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ORIGINAL RESEARCH

Effects of palm bunch ash and mycorrhiza on cucumber (*Cucumis sativum* L.) performance on coarse-textured soil of Calabar, Southern Nigeria

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Abstract

Purpose To evaluate the effect of palm bunch ash and mycorrhiza on soil properties and the performance of cucumber in Calabar.

Method Factorial combination of five levels of palm bunch ash – PBA (0, 3, 6, 9 and 12 t/ha) and two mycorrhiza treatments (inoculated and non-inoculated), laid out in randomized complete block design (RCBD) with three replications. Data were collected on crop growth and yield indices, soil properties (physical, chemical and biological) each year, then combined and analyzed. Duncan's Multiple Range Test (DMRT) at 5% probability was used to compare the means.

Results There was increase in soil pH, organic carbon, phosphorus, potassium, calcium and magnesium as a result of PBA and mycorrhiza applications. PBA, mycorrhiza and their interactions significantly (p <.0. 05) influenced the vegetative growth and fruit yield of cucumber. Cucumber treated with 12 t/ha PBA had the highest vegetative growth and fruit yield values, which however were similar with those obtained from cucumber treated with 9 t/ha of PBA. Cucumber inoculated with mycorrhiza had superior growth and fruit yield than non-inoculated cucumber. The interaction of mycorrhiza and 12 t/ha PBA produced the highest values of vegetative growth and fruit yield indices, though similar with the interaction of mycorrhiza and 9 t/ha PBA.

Conclusion Palm bunch ash was sufficient at 9 t/ha and is therefore recommended with mycorrhiza for effective soil nutrient enhancement and optimum cucumber production in Calabar.

Keywords Cucumber, Palm bunch ash, Mycorrhiza, Soil properties, Fruit yield

Introduction

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The productivity of humid tropical soils is constrained mostly by high soil acidity and nutrient fixation due to torrential rainfall and continuous use of inorganic fertilizers in the region. Use of ashes of plant origin as liming material and biofertilizers is a sound soil fertility management technique for these soils (Nwite et al. 2011a, b; Okorie et al. 2017; Ndzeshala et al. 2022). Oil palm bunch ash (PBA) and mycorrhizal biofertilizer could potentially help to increase the productivity of vegetable crops in these soils. Oil palm bunch ash is a product of the incineration of palm bunch refuse, an agricultural waste product of palm oil milling (Awodun et al. 2007). The incineration of palm bunch refuse after the ripped fruits have been extracted for further processing into palm oil saves the environment from imminent pollution by palm bunch refuse dumps (Adjei-Nsiah and Obeng 2013). The resultant ash has high pH and contains essential plant nutrients such as potassium, calcium, magnesium, phosphorus and nitrogen (Mbah et al. 2010), and could be used as liming material, fertilizer supplement (Awodun et al. 2007), and organic fertilizer (Law-Ogbomo and Ogedegbe 2019). The works of Ojeniyi et al. (2009), Awodun et al. (2007) and Adjei-Nsiah and Obeng (2013) showed that the use of PBA as organic fertilizer increased soil pH, organic matter content, available nutrients, microbial activities in the soil and enhanced the yield of cassava, maize and garden egg, respectively.

Effective soil management approach can integrate biofertilizers such as mycorrhiza to achieve a low-cost sustainable agricultural system. Mycorrhizal fungi improve soil quality (Denison and Kiers 2011; Xie et al. 2013) and have positive effects on the growth and yield of their host plant (Babaj et al. 2014) and could be adopted in organic cucumber farming (Wang et al. 2008). Cucumber is a vegetable belonging to the Cucurbitaceae family, cultivated mainly for its fruits that are very rich sources of vitamins and minerals. The crop has both nutritional and medicinal values making it to be in very high demand in both local and international market (Ogunezi et al. 2019). The symbiotic cucumber root-mycorrhizal fungal association can facilitate the absorption of water beyond the root zone of cucumber (Ortas 2010), improve the uptake of most fixed soil nutrients such as phosphorus, zinc and manganese (Cagras et al. 2000) and enhance the availability and accessibility of nitrogen, copper and magnesium (Wang et al. 2008).

As noted by Babaj et al. (2014), the fungi develop a dense hyphal network that extends far into the soil while still remaining connected to the root. This extra radical mycelium provides the plant with water and nutrients that would otherwise remain inaccessible to roots. AMF inoculation considerably promoted the uptake of nitrogen, phosphorus, potassium, increased chlorophyll (a, b), total chlorophyll, and carotenoid contents, and enhanced the essential oil yield of tobacco (Begum et al. 2021). Generally, this association can help the cucumber crop adjust to soil salinity and drought stresses (Aggarwal et al. 2012, Augé et al. 2015), increase the ability of the cucumber plant to resist soil-borne diseases and pests (Al-karaki 2006), inhibit the leaching of nitrogen (He et al. 2021), increase photosynthetic efficiency, stimulate the production of growth regulating hormones (Ortas 2010) and increase the physiological and ecological fitness of the crop (Babaj et al. 2014).

There is dearth of information on the effect of PBA and mycorrhiza on the production of cucumber on the coarse-textured soil of Calabar, Nigeria, thus, necessitating this present research.

Materials and methods

A field experiment was conducted in the 2020 and 2021 early cropping seasons at the University of Calabar Teaching and Research Farm, Calabar, Nigeria. Calabar (Fig. 1) is located at the southeastern rainforest agro-ecological zone of southern Nigeria (4.5^0N - 5.2^0N, 8.3^{0}E; about 39 m above sea level), and has a bimodal annual rainfall distribution that ranges from 3,000 to 3,500 mm with mean annual temperature range of 27 - 35^{0}C and relative humidity of 75% to 88% (Efiong 2011). The experiment was a 5 x 2 factorial laid out in Randomized Complete Block Design (RCBD) with three replications. Each replication comprised ten treatment combinations of five PBA levels (0, 3, 6, 9 and 12 t/ha) and two mycorrhizal treatments (inoculated and non-inoculated). The experimental area was a gross plot measuring 24 m × 25 m (600 m^2) mapped out into 30 uniform experimental units of 3 m × 4 m (12 m^2) separated by 1 m paths between blocks and 0.5 m between treatment plots within a replicate. Empty oil palm bunches were obtained from University of Calabar Teaching and Research Oil Palm Plantation, incinerated to ash and allowed a few days to cool. The PBA was added at the rates of 3.6, 7.2, 10.8 and 14.4 kg per the 12 m^2 plot according to treatment specifications and field randomization, equivalent to 3, 6, 9 and 12 t/ha respectively. The PBA thoroughly mixed up to 30 cm into the soils during seedbed preparation before sowing of cucumber seeds. Seeds of marketer cucumber variety were sourced from Cross River Agricultural Development Project (CRADP) and sown at 30 cm × 100 cm spacing, two per hole, and later thinned to one, giving a population of 30,000 plants per hectare. Seven days after seedling emergence, spores of Acaulospora Mycorrhiza fungi were inoculated on the rhizosphere soil of each cucumber seedling receiving mycorrhiza treatment, by placing 10 g of inoculum containing about 1000 spores around the root zone. Plant growth and fruit yield data were collected, including vine length, number of leaves, leaf area index (LAI), number of fruits per plant, fruit length, fruit girth and fruit yield per hectare. Data were collected from six middle plants per plot and subjected to analysis of variance (ANOVA) procedures for factorial experiments in randomized complete block design (RCBD) using the GenStat Package Version 8.1 of 2015. Means were compared using the Duncan's multiple range test (DMRT) method at 5% level of probability as described by Wahua (2010). The LAI was calculated using LA / GC as described by Blanco and Follegatti (2003), where LA is leaf area = L × B × 0.85 (L = length, B = breadth, 0.85 = correction factor) and GC is ground coverage or plant spacing = 30 cm × 100 cm.

Composite soil samples were taken randomly 5 meters apart at a depth of 0 – 30 cm pre- and post-cropping in each of the study years using soil auger. Sub-sample was removed from the composite sample obtained, for microbiological analysis and the remaining was air-dried, ground and sieved through a 2 mm sieve and closed in plastic bags for physico-chemical analyses following the procedures described by Udo et al. (2009). Mycorrhizal fungi spores were isolated from 100 g soil in the Department of Soil Science Research Laboratory, University of Calabar, Calabar, by wet sieving and decanting techniques as described by Gerdemann and Nicolson (1963). Mycorrhizal colonization was determined following the method described by Giovanneti and Mosse (1980). In this technique, feeder roots of cucumber plants in the net plot were washed and bleached by soaking in 10% KOH for 24 h and acid-stained with 70% glycerol. Thereafter, Giovannetti and Mosse (1980) grid-line counting intersect method, under dissecting Microscope was used to obtain the colonization. Percentage mycorrhizal colonization was thereafter determined using the formula described by Giovanneti and Mosse (1980):

$$\frac{\text{No. of roots/intersect with colonization}}{\text{Total number of roots/grid line intersect counted}} \times \frac{100}{1}$$

