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Effect of Palm Bunch Ash Application on Soil and Plant Nutrient Composition and Growth and Yield of Garden Eggs, Pepper and Okra

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Authors' contributions

This study was carried out in collaboration between the two authors. Authors SAN and CBO designed the study. Author CBO performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors SAN and CBO managed the analyses of the study. All authors managed the literature searches, read and approved the final manuscript.

Research Article

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ABSTRACT

The effects of palm bunch ash (PBA) application on growth, nutrient uptake and yield of three vegetable crops; garden eggs, pepper and okra were studied both in the field and in the pot. The study which was carried out at the Forest and Horticultural Crops Research Centre, Kade in the forest zone of Ghana was conducted in a split plot fitted in a randomised complete block design. The results of the study showed that PBA application significantly ($P<0.05$) increased soil pH, soil phosphorus and exchangeable cations. In the field experiment, mineral fertilizer application resulted in an increase in the fresh fruit yield of the garden eggs and the pepper over the control by as much as 93% while PBA application resulted in fresh fruit yield increase of between 55-91%. For okra, fertilizer application resulted in fresh fruits yield increase of about 83% over the control while yield increase as a result of PBA application ranged between 8 and 69%. There were also significant interactions between the vegetables and the PBA application rates. For the garden eggs, the highest fruit yield of 9.52 t ha^{-1} was obtained at PBA application rate of 4

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t ha^{-1} while for the pepper and the okra, the highest fruit yields of 6 and 4.96 t ha^{-1} were obtained at the PBA application rate of 2 t ha^{-1}. Our study suggests that PBA could be used as a liming material and fertiliser supplement to increase soil pH of acid soils and increase the yield of vegetable crops.

Keywords: Exchangeable cations; fertilizer; fresh fruit yield; soil chemical properties; vegetables.

1. INTRODUCTION

Most soils in the forest and humid tropical regions are acidic due to the high rainfall regime and intensity and associated leaching of nutrients [1]. In the forest zone of Ghana, this problem is being worsened by increasing soil fertility decline caused by continuous cropping as a result of population pressure [2] and competition between food and tree crops for available land. Crops planted on these soils therefore suffer essential plant nutrient deficiency in just a few years after cropping [1,3]. To raise the pH levels of these soils to slightly acidic to neutral and also increase the nutrient content of these soils require sustainable liming and fertilizer application [4].

Mineral fertilizer use in Ghana is extremely low; application rate is estimated to be 7.42 kg per hectare per year which is one of the lowest in sub Saharan Africa [5] due to prohibitive cost as a result of privatization and removal of government subsidies [6]. Besides this, the intensity of rainfall during the cropping season makes the use of inorganic fertilizers less effective because of leaching [1,3,4,7]. This situation therefore suggests the need to identify an alternative cheap source of nutrients for replenishing soil nutrients without necessarily resorting to the use of mineral fertilisers. One option of improving soil fertility among small holder farmers without resorting to the use of mineral fertilizers is to use agricultural and agro- industrial residues as soil organic amendments [1,8]. This is because, besides the nutrients release to the crops, agro-industrial and agricultural residues also have positive residual effects on the soil chemical and physical properties. In the south-eastern forest zone of Ghana where there is intensive cultivation of oil palm, empty fruit bunch (EFB) of oil palm is one of the major waste products resulting from the processing of oil palm fresh fruit bunches (FFB). One ton of FFB when processed produces about 220kg of EFB which contains about 0.8% nitrogen (N), 0.1% phosphorus (P), 2.5% potassium (K) and 0.2% magnesium (Mg) on dry weight basis [9]. The EFB generated can be used as a fertilizer supplement, organic mulching material or composted into readily available organic manure for crop production.

Currently, Ghana produces about 1, 900, 000 metric tonnes (MT) of FFB annually [10] which when processed into oil generate 418, 000 MT of EFB annually. In the large scale oil palm processing industrial estates, EFB are either incinerated in the mills as a means of getting rid of these waste as well as to provide energy for the boilers in FFB sterilization or used as organic mulch in the plantations. However, the small scale mills which process about 80% of the total FFB produced in Ghana [11] burn the EFB as a means of disposing them off, resulting in heaps of ash dotted around small scale mills in the major oil palm producing areas in Ghana [8]. According to [8], there is currently no large-scale use for palm bunch ash in Ghana, although it could be used for the manufacture of local soap due to its high potassium content.

The burnt ashes produced as a result of the burning of the EFB constitute about 6.5% by weight of EFB and contain about 30%-40% K_2O [9]. Besides K_2O, oil palm bunch ash (PBA) also contains varying amount of other nutrients such as Mg, P and calcium (Ca) which can improve the pH of acidic soils [8].

Studies carried out in parts of Africa shows that plant derived ash including those of wood and cocoa pod increased P, K, Mg, Ca status and pH of the soil and yield of amarantus, tomato and pepper [12,13]. [13] also reported of reduced acidity (increased pH) and increased cation availability in soils amended with wood-ash.

