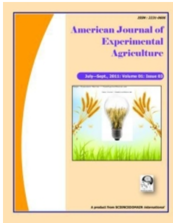

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Growth and Foliar Yield Responses of Waterleaf (*Talinum triangulare* Jacq) to Complementary Application of Organic and Inorganic Fertilizers in a Ultisol

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Authors' contributions

This work was carried out in collaboration between all authors. Author NUN designed the study and performed the statistical analysis, author AOI wrote the protocol, while author KKN wrote the first draft of the manuscript. Author EAA analyzed of the study. Author EIU managed the literature searches. All authors read and approved the final manuscript.

Research Article

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ABSTRACT

Aims: Growth and foliar yield responses of waterleaf (*Talinum triangulare* Jacq) to complementary application of organic and inorganic fertilizers were studied in a Ultisol.
Study Design: The experiment was laid out in a randomized complete block design with three replicates.
Place and Duration of Study: The University of Uyo Teaching and Research Farm, located at Use Offot - Uyo, Akwa Ibom State, Nigeria and was conducted between March, 06 and June, 06 in both 2009 and 2010 cropping seasons.
Methodology: Treatments were various combinations of organic and inorganic fertilizers applied to the soil, and these included NPK (15:15:15) at 400 kg ha^{-1}, poultry manure (PM) at 5 t ha^{-1}, PM at 2.5 tha^{-1} + NPK at 200 $kgha^{-1}$, PM at 3.75 tha^{-1} + NPK at 100 $kgha^{-1}$, PM at 1.25 tha^{-1} + NPK at 300 $kgha^{-1}$ and control (without amendment).
Results: There were significant differences (P<0.05) among treatments in height, number

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of branches, number of leaves, stem girth, leaf area, and total foliage yield of waterleaf in both years. Generally, application of PM alone and complementary use of PM and NPK, irrespective of the ratio, enhanced waterleaf growth and total foliage yield better compared to application of NPK alone and the control treatment. Total foliage yield from 100 $kgha^{-1}$ NPK + 3.75 tha^{-1} of PM treatment (56 .03 tha^{-1} 30 and 54 36 tha^{-1} 31 in 2009 and 2010, respectively) superseded other treatments by 38 - 78% in 2009 and 35 -78% in 2010.
Conclusion: With the high cost, scarcity, and environmental problems associated with the use of mineral fertilizer in Nigeria; and based on the foliage yield obtained in this study, it is obvious that the use of organic manure in combination with mineral fertilizer (particularly with 100$kgha^{-1}$ NPK + 3.75tha^{-1} PM or 200$kgha^{-1}$ NPK + 2.5tha^{-1} PM treatment) can sustain waterleaf production. It is also demonstrated that it would be more rewarding to apply 5tha^{-1} PM alone compared to sole application of 400$kgha^{-1}$ mineral fertilizer for waterleaf production in a Ultisol.

Keywords: Waterleaf; organic inorganic fertilizers; growth; foliar yield; ultisol.

1. INTRODUCTION

Waterleaf *(Talinum triangulare* Jacq), a leafy vegetable crop that originated from tropical Africa [1], is an all -season vegetable that is extensively grown in many countries in Asia, South America and West Africa. In Nigeria, it is widely cultivated and consumed in the southern part, particularly in Cross River and Akwa Ibom States [2,3]. The demand for waterleaf is high in these states, and it is therefore a major source of income for farmers. Its high demand is attributed to its nutritional value and importance as a "softener" when cooking the common fibrous leafy vegetables [4] such as Afang *(Gnetum africana),* Atama *(Heinsia crinata),* and Editan *(Lasienthera bulchozianum)*. It is also cooked with green amaranthus *(Amaranthus curentus)* and fluted pumpkin *(Telfairia occidentalis).* Waterleaf has a colloidal property and this favours its use for preparation of popular soups known as *Ukwoho afang* and *edikang ikong* in some parts of southern Nigeria. Ibeawuchi et. al. [5] stated that the leaves and young shoots are used to thicken sauce and is consumed in large quantities in the southern part of Nigeria. It is considered medicinal in southern Nigeria as it is used as herb for measles and stomach upsets [3]. Also, it performs well as fodder for raising giant snails [6].

The increasing demand for waterleaf due to urbanization has therefore pushed farmers into small and medium scale production of waterleaf in Akwa Ibom State. Consequently, to obtain optimum yield, organic fertilizers are being developed by farmers from farm and city wastes for vegetable production. Also, organo-mineral fertilizers (OMF) in which organic wastes are fortified with inorganic N or NP fertilizers are being utilized by crop farmers. Organic and organo-mineral fertilizers have been reported to significantly increase yield of vegetables such as pepper (*Capsicum annum*), tomato (*Lycopersicon esculentus*), okra (*Abelmoschus esculentus*), egusi-melon (*Cucumeropsis mannii*) and amaranthus (*Amaranthus cruentus*) [7,8,9,10,11,12,13,14].

Most farmers apply these assorted types of fertilizers (organic and inorganic) but sometimes the yields hardly compensate for the money spent to purchase these fertilizers. This is partly because most farmers are yet to determine the best local fertilizer source to use in the vegetable crop production. The use of animal and plant wastes in crop production is indeed a long standing practice in the world. The use of inorganic fertilizers among farmers to improve waterleaf yield is also common although some farmers and consumers still question the desirability of using inorganic fertilizer for leafy vegetable production. Most farmers broadcast large quantity of inorganic fertilizer in waterleaf plots at intervals of 2 to 30 weeks to stimulate growth. This is always aimed at achieving maximum growth and yields [15,16]. The inorganic fertilizer is considered a major source of plant nutrients [17] while organic manure has ability of improving soil structure in addition to supplying nutrients [16] and increasing microbial biomass [18]. However, the use of inorganic fertilizers alone may have negative implications for human health and the environment [19]. The utilization of organic manures by vegetable producers may have an additional advantage of ensuring environmental harmony compared to chemical fertilizers.

Udoh et. al. [3] recommended application of organic manures like cow dung, poultry droppings and nitrogenous fertilizers immediately after harvest. Farmers find it difficult to maintain a standard fertilizer regime in the cultivation of water leaf as they often supplement organic manure with mineral fertilizers. However, information on the interaction due to combined application of organic manure and mineral fertilizer for waterleaf is scanty. Combined application of organic manure and mineral fertilizers often goes with such additional advantages as buffering the soil against undesirable acidification and increasing the availability of micronutrients [20]. The blending of organic manures with mineral fertilizer may help to increase the productivity of crops on fragile soil by reducing the problem of nutrient losses via leaching or denitrification. Olsen et. al. [21] found that a substantial portion of nitrogen fertilizer needs of most cereals could be met by organic manure blended with mineral fertilizer. The use of both mineral and organic fertilizers has been found to be a sustainable technology for crop production, and the full integration of this technology into the cropping systems of Akwa Ibom State could further increase crop yields [22]. Improved vegetable crop growth and yield performances with complementary application of inorganic and organic fertilizers compared to sole application of either organic or inorganic fertilizer have been reported [23,22,24,25,26].

The complementary use of organic manure and inorganic fertilizers have been proven to be a sound soil fertility management and crop production strategy in many countries of the world [27,28]. In Nigeria, Makinde et al. [29] in their study on combined application of organic manures and mineral fertilizers recommended the use of either kola pod husk and pacesetter organic fertilizer at 3tha^{-1} alone or combined with NPK fertilizer at reduced levels as being suitable for improving yield and nutritional quality of amaranthus. High and sustained crop growth and yield could therefore be obtained with combined and judicious use of balanced inorganic and organic fertilizers. This study was therefore conducted to evaluate the effects of amending the soil with different organic manures supplemented with a nitrogen fertilizer on growth and foliar yield of waterleaf in Uyo, southeastern Nigeria.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was conducted at the University of Uyo Teaching and Research Farm, located at Use-Offot- Uyo, Akwa Ibom State of Nigeria and was conducted between March, 06 and June, 06 in both 2009 and 2010 early cropping seasons. The site is located at Latitude 5º17^{I} and 5º27^{I} N, Longitude 7º27^{I} and 7º58^{I} E and on altitude of 38.1m above sea level. This rainforest zone receives about 2500 mm rainfall annually. The rainfall pattern is bimodal, with long (March - July) and short (September – November) rainy seasons separated by a short dry spell of uncertain length usually during the month of August. The mean relative humidity is 78% and the atmospheric temperature is 30ºC. The mean sunshine hour is 12 [30]. Soil analysis revealed the following physico-chemical characteristics: pH in water of 5.6, 1.37% organic matter, 0.10 % total nitrogen, 31.77 mg/kg available P while exchangeable bases values were 199. 02, 2.88 and 1.20 cmolkg-^{1} for K, Ca and Mg, respectively. The soil particle distribution was: sand 86.9 %, silt 2.8% and clay 10.3%.