Results and discussion

Properties of PBA and soils of the experimental site

The chemical properties of PBA used for the experiment as well as the physico-chemical and biological properties of the pre- and post-cropping soils of the experimental site are presented in Table 1. Analysis of the PBA showed that it was alkaline with pH of 8.47 and had very high contents of potassium, magnesium, calcium, phosphorous and organic carbon, but moderate content of sodium and low content of total nitrogen. The textural class was sandy loam pre- and post-cropping. The soil pH, organic carbon, organic matter, potassium, magnesium, sodium, effective cation exchange capacity (ECEC) and base saturation all increased post cropping. The values of total nitrogen and exchangeable acidity (H^+) slightly decreased post cropping. The mycorrhizal spore count and percentage colonization increased post cropping. The increase in mycorrhizal spore count and percentage colonization of the soil post cropping suggests a successful association of the mycorrhizal fungi with the roots of cucumber and a positive influence on the rhizosphere soil. This observation is in tandem with the reports of Xie et al. (2013), that mycorrhiza improves the soil health and productivity.

Fig. 1 Map of Cross River showing the location of Calabar

The increase in the organic carbon contents of the soil post cropping suggests that the added PBA had enhanced the availability of organic materials to the soil which may have improved the soil microclimate by providing organic substrate to soil organisms. This observation corroborates the works of Awodun et al. (2007); Ojeniyi et al. (2009) and, Adjei-Nsiah and Obeng (2013). Also, the activities of the mycorrhizal fungi may have enhanced the soil quality as averred by Xie et al. (2013). The increased soil pH, calcium, organic matter, sodium, organic carbon, potassium, magnesium, effective cation exchange capacity (ECEC) and base saturation post cropping suggests that organic soil amendments such as PBA and mycorrhizal fungi could reduce the acidity of the soil and enhance the availability of essential soil nutrients.

This observation is at par with the findings of Cagras et al. (2000), Ortas (2010), Adjei-Nsiah and Obeng (2013) and Law-Ogbomo and Ogedegbe (2019).

Table 1 Properties of PBA and soils of the experimental site

	Palm bunch ash	Preplanting soil	Soil after harvest
Biological properties			
Mycorrhizal spores/100 g soil	-	2	134
Mycorrhizal colonization (%)		0.02	65.33
Physical properties			
Sand (%)	-	87.04	75.22
Silt (%)	-	7.65	12.03
Clay (%)	-	5.31	12.75
Texture	-	Loamy sand	Loamy sand
Chemical properties			
pH (H_2O)	8.74	5.5	6.84
Organic carbon (%)	32.88	1.91	25.89
Total nitrogen (%)	0.41	0.14	0.12
Available phosphorus (mg/kg)	124.00	67.01	88.50
Exchangeable potassium (cmol/kg)	68.19	0.19	20.88
Exchangeable calcium (cmol/kg)	45.34	6.00	16.44
Exchangeable magnesium (cmol/kg)	47.29	1.80	16.32
Exchangeable sodium (cmol/kg)	9.54	0.07	4.25
Exchange acidity (H^+)	-	1.23	0.88
Effective cation exchange capacity(cmol/kg)	-	9.29	58.77
Base saturation (%)	-	86.75	98.50

Effects of PBA and mycorrhiza on the growth parameters of cucumber

The effects of PBA and mycorrhiza, and their interaction effects on the growth parameters of cucumber at 4, 8 and 12 WAP are presented in Table 2. Results indicated significant effects of PBA on all the growth parameters of cucumber measured across the sampling periods. The longest vines were obtained from the plots treated with 12 t/ha of PBA across the sampling periods while the shortest vines were obtained from the plot without PBA application (control). However, at 8 and 12 WAP, the length of vines obtained from plots treated with 9 and 12 t/ha of PBA were statistically similar ($P > 0.05$). Significantly more vines were obtained from the plots treated with 12 t/ha of PBA across the sampling periods which however, were similar with those obtained from the plots treated with 9 t/ha of PBA, while the lowest values were obtained from the plots not treated with PBA.