[1] Also found that PBA improved soil chemical properties by supplying organic matter (OM), N, P, Ca and Mg to the soil and increased maize yield by 26% when used at 4 t ha^{-1}. Palm bunch ash was also found to increase nutrient supply to cassava and increased the yield of cassava significantly [14]. In Ghana, [8] reported of increase in maize grain and dry matter yields when PBA was applied at 2t ha^{-1}. In spite of the positive effects of PBA on growth and yield of food crops including maize and cassava, published works on effect of oil palm bunch ash on yield and nutrient content of vegetables are limited. Also information on the comparative response of different vegetables to oil palm bunch ash is very scanty. The objective of this study was therefore to ascertain the effect of oil palm bunch ash on growth, yield and nutrient content of garden eggs, pepper and okra and soil chemical properties in the semi-deciduous forest zone of Ghana.

2. MATERIALS AND METHODS

The experiment was carried out at the Forest and Horticultural Crops Research Centre (FOHCREC), Kade (latitude 6º 09 and 6º 06 N and longitude 0º 55 and 0º49 W and 135.9 m above sea level) of the University of Ghana both in the field and in the pot. The centre is located in the semi-deciduous forest agro-ecological zone of Ghana in the Kwaebibrim District of the Eastern Region.

The soils at the experimental site which are mainly forest ochrosol derived from precambium phyllitic rocks [15] are deep and well drained and are generally classified as Acrisols in the FAO-UNESCO Revised Legend [16] and as Ultisols in Soil Taxonomy [17].

The study site is characterized by a bi-modal rainfall pattern with a 30 – year average of 1433 mm with peaks in June and October and a brief dry spell in August and a dry season from December to March. The total annual rainfall amount during the experimental period was 1677.9 mm.

Field experiments were conducted from April to December, 2011 both in the major and minor growing seasons. The field used for the major season planting was dominated by *Chromolaena odorata* and *Pueraria spp* weeds. The land had been previously cultivated to soybean and had been fallowed for one year. The land was initially cleared by slashing. Five weeks later; herbicide (glyphosate) was applied at 900 g a.i. ha^{-1}. The field used for the minor season planting had been cultivated with maize in the major season after pigeonpea had been grown on the land for one year. The land was ploughed and harrowed.

The experiments were conducted in a split-plot design with four replications fitted into a randomized complete block design (RCBD). The main plot factor was the vegetable type and the subplot factor was made up of the different rates of PBA application. Main plot size was 9 m x 6 m with 2m alley between each main plot. The treatments which were applied to pepper (Legon 18), garden eggs (Legon 1) and okra (Clemson Spineless) were 0 t ha^{-1} PBA, 2 t ha^{-1} PBA, 4 t ha^{-1} PBA and 6 t ha^{-1} PBA and 200 kgha^{-1} (NPK 15:15:15). Transplanting of pepper and garden eggs seedling as well as planting of okra seeds in the field were done on 7th June 2011 for the major season planting and 27th September 2011 for the minor season planting. The vegetables were planted at 0.6 m by 0.6 m in single stands giving a plant population of 4 plants per square meter. Thinning and gap filling was done 7 days after planting. The PBA were randomly assigned to the treatment rows and applied manually in a ring around the plant in a radius of about 4 cm away from the stem of the plant 14 days after planting. The experimental plot was kept free from weeds by regular hand hoeing. The pepper and garden egg seedlings were protected from termite attack at transplanting in the field by applying Cymethoate at a rate of 7.5ml/l of water. Pyrinex 48EC (emulsifiable concentrate) at 1ml/l was applied when okra seedlings were three weeks old to control variegated grasshopper (*Zonocerus variegates*) and flea beetle (*Podagrica sjostedti*). Pyrinex 48EC at 3ml/l was applied on pepper and garden eggs seedlings four weeks after transplanting to control aphids (*Aphis spp*) and white flies (*Bemisia tabaci*) on the field. At fruiting, Pyrinex 48EC at 2ml/l was applied to control cotton strainer (*Dydercus superstitiosus*) on okra. 3ml/l Pyrinex 48EC was sprayed on the pepper and garden eggs plants fortnightly to control fruit flies (*Atherigona orientalis*) and fruit borers (*Helicoverpa armigera*). A broad spectrum fungicide “FOKO” (a.i. Mancozeb 800g/kg) was sprayed against fungal diseases at a rate of 4.0 g/l. At flowering, plant height, plant girth, plant canopy diameter and the number of fruiting branches were recorded. During the same period, the above ground biomass of five randomly selected plants was sampled and oven dried at 70º C for 48 hours for the determination of dry matter (DM). Harvesting of matured fruits of the garden eggs and pepper was done only in the major season. Okra fruits were not harvested in the major season due to feeding activity of Deer on the okra plants at the research site. Harvesting of garden eggs and pepper fruits were done when the fruits were matured but not ripened. Matured fruits were harvested 10-14 days interval. Five plants in each treatment and replications were randomly selected and tagged for yield and yield components.

Plant samples collected at flowering were analyzed for N, P, K, Ca, and Mg. The N was determined using micro-Kjeldal method, P by molybdenum blue colorimetry, K by flame photometer, and Ca and Mg by atomic absorption spectrophotometry.

Prior to the commencement of the experiment, core soil samples were collected randomly from the 0-20 cm depth of the soil for both physical and chemical properties. PBA sample was also analyzed for chemical properties. After 110 days of PBA application, soil samples were collected from 0-20 cm depth of each plot and analyzed for chemical properties. Soil pH was determined in water suspension at 1 : 1 ratio; organic C by Walkley-Black procedure; total N by Kjeldahl method; available P by Bray-1 method and exchangeable bases (K, Na, Ca, and Mg) by 1M NH4 OAC method [18]. In order to reduce cost, only soil and plant samples collected in the major season were analyzed.

Soil samples from the top 0-15 cm depth of soil were collected from the field, air dried for 14 days and later used to fill seventy two poly bags each measuring 36 cm by 28 cm for the pot experiment. Each poly bag was filled with 5 kg soil.

The experimental set up was arranged in a completely randomized design (CRD) with four replications. The bags were arranged on wooden boards at a distance of 0.6 m by 0.6 m to prevent direct contact of the roots of the plants with the soil. Pepper and garden eggs seedlings and okra seeds were planted on 6th October 2011 in single stands. One week after transplanting, the following treatments were applied to the seedlings: 0g PBA kg^{-1} soil, 1 g PBA kg^{-1} soil, 2 g PBA kg^{-1}soil, 3 g PBA kg $^{-1}$ soil, 0.1 g NPK kg^{-1} soil and 0.5 g PBA + 0.05 g NPK kg^{-1} soil representing 0 t PBA ha^{-1}, 2 t PBA ha^{-1}, 4 t PBA ha^{-1}, 6 t PBA ha^{-1}, 200 kg NPK ha^{-1} and 100 kg NPK + 1 t PBA ha^{-1}.

The pots were kept free from weeds by regular hand picking. Supplementary irrigation was given as and when required by the plants. Cymethoate and Pyrinex 48EC were applied to control insects attack on the plants. Mancozeb was sprayed on the plants to control fungal diseases.

At flowering, plant height, plant girth, number of fruiting branches, canopy diameter and plant chlorophyll content were measured. Plant samples were collected, oven-dried at 65ºC for 72 hrs and the dry matter determined. At harvest yield and yield components such as number of fruits per plant, fruit weight per plant, individual fruit weight, fruit length and fruit diameters were measured.

Plant shoot biomass samples collected at flowering were analyzed for N, P, K, Mg and Ca. The N was determined using micro-Kjeldal method and P by molybdenum blue calorimetric, K by flame photometer, and Ca and Mg by atomic absorption spectrophotometer method.

Data collected were analyzed using analysis of variance (ANOVA), Genstat version 9. The least significant differences (LSD) were calculated and the probability of treatment means being significantly different was set at $P< 0.05$.

3. RESULTS AND DISCUSSION

Results of the initial soil analysis for the experimental site are presented in Table 1. The soil of the experimental site was strongly acidic, moderately high in N and exchangeable Ca and Mg and low in organic carbon [19,20]. The PBA used for the experiment was alkaline (pH, 10.89), very low in organic carbon and N [19] and contained relatively high values of K, P, Ca and Mg (Table 2).

Table 1. Initial soil chemical and physical properties of the experimental soil

pH	OC*	Total N	Available P	Exchangeable cations			Bulk density	Sand	Silt	Clay
				K	Ca	Mg				
(1:1$H_2$0)	%		ppm	me100g^{-1}			kgm^{-3}	100%		
4.52	2.4	0.23	6.24	0.61	5.36	1.63	1.34 x10^3	36	53	11

Organic carbon

Table 2. Chemical properties of PBA used in the experiment

pH	OC	Total N	P Bray	Exchangeable cations		
				K	Ca	Mg
1: 2.5 H_2O	%	%	ppm	me 100g^{-1}		
10.89	0.55	0.08	269.57	582.77	34.93	29.08

The pH value of 10.89 of the PBA used in this study is similar to that reported by [8] who reported a pH value of about 10.9. This value is significantly different from the value of 8.8 reported by [1]. The high values of the pH and the exchangeable cations of the PBA used in this and other studies [1,8,21] justifies the use of PBA as a liming material and source of nutrients for plants. The pH (4.52) at the experimental site at the beginning of the experiment (Table 1) compared to a range of 5.2 to 5.9 after the PBA application (Table 3) confirms the ability of PBA to increase soil pH. The increase in the pH of the soil after the application of the PBA was due to the high pH level of the PBA and relatively high values of Ca and Mg which had a liming effect on the soil [19] (Hoskins, 1997). The increased available P content of the soil with increased application of PBA (Table 3) could be attributed to release of P from complexes of Al and Fe under increasing soil pH [8,22].

The high concentration of potassium, calcium and magnesium in the PBA amended fields (Table 3) could also be due to low exchangeable acidity as a result of precipitation of Al as hydroxyl-Al [20,23,24] thereby releasing these cations in the soil.

Plant nutrient analysis as shown in Table 4 indicate that, except for P and K, increased PBA application generally resulted in decreased plant nutrient uptake compared with the control and the plots that received 200 kg ha^{-1} NPK. Several authors [4,8,25] have reported of similar observations in other crops such as maize and attributed the reduction in plant nutrient content, especially for N, Mg and Ca with increasing application of PBA to excessive uptake of K. The excessive uptake of K by plants from PBA amended plots affected uptake of Mg which plays important role in chlorophyll formation [26] as high soil K is known to negatively affect uptake of Mg [8,19,20,21]. The lower Mg content of plants from PBA amended plots thus resulted in lower leaf chlorophyll content in plants from the PBA treated plots compared with those from the control plots and the plots that received the 200 kg ha^{-1} NPK in all the three vegetables in both the major and minor growing season plantings (Tables 5 and 6).

Palm bunch ash application significantly (P = .05) reduced the number of days to flowering compared with the control (Table 5). Days to 50% flowering ranged from 37 days with NPK to 41 days with 0 t ha^{-1} PBA application rate during the major season (Table 5) and from 38 days with the NPK treated plots to 44 days with the 0 t ha^{-1} PBA application rate during the minor season (Table 6). For both the major and minor season plantings, PBA application resulted in early flowering compared with the control although increasing application rate beyond 2 t ha^{-1} generally resulted in delayed flowering. The early flowering associated with the plots that received NPK and PBA could be attributed to increased availability and uptake of plant nutrients particularly, P and K by the vegetables which might have resulted in fast plant growth and therefore early flowering. Increased application of nutrients, particularly, N, P and K has been found to result in early flowering in vegetables such as chilli pepper [27].

Shoot dry matter at flowering was also significantly (P = .05) affected by palm bunch ash application. The least shoot dry matter in both the major and minor planting seasons was found in the control plots (Tables 5 and 6). In the major season planting, the highest shoot dry matter for the PBA treated plots was recorded at the 4 t ha^{-1} PBA application rate while in the minor season planting the highest shoot dry matter was obtained at 2 t ha^{-1} application rate. The increase in dry matter as a result of PBA or fertilizer application has been reported in cowpea [21] and garden eggs [28]. Increase in shoot dry matter as a result of nutrient application is attributed to balanced nutrient uptake by plants [28] which results in enhanced cell division and enlargement [29] leading to shoot growth and development. The bigger plant canopy diameter associated with plants on plots that received the NPK and the PBA as shown in Table 5 and 6 resulted in increased number of fruiting branches compared to the control plots in all the three vegetable (Tables 5 and 6).

Table 3. Chemical properties of the 0-20 cm layer of the soil 110 days after application of the treatment regime (TR) for the major season planting