2.2 Experimental Design, Treatment and Cultural Details

The experiment was laid out in a randomized complete block design with three replicates. Treatments were six fertilizer rates: NPK (15:15:15) at 400 kg ha^{-1}, poultry manure (PM) at 5 t ha^{-1} , PM at 2.5 tha^{-1} + NPK at 200 kgha^{-1}, PM at 3.75 tha^{-1} + NPK at 100 kgha^{-1} , PM at 1.25 tha^{-1} + NPK at 300 kgha-^{1} and control (without amendment). Each plot measured 6m x 6m with 1m inter- plot and replicate spacing. The site was cleared manually and organic manures incorporated into the soil during preparation of raised seedbeds of 25 cm depth using garden fork and spade while NPK (15:15:15) fertilizer was applied two weeks after planting according to treatment. A waterleaf landrace, locally called *mmong mmong ikong Uyo* was planted manually at a spacing of 5cm x 5cm using stem cuttings of 10 cm length with leaves still attached. Manual weeding was carried out at 3, 6 and 9, weeks after planting (WAP).

2.3 Data Collection and Analysis

Fifty plants were randomly selected and tagged per plot (excluding the border rows) for data collection. Growth and yield parameters measured included: height, number of leaves per plant, leaf area (determined graphically), number of branches per plant, stem girth (using an inelastic string around the stem) and total fresh foliage yield (i.e. from sequential harvesting done at 3, 6, 9 and 12 WAP). Data collected were subjected to analysis of variance and means compared using least significant difference (P=0.05).

3. RESULTS

3.1 Plant Height and Number of Branches

Table 1 shows that at 3, 6, 9 and 12 WAP, there were significant differences (P=0.05) in the height of waterleaf among the different fertilizer treatments in 2009. At 3, 6, 9 and 12 WAP, waterleaf in the 100 kgha^{-1} of NPK + 3.75 tha^{-1} PM treatment was taller than those of other treatments by 12-15%, 9-54%, 13-55% and 12-15%, respectively. The control treatment consistently produced the shortest waterleaf. Application of poultry manure alone at 5 tha^{-1} enhanced plant height compared with the application of NPK alone at 400 kgha^{-1}.In 2010, waterleaf height also differed significantly (p=0.05) at all sampling months among the fertilizer treatments (Table 1). Percentage differences observed in waterleaf height in 2009 at the different sampling intervals were also maintained in 2010. Also, the use of poultry manure alone was better than the use of NPK (15:15:15) alone Table 2 shows that at 3, 6, 9 and 12 WAP, there were significant differences in the number of branches per plant (P=0.05) among the different fertilizer treatments in 2009 but no clear pattern was maintained. However at 3 and 6 WAP, the 100 kg ha^{-1} of NPK + 3.75 t ha^{-1} PM produced more branches per plant than other treatments by 28-56%, and 19- 46%, respectively. At 9WAP, 5tha^{-1} poultry manure (PM) produced 24-75% more branches than other treatments whereas at

12WAP, the number of branches from the 300kgha^{-1} NPK + 1.25tha^{-1} PM plot superseded other treatments by 52-78%. The control treatment had the least number of branches per plant. In contrast, the number of branches per plant in 2010 in the 100 kg ha^{-1} of NPK + 3.75 t ha^{-1} PM treatment superseded others at 3, 6, 9 and 12 WAP by corresponding differences of 17- 58%,11- 43%, 4- 40% and 17- 55%. Application of poultry manure alone produced more branches than the NPK 400kgha^{-1} treatment in both seasons.

Table 1. Waterleaf height (cm) as influenced by organic/inorganic fertilizer combinations in 2009 and 2010 cropping seasons

Treatment	Weeks	after	planting	
	3	6	9	12
		2009		
400 kg of NPK ha-^{1}	8.3	9.6	9.3	8.6
5tha^{-1} poultry manure (PM)	8.8	10.7	10.9	9.8
200kgha^{-1} NPK + 2.5tha^{-1} PM	13.3	15.3	14.4	13.7
300kgha^{-1} NPK + 1.25tha^{-1} PM	11.8	13.7	13.2	12.4
100kgha^{-1} NPK + 3.75tha^{-1} PM	15.1	16.8	16.6	15.5
Control (no fertilizer Application)	7.0	7.8	7.4	6.8
LSD (P=0.05)	0.5	0.4	0.5	0.5
		2010		
400 kg of NPK ha-^{1}	4.9	7.2	6.1	5.1
5tha^{-1} poultry manure (PM)	6.3	7.2	74	6.5
200kgha^{-1} NPK + 2.5tha^{-1} PM	8.1	8.7	8.6	7.7
300kgha^{-1} NPK + 1.25tha^{-1} PM	7.6	8.4	8.8	6.2
100kgha^{-1} NPK + 3.75tha^{-1} PM	9.8	9.8	9.2	9.3
Control (no fertilizer Application)	4.1	5.6	5.5	4.2
LSD (P=0.05)	1.3	1.5	1.4	1.7

3.2 Number of Leaves and Stem Girth

In 2009 , the number of leaves per plant differed significantly (P=0.05) among the different fertilizer treatments but showed no clear direction (Table 3). At 3 WAP, 200kgha^{-1} NPK + 2.5tha^{-1} PM treatment had 9- 47% more number of leaves per plant than others while at 6 and 9 WAP, the 5tha^{-1} poultry manure (PM) had 48-75% and 11- 60% more number of leaves than others. The number of leaves in the 100kgha^{-1} NPK + 3.75tha^{-1} PM plot superseded other treatments by 4- 55%.

All the fertilized plots had higher number of leaves per plant than the control treatment. Application of poultry manure alone produced more leaves than NPK 400kgha^{-1}. The number of leaves per plant also differed significantly (P=0.05) among the fertilizer treatments in 2010 (Table 3). At 3 WAP, 200kgha^{-1} NPK + 2.5tha^{-1} PM treatment had 7-48% more leaves than others whereas at 6, 9 and 12WAP, the 100 kgha^{-1}of NPK + 3.75 tha^{-1} PM produced 11- 58%, 14-59% and 16- 54% more number of leaves per plant than others. The control treatment consistently produced the least number of leaves per plant Application of poultry manure alone produced more leaves than application of NPK at 400kgha^{-1}.

Table 2. Number of branches per pant of waterleaf as influenced by organic/inorganic fertilizer combinations in 2009 and 2010 cropping seasons

Treatment	Weeks	After	planting	
	3	6	9	12
		2009		
400 kg of NPK ha-^{1}	5.7	7.2	6.0	5.1
5tha^{-1} poultry manure (PM)	6.5	7.2	21.3	6.4
200kgha^{-1} NPK + 2.5tha^{-1} PM	8.0	8.7	8.6	7.7
300kgha^{-1} NPK + 1.25tha^{-1} PM	7.6	8.4	12.8	19.3
100kgha^{-1} NPK + 3.75tha^{-1} PM	10.8	10.8	16.1	9.3
Control (no fertilizer Application)	4.8	5.8	5.3	4.2
LSD (P=0.05)	1.3	1.6	1.7	1.2
		2010		
400 kg of NPK ha-^{1}	5.0	7.2	6.1	5.1
5tha^{-1} poultry manure (PM)	6.3	7.2	7.4	6.5
200kgha^{-1} NPK + 2.5tha^{-1} PM	8.1	8.7	8.6	7.7
300kgha^{-1} NPK + 1.25tha^{-1} PM	7.6	8.4	8.8	6.2
100kgha^{-1} NPK + 3.75tha^{-1} PM	9.8	9.8	9.2	9.3
Control (no fertilizer Application)	4.1	5.6	5.5	4.2
LSD (P=0.05)	1.3	1.46	1.4	1.7

Table 3. Number of leaves per plant of waterleaf as influenced by organic/inorganic fertilizer combinations in 2009 and 2010 cropping seasons

Treatment	Weeks	after	planting	
	3	6	9	12
		2009		
400 kg of NPK ha-^{1}	10.2	12.9	13.4	13.3
5tha^{-1} poultry manure (PM)	14.1	39.1	26.2	24.2
200kgha^{-1} NPK + 2.5tha^{-1} PM	15.7	18.6	18.7	15.9
300kgha^{-1} NPK + 1.25tha^{-1} PM	14.3	18.6	20.6	20.9
100kgha^{-1} NPK + 3.75tha^{-1} PM	13.6	20.3	23.4	24.3
Control (no fertilizer Application)	8.3	9.7	10.4	10.9
LSD (P=0.05)	1.4	1.5	2.7	3.1
		2010		
400 kg of NPK ha-^{1}	10.1	12.1	13.1	13.4
5tha^{-1} poultry manure (PM)	12.4	14.1	18.0	18.3
200kgha^{-1} NPK + 2.5tha^{-1} PM	15.5	18.5	19.0	15.4
300kgha^{-1} NPK + 1.25tha^{-1} PM	14.4	18.5	20.0	20.2
100kgha^{-1} NPK + 3.75tha^{-1} PM	14.1	20.9	23.2	24.1
Control (no fertilizer Application)	8.0	8.7	10.0	11.0
LSD (P=0.05)	1.3	1.5	2.6	3.0

In 2009, stem girth at 3, 6, 9 and 12 WAP differed significantly (Table 4) among the different fertilizer treatments. Stem girth in the 100 kgha^{-1} of NPK + 3.75 tha^{-1} PM plot was bigger than in other treatments at 3, 6, 9 and 12 WAP by 13- 55%,7-28%, 7- 29% and 6-73%, respectively. The smallest stem girth was produced by the control treatment. Waterleaf stem girth differed significantly (P=0.05) among fertilizer treatments in 2010 (Table 4) with the trend observed in 2009 maintained in 2010. The application of 100 $kgha^{-1}$ of NPK + 3.75 tha^{-1}PM resulted in the production waterleaf with bigger stem girth while the control consistently had the smallest stem girth. The application of poultry manure only had bigger stem girth than 400kg ha^{-1} of NPK (15:15:15) treatment.

Table 4. Waterleaf stem girth (cm) as influenced by organic/inorganic fertilizer combinations in 2009 and 2010 cropping seasons

Treatment	Weeks	after	planting	
	3	6	9	12
		2009		
400 kg of NPK ha^{-1}	1.10	2.37	2.51	2.37
5tha^{-1} poultry manure (PM)	1.27	2.30	2.43	2.53
200$kgha^{-1}$ NPK + 2.5tha^{-1} PM	2.10	2.70	2.80	2.90
300$kgha^{-1}$ NPK + 1.25tha^{-1} PM	1.77	2.53	2.50	2.70
100$kgha^{-1}$ NPK + 3.75tha^{-1} PM	2.40	2.90	3.00	3.10
Control (no fertilizer Application)	1.07	2.10	2.13	2.59
LSD (P=0.05)	0.32	0.15	0.19	0.84
		2010		
400 kg of NPK ha^{-1}	1.12	2.38	2.48	2.32
5tha^{-1} poultry manure (PM)	1.25	2.31	2.47	2.51
200$kgha^{-1}$ NPK + 2.5tha^{-1} PM	2.12	2.75	2.85	2.94
300$kgha^{-1}$ NPK + 1.25tha^{-1} PM	1.79	2.51	2.47	2.80
100$kgha^{-1}$ NPK + 3.75tha^{-1} PM	2.37	2.92	3.06	3.07
Control (no fertilizer Application)	1.04	2.06	2.00	2.11
LSD (P=0.05)	0.29	0.17	0.16	0.86