Table 2 Effect of PBA and mycorrhiza on vine length, number of leaves and leaf area index of cucumber

Treatment	Vine length (cm)			Number of leaves			Leaf area index		
	4WAP	6WAP	8WAP	4WAP	6WAP	8WAP	4WAP	6WAP	8WAP
Palm bunch ash – PBA									
0 t/ha (PBA0)	12.07^{d}	47.20^{c}	61.60^{d}	6.01^{b}	17.70^{c}	24.95^{d}	0.09^{d}	0.56^{c}	1.40^{c}
3 t/ha (PBA3)	18.72^{c}	71.70^{b}	80.10^{c}	6.72^{b}	22.05^{b}	31.07^{c}	0.17^{c}	1.15^{b}	2.11^{b}
6 t/ha (PBA6)	19.48^{c}	78.50^{ab}	111.00^{b}	8.48^{ab}	24.61^{b}	38.21^{b}	0.22^{b}	1.30^{b}	2.38^{b}
9 t/ha (PBA9)	21.82^{b}	83.50^{a}	119.80^{ab}	9.24^{a}	25.31^{ab}	46.62^{a}	0.22^{b}	1.35^{b}	2.50^{ab}
12 t/ha (PBA12)	26.04^{a}	86.70^{a}	132.70^{a}	10.24^{a}	28.76^{a}	50.36^{a}	0.27^{a}	1.64^{a}	2.90^{a}
Mycorrhiza – M									
No inoculation (M0)	16.13^{b}	60.90^{b}	82.20^{b}	6.31^{b}	20.59^{b}	33.79^{b}	0.16^{b}	1.06^{b}	1.98^{b}
Inoculated (M1)	23.12^{a}	86.20^{a}	119.90^{a}	9.97^{a}	26.78^{a}	42.69^{a}	0.23^{a}	1.34^{a}	2.54^{a}
PBA X M									
PBA0 x M0	10.11^{g}	41.40^{e}	54.10^{e}	4.96^{c}	13.76^{e}	23.25^{e}	0.08^{e}	0.45^{d}	1.09^{d}
PBA0 x M1	14.02^{f}	53.10^{de}	69.10^{de}	7.07^{bc}	21.63^{cd}	26.66^{de}	0.11^{de}	0.69^{d}	1.71^{cd}
PBA3 x M0	15.36^{f}	63.00^{d}	70.00^{de}	5.76^{c}	19.95^{d}	26.64^{de}	0.13^{d}	1.04^{c}	1.98^{bc}
PBA3 x M1	22.08^{bc}	80.40^{bc}	90.30^{cd}	7.68^{bc}	24.16^{bcd}	35.50^{c}	0.21^{c}	1.25^{bc}	2.25^{bc}
PBA6 x M0	16.34^{ef}	64.50^{cd}	80.40^{cd}	6.44^{c}	22.66^{bcd}	34.72^{cd}	0.19^{c}	1.21^{bc}	2.21^{bc}
PBA6 x M1	22.61^{bc}	92.60^{ab}	141.50^{a}	10.53^{ab}	26.56^{bc}	41.69^{bc}	0.25^{b}	1.38^{b}	2.55^{b}
PBA9 x M0	18.66^{de}	66.90^{cd}	93.90^{bc}	6.94^{bc}	22.20^{cd}	39.36^{bc}	0.19^{c}	1.29^{bc}	2.25^{bc}
PBA9 x M1	24.98^{b}	100.10^{a}	145.80^{a}	11.53^{a}	28.42^{ab}	53.88^{a}	0.25^{b}	1.41^{b}	2.75^{ab}
PBA12 x M0	20.18^{cd}	68.70^{cd}	112.80^{b}	7.43^{bc}	24.39^{bcd}	44.98^{b}	0.21^{c}	1.32^{bc}	2.39^{bc}
PBA12 x M1	31.90^{a}	104.70^{a}	152.70^{a}	13.05^{a}	33.14^{a}	55.74^{a}	0.34^{a}	1.96^{a}	3.42^{a}

In a column, means followed by the same letter are not significantly different by DNMRT at 5 % probability level; Key: WAP:weeks after planting