PBA rates / Vegetable	0 t ha^{-1}	2 t ha^{-1}	4 t ha^{-1}	6 t ha^{-1}	NPK	Mean
pH (1:1 H_20)						
G eggs	5.20	5.71	6.00	5.76	5.13	5.56
Okra	5.22	6.01	5.78	5.71	5.13	5.57
Pepper	5.15	5.69	5.91	5.76	5.09	5.52
Mean	5.19 a	5.80 b	5.90 c	5.74 b	5.12 a	
LSD (0.05):	V: NS	TR: 0.08		V*TR: 0.14		
Organic Carbon (%)						
G eggs	1.54	1.82	1.89	1.59	1.66	1.70
Okra	1.45	1.89	1.68	1.60	1.55	1.63
Pepper	1.37	1.52	1.82	1.58	1.40	1.54
Mean	1.45 a	1.74 b	1.80 bc	1.59 d	1.53 ad	
LSD (0.05):	V: NS	TR: 0.096		V*TR: 0.212		
Total N (%)						
G eggs	0.14	0.17	0.19	0.16	0.16	0.17
Okra	0.14	0.17	0.18	0.16	0.17	0.16
Pepper	0.12	0.16	0.16	0.16	0.16	0.15
Mean	0.13 a	0.17 b	0.18 c	0.16 d	0.16 d	
LSD (0.05):	V: NS	TR: 0.007		V*TR: NS		
Available P (ppm)						
G eggs	7.87	12.30	13.05	12.58	11.43	11.43 a
Okra	8.15	13.51	13.32	13.23	12.05	12.05 a
Pepper	8.22	14.81	16.75	16.85	13.88	13.88 b
Mean	8.08 a	13.54 b	14.37 b	14.22 b	12.45 c	
LSD (0.05):	V: 1.11	TR: 0.91		V*TR: 1.69		
Exchangeable K (me 100g^{-1})						
G eggs	0.62	0.96	1.03	0.81	0.62	0.81
Okra	0.67	1.03	1.00	0.79	0.59	0.81
Pepper	0.69	1.03	0.96	0.90	0.59	0.84
Mean	0.66 a	1.01 b	1.00 b	0.83 c	0.62 a	
LSD (0.05):	V: NS	TR: 0.062		V*TR: NS		
Exchangeable Ca (me 100g^{-1})						
G eggs	3.34	3.87	4.11	3.78	2.20	3.46 a
Okra	3.37	4.34	4.37	4.31	2.75	3.83 b
Pepper	2.52	2.88	3.00	2.58	2.03	2.60 c
Mean	3.07 a	3.70 b	3.83 b	3.56 b	2.33 c	
LSD (0.05):	V: 0.301	TR: 0.274		V*TR: 0.492		
Exchangeable Mg (me 100g^{-1})						
G eggs	1.28	2.40	2.60	2.45	1.25	2.00
Okra	2.17	2.80	2.48	2.37	1.43	2.25
Pepper	1.65	1.96	3.19	3.16	1.84	2.36
Mean	1.70 a	2.39 b	2.76 c	2.66 c	1.50 ad	
LSD (0.05):	V: NS	TR: 0.262		V*TR: 0.497		

Values in a row followed by the same letters are not significantly different at 5% by LSD test

The bigger canopy diameter observed in the PBA and the 200kg NPK ha^{-1} treated plots could be attributed to increased uptake of nutrients by the plants leading to enhanced carbohydrate synthesis which might have resulted in increased cell division and enlargement and therefore increased in the size of plant canopy [29]. Similar observations have been made in bell pepper [30] and in garden eggs [29]. The increased uptake of plant nutrients supplied by the ash and the mineral fertilizer resulted in improved vegetative structure development [31]. Balanced nutrition has been found to result in active cell division, cell elongation as well as development of meristematic tissues which consequently results in development of more fruiting branches [32]. [28] also reported an increased number of fruiting branches with increased levels of nitrogen, phosphorus and potassium supply in bell pepper.

Table 4. Effect of vegetable type (V) and treatment regime (TR) application on plant nutrient composition at flowering for the major season planting

PBA rates / Vegetable	0 t ha^{-1}	2 t ha^{-1}	4 t ha^{-1}	6 t ha^{-1}	NPK	Mean
N (%)						
G eggs	2.29	2.28	2.24	2.20	2.67	2.34
Okra	2.41	2.37	2.32	2.27	2.96	2.47
Pepper	2.35	2.27	2.21	2.16	2.60	2.32
Mean	2.35 a	2.31 a	2.26 ac	2.12 d	2.75 e	
LSD (0.05):	V: NS	TR: 0.058		V*TR: 0.156		
P (%)						
G eggs	0.29	0.36	0.40	0.34	0.31	0.34
Okra	0.28	0.37	0.34	0.33	0.34	0.33
Pepper	0.23	0.37	0.38	0.38	0.31	0.33
Mean	0.27 a	0.37 b	0.37 b	0.35 b	0.32 c	
LSD (0.05):	V: NS	TR: 0.021		V*TR: 0.041		
K (%)						
G eggs	0.89	0.98	0.98	0.97	0.95	0.96
Okra	0.90	0.97	0.96	0.96	0.96	0.95
Pepper	0.87	0.99	1.04	0.99	0.95	0.97
Mean	0.89 a	0.98 b	0.99 b	0.97 bc	0.95 c	
LSD (0.05):	V: NS	TR: 0.023		V*TR: 0.401		
Ca (%)						
G eggs	0.29	0.24	0.23	0.26	0.35	0.27
Okra	0.31	0.26	0.24	0.28	0.34	0.29
Pepper	0.34	0.30	0.28	0.25	0.39	0.31
Mean	0.31 a	0.27 b	0.25 b	0.26 b	0.36 c	
LSD (0.05):	V: NS	TR: 0.032		V*TR: NS		
Mg (%)						
G eggs	0.17	0.15	0.15	0.13	0.19	0.16
Okra	0.19	0.17	0.17	0.15	0.18	0.17
Pepper	0.18	0.15	0.15	0.14	0.19	0.17
Mean	0.18 a	0.16 b	0.16 b	0.14 c	0.19 d	
LSD (0.05):	V: NS	TR: 0.009		V*TR: NS		

Values in a row followed by the same letters are not significantly different at 5% by LSD test

Table 5. Effect of vegetable type (V) and treatment regime (TR) application on plant growth for the major season planting

PBA rates / Vegetable	0t/ha PBA	2t/ha PBA	4t/ha PBA	6t/ha PBA	NPK	Mean
Number of days to flowering						
G eggs	43 a	39 b	42 ac	41 c	39 b	41
Okra	37 a	33 b	35 c	37 a	33 b	35
Pepper	42 a	39 a	39 a	39 a	39 a	39
Mean	41 a	39 b	39 b	39 b	37 c	
LSD (0.05)	V: NS		TR: 1.069		V*TR: 6.420	
LSD (0.05): garden eggs at different TR= 1.65; okra at different TR=1.50; pepper at different TR=NS						
Shoot dry matter ($t\ ha^{-1}$)						
G eggs	0.48 a	0.61 a	0.60 a	0.72 a	0.68 a	0.62
Okra	0.50 a	0.63 bc	0.64 b	0.51 ac	0.67 b	0.59
Pepper	0.18 a	0.23 a	0.29 a	0.21 a	0.28 a	0.24
Mean	0.39 a	0.49 b	0.51 b	0.48 ab	0.54 b	
LSD (0.05)	V: 0.089		TR: 0.093		V*TR: NS	
LSD (0.05): garden eggs at different TR= NS; okra at different TR=0.12; pepper at different TR=NS						
Canopy diameter (m)						
G eggs	0.56 a	0.70 b	0.63 c	0.60 c	0.81 d	0.66
Okra	0.53 a	0.72 b	0.63 c	0.61 c	0.83 d	0.66
Pepper	0.23 a	0.39 a	0.45 a	0.30 a	0.48 a	0.37
Mean	0.44 a	0.60 b	0.57 c	0.50 d	0.70 e	
LSD (0.05)	V: 0.056		TR: 0.027		V*TR: 0.062	
LSD (0.05): garden eggs at different TR= 0.05; okra at different TR=0.066; pepper at different TR=NS						
Number of fruiting branches						
G eggs	7.00 a	8.00 a	8.00 a	8.00 a	9.00 a	8.00
Okra	2.00 a	3.00 a	3.00 a	3.00 a	4.00 a	3.00
Pepper	11.00 a	15.00 ab	18.00 bc	15.00 ab	19.00 c	14.00
Mean	7.00 a	9.00 bc	9.00 bc	8.00 ab	10.00 c	
LSD (0.05)	V: 3.355		TR: 1.616		V*TR: 3.880	
LSD (0.05): garden eggs at different TR= NS; okra at different TR=NS; pepper at different TR=4.3						
Chlorophyll content						
G eggs	77.80 a	60.70 a	61.50 a	53.90 a	130.90 b	76.90
Okra	23.30 a	32.30 a	29.30 a	29.40 a	43.10 a	31.50
Pepper	45.60 a	70.60 bc	47.50 a	58.70 ab	75.30 c	59.50
Mean	48.90 a	54.50 a	46.10 a	47.30 a	83.10 b	
LSD (0.05)	V:12.16		PBA:11.28		V*PBA:20.13	
LSD (0.05): garden eggs at different TR= 30.87; okra at different TR=NS; pepper at different TR=13.53						

Values in a row followed by the same letters are not significantly different at 5% by LSD test

Table 6. Effect of vegetable type (V) and treatment regime (TR) application on plant growth for the minor season planting

PBA rates / Vegetable	0t/ha PBA	2t/ha PBA	4t/ha PBA	6t/ha PBA	NPK	Mean
Number of days to flowering						
G eggs	49 a	45 bc	46 b	47 b	42 c	46
Okra	39 a	35 b	36 b	38 ab	32 c	36
Pepper	45 a	41 b	44 ab	46 a	39 b	43
Mean	44 a	41 b	42 b	43 ab	38 c	
LSD (0.05): V: 2.672 TR: 1.634 V*TR: NS						
LSD (0.05): garden eggs at different TR= 3.2; okra at different TR=2.9; pepper at different TR=3.0						
Shoot dry matter (t ha^{-1})						
G eggs	0.52 a	0.61 ab	0.64 b	0.59 ab	0.74 c	0.62
Okra	0.56 a	0.68 b	0.58 a	0.59 a	0.73 b	0.63
Pepper	0.24 a	0.26 a	0.26 a	0.25 a	0.32 b	0.27
Mean	0.44 a	0.52 b	0.52 b	0.48 a	0.59 c	
LSD (0.05): V: 0.078 TR: 0.042 V*TR: NS						
LSD (0.05): garden eggs at different TR= 0.098; okra at different TR=0.083; pepper at different TR=0.039						
Canopy diameter						
G eggs	0.55 a	0.74 b	0.64 c	0.60 c	0.82 d	0.67
Okra	0.59 a	0.80 b	0.64 a	0.63 a	0.84 b	0.70
Pepper	0.37 a	0.44 b	0.41 b	0.40 ab	0.56 c	0.53
Mean	0.50 a	0.66 b	0.56 a	0.54 a	0.73 c	
LSD (0.05): V: 0.067 TR: 0.045 V*TR: NS						
LSD (0.05): garden eggs at different TR= 0.085; okra at different TR=0.102; pepper at different TR=0.056						
Number of fruiting branches						
G eggs	7.00 a	8.00 a	10.00 a	8.00 a	10.00 a	9.00
Okra	2.00 a	4.00 b	3.00 c	3.00 c	4.00 b	3.00
Pepper	13.00 a	18.00 b	19.00 b	18.00 b	19.00 b	17.00
Mean	7.00 a	10.00 b	11.00 b	9.00 c	11.00 b	
LSD (0.05) V: 2.564 TR: 1.117 V*TR: 2.873						
LSD (0.05): garden eggs at different TR= NS; okra at different TR=0.545; pepper at different TR=3.078						
Chlorophyll content						
G eggs	69.18 a	54.73 b	52.73 b	45.65 b	79.18 c	60.29
Okra	34.88 a	38.25 a	32.93 a	36.68 a	53.48 b	39.12
Pepper	46.70 a	42.70 a	38.15 a	24.40 b	65.40 c	43.47
Mean	50.25 a	45.23 ab	41.27 b	35.38 d	66.62 e	
LSD (0.05): V: 6.002 TR: 5.239 V*TR: 9.512						
LSD (0.05): garden eggs at different TR= 9.83; okra at different TR=8.57; pepper at different TR=10.73						

Values in a row followed by the same letters are not significantly different at 5% by LSD test

Palm bunch ash application significantly (*P* = .05) increased fruit yield of the vegetables (Tables 7 and 8). In the field experiment and among the PBA treated plots, the highest fresh fruit yield per plant (kg) and fresh fruit yield per hectare (t) were obtained with the application rate of 4t ha^{-1} which was not significantly different from those from the 200 kg ha^{-1} NPK treated plots but almost twice that of the control. There was also significant (P = .05) interaction between the vegetable and the PBA application rate. For the garden egg, the highest fruit yield was obtained at PBA application rate of 4 t ha^{-1} while for the pepper and okra, the highest fruit yield was obtained at 200 kg ha^{-1} NPK. With the garden eggs, fertiliser application resulted in about 91% increase in fresh fruit yield over the control while PBA application resulted in about between 44.9 and 97% increase in fresh fruit yield over the control. In the pepper, fertiliser application resulted in fresh fruit yield increase of about 95% while PBA application resulted in fresh fruit yield increase of about between 68-88%. Similar observations were made in the pot experiment. However in the pot experiment, higher fruit yields were always obtained at application rate of 1tons ha^{-1} PBA+100 kg ha^{-1} NPK while PBA application rate of 2 t ha^{-1} appeared to be the optimum application rate when PBA alone was applied (Table 8). The increased availability and uptake of plant nutrients particularly, N, P and K by the vegetables (Table 5) as a result of PBA and NPK application might have resulted in the higher yields. Higher numbers of fruits as a result of nutrient application have been reported in garden eggs [31] and chilli pepper [33]. Higher number of fruits as a result of nutrient application is attributed to the cumulative effect of plant vegetative growth such as number of leaves, plant height and branches due to balanced nutrition supplied to the plants leading to effective photosynthesis and distribution of the carbohydrates that resulted in the higher number of fruits [34]. Higher number of fruits has also been attributed to large plant canopy size and higher number of fruiting branches due to nutrient application which provided more space for flowering and subsequent higher number of fruits [33]. In this study higher number of fruits (Table 7) was associated with large canopy size and higher number of fruiting branches (Tables 5 and 6). Application of PBA might have also resulted in increased microbial activity in the soil and increased organic matter production with its concomitant increased availability of nutrients such as N, P and K [35; 36]. Increased application of nutrients, particularly, N, P and K has been found to result in yield increase in vegetables such as garden eggs [37; 27; 38;39] and chilli pepper [40].

Table 7. Effect of vegetable type (V) and treatment regime (TR) application on fresh fruit yield

Fresh fruit yield (tons) per hectare of garden eggs and pepper in the major season						
TR / Vegetable	**0t ha^{-1}**	**2t ha^{-1}**	**4t ha^{-1}**	**6t ha^{-1}**	**NPK**	**Mean**
G eggs	4.83 a	7.51 b	9.52 c	7.00 b	9.22 c	7.61
Pepper	3.30 a	6.00 bc	5.96 bc	5.57 b	6.45 c	5.46
Mean	4.06 a	6.75 b	7.74 c	6.28 b	7.84 c	
LSD (0.05):	V: 1.989	TR: 0.687	V*TR: 1.831			
LSD (0.05): garden eggs at different TR = 1.26; pepper at different TR = 0.72						
Fresh fruit yield (tons) per hectare of okra in the minor season						
Okra	2.93 a	4.96 b	3.46 a	3.16 a	5.36 b	7.61
LSD (0.05):	0.957					

Values in a row followed by the same letters are not significantly different at 5% by LSD test

Table 8. Effect of vegetable type (V) and treatment regime (TR) application on fruit yield and yield components of three vegetables grown in the pot

TR / Vegetable	0 t ha^{-1}	2 t ha^{-1}	4 t ha^{-1}	6 t ha^{-1}	NPK	NPK+PBA	Mean
Number of fruits per plant							
G eggs	8.00 a	11.00 b	10.00ab	9.00 ab	15.00 c	15.00 c	11.00
Okra	8.00 a	11.00 b	10.00 ab	9.00 ab	12.00bc	13.00 bc	11.00
Pepper	28.00a	48.00bd	44.00 bc	37.00 c	53.00 de	61.00 e	45.00
Mean	15.00a	23.00 b	21.00 b	18.00 c	27.00 d	30.00 e	
LSD (0.05): V: 1.938 TR: 2.741 V*PBA: 4.748							
LSD (0.05): garden eggs at different TR= 2.59; okra at different TR=2.52; pepper at different TR=8.07							
Fruit girth (cm)							
G eggs	14.33 a	16.12 bc	16.63 b	15.25 c	16.34 bc	16.87 b	15.92
Okra	6.63 a	8.37 b	7.23 c	7.20 c	8.70 bd	8.83 d	7.83
Pepper	3.21 a	3.67 b	3.72 b	3.57 b	3.87 c	4.03 c	3.67
Mean	8.06 a	9.38 b	9.20 b	8.67 c	9.62 d	9.91 d	
LSD (0.05): V: 0.2925 TR: 0.4136 V*PBA: 0.7165							
LSD (0.05): garden eggs at different TR= 1.25; okra at different TR=0.37; pepper at different TR=0.28							
Fruit length (cm)							
G eggs	5.27 a	5.50 ab	5.67 abd	5.33 ac	5.83 b	5.93 d	5.59
Okra	6.97 a	10.07 b	8.33 c	8.13 c	10.83 b	10.33 b	9.11
Pepper	7.80 a	8.60 ab	8.67 ab	8.27 ab	9.07 b	9.07 b	8.60
Mean	6.68 a	8.06 b	7.56 c	7.24 c	8.43 b	8.44 b	
LSD (0.05): V: 0.274 TR: 0.388 V*TR: 0.671							
LSD (0.05): garden eggs at different TR=0.42; okra at different TR=0.59; pepper at different TR=1.02							
Fresh fruit yield/plant (g)							
G eggs	180 a	290 b	250 ab	230 ab	440 c	450 c	310
Okra	60 a	140 b	100 c	80 c	150 b	160 b	120
Pepper	110 a	200 bc	180 b	150 ab	250 cd	270 d	190
Mean	120 a	210 b	180 c	150 d	280 e	300 e	
LSD (0.05): V: 20.00 TR: 29.67 V*TR: 51.38							
LSD (0.05): garden eggs at different TR= 72; okra at different TR=26; pepper at different TR=58							
Dry fruit yield/plant (g)							
G eggs	9.99 a	11.19 ab	11.62 b	11.58 b	13.34 c	13.23 c	11.83
Okra	11.32 a	12.85 a	11.53 a	11.75 a	13.06 a	13.30 a	12.30
Pepper	13.90 a	15.74 b	16.07 bc	15.24 b	17.57 c	17.07 c	15.93
Mean	11.74 a	13.26 b	13.08 b	12.85 b	14.65 c	14.52 c	
LSD (0.05): V: 0.680 TR: 0.962 V*TR: NS							
LSD (0.05): garden eggs at different TR= 1.26; okra at different TR=NS; pepper at different TR=1.60							

Values in a row followed by the same letters are not significantly different at 5% by LSD test

4. CONCLUSION

The study has shown that PBA application can promote vegetative growth and increased yield in garden eggs, okra and pepper. The results also suggest that, PBA can be used as a liming material to correct pH of acidic soils as well as a nutrient supplement in soils with leached nutrients. Application of PBA contributed to the improvement in soil chemical properties of the acid soils used in this study by increasing soil pH and the level of macro nutrients such as N, P, K, Ca and Mg in the soil. Four tons PBA per hectare was the optimal rate for improving vegetative growth and fruit yield in garden eggs while 2 t ha^{-1} proved to be the optimal application rate for pepper and okra. However, where mineral fertiliser is available, yield of vegetables could be improved tremendously if it is supplemented with PBA. The study suggests that small holder vegetable growers in the oil palm growing areas in the country where there is substantial quantities of PBA dotted around oil palm processing mills should be encouraged to adopt the use of PBA as a soil amendment for increased productivity.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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