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Comparative Efficacy of Organic Manures for Improved Performance of Waterleaf (Talinum fructicosum (L) Juss.) in the Humid Tropical Rainforest

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Abstract: Waterleaf apart from being a source of food provides employment and income to mostly female peasant farmers. Field experiments were conducted to evaluate effects of organic manure types and their combinations on the growth and yield of water leaf in a typical tropical humid rainforest in 2016 and 2017 Cropping seasons. The experiment was laid out in a randomized complete block design (RCBD) with three replications. Treatments included sole poultry manure (PM) at 10 t ha^{-1}, 10 t ha^{-1} cow dung (CD), 8 t ha^{-1} oil palm bunch ash (OPBA) and their combinations including; 5 t ha^{-1} PM + t ha^{-1}CD, 5 t ha^{-1} PM +4 t ha^{-1} OPBA, 5 t ha^{-1} CD+4 t ha^{-1} OPBA and the control where no manures were applied. Data collected included; plant height, number of leaves and branches and leaf area plant $^{-1}$, fresh and dry weights of water leaf. These were analyzed using analysis of variance and means compared using Fisher's least significant difference (LSD) at 5%. Waterleaf plants fertilized with 10 t ha^{-1} PM and combination of 5 t ha^{-1} PM +4 t ha^{-1} OPBA showed better performance in all the parameters measured. Hence, 10 t ha^{-1} PM was recommended amongst other forms of organic manure applied as sole or in combination in Calabar agro ecology of Nigeria.

Keywords: Talinum fructicosum, Organic Manure, Improved Performance, Efficacy, Growth and Yield

Introduction

Waterleaf (*Talinum Talinum fructicosum* (L) Juss.), which originated in tropical Africa (Tindall, 1983) is an underutilized leafy vegetable crop grown in small corner plots in the southern part of Nigeria, where it serves as a source of food, employment and income for farmers (Idiong *et al*., 2002, Udo and Akpan, 2007). Most farmers involved in its cultivation are resource poor and may not have access or afford to buy inorganic fertilizers to boost the growth of their crops, thus they resort to the use of various animal/ plant wastes as their fertilizers

Most soils in southern Nigeria are acidic due to the nature of parent materials, weathering, intensive cropping, heavy leaching, and may have multiple nutrient deficiencies (Akinmutimi *et al.*, 2013, Owolabi *et al*., 2003). Such degraded soils are often associated with loss of organic matter and aggravated by repeated application of inorganic fertilizers (Obi and Ebo, 1995). This may ultimately result in reduction of crop growth and yield (Ayoola & Adeniyan, 2008, Ismaeil *et al*., 2012). However, Chongrak (1996) reported that organic wastes apart from improving crop production also improve the organic matter status of soils, increase nutrient availability in soils as well as improve the soil physical and chemical properties.

The use of animal and plant wastes in crop production is an acknowledged long standing practice in peasant Agriculture (Ndaeyo *et al.*, 2013) and is becoming a more prominent and widely acceptable feature in crop production, especially vegetables in Nigeria. Numerous studies have been carried out on one or more aspects of organic fertilizers as they influence crop growth and yield (Akinmutimi *et al.*, 2013, Ndaeyo *et al.*, 2013, Law-Ogbomo & Ajayi, 2009, Uko *et al*., 2009).

Cow dung (CD) contains a good amount of nitrogen, phosphorus and potassium and is ideal for use in top dressing and in compost for garden crops (Ukpai & Nnabuchi, 2012). The potassium content (3%) as reported by Sokoto *et al*. (2007) makes CD a good alternative to overcome the problem of unavailability of straight k fertilizer in the market. Udoh *et al.* (2005) recommended application of organic manures like cow dung (CD), poultry droppings (PM) and/or nitrogenous fertilizers immediately after each harvest of waterleaf. Poultry manure is the most widely used OM in the production of many crops including vegetables in Nigeria and other countries of the world

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(Ismaeil *et al.*, 2012, Ndaeyo *et al.*, 2013, Law-Ogbomo & Ajayi, 2009, Twanya *et al.*, 2017, Ndubuaku *et al.*, 2015, Uko *et al.*, 2013, Awe *et al.*, 2011). PM contains numerous mineral elements needed by plants for growth including nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) (Akanbi *et al*., 2014). The gradual release of these nutrients to the soil due to decomposition process has a significant effect on soil physical and chemical properties, which in-turn determine crop growth and yield [Ewulo *et al*., 2008]. PM has been reported to have positive effects on growth and yield of many crops such as *Amaranthus cruentus* (Ismaeil *et al*., 2012), Sorghum (Agbede *et al*., 2008), *Talinum triangulare* (Ndaeyo *et al*., 2013) among others. Law-Ogbomo and Ajayi (2009) found that PM application affected the number of leaves, leaf area index and the general growth and yield of *Amaranthus cruentus*.

Oil palm bunch ash (OPBA) contains K, has high pH and varying amounts of other nutrients such as Ca, P and Mg, which make it suitable as a liming material and fertilizer supplement [Adjei-Nsiah, 2012]. Oil palm bunch ash has been used by various researchers to improve soil fertility and crop yield (Ojeniyi *et al.*, 2009, Ojeniyi *et al.*, 2010, Awodun, 2012, Adjei-Nsiah & Obeng, 2013). Ash derived from burnt empty palm bunch is known to reduce soil acidity as a result of the K content (Sokoto *et al*., 2007), increase availability of cationic nutrients and improve yield of crops (Araki, 1993). The N, P and K contents of OPBA makes it a good alternative and cheaper source of the nutrients than the inorganic NPK as it easily affordable by small scale poor resource farmers (Akinmutimi *et al*., 2013, Adjei-Nsiah & Obeng, 2013). Palm bunch ash at 2 t ha^{-1} application rate yielded the highest maize grain describing it's suitability for crop growth and yield (Adjei-Nsiah , 2012). The application of OPBA to soil is also known to induce good effects on fruit yield, leaf yield, plant height and general plant vigor in maize, garden egg, pepper and okra amongst other vegetable crops (Adjei-Nsiah, 2012, Ojeniyi *et al.*, 2009, Ojeniyi *et al*., 2010, Awodun, 2012).

This study was therefore conducted to evaluate the effects of different organic manures and combinations on the growth and yield performance of waterleaf (*Talinum fructicosum*) in Calabar - a humid rainforest region of South Eastern Nigeria.

2 Materials and Methods

2.1 Description of experimental site

This study was carried out at Teaching and Research Farm of the University of Calabar in the early cropping season of 2016 and 2017 respectively. Calabar is located in the humid tropical rain forest of South Eastern Nigeria with coordinates 04° 57' N and 8° 19.5' E with an altitude of 39 meters above sea level. It has a bimodal annual rainfall distribution ranging from 2,500 to 3,500 mm, mean annual temperature range of 27^{o}c to 35^{o}c and relative humidity between 75 – 85 % (NIMET 2016)

2.2 Land preparation, soil sampling and analysis

The land was cleared of the existing vegetation, ploughed and harrowed into a fine tilled flat. Prior to this, soil was randomly sampled at depth of 0-15cm using soil auger. Samples were bulked, air-dried and sieved through 2mm mesh sieve before physico-chemical analysis following methods outlined by IITA (1989).

2.3 Treatments, experimental design and plot layout

The experiment comprised of seven treatments including; 10 t ha^{-1} poultry manure (PM), 10 t ha^{-1} cow dung (CD) and 8 t ha^{-1} oil palm bunch ash (OPBA) and their combinations at half of the rates 5 t ha^{-1} PM + 5 t ha^{-1} CD, 5 t ha^{-1} PM + 4 t ha^{-1} OPBA, 5 t ha^{-1} CD + 4 t ha^{-1} OPBA and a control (to which no organic amendment was applied). This experiment was laid out in a randomized complete block design (RCBD) with three (3) replications. Each plot measured 3 m by 2m (6 m^2) separated by 0.5 m^2 path and each block also by 1 m^2 path. Growth and yield data were measured from a net plot of 1.5 m^2 (1.0 m x 1.5 m).

2.4 Application of treatments and planting

Poultry manure was sourced from the broiler unit of University of Calabar Poultry Farm, cow dung from University farm feedlot while the oil palm bunch ash was sourced from a local oil mill in Akpabuyo, Cross River State. Both poultry manure and cow dung were cured for two week before application. They were soil incorporated two weeks before planting. Stem cuttings of a locally sourced waterleaf land race, were planted manually at a spacing of 5cm x 5cm using 10 cm long stem cuttings with few half cut leaves still attached to them. Weeding was done manually by hand-pulling at 3, 5 and 7 weeks after planting (WAP).

2.3 Data collection and analysis

Data were collected from plants within the net plots at 2 weekly intervals starting from 3 weeks after planting (WAP) for growth and yield data including; plant height, number of branches per plant, number of leaves per plant, leaf area/plant, stem girth, fresh and dry weights. Data were analyzed using ANOVA (analysis of variance) and significant treatment means were compared using the Fisher's least significant difference (FLSD) as suggested by Gomez and Gomez (1984).

3. Results

3.1 Properties of the soil and materials used for the experiment

The result of analysis of soil and organic fertilizers used study are presented in Table 1. Texturally, the soil was loamy sand and strong acidic pH of 5.1 and 4.9 were recorded for 2016 and 2017 cropping seasons respectively. Organic carbon (OC) contents of the soil in both years were moderate, available phosphorus and base saturation were high while total nitrogen, exchangeable cations (Ca, Mg, Na and K) and ECEC were low. The value obtained for Na^{+} in 2016 and 2017 were 0.06 and 0.07 cmol/kg and was rated low. The exchangeable acidity (Al^{+++} and H^{+}) in both years were also low. The acidic pH, low N and exchangeable cations (Ca, Mg, Na and K) observed in the soil analysis indicates the need for soil fertility improvement in the area for increased crop production, and good soil quality.

Also the pre-cropping analysis showed that cow dung had the highest OC and K value compared to other organic sources while poultry manure also had the highest total nitrogen and phosphorus values compared to other organic sources. Oil palm bunch ash had the highest Ca, Mg and Na values followed by poultry manure and cow dung. These organic amendments had much higher levels of N, OC and exchangeable cations (Ca, Mg, Na and K) compared to the soil medium and can help improve soil properties when applied.

3.2 Effects of organic manure on the plant height of waterleaf

The effects of organic manure on the height of waterleaf are shown in Table 2. Application of organic manure had a significant effect on the plant height of waterleaf at 3, 6 weeks after planting (WAP) in 2016 and 2017 at 9 WAP in 2016 only. At 3 WAP, the application of 10 t ha^{-1} PM resulted in the tallest waterleaf plants but these were not significantly taller when compared to those that received 5 t ha^{-1} PM+4 t ha^{-1} OPBA in both years. Also, plant heights in plot fertilized with 5 t ha^{-1} PM+4 t ha^{-1} OPBA in turn did not differ significantly from those treated with 5 t ha^{-1} PM+5 t ha^{-1} CD in 2016 but significantly taller in 2017. However, in both years, waterleaf that received, 10 t ha^{-1}, 5 t ha^{-1} PM+4 t ha-^{1} OPBA and 5 t ha^{-1} PM+5 t ha^{-1} CD were significantly taller than those that receive other sole or combined organic fertilizer treatments. At 6 WAP, waterleaf plants fertilized with 10 t ha^{-1} PM, 5 t ha^{-1} PM+4 t ha^{-1} OPBA and 5 t ha^{-1} PM+5 t ha^{-1} CD did not differ significantly from each other in plant height in 2016. However, plants in these respective plots were significantly taller when compared those fertilized with 5 t ha^{-1} CD+4 t ha^{-1}, 8 t ha^{-1} OPBA and 10 t ha^{-1} CD respectively. In 2017, plants that received 10 t ha^{-1} and 5 t ha^{-1} PM+4 t ha^{-1} OPBA had statistically similar plant heights but had significantly taller plants when compared to those in plots fertilized with 5 t ha^{-1} PM+5 t ha^{-1} CD. These in turn significantly outpaced plants in other manurial treatments whether sole or combined. At 9 WAP in 2016, plants fertilized with 10 t ha^{-1} PM were not significantly taller than those that received 5 t ha^{-1} PM+4 t ha^{-1} OPBA and 5 t ha^{-1} PM+5 t ha^{-1} CD. However, plants in these respective plots were significantly taller when compared to those fertilized with 5 t ha^{-1} CD + 4 t ha^{-1} OPBA which in turn had significantly taller plants compared to those in plots fertilized with 8 t ha^{-1} OPBA. Waterleaf plants in plots fertilized with 8 t ha^{-1} OPBA were also significantly taller when compared to those in plots fertilized with 10 t ha^{-1} CD. Waterleaf plants in the control plots at all sampling periods in both years of study had significantly shorter plants when compared to plants in the plots that received any fertilizer treatment whether combined or sole.

