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Effects of Organic and Inorganic Nutrient Sources on the Growth, Total Chlorophyll and Yield of Three Bambara Groundnut Landraces in the Coastal Region of Cameroon

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Abstract: Growth and yield parameters of bambara groundnut [*Vigna subterranea* L. Verdc. landraces: White Seed Coat (WSC), Black Seed Coat (BSC) and Light Red Seed Coat (RSC)] were evaluated under organic and inorganic fertilization in order to determine the field performance, for the improvement of smallholder agriculture in Cameroon. Four fertilizer application rates (0, 3, 6 and 12 t ha^{-1}) of Water Lettuce (WL) and Poultry Manure (PM) and four fertilization rates (0, 100, 150 and 200 kg ha^{-1}) of N, P and K were used in a randomized complete block design experiment with four replications. Application of WL or PM at 12 t ha^{-1} significantly ($p<0.001$) increased leaf water content, plant dry weight and total chlorophyll content in RSC landrace. Application of PM at 12 t ha^{-1} increased significantly ($p<0.001$) the number of pods per plant, the number of seeds per pods, the 1000 grain weight, the grain yield and the pod yield in RSC landrace. Significant ($p<0.001$) increase in plant dry weight was observed in all landraces at 100 kg ha^{-1} N, P or K fertilization. The fertilization rates above 100 kg ha^{-1} N, P or K led to a decline in yield in all the bambara groundnut landraces compared to the optimum 100 kg ha^{-1} N, P or K fertilization. RSC landrace showed better growth and yield than WSC and BSC landraces revealing a greater response of this cultivar to fertilization.

Key words: *Vigna subterranea*, organic fertilization, mineral fertilization, growth, yield

INTRODUCTION

Bambara groundnut is an edible legume which serves as one of the main sources of income for small holder farmers. The seeds contain sufficient quantities of protein (19%), carbohydrate (63%), fat (6.5%) and essential amino acids such as lysine, cysteine and methionine (Oliveira, 1976; Linnemann, 1988; Brough and Azam-Ali, 1992). It is cultivated in altitude ranging from 0-1550 m and is generally intercropped with cereals, cassava, yam and cow pea. By fixing atmospheric nitrogen, bambara groundnut improves the soil supply of nitrogen that is of benefit to other crops (Mukurumbira, 1985). In Cameroon, the cultivation of bambara groundnut is located in the coastal region, characterized by yellow ferralitic soil, with low levels of fertility due to sandy structure (Duchaufour, 1976). Although, it is still considered a delicacy by the communities which use Bambara groundnut in Cameroon, current levels of production are lower than those of the past. Since the nitrogen requirement is met through natural N fixation, interest has been developed in cultivating bambara groundnut for its tremendous potentials (Somasegaran *et al*., 1992; European Union, 1997).

Crop production in Sub-Saharan Africa is hindered by several factors such as drought, low soil fertility as well as restricted access to mineral fertilizers (Nyamangara and Nyagumbo, 2010). In Cameroon, farmers are always faced with the problem of soil fertility decline which has been considered as the most important biophysical constraints to crop yield and productivity (Odendo *et al*., 2004). Integration of organic fertilizers such as green manure and poultry manure into the farming systems can be a cheaper alternative to alleviating low soil fertility and erosion problems (Odendo *et al*., 2004). Numerous studies have shown the positive influence of green manure on growth and yield of maize (Hairiah and Noordwijk, 1989; Ayuke *et al*., 2004; Nziguheba *et al*., 2004) and wheat (Marschner and McNeill *et al*., 2011). This can, in part, be due to nutrients released by the decomposing green manure (Leconte *et al*., 2011). Large-scale investigations over many years on the cultivation of

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water lettuce on various effluents have shown that they give an increase in leaves and stems biomass of up to 1 kg m^{-2} and more per day, which amounts to 1800-2700 t of raw material or 90-135 t (Shoyakubov and Aitmetova, 1999). Investigation to use the plant as green manure to enhance growth and yield of crops are not well documented (Edema *et al*., 2007).

Poultry manure is a nutrient source for crop production (Perkins, 1964; Boateng *et al*., 2006; Schomberg *et al*., 2011). Poultry manure amendment has been shown to increase soil organic C, total N and available P (Lv *et al*., 2011). Incorporation of poultry manure into soil promoted transformation and mineralization of less-labile inorganic and organic P into labile-P_i in the rhizosphere, which resulted in higher root P concentrations and higher total P uptake by plants (Waldrip *et al*., 2011). The poultry manure could be a valuable fertilizer and could serve as a suitable alternative to chemical fertilizer in the coastal region of Cameroon. However, there seems to be little use of green and poultry manure in Cameroon and there is little knowledge available on their effects on crops for efficient utilization.

Developing soil fertility management options for increasing productivity of stable food crops is a challenge in most parts of sub-Saharan Africa, where soils are constrained by nitrogen and phosphorus deficiencies (Jemo *et al*., 2010; Tauro *et al*., 2010). Nitrogen, phosphorus and potassium are among the limiting nutrients for cereals and food legumes production (Christianson and Vlek, 1991; Manu *et al*., 1991). Adequate supply of nitrogen is beneficial for carbohydrates and protein metabolism, promoting cell division and cell enlargement (Shehu *et al*., 2010). Similarly, good supply of P is usually associated with increased root density and proliferation which aid in extensive exploration and supply of nutrients and water to the growing plant parts, resulting in increased growth and yield traits (Maiti and Jana, 1985). Due to the vital role that potassium plays in plant growth and metabolism, potassium-deficient plants show a very general phenotype, which is characterized by reduced growth, photosynthesis and impaired osmoregulation and transpiration (Amtmann *et al*., 2006). Numerous studies have shown the positive influence of potassium, phosphorus and nitrogen on growth and yield of soybean and maize (MMhango *et al*., 2008; Anyanzwa *et al*., 2010; Tauro *et al*., 2010), on rice (Bado *et al*., 2010) and groundnut (Bala *et al*., 2011). Nutrients exported from the soil through harvested biomass or loss from soil by gaseous loss, leaching, or erosion must be replaced with nutrients from external sources. The judicious use of chemical fertilizer is also essential to maintain soil fertility (Hossner and Juo, 1999). There is little knowledge available on the effects of the chemical fertilizers on bambara groundnut for efficient utilization. Therefore, this study was undertaken to evaluate the effects of organic and inorganic nutrient sources on the growth, total chlorophyll and yield of three bambara groundnut landraces grown in field conditions.

MATERIALS AND METHODS

Site description: The field experiments were conducted during the 2009 and 2010 cropping seasons at the University of Douala research farm (4°01 N, 9°44 E, 13 m.a.s.l.), in the coastal region of Cameroon. The climate belongs to the equatorial domain of a particular type called Cameroonian characteristics by two seasons with a lengthy rainy season (at least 9 months), abundant rainfalls (about 3597 mm per year), high and stable temperatures (26.7°C). The relative humidity remains high the whole year and near to 100%. The soil of the experimental site is classified as yellow ferralitic soil.

Field experiment: Three bambara groundnut (*Vigna subterranea* L. Verdc.) