.04
April	156.24	31.20	23.70	75.20
May	248.00	30.65	28.50	76.80

Source: ADP, Imo State.

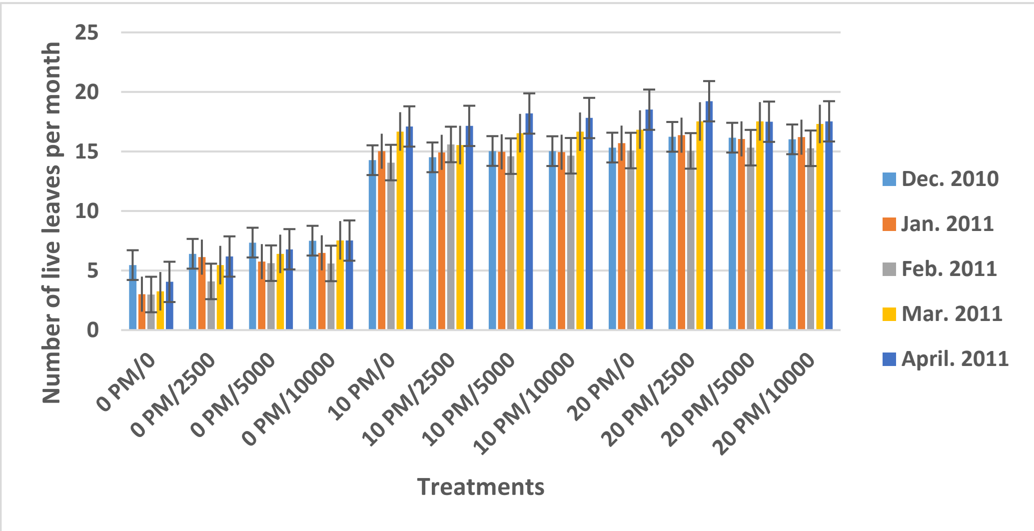

Figure-1. Number of live leaves on plantain through the dry season as influenced by manure rates on late season plantain/watermelon intercropping.

Note: Bars = Mean ± SD; PM = Poultry manure; 0, 2500, 5000 and 10,000 = watermelon population ha^{-1}.

3.5. Plantain Survivability (%)

Plantain manured with 20 t ha^{-1} and intercropped with 5000 stands ha^{-1} of watermelon had highest percentage survivability (96.07 %) while unmanured sole plantain had least percentage survivability (33.09 %) Table 3.

3.6. Weeks to 50 % Vegetal Cover

The increasing populations of watermelon and the application of poultry manure significantly reduced the number of weeks for 50 % vegetal cover Table 3. In the unmanured sole plantain plot, 50 % vegetal cover delayed for over 10 weeks after planting. Plantain manured with 20 t ha^{-1} and intercropped with 5000 stands ha^{-1} of watermelon had 50 % of the ground covered with vegetation in four weeks while sole plantain cultivated without manure achieved 50 % vegetal cover in ten weeks. There was no significant difference between plantain/watermelon intercrops manured with 10 t ha^{-1} and 20 t ha^{-1} of poultry manure.

3.7. Weed Dry Weight (kg ha^{-1})

The increasing populations of watermelon and the application of poultry manure significantly suppressed weed growth Table 3. In the unmanured sole plantain, weed dry weight was highest (12.07 kg ha^{-1}) and while in plot of plantain intercropped with 2500 stands of watermelon and manured with 20 t ha^{-1} of poultry manure had least weed dry weight (5.51 kg ha^{-1}). There was no significant difference in the weed dry weight of plantain plots intercropped with 2500 and 5000 stands of watermelon and manured with 10 t ha^{-1} of poultry manure.

3.8. Watermelon Yield (t ha^{-1})

Watermelon of 10,000 stands ha^{-1} manured with 10 t ha^{-1} of poultry manure gave highest yield (12.86 t ha^{-1}) and was not significantly different from yield of 5000 stands ha^{-1} of watermelon manured with 10 t ha^{-1} of poultry manure (12.44 t ha^{-1}). A decline in yield was observed in 5000 and 10,000 stands of watermelon per hectare manured with 20 t ha^{-1} of poultry manure compared to the yield of watermelon of the same populations manured with 10 t ha^{-1} of poultry manure. Yield was lowest in 2500 stands ha^{-1} of watermelon (5.74 t ha^{-1}) grown without poultry manure Table 4.

3.9. Crop Plantain Yield (t ha^{-1})

Plantain intercropped with 2500 stands ha^{-1} of watermelon and manured with 10 t ha^{-1} of poultry manure produced highest crop plantain yield (11.91 t ha^{-1}) while unmanure sole plantain produced least crop plantain yield (3.26 t ha^{-1}). Plantain cultivated with 10 and 20 t ha^{-1} of poultry manure irrespective of the watermelon population significantly improved crop plantain yield in comparison with sole plantain Table 4.

3.10. Ratoon Yield (t ha^{-1})

Plantain intercropped with 2500 stands ha^{-1} of watermelon and manured with 10 t ha^{-1} of poultry manure produced highest ratoon plantain yield (8.88 t ha^{-1}) while unmanure sole plantain produced least ratoon plantain yield (2.17 t ha^{-1}). Yield of ratoon plantain followed similar pattern as the crop plantain yield Table 4.

3.11. Cost Benefit Ratio

The difference in the input cost for the late season plantain/watermelon intercropping lied in the cost of weeding carried out Table 5. Plantain cultivated without watermelon intercrop had highest cost of weeding. Labour cost of weeding decreased as the watermelon stand ha^{-1} increased. Yield of plantain crop, ratoon and watermelon influenced the profit made from the sales and subsequently determined the benefit cost ratio obtained in each treatment. Plantain intercropped with 2500 stands ha^{-1} of watermelon and manured with 10 t ha^{-1} of poultry manure had highest benefit cost ratio (6.68) while unmanured sole plantain had least benefit cost ratio (0.51).

3.12. Post-harvest Soil Analysis

The post-harvest soil chemical properties Table 6 during 2010 - 2011 late cropping season were affected by the amendment of soil with poultry manure. The fertility status after the first ratoon showed significant nutrient loss in unmanured plot. Results showed overall improvement in the soil chemical properties in soils amended with 10 and 20 t ha^{-1} of poultry manure. Soil pH decreased to 4.38 in unmanured sole plantain plot and increased to 5.20 in plots of plantain intercropped with 10,000 stands ha^{-1} of watermelon and manured with 20 t ha^{-1} of poultry manure.

4. DISCUSSION

The leaf growth pattern of plantain followed very closely the rainfall pattern of the location and is characteristics of plantain vegetative growth phase especially during dry spell [3]. Thus, plantain at the pre-floral growth phase tolerate moisture stress and retained a sizeable number of leaves to perennate through dry season [11]. Plantain planted in late season and adequately manured [1] attained the pre-floral stage and resumed active leaf growth at the outset of rains in March – April the following year. Poorly manured plantain died as a result of poor bulking on the rhizome [11].

The late season is thus advantageously utilized in plantain/watermelon intercropping system because the rapid vegetal cover from short season watermelon posed minimal intercrop competition for plantain, conserved soil moisture and moderated favourable microclimate for plantain growth as reported in oil palm [12] 50% vegetal cover was achieved due to increased watermelon density and poultry manure application that improved the growth of watermelon. Effective vegetal cover smothered weed growth and thus reduced competition with weeds in plantain/watermelon intercropped plot. Although growth was retarded during the dry season, the availability of adequate poultry manure rates at the onset of 2011 rainy season kick started rapid and vigorous growth resumption in plantain and thus improved plantain growth vigour.

The conventional application of 10 tha^{-1} of poultry manure for late season plantain production [3] also satisfied plantain-watermelon intercrops and even favoured high yield in plantain and watermelon [2]. Therefore, the resource use efficiency is high and so constitutes a new dimension in income generation for farmers who adopt late season plantain/watermelon intercropping in Southeastern Nigeria. Intercropping of plantain with watermelon helped reduced moisture stress and created a favourable micro-climate for the growth and yield of plantain during the dry season. Application of poultry manure improved watermelon yield because poultry manure is rich in macro nutrients necessary for optimum growth and yield of watermelon.

The rule of thumb for benefit cost ratio (BCR) is if BCR is greater than 1, the project is a good investment [12]. Cost of production was higher in sole plantain plots because of high weed infestation and thus, incurred more labour cost for weeding. Also, lower yield in unmanured sole plantain reduced the profit made from sales of plantain bunches and thus, had lower benefit cost ratio. In manured plantain/watermelon intercrops, improved yield of plantain and watermelon gave higher profit and subsequently greater benefit cost ratio. Late season cropping of Plantain-watermelon intercrop using poultry manure is a profitable enterprise as reported in cassava [13].

Table-3. The effect of poultry manure rates and watermelon populations on plantain survivability, weeks for 50 % vegetal cover and weed dry weight

Poultry manure (t ha⁻¹)	**Plantain/watermelon Population (ha⁻¹) Plantain survivability (%)**					**Plantain/watermelon Population (ha⁻¹) Weeks for 50 % vegetal cover**					**Plantain/watermelon Population (ha⁻¹) Weed dry weight (kg ha⁻¹)**				
	0.00	2500	5000	10,000	Mean	0.00	2500	5000	10,000	Mean	0.00	2500	5000	10,000	Mean
0.0	33.09	58.99	68.65	68.59	57.33	10.47	6.16	5.48	5.06	6.79	12.07	8.85	7.18	7.85	9.00
10.0	72.57	78.29	86.10	89.91	81.72	6.42	4.66	4.58	4.15	4.95	9.645	6.82	6.88	6.05	7.35
20.0	76.15	84.43	96.07	95.78	88.11	6.15	4.54	4.46	4.11	4.82	9.55	6.62	6.05	5.51	6.93
Mean	60.61	73.90	83.61	84.76		7.68	5.12	4.84	4.44		10.42	7.43	6.70	6.47	
LSD $_{0.05}$ for manure				0.28		0.10					0.03				
LSD $_{0.05}$ for watermelon population				0.32		0.12					0.03				
LSD $_{0.05}$ for manure x watermelon population				0.56		0.20					0.05				

Table-4. The effect of poultry manure rates and watermelon populations watermelon yield, crop plantain yield and ratoon yield.

Poultry manure (t ha⁻¹)	**Plantain/watermelon Population (ha⁻¹) Watermelon yield (t ha⁻¹)**					**Plantain/watermelon Population (ha⁻¹) Crop plantain yield (t ha⁻¹)**					**Plantain/watermelon Population (ha⁻¹) Ratoon plantain yield (t ha⁻¹)**				
	0.00	2500	5000	10,000	Mean	0.00	2500	5000	10,000	Mean	0.00	2500	5000	10,000	Mean
0.0	0.00	5.74	8.44	8.35	5.63	3.26	4.60	4.30	4.80	4.24	2.17	2.40	3.18	2.61	2.59
10.0	0.00	7.35	12.44	12.86	8.16	10.40	11.91	10.81	10.83	10.99	6.07	8.88	8.86	7.66	7.87
20.0	0.00	8.74	10.95	11.20	7.72	10.37	10.51	11.45	10.66	10.75	8.45	8.68	8.08	8.50	8.43
Mean	0.00	7.28	10.61	10.80		8.01	9.00	8.85	8.76		5.57	6.65	6.71	6.25	
LSD $_{0.05}$ for manure			0.27			0.09					0.16				
LSD $_{0.05}$ for watermelon population			0.31			0.10					0.18				
LSD $_{0.05}$ for manure x watermelon population			0.54			0.18					0.31				

Table-5. Cost benefit ratio of late season plantain/watermelon intercropping production in Southeastern Nigeria.

Treatments		**Variable Costs (#000 ha⁻¹)**						**Income (#000 ha⁻¹)**				
Poultry Manure (t ha⁻¹)	**Plantain/ watermelon Populations (ha⁻¹)**	**Farm operations**	**Labour**	**Poultry manure**	**Plantain suckers**	**Water melon seeds**	**Total variable cost**	**Plantain bunch**	**Plantain suckers**	**Water Melon fruits**	**Total income**	**Benefit Cost Ratio**
0.0	Plantain/0.00	130.25	62.54	0.00	166.70	0.00	359.49	544.00	0.00	0.00	544.00	0.51
	Plantain/2500	130.25	56.74	0.00	166.70	0.15	353.84	763.00	0.00	136.80	839.80	1.37
	Plantain/5000	130.25	56.40	0.00	166.70	0.30	353.65	787.00	33.34	169.60	989.54	1.80
	Plantain/10,000	130.25	51.54	0.00	166.70	0.60	354.49	740.00	25.00	166.60	931.60	1.63
	Mean	130.25	56.81	0.00	166.70	0.26	366.39	708.50	14.59	112.50	826.24	1.33