Table 1: Physico-chemical properties of soil at the study site and organic manure used for the study

Physical and chemical properties	Soil		Poultry manure		Oil palm bunch ash		Cow dung	
	2016	2017	2016	2017	2016	2017	2016	2017
Sand (%)	83.30	80.50						
Silt (%)	10.70	11.70						
Clay (%)	6.00	8.80						
pH	5.10	4.96						
Org. C (%)	1.53	1.78	23.40	24.06	20.67	21.45	33.90	31.50
Total Nitrogen (%)	0.09	0.10	3.84	4.04	1.86	1.79	2.66	2.42
Available P	56.00 mg/kg	54.60 mg/kg	1.68%	1.66%	1.30	1.27	0.99	0.96
Ca	3.60 Cmol/kg	3.88 Cmol/kg	2.27%	2.32%	2.64	2.70	1.10	1.20
Mg	1.20 Cmol/kg	1.34 Cmol/kg	0.86%	0.84%	1.20	1.16	0.39	0.40
Na	0.06 Cmol/kg	0.07 Cmol/kg	0.41%	0.36%	1.24	1.18	0.16	0.18
K	0.11 Cmol/kg	0.15 Cmol/kg	1.10%	1.03%	1.20	1.19	3.20	2.80
Al	0.76	0.82						
H	1.02	1.06						
Exchangeable acidity	1.78	1.88						
ECEC (cmol/kg)	6.75	7.32						
BS (%)	74.00	74.32						
Soil texture	Loamy sand							

3.3 Effect of organic manure on the number of leaves of waterleaf

The effect of organic manures on the number of leaves of waterleaf is shown in Table 3. Application of organic manure had significant (P≤0) effect on the number of leaves of waterleaf at 3 and 6 WAP in 2016, 6 and 9 WAP in 2017 and not at 9 and 3 WAP in 2016 and 2017 respectively .

Table 2: Effect of organic manure on the plant height and leaf area of waterleaf at different sampling periods

Treatments	**Plant Height (cm)**			**Number of Leaves per Plant**			**Stem girth (cm)**		
	3 WAP	6 WAP	9 WAP	3 WAP	6 WAP	9 WAP	3WAP	6WAP	3WAP
					2016				
Control	19.13	18.00	15.05	18.75	8.73	9.50	1.11	1.76	2.06
10t/ha PM	44.00	46.60	34.45	51.65	14.35	14.03	2.24	2.94	3.16
10t/ha CD	24.25	21.25	17.50	31.00	11.25	12.25	1.53	2.45	2.75
8t/ha OPBA	24.00	22.50	18.30	29.75	12.48	11.65	2.07	2.63	2.76
5t/ha PM+5t/ha CD	40.03	43.33	31.53	47.58	13.43	12.53	1.69	2.38	2.75
5t/ha PM+4t/ha OPBA	42.80	45.48	32.10	48.88	14.33	12.55	1.91	2.80	2.95
5t/ha CD+4t/ha OPBA	34.28	26.50	20.48	31.45	12.70	13.55	2.14	2.67	2.80
LSD (0.05)	3.42	3.97	2.63	4.43	4.37	4.54	NS	NS	NS
				2017					
Control	19.44	18.38	14.07	18.88	22.33	20.99	1.01	1.70	2.10
10t/ha PM	43.38	46.65	35.50	52.90	57.85	51.88	2.25	2.93	3.20
10t/ha CD	23.50	20.63	15.00d	31.63	41.45	35.91	1.59	2.33	2.63
8t/ha OPBA	23.87	22.50	17.38	29.88	39.24	32.95	2.07	2.58	2.78
5t/ha PM+5t/ha CD	40.18	43.24	31.97	48.03	44.23	50.60	1.80	2.40	2.70
5t/ha PM+4t/ha OPBA	42.68	45.81	34.68	48.43	50.26	46.34	1.93	2.68	2.75
5t/ha CD+4t/ha OPBA	34.04	26.00	23.88	32.68	37.33	38.73	2.14	2.56	2.81
LSD (0.05)	1.81	2.09	NS	2.13	2.17	1.63	NS	NS	NS

Key: PM: Poultry manure; CD: Cow dung; OPBA: oil palm bunch ash; NS: not significant