3.3 Leaf Area and Total Foliage Yield

Table 5 shows that at 3, 6, 9 and 12 WAP, the leaf area of waterleaf differed significantly (P=0.05) among the different fertilizer treatments in 2009. The leaf area in the 100 $kgha^{-1}$ of NPK + 3.75 tha^{-1} PM plot was larger than other treatments at 3, 6, 9 and 12 WAP by 12-45%, 16-53%, 5-39% and 11- 43%, respectively. The control treatment produced the smallest leaf area. Waterleaf leaf area was significantly (P=0.05) influenced by the fertilizer treatments in 2010 (Table 5). The 100 kg ha^{-1} of NPK + 3.75 t ha^{-1} PM treatment produced the widest leaves and exhibited the same pattern observed in 2009 while the control treatment had the smallest leaf size. Generally, the 5 tha^{-1}PM treatment produced bigger leaves than sole application of 400kg/ha NPK (15:15:15) fertilizer.

Table 6 shows that, the total fresh foliage yield of waterleaf differed significantly (P=0.05) among the different fertilizer treatments in 2009 and 2010. The 100 kg ha^{-1} of NPK + 3.75 t ha^{-1}PM treatment produced the highest total foliage yield (56.03tha^{-1} and 54.36 tha^{-1} in 2009 and 2010, respectively) while the control had the least total foliage yield (12.12 t ha^{-1} and 11.71 tha^{-1}, in 2009 and 2010, respectively). The 100 $kgha^{-1}$ of NPK + 3.75 t ha^{-1}PM treatment produced 38 –78% and 35-78%, more total foliage than other treatments in 2009 and 2010, respectively. Foliage yield from the sole application of 5t ha^{-1} PM was higher than that of 400kg ha^{-1} NPK by 15% and 13% in 2009 and 2010, respectively. There were slight differences in some of the parameters measured between 2009 and 2010 cropping seasons.

Table 5. Waterleaf leaf area (cm^2) as influenced by organic/inorganic fertilizer combinations in 2009 and 2010 cropping seasons

Treatment	Weeks after planting			
	3	6	9	12
		2009		
400 kg of NPK ha-^{1}	7.97	10.70	8.84	8.31
5tha^{-1} poultry manure (PM)	8.19	11.66	10.01	8.99
200kgha^{-1} NPK + 2.5tha^{-1} PM	10.63	14.48	12.99	11.28
300kgha^{-1} NPK + 1.25tha^{-1} PM	9.80	13.31	11.09	10.07
100kgha^{-1} NPK + 3.75tha^{-1} PM	12.08	15.83	13.72	12.70
Control (no fertilizer application)	6.67	10.56	8.36	7.28
LSD (P=0.05)	0.59	0.30	0.49	0.56
		2010		
400 kg of NPK ha-^{1}	8.01	10.72	8.80	8.36
5tha^{-1} poultry manure (PM)	8.12	11.86	10.21	9.06
200kgha^{-1} NPK + 2.5tha^{-1} PM	11.12	15.03	13.01	11.57
300kgha^{-1} NPK + 1.25tha^{-1} PM	9.82	13.34	11.12	10.04
100kgha^{-1} NPK + 3.75tha^{-1} PM	12.11	15.67	13.69	12.68
Control (No fertilizer application)	6.62	10.11	8.32	7.30
LSD (P=0.05)	0.62	0.41	1.26	1.13

Table 6. Total fresh foliage yield (tha^{-1}) of waterleaf as influenced by organic/inorganic fertilizer combinations in 2009 and 2010 cropping seasons

Treatment	2009	2010
400 kg of NPK ha-^{1}	19.73	20.06
5tha^{-1} poultry manure (PM)	23.33	22.96
200kgha^{-1} NPK + 2.5tha^{-1} PM	34.93	35.13
300kgha^{-1} NPK + 1.25tha^{-1} PM	28.40	27.99
100kgha^{-1} NPK + 3.75tha^{-1} PM	56.03	54.36
Control (no fertilizer application)	12.13	11.71
LSD (P=0.05)	10.23	9.86

4. DISCUSSION

Results of this study showed significant differences on all the vegetative characteristics and foliage yield. The study has also demonstrated that application of 5 t ha^{-1}of poultry manure alone performed better than the 400kg ha^{-1} treatment. However, combined application of 100 kgha^{-1} NPK + 3.75 tha^{-1}of PM resulted in increase in vegetative growth and foliage yield of waterleaf than other treatments. This may be due to synergistic effects of combining organic and inorganic fertilizers which optimally supplied needed plant nutrients. The mineral fertilizer supplied the needed nutrients to the waterleaf at the initial growth stage while the poultry manure provided the needed nutrients at later growth stages. Udoh et al. [3] and Ndaeyo et. al. [25] stated that the use of organic manure can enhance soil productivity and crop yield. Alves et.al [31] stressed the need to supplement organic manures with nitrogen fertilizers so as to increase nitrogen supply and in addition contribute to the increase in organic matter of the soil and other macro and micro nutrients required for crop growth.

Most of the time, the best results came from plots amended with NPK at 100 kg ha^{-1} + PM at 3.75 t ha^{-1}, which had the highest level of organic manure (PM) blended with mineral fertilizer. This agrees with that of Gill and Meelu [20] who found that crop yield increased with an increase in the level of nitrogen blended manure. Also combined application of organic manure and mineral fertilizers, particularly in the tropics, has additional advantages of buffering the soil against undesirable acidification and also increase the availability of micro nutrients [28,26,34]. Studies [32,33,35] have also demonstrated that application of organic waste alone and in combination with mineral fertilizer enhanced root and shoot biomass, and general growth and yield and components of crops compared to sole application of NPK fertilizer (400 $kgha^{-1}$). Similarly, Amalu and Oko [36] reported that yield performance was better in manured than in control plots and that responses varied very widely with sources of manures in terms of vegetative growth and yields. The variability in the performance of the fertilizer treatments could be due to variation in their nutrient composition since different ratios were combined [37]. Aliyu [37] and Dauda et.al. [16] also reported that application of poultry manure at $5tha^{-1}$ and farm yard manure at $5\text{-}10tha^{-1}$ supplemented with $50kgNha^{-1}$ resulted in adequate crop growth and maximum fruit yield of pepper (*Capsicum annum* L) and water melon [C*itrullus lanatus* (Thum.) Matsum & Nakai], respectively. Findings from the present study are in consonance with that of Abgede [38] who reported that combined application of sub-optimal rates of NPK fertilizer and poultry manure enhanced plant performance compared with application of NPK fertilizer or poultry manure alone. Also, Makinde et al. [29] in their findings stated that combined application of organic manures and mineral fertilizers, either as kola pod husk and pacesetter organic fertilizer at $3tha^{-1}$ alone or combined with NPK fertilizer at reduced levels, is suitable for vegetable production. Integrated nutrient management through combined use of organic wastes and chemical fertilizers has been reported to be an effective approach to combat nutrient depletion and promote sustainable crop productivity [39,40,41,42].The slight differences observed in vegetative growth of waterleaf in both cropping seasons could be attributed to vagaries of weather.

5. CONCLUSION

With the high cost, scarcity, and environmental problems associated with the use of mineral fertilizer in Nigeria; and based on the foliage yield obtained in this study, it is obvious that the use of organic manure in combination with mineral fertilizer (particularly with $100kgha^{-1}$ NPK+$3.75tha^{-1}$ PM or $200kgha^{-1}$ NPK+$2.5tha^{-1}$ PM treatment) can sustain waterleaf production. It is also demonstrated that it would be more rewarding to apply $5tha^{-1}$ PM alone compared to sole application of $400kgha^{-1}$ mineral fertilizer for waterleaf production in a Ultisol.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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