The highest LAI values were obtained from the plots treated with 12 t/ha of PBA across the sampling periods while the lowest values were obtained from the plot without PBA application. However, at 12 WAP, the LAI values obtained from plots treated with 9 and 12 t/ha of PBA were statistically similar ($P > 0.05$). The effects of mycorrhiza on all the growth parameters of cucumber measured across the sampling period were significant ($P \leq 0.05$). Longer vines with more leaves and higher LAI were obtained from the plots treated with mycorrhiza compared with those not treated with mycorrhiza. The interaction of PBA and mycorrhiza on the growth parameters of cucumber measured was significant ($P \leq 0.05$) across the sampling periods. The longest vines with more leaves and higher LAI were obtained with the combination of 12 t/ha PBA and mycorrhiza, which however, were statistically similar with those obtained from the combination of 9 t/ha of PBA and mycorrhiza, while the lowest values were obtained from the plots treated with neither PBA nor mycorrhiza. The superior vegetative growth characteristics observed on the cucumber plants treated with PBA relative to those not treated with PBA could be attributed to the richness of the PBA in organic carbon and essential plant nutrients such as phosphorus, potassium, calcium and magnesium, which might have improved the rhizosphere soil health and productivity to the benefit of the cucumber crop. This observation is consistent with the results obtained from the evaluation of PBA application on other fruit vegetables (Ojeniyi et al. 2010; Adjei-Nsiah 2012; Adikuru et al. 2016). The differences observed in the vegetative growth characteristics of cucumber across the various rates of PBA used in this present research, suggest that mineral nutrients essential for the growth of cucumber abound in PBA, varying with the amount of PBA applied. This observation is consistent with the works of Awodun et al. (2007) and Adjei-Nsiah and Obeng (2013), who averred that basic plant nutrients abound in PBA. The similarity observed in the vegetative growth characteristics of cucumber treated with 9 and 12 t/ha PBA, suggests that 9 t/ha might be the PBA rate for optimum cucumber production in Calabar. Similarly, Law-Ogbomo and Ogedegbe (2019), while working on the effect of PBA on cucumber production in Benin, observed 8 t/ha of PBA to optimally enhance the performance of the crop. The superior performance of cucumber inoculated with mycorrhiza relative to those without mycorrhiza suggests that the symbiotic cucumber root-mycorrhizal fungal association was beneficial to the crop. These benefits have been reported to include enabling the absorption of water beyond the root zone of the host crop (Ortas 2010), enhancing the availability and absorption of fixed soil nutrients (Wang et al. 2008), conferring protection against soil pathogens (Al-karaki 2006; Boutaj et al. 2022), and helping the crop adjust to moisture and salt stresses (Aggarwal et al. 2012; Augé et al. 2015).

Effect of PBA and mycorrhiza on cucumber fruit yield indices

The effects of PBA and mycorrhiza, and their interaction effects on cucumber fruit yield indices are presented in Table 3. Results indicated significant effect of PBA on all the fruit yield indices measured. Higher number of fruits per plant (5.26), longer fruits (13.65 cm), thicker fruits (4.84 cm) and higher fruit yield (25.86 t/ha) were obtained from the plots treated with 12 t/ha of PBA, which however, were similar with those obtained from 9 t/ha of PBA, while the lowest values were obtained from the plots without PBA application (control).

Table 3 Effect of PBA and mycorrhiza on cucumber fruit yield indices

Treatment	Number of fruits per plant	Fruit length (cm)	Fruit diameter (cm)	Fruit yield (t/ha)
Palm bunch ash – PBA				
0 t/ha (PBA0)	1.42 d	7.95 d	3.56 c	6.19 c
3 t/ha (PBA3)	2.43 c	9.62 cd	3.88 bc	16.23 b
6 t/ha (PBA6)	3.03 c	11.36 bc	4.54 ab	18.62 b
9 t/ha (PBA9)	4.26 b	12.75 ab	4.66 ab	21.37 ab
12 t/ha (PBA12)	5.26 a	13.65 a	4.84 a	25.86 a
Mycorrhiza – M				
No inoculation (M0)	2.76 b	10.02 b	3.96 a	14.31 b
Inoculated (M1)	3.80 a	12.12 a	4.63 a	21.00 a
PBA X M				
PBA0 x M0	1.09 f	7.49 e	3.53 c	5.11 f
PBA0 x M1	1.74 ef	8.40 e	3.68 c	7.26 ef
PBA3 x M0	2.24 def	9.13 de	3.74 bc	12.18 def
PBA3 x M1	2.61 de	10.11 cde	4.01 abc	20.29 bcd
PBA6 x M0	2.71 de	10.04 cde	4.03 abc	15.26 cde
PBA6 x M1	3.36 cd	12.69 bc	5.06 ab	21.98 bc
PBA9 x M0	3.41 cd	11.63 bcd	4.13 abc	18.26 bcd
PBA9 x M1	5.11 ab	13.88 ab	5.19 a	24.47 ab
PBA12 x M0	4.33 bc	11.80 bcd	4.37 abc	20.73 bcd
PBA12 x M1	6.19 a	15.50 a	5.31 a	30.99 a