At 3 WAP in 2016, waterleaf plants that received 10 t ha^{-1} PM had the highest number of leaves though not significantly different from that produced when 5 t ha^{-1} PM+4 t ha^{-1}OPBA and 5 t ha^{-1} PM+4 t ha^{-1} CD were applied respectively. However, plants in these respective plots produced significantly more leaves compared to those produced when 8 t ha^{-1} OPBA and 10 t ha^{-1} CD were applied respectively. At 6 WAP in 2016, plants in plots fertilized with 10 t ha^{-1}PM bore the highest number of leaves though not significantly higher when compared to number of leaves produced when 5 t ha^{-1} PM+4 t ha^{-1} OPBA was applied. Also, the number of leaves produced with the application of 5 t ha^{-1} PM+4 t ha^{-1} CD was significantly higher than that produced when 8 t ha^{-1} OPBA was applied which in turn was significantly higher when compared to when 10 t ha^{-1} CD was applied. In 2017 however, waterleaf plants fertilized with 10 t ha^{-1} PM had significantly more number of leaves compared to every other treatment. At 9 WAP in 2017, application of 10 t ha^{-1}PM and 5 t ha^{-1} PM+5 t ha^{-1} CD had statistically same number of leaves but significantly higher than the number of leaves when 5 t ha^{-1}PM+4 t ha^{-1} OPBA was applied. This in turn had significantly higher the number of leaves when compared to 5 t ha^{-1} CD+5 t ha^{-1} OPBA, 10 t ha^{-1} CD, 8 t ha^{-1} OPBA and control in that decreasing order of magnitude. However, the control plot had significantly the least number of leaves per plant at all sampling period and years of study.

3.4 Effects of organic manure on the leaf area of waterleaf

The effect of organic manures on the leaf area of waterleaf is shown in Table 2. Organic manure application had significant (P≤0) effect on the leaf area of waterleaf at 3 and 6 WAP in 2016 and at 3, 6 and 9 WAP in 2017 but not at 9 WAP in 2016. At 3 WAP in 2016, application of 10 t ha^{-1}PM produced waterleaf plants with the widest leaf areas but these were not significantly wider that those in plots that received 5 t ha^{-1}PM+4 t ha^{-1} OPBA and 5 t ha^{-1}PM+5 t ha^{-1} CD respectively. Also, waterleaf plants in plots that received 5 t ha^{-1}PM+4 t ha^{-1} OPBA and 5 t ha^{-1} PM+5 t ha^{-1} CD did not differ significantly (P≥0.05) in plant height when compared to plants in the plot that received 8 t ha^{-1}OPBA. Furthermore, the plots that received 5 t ha^{-1} CD+4 t ha^{-1} OPBA and 10 t ha^{-1} CD did not differ significantly P≥0.05 from each other in terms of leaf area but the control plot had significantly (P≤0) the least leaf area. Also, in 2017, plants that were fertilized with 10 t ha^{-1} PM, 5 t ha^{-1} PM+4 t ha^{-1} OPBA, and 5 t ha^{-1}PM+5 t ha^{-1} CD had statistically same leaf area but which were significantly higher than respective leaf areas in other treatments comprising of either single or combined organic manures At 6 WAP in 2016, the application of 10 t/ha PM also produced the widest leaf area but that was not significantly different from that produced when 5 t ha^{-1}PM+4 t ha^{-1}OPBA was applied. Their respective applications however produce significantly wider leaves when compared to the application of 5 t ha^{-1} PM+5 t ha^{-1} CD which in turn produced plants with significantly wider leaf areas compared to when 5 t ha^{-1} CD+4 t ha^{-1} OPBA and 8 t ha^{-1} OPBA were applied respectively. The plants that received 5 t ha^{-1} CD+4 t ha^{-1} OPBA and 8 t ha^{-1} OPBA also produced significantly wider leaves than the plot that received 10 t ha^{-1} CD. The control had significantly ($P \leq 0$) the least leaf area whereas, in 2017, plants that received 10 t ha^{-1} PM had significantly wider leaves compared to every other treatment.

Table 3: Effect of organic manure on the number of branches and number of leaves of waterleaf at different sampling periods

Treatments	Number of branches			Leaf area (cm^2)		
	3 WAP	6 WAP	9 WAP	3 WAP	6 WAP	9 WAP
				2016		
Control	1.50	2.48	2.20	11.45	8.73	9.50
10t/ha PM	6.75	8.45	7.68	18.80	14.35	14.03
10t/ha CD	2.25	3.73	4.13	13.45	11.25	12.25
8t/ha OPBA	2.50	4.10	3.23	17.55	12.48	11.65
5t/ha PM+5t/ha CD	6.50	7.93	6.43	18.35	13.43	12.53
5t/ha PM+4t/ha OPBA	6.75	7.68	6.83	18.38	14.33	12.55
5t/ha CD+4t/ha OPBA	3.00	4.35	4.05	14.47	12.70	13.55
LSD (0.05)	0.95	0.78	NS	1.02	0.47	NS
				2017		
Control	1.38	2.45	2.10	11.52	9.27	8.73
10t/ha PM	7.20	8.33	7.66	18.46	14.11	14.35
10t/ha CD	2.13	3.58	4.28	13.46	11.97	11.25
8t/ha OPBA	2.50	4.20	3.23	17.51	11.86	12.48
5t/ha PM+5t/ha CD	6.63	7.88	6.54	18.36	12.97	13.43
5t/ha PM+4t/ha OPBA	6.88	7.63	7.08	18.40	13.17	14.33
5t/ha CD+4t/ha OPBA	2.88	4.30	3.98	14.45	12.83	12.70
LSD (0.05)	0.61	0.39	0.84	0.39	0.65	0.47

Key: PM: Poultry manure; CD: Cow dung; OPBA: oil palm bunch ash; NS: not significant

At 9 WAP in 2017, application of 10 t ha^{-1} PM produced higher leaf areas though not significantly different that of 5 t ha^{-1} PM+4 t ha^{-1} OPBA but respectively they differed significantly from plants fertilized with 5 t ha^{-1} PM+5 t ha^{-1} CD, 5 t ha^{-1} CD+4 t ha^{-1} OPBA, 8 t ha^{-1} OPBA, 10 t ha^{-1} CD, and the control in that decreasing order of magnitude.

3.5 Effect of organic manure on the number of branches of waterleaf

The effect of organic manures on the number of branches of waterleaf is shown in Table 3. Organic manure application had significant ($P \leq 0$) effect on the number of branches of waterleaf at 3 and 6 WAP in 2016 and at 3, 6 and 9 WAP in 2017 but not significant ($P \geq 0.05$) at 9 WAP in 2016 At 3 WAP in 2016, waterleaf plants that received 10t/ha PM, 5 t ha^{-1} PM+4 t ha^{-1} OPBA and 5 t ha^{-1} PM+4 t ha^{-1} CD respectively produced the largest but statistically same number of branches However, plants fertilized with these fertilizer treatments whether as single or in combination with others produced significantly more branches compared to other manure treatments and the control. Also, waterleaf fertilized with 8 t ha^{-1} OPBA and 10 t ha^{-1} CD had 2.50 and 2.25 branches which were not significantly different from that in control. In 2017, plants that received 10t/ha PM, 5 t ha^{-1} PM+4 t ha^{-1} OPBA and 5 t ha^{-1} PM+4 t ha^{-1} CD had statistically same number of branches which significantly higher compared to those produced with other manure treatments and the control. At 6 WAP in 2016, waterleaf plants that received 10 t ha^{-1} PM had the highest number of branches though not significantly different when compared to those produced when 5 t ha^{-1} PM+4 t ha^{-1} OPBA was applied but significantly higher than those in all other treatments. Also plants fertilized with 5 t ha^{-1} PM+4 t ha^{-1} OPBA in turn had more branches compared to plants fertilized with 5 t ha^{-1} PM+4 t ha^{-1} CD then followed with 5 t ha^{-1} CD+4 t ha^{-1} OPBA , 8 t ha^{-1} OPBA and 10 t ha^{-1} CD. However, the number of branches produced when 8 t ha^{-1} OPBA and 10 t ha^{-1} CD were statistically similar but were significantly higher than those in the control. Almost a similar trend of response were observed in 2017, application of 10 t ha^{-1} PM and 5 t ha^{-1} PM+4 t ha^{-1} were not statistically different in terms of number of branches. At 9 WAP in 2016, the number of branches obtained from all the plots were not significantly different from each other although, 10 t ha^{-1} PM had more branches followed by 5 t ha^{-1} PM+4 t ha^{-1} OPBA, 5 t ha^{-1} PM+4 t ha^{-1} CD, 5 t ha^{-1} PM+5 t ha^{-1} CD, 10 t ha^{-1} CD, 8 t ha^{-1} OPBA and then the control plot in that order of magnitude. However, in 2017, plants fertilized with10 t ha^{-1}PM had the highest number of branches did not differ from those in plots fertilized with 5 t ha^{-1} PM+4 t ha^{-1} OPBA. This in turn did not differ significantly from those fertilized with 5 t ha^{-1} PM+4 t ha^{-1} CD in terms of number of branches but differed significantly from 10 t ha^{-1} CD, 5 t ha^{-1} CD+4 t ha^{-1} OPBA, 8 t ha^{-1} OPBA as well as the control

3.6 Effect of organic manure on the fresh and dry weights of waterleaf

The effects of organic manure on fresh and dry weights of water leaf are presented in Table 4. Organic manure had a significant ($P \leq 0$) effect on fresh weight of waterleaf at 3, 6 and 9 WAP in 2016 and 2017. At 3 WAP in both years, application of 10 t ha^{-1} of poultry manure (PM) had significantly higher weight when compared to other sources of organic manure whether single or as a combined application. However, in 2016 this was followed by application of 5 t ha^{-1} PM + 5 t ha^{-1} CD which in turn was significantly higher when compared to fresh weights obtained when 8 t ha^{-1} OPBA, 10 t ha^{-1} CD, 5 t ha^{-1} PM + 4 t ha^{-1} OPBA and 5 t ha^{-1} CD + 4 t ha^{-1} OPBA with fresh weights of 2.70, 2.68, 2.48 and 2.48 t ha^{-1} respectively whereas slight differences occurred in 2017 where fresh weight at 10 t ha^{-1} PM was followed by that of 5 t ha^{-1} PM + 4 t ha^{-1} OPBA which in turn was significantly higher when compared to fresh weight for all other fertilizer treatment irrespective of whether it is sole or combined. At 6 WAP in both years of study, application of 10 t ha^{-1} PM produced significantly higher fresh weights when compared to that of 5 t ha^{-1} PM+4 t ha^{-1} OPBA which in turn significantly outpaced fresh weights in other manure treatments. This was followed by fresh weights of waterleaf at application of 5 t ha^{-1} PM+ t ha^{-1} CD, 8 t ha^{-1} OPBA and 5 t ha^{-1} CD+4 t ha^{-1} OPBA and 10 t ha^{-1} respectively. At 9 WAP in both years, 10 t ha^{-1} PM had significantly higher fresh weight when compared to fresh weight in all other treatments. Also, 5 t ha^{-1} PM+ 4 t ha^{-1} OPBA did not differ significantly from 5 t ha^{-1} CD + 4 t ha^{-1} OPBA in terms of fresh weights in both years, but were significantly different when compared with fresh weights obtained when 8 t ha^{-1} OPBA and 10 t ha^{-1} CD were applied in 2016 whereas, a slightly different observation was made in 2017 where plants fertilized with 5 t ha^{-1} PM+ 5 t ha^{-1} CD, 5 t ha^{-1} CD + 4 t ha^{-1} OPBA and 8 t ha^{-1} OPBA were statistically similar fresh weight. Generally, all the plots that received either single or combined organic manure treatment had significantly higher fresh weights when compared with the control which did not receive any manure treatment.

Dry weights of water leaf were significantly ($P \leq 0.05$) influenced by organic manure application at 3, 6 and 9 WAP in both years of study (Table 4). At 3 WAP, plants in plots fertilized with 5 t ha^{-1} PM+ t ha^{-1} OPBA and 10 t ha^{-1} PM had statistically same dry weights in both years. However, these were significantly higher when compared to dry weights of plant that received 8 t ha^{-1} OPBA, 10 t ha^{-1} CD, 5 t ha^{-1} PM+5 t ha^{-1} CD and 5 t ha^{-1} CD+4 t ha^{-1} OPBA respectively and which did not differ significantly in 2016 whereas in 2017, the order was slightly different as follows; 8 t ha^{-1} OPBA, 5 t ha^{-1} PM+5 t ha^{-1} CD, 5 t ha^{-1} CD+4 t ha^{-1} OPBA and 10 t ha^{-1} CD but still maintaining their statistical similarity. Similar trend of response was observed at 6 WAP, dry weights obtained from plots that received 10 t ha^{-1} PM and 5 t ha^{-1} PM+4 t ha^{-1} OPBA were statistically similar in both years but significantly higher when compared to all other treatments. However, in 2016 these were followed by 5 t ha^{-1} PM+5 t ha^{-1} CD and 5 t ha^{-1} CD+4 t ha^{-1} OPBA having non-significant different dry weights but significantly dry weight when compared to 8 t ha^{-1} OPBA which in turn had higher dry weights when compared to plants fertilized with 10 t ha^{-1} CD. Whereas, in 2017, plots that received 5 t ha^{-1} PM+5 t ha^{-1} CD, 5 t ha^{-1} CD+4 t ha^{-1} OPBA, 8 t ha^{-1} OPBA and 10 t ha^{-1} CD had no significant difference in dry weights. Also, 8 t ha^{-1} OPBA and 10 t ha^{-1} CD had no significant difference in dry weights compared to the control. At 9 WAP in 2016, 10 t ha^{-1} PM resulted in the highest dry weight when compared to other organic amendments irrespective of combined or sole application and control whereas, in 2017, dry weights obtained from plots that received 10 t ha^{-1} PM and 5 t ha^{-1} PM+4 t ha^{-1} OPBA were statistically at par but differed significantly from all other treatments including control.

Table 4: Effect of organic manure on the fresh weight dry weight of waterleaf at different growth stages

Treatments	Fresh Weight (t/ha)			Cumulative fresh weight	Dry Weight (t/ha)			Cumulative dry weight
	3 WAP	6 WAP	9 WAP		3 WAP	6 WAP	9 WAP	
				2016				
Control	3.08	3.61	3.98	10.67	2.18	2.10	2.21	6.49
10t/ha PM	10.69	11.13	11.44	33.26	3.56	3.35	3.43	10.34
10t/ha CD	6.72	7.97	9.09	23.78	2.56	2.44	2.31	7.31
8t/ha OPBA	6.66	8.31	9.25	24.22	2.74	2.54	2.71	7.99
5t/ha PM+5t/ha CD	7.75	8.72	10.06	26.53	2.55	2.70	2.53	7.78
5t/ha PM+4t/ha OPBA	6.16	10.75	10.44	27.35	3.60	3.20	3.25	10.05
5t/ha CD+4t/ha OPBA	6.13	8.06	9.84	24.03	2.54	2.61	2.61	7.76
LSD	0.52	0.36	0.62	0.58	0.36	0.23	0.10	0.72
				2017				
Control	3.20	3.53	3.89	10.62	2.20	2.13	2.23	6.56
10t/ha PM	10.63	11.19	11.38	33.20	3.48	3.28	3.33	10.09
10t/ha CD	6.69	8.00	8.96	23.65	2.53	2.40	2.30	7.23
8t/ha OPBA	6.75	8.38	9.16	24.29	2.70	2.43	2.58	7.71
5t/ha PM+5t/ha CD	7.81	8.69	9.94	26.44	2.63	2.68	2.48	7.79
5t/ha PM+4t/ha OPBA	6.19	10.81	10.31	27.31	3.55	3.15	3.20	9.90
5t/ha CD+4t/ha OPBA	6.19	8.13	9.88	24.20	2.60	2.60	2.60	7.80
LSD	0.86	0.65	0.97	0.28	0.60	0.39	0.37	0.72

Key

PM: Poultry manure; CD: Cow dung; OPBA: oil palm bunch ash; NS: not significant

3.7 Effect of organic manure on the cumulative fresh and dry weights of waterleaf

The application of organic manure had a significant ($P \leq 0$) effect on cumulative fresh and dry weights of waterleaf in 2016 and 2017 (Table 4). The results obtained showed that in 2016 and 2017, the plot that received 10 t ha^{-1} PM had significantly higher cumulative fresh weight relative to the plots that received 5 t ha^{-1} PM+4 t ha^{-1} OPBA which in turn produced higher cumulative fresh weight compared to other treatments. Whereas, in 2016, the application of 10 t ha^{-1} of poultry manure (PM) had significantly higher cumulative dry weight than other forms of manure applied be it single or as combined, however, the application 8 t ha^{-1} OPBA, 5 t ha^{-1} PM+4 t ha^{-1} OPBA and 5 t ha^{-1} CD+4 t ha^{-1} OPBA and 10 t ha^{-1} CD were statistically at par but had significant higher cumulative fresh weights relative to the control plot. In 2017, the cumulative dry weight obtained when 10 t ha^{-1} PM was applied did not significantly differ from that obtained when 5 t ha^{-1} PM+4 t ha^{-1} OPBA was applied. Successive higher but statistically similar cumulative fresh weights were in this order 5 t ha^{-1} CD+4 t ha^{-1} OPBA > 5 t ha^{-1} PM+5 t ha^{-1} CD> 8 t ha^{-1} OPBA>10 t ha^{-1} CD but the control plot had the least cumulative fresh weights than other treated plot . 5 t ha^{-1} CD+4 t ha^{-1} OPBA and 10 t ha^{-1} CD which had cumulative dry weights of 0.98, 0.96 and 0.95 kg respectively. However, 5 t ha^{-1} PM+5 t ha^{-1} CD was significantly different from 5 t ha^{-1} PM+4 t ha^{-1} OPBA and 8 t ha^{-1} OPBA which were not significantly different from 5 t ha^{-1} CD+4 t ha^{-1} OPBA and 10 t ha^{-1} CD. These plots with treatment had significantly higher weights than the control plot which was significant with 1.42kg.

3.8 Effects of poultry manure, oil palm bunch ash and cow dung application on soil properties

The effects of sole and combined applications of poultry manure, oil palm bunch ash and cow dung are shown in Table 3. Soil treated with 10 t ha^{-1} PM, 8 t ha^{-1} OPBA, 5 t ha^{-1}PM+4 t ha^{-1} OPBA and 5 t ha^{-1} CD+4 t ha^{-1} OPBA had pH of 5.84, 5.95, 5.66 and 5.61 in 2016 and 5.85, 5.94, 5.68 and 5.60 in 2017 respectively. These were moderately acidic and differed significantly ($p \leq 0.05$) when compared to the control plot with pH of 4.61 and 4.60 in 2016 and 2017 respectively. Soils in these control plots were strongly acidic.

All organic manure treated soils had significantly ($p \leq 0.05$) higher nitrogen (N) content than the control soil with 5 t ha^{-1}PM+4 t ha^{-1} OPBA (2.48 %) in 2016 and 5 t ha^{-1} PM+4 t ha^{-1} OPBA (2.44 %) in 2017 having the highest N values. The organic matter (OM) content of the soil was significantly ($P < 0.05$) increased with PM, OPBA and CD application compared with the control plots. However, in 2016, the highest OM value of 2.95 % was obtained in plots amended with 5 t ha^{-1} PM+5 t ha^{-1} CD and was closely followed by plots amended with 10t/ha CD (2.93 %). Similarly, in 2017, the highest OM value of 2.96 % was obtained in plots amended with 5 t ha^{-1} PM+5 t ha^{-1} CD and was closely followed by plots amended with 10 t ha^{-1} CD (2.86 %). In both years, the exchangeable calcium (Ca) of the soil increased significantly ($p \leq 0.05$) with organic manure application compared with the untreated plots (control) excepting plots amended with 10 t ha^{-1} PM in 2016 cropping season.

Table 5: Effect of organic manure on Soil chemical properties at the end of experiment

Treatments	**pH**		**N**		**Ca**		**K**		**Mg**		**Na**		**org M**		**CEC**		**BS**	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
control	4.61	4.60	0.09	0.08	3.14	3.19	0.13	0.13	1.30	1.29	0.11	0.10	1.83	1.86	7.32	6.83	66.74	68.96
10t/ha PM	5.84	5.85	3.15	3.14	3.15	3.63	1.18	1.18	1.88	1.90	0.16	0.16	2.52	2.53	8.16	8.16	85.00	84.46
10t/ha CD	4.98	4.98	1.83	1.81	3.49	3.48	1.48	1.49	1.98	1.96	0.15	0.16	2.93	2.86	9.14	9.17	76.40	77.35
8t/ha OPBA	5.95	5.94	1.50	1.48	4.75	4.83	1.73	1.76	1.98	1.96	0.18	0.18	2.15	2.16	9.94	11.04	81.16	79.22
5t/ha PM+5t/ha CD	5.35	5.35	2.35	2.33	3.50	3.68	1.30	1.33	1.71	1.71	0.17	0.17	2.95	2.96	8.28	8.81	79.81	79.10
5t/ha PM+4t/ha OPBA	5.66	5.68	2.48	2.44	3.50	3.45	1.46	1.46	1.83	1.85	0.19	0.20	2.72	2.71	8.93	8.74	81.14	79.82
5t/ha CD+4t/ha OPBA	5.61	5.60	1.98	1.98	4.68	4.71	2.10	2.10	2.08	2.11	0.22	0.23	2.78	2.81	10.72	11.00	82.83	83.23
LSD	0.14	0.18	0.29	0.12	0.30	0.23	0.23	0.10	NS	0.08	NS	NS	0.12	0.07	NS	NS	2.32	NS

The soil potassium (K) content was also significantly ($P < 0.05$) increased with addition of PM, OPBA and CD sole or in combination compared with the control plots. However, in both 2016 and 2017 cropping seasons the highest K value of 2.10 % was obtained in plots amended with 5 t ha^{-1} CD+4 t ha^{-1}OPBA and was closely followed by plots amended with 8 t ha^{-1} OPBA. Application of PM, OPBA and CD sole or in combination in 2016 did not significantly ($p > 0.05$) increase the Magnesium (Mg) content compared with the soil with no fertilizer application. However, in 2017 exchangeable Mg application increased significantly when compared to the untreated plots (control) with 5 t ha^{-1} CD+4 t ha^{-1} OPBA having the highest value (2.11 cmol/kg) closely followed by 8 t ha^{-1} OPBA (1.96 cmol/kg) and 10 t ha^{-1} CD (1.96cmol/kg). In both 2016 and 2017, application of PM, OPBA and CD sole or in combination did not significantly ($p > 0.05$) Sodium (Na) and cation exchange capacity (CEC) of the soil relative to no fertilizer application. Application of organic manure in 2016 resulted in significant ($p \leq 0.05$) increment in soil base saturation (BS) compared with the untreated plots (control) with 10 t ha^{-1} PM having the highest value (85 %) closely followed by 5 t ha^{-1} CD+4 t ha^{-1} OPBA (82.83 %). However, in 2017 cropping season, application of PM, OPBA and CD sole or in combination did not produce significant ($P > 0.05$) increment in BS compared with the soil with no fertilizer application.

4 Discussion

The physico-chemical analysis of the soil showed that the soil is of loamy sand texture, low in organic matter, pH, total nitrogen and exchangeable bases. Brady and Weil (1996) and Agbede (1984) stated that these properties are typical of highly leached tropical soils classified as ultisols and according to Enwezor *et al*. (1991), soils with these properties is considered to be poor in terms of soil fertility status and needs amelioration through application of fertilizer. Tisdale and Nelson (1985) noted that crops respond more to fertilizer application in soils with inherent low nutrient reserves than soils with high reserves. Therefore, the application of fertilizing amendments to supply these nutrients for improvement of soil quality and enhancement of crop growth is necessary. This study has shown that the application PM, OPBA and CD sole or in combination as soil amendments significantly ($P<0.05$) raised post-harvest soil pH, total N, exchangeable Ca, Mg, and K, BS and organic matter contents of the soil in both years. Gbaraneh and Chu (2016) and Chongrak (1996) reported that organic wastes apart from improving crop production also improve the organic matter status of soils, increase nutrient availability in soils as well as improve the soil physical and chemical properties as well as increase the initial value of soil pH from strongly acidic to moderately acidic condition. In this study, it was observed that combination of 5 t ha^{-1} CD+4 t ha^{-1} OPBA and 8 t ha^{-1} OPBA had higher values of soil Ca, Mg and K, 5 t ha^{-1} PM+5 t ha^{-1} CD had highest OM, 10 t ha^{-1} PM had highest total N and 8 t ha^{-1} OPBA had highest pH in both 2016 and 2017. The observed increment in reserve soil nutrients due to application of PM, OPBA and CD is consonant with earlier findings (Gbaraneh and Chu, 2016, Iren *et al*., 2016, Moyin-Jesu, 2019) and the fact that ash is an effective source of K, Ca and Mg (Gbaraneh and Chu, 2016) for increasing pH and improving soil nutrients. Poultry manure apart from releasing nutrients for improved crop growth and yield, its good organic matter content improves the physical properties of soil [Ayeni *et al*., 2008]. Ibeawuchi *et al*. (2006) reported that in a degraded soil of Nigeria, poultry manure application increased the residual soil N, K, Ca, Mg, and organic matter.

The results from this study showed that application of

10 t/ha poultry manure, 5 t/ha PM + 4 t/ha OPBA and 5 t/ha+ 4 t/ha CD in both years significantly increased the growth and yield performance of waterleaf in Calabar. As the stage of development progressed, application of 10 t/ha PM, 5 t/ha PM + 4 t/ha OPBA and 5 t/ha+ 4 t/ha CD appears to support greater growth and yield of waterleaf plant more than other manure treatments. As observed in the study, application of 10 t ha^{-1} PM gave the tallest plants with highest number of leaves and greater branching, broader leaves as well as highest fresh weights. The positive growth and yield response from PM treatment is attributed to increased nitrogen nutrition as indicated by increased N concentration in plant tissues as also observed by Hochmuth *et al*. (1991) and Opara and Asiegbu, (1996). Wider leaf surfaces, profuse branching and a higher leaf area index contribute to robust plant architecture for higher yield as a result of higher interception of photosynthetically active radiation which is easily converted to photosynthates. A high accumulation of photoassimilates enhances dry matter partitioning and yield. Nutrients in poultry manure (PM) are released more slowly and over a longer period of time in the soil, thereby ensuring a long residual effect (Sharma &Mittra, 1991), PM has also been rated as a good source of nitrogen (Mohammed *et al*., 2013) which stimulates plant growth and yield (Uko *et al*., 2013, Mohammed *et al*., 2013, Parnes, 1990). Hue & Sobieszczyk (199) had observed that approximately 30 – 50% of N becomes available to plants following application of PM. Also, because of low C : N ratio, PM has a higher mineralization rate to meet nutrient needs of the plant in the short run while its combination with cow dung and OPBA ensured a more sustained release of nutrients over a longer period of time as well as its residual effect on the soil. The study revealed that application of 10 t/ha^{-1} PM to the soil medium ensured an increase in the plant height, number of leaves leaf area, number of branches, the fresh and dry weight of water leaf. However, performance was often similar to when 5 t ha-^{1}PM was applied in addition to 4 t ha-^{1} OPBA Therefore use of PM alone or in combination with OPBA has been observed to have beneficial effect on growth and yield of waterleaf. PM with the high N content and OPBA with high K and available P content increased the nutrient content of the soil and neutralize effect of soil acidity as well, thereby creating atmosphere of balanced nutrients around the rhizosphere. Wood ash or poultry manure had earlier been reported to positively affect crop yield. Amujityegbe *et al*. (2007) and Adekayode and Olujugba, (2010) observed that wood ash in combination with other organic or inorganic manure may give better soil fertility improvement for higher increases in crop production. OPBA as well as other wood ash have liming effect on the soils (Adekayode and Olujugba, (2010), Rogers and Sharland (1997). Although CD has a high C: N ratio, its application in combination with PM and OPBA resulted in an enhanced mineralization and nutrient profile, as against its sole application implying that conjunctive use of some organic manures is an imperative if their best potentials are to be realized.

5.0 Summary and conclusion

The comparative efficacy of sole poultry manure (PM) at 10 t ha^{-1}, 10 t ha^{-1} cow dung (CD), 8 t ha^{-1} oil palm bunch ash (OPBA) and their combinations including; 5 t ha^{-1} PM + t ha^{-1}CD, 5 t ha^{-1} PM +4 t ha^{-1} OPBA, 5 t ha^{-1} CD+4 t ha^{-1} OPBA were tested on the performance of water leaf in Calabar. From our study, the 10 t ha^{-1} PM, 5 t ha^{-1} PM +4 t ha^{-1} OPBA and 5 t ha^{-1} CD+4 t ha^{-1} OPBA were equally effective in enhancing growth and yield performance of water leaf. Therefore, organic manure can be applied singly or as a complement of another at half the recommended rate of sole for maximum advantage realizable

6. Conflict of interest

The authors declare that there is no conflict of interest whatsoever.

7. Authors' contributions: the work was conceptualized and validated by Aniefiok Uko, Otobong Iren drew up the methodology and handled soil analysis and interpretation, Emmanuel Effa did the initial statistical analysis but assisted by Isong, Isong, A. the detailed final statistical analysis.

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