10.0	Plantain/0.00	130.25	51.44	15.00	166.70	0.00	362.84	1670.00	413.42	0.00	2083.40	4.69
	Plantain/2500	130.25	50.74	15.00	166.70	0.15	358.63	1938.00	436.74	206.66	2568.40	6.68
	Plantain/5000	130.25	46.08	15.00	166.70	0.30	360.31	1956.00	435.09	256.80	2639.69	6.36
	Plantain/10,000	130.25	48.56	15.00	166.70	0.60	362.04	1964.00	430.09	248.60	3639.69	5.28
	Mean	130.25	49.21	15.00	166.70	0.26	376.37	1882.00	428.84	178.02	2732.80	5.75
20.0	Plantain/0.00	130.25	51.42	28.00	166.70	0.00	375.44	1916.00	426.75	0.00	2343.75	5.23
	Plantain/2500	130.25	50.34	28.00	166.70	0.15	371.71	1930.00	417.75	213.60	2561.35	5.82
	Plantain/5000	130.25	46.46	28.00	166.70	0.30	371.37	1972.00	436.75	205.60	2614.35	6.03
	Plantain/10,000	130.25	44.02	28.00	166.70	0.60	373.72	1952.00	433.42	223.60	2609.02	6.03
	Mean	130.25	48.06	28.00	166.70	0.26	386.17	1942.00	361.17	160.70	2583.12	5.78

Note: Farm operations @ #800.00 per man day. Plantain sucker = #100 each, Plantain bunch = #100,000 (t^{-1}), Watermelon = #20,000 (t^{-1}).

Table-6. Physico-chemical properties of the soil after the experiment.

Poultry manure (t ha^{-1})	**Plantain/water melon** Populations **(ha^{-1})**	**pH in water**	**N (%)**	**Organic Carbon (%)**	**Organic Matter (%)**	**Ca (cmol kg^{-1})**	**Mg (cmol kg^{-1})**	**K (cmol kg^{-1})**	**Na (cmol kg^{-1})**	**Al (cmol kg^{-1})**	**P (cmol kg^{-1})**
0.0	Plantain/0.00	4.38	0.03	0.68	1.17	0.61	0.15	0.04	0.06	0.16	4.69
	Plantain/2500	4.43	0.03	0.66	1.19	0.72	0.35	0.01	0.02	0.20	6.72
	Plantain/5000	4.60	0.04	0.59	1.19	0.70	0.38	0.02	0.04	0.15	5.69
	Plantain/10,000	4.89	0.04	0.68	1.22	0.69	0.42	0.02	0.05	0.31	5.18
10.0	Plantain/0.00	5.03	0.04	0.67	1.33	0.74	0.47	0.02	0.05	0.18	6.01
	Plantain/2500	5.06	0.05	0.66	1.40	0.78	0.49	0.02	0.08	0.21	6.25
	Plantain/5000	5.08	0.04	0.68	1.43	0.82	0.53	0.02	0.05	0.24	7.32
	Plantain/10,000	5.10	0.06	0.65	1.53	0.76	0.58	0.01	0.07	0.34	8.18
20.0	Plantain/0.00	5.08	0.03	0.84	1.35	1.00	0.33	0.01	0.01	0.28	8.28
	Plantain/2500	5.10	0.05	0.83	1.55	0.88	0.38	0.01	0.09	0.20	7.57
	Plantain/5000	5.15	0.05	0.86	0.86	0.89	0.45	0.01	0.08	0.31	7.63
	Plantain/10,000	5.24	0.05	0.86	0.88	0.80	0.47	0.01	0.08	0.35	8.00

5. CONCLUSION

The on-farm watermelon live mulch is practicable and sustainable. The practice minimized the tedious labour demand for mulch collection, transportation and application. The biomass generated is rapidly enhanced by poultry manure application. Watermelon created a micro-climate that was favourable for the late season plantain production and the application of poultry manure enhanced the growth and yield of watermelon, plantain crop and first ratoon yield. Therefore, the application of 10 t ha^{-1} of poultry manure to plantain intercropped with 2500 stands ha^{-1} of watermelon population in the late cropping season had highest crop and first ratoon yield and is therefore recommended to farmers for sustainable plantain production in drier zones and in late cropping season in Southeastern Nigeria.

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