In a column, means followed by the same letter are not significantly different by DNMRT at 5 % probability level

The effects of mycorrhiza on all the fruit yield indices measured were also significant ($P \leq 0.05$), except for fruit girth. Higher number of fruits per plant (3.80), longer fruits (12.12 cm) and higher fruit yield (21.00 t/ha) were obtained from the plots treated with mycorrhiza compared with the non-mycorrhizal treatment. The interaction effects of PBA and mycorrhiza on all the fruit yield indices measured were significant ($P \leq 0.05$). The highest values for number of fruits per plant, fruit length, fruit girth and fruit yield per hectare were obtained from the combination of 12 t/ha PBA and mycorrhiza, which however, were similar with those obtained from the combination of 9 t/ha of PBA and mycorrhiza, while the lowest values were obtained from the plots treated with neither PBA nor mycorrhiza. The higher fruit yield obtained from cucumber plants treated with

PBA relative to those not treated with PBA suggests that the enhancement of vegetative growth of cucumber by PBA was translated into higher yield. Also, the PBA must have released enough nutrients that benefited the cucumber plant from the seedling stage through the reproductive phase. Reports on the effects of PBA showed significant increase in yield on other crops such as garden egg, pepper, okra (Adjei-Nsiah and Obeng 2013); maize (Awodun et al. 2007, Ojeniyi et al. 2010, Mbah et al. 2010, Adjei-Nsiah 2012, Adikuru et al. 2016) and cassava (Ojeniyi et al. 2009). The longest and broadest fruits as well as the highest fruit yield were obtained from cucumber plants treated with 12 t/ha PBA and 9 t/ha PBA rates, suggesting that the essential elements for optimum cucumber productivity abounds in PBA and that the rate to 9 t/ha will sufficiently support the cucumber crop through the reproduction phase. Similarly, Law-Ogbomo and Ogedegbe (2019) observed that the application of PBA at 6 and 8 t/ha rates significantly increased fruit length, girth, size and yield. The PBA's promotion of cucumber growth and yield in the present study may be summarized by its soil-liming ability and the associated positive effect on 'physical' fertility of the soil that influences cucumber development and which could even be guide more reliably the choice of optimum application rate of this soil amendment (Ebido et al. 2021). The higher fruit yield of cucumber plants treated with mycorrhiza as compared with those without mycorrhiza suggests that the symbiotic cucumber root-mycorrhizal fungal association enhanced the vegetative growth which translated into superior fruit yield.

This observation is consistent with the findings of Wang et al. (2008), Hu et al. (2010), Xie et al. (2013) and Augé et al. (2015). Habibzadeh (2015) averred that the symbiotic mycorrhizal plant roots association makes sufficient nutrients available to plants which is translated into high photosynthetic assimilate accumulation.

The longest and broadest fruits as well as the highest fruit yield obtained from cucumber plants treated with a combination of mycorrhiza and 12 t/ha PBA or 9 t/ha PBA rates suggest a synergistic effect of the interaction of PBA and mycorrhiza. The organic carbon in the PBA must have benefited the mycorrhizal fungi and the cucumber crop altogether. This observation is in consonant with Smith and Read (2008) and Xie et al. (2013) who averred that mycorrhizal fungi depend solely on external source of carbon which is achieved in a mutualistic association.

Conclusion

Mycorrhizal-plant root mutualistic symbiosis improves the plant's efficiency for uptake of mineral nutrients while PBA boosts soil pH and provides essential soil nutrients such as potassium. In this study, the pre- and post-cropping composite soil analysis showed that soil pH, organic carbon, potassium, magnesium, sodium, effective cation exchange capacity (ECEC) and base saturation increased post cropping as well as mycorrhizal spore count and percentage colonization. The application of PBA and mycorrhiza significantly enhanced the vegetative growth and fruit yield of cucumber. The interaction of PBA and mycorrhiza resulted in synergistic effect that enhanced the vegetative growth and fruit yield of cucumber. Palm bunch ash was optimum at 9 t/ha with or without combination with mycorrhiza whose positive effects on cucumber growth and yield were also evident. Therefore, a combination of 9 t/ha PBA and mycorrhiza inoculation is recommended for optimum cucumber production in Calabar, Nigeria.

Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest associated with this study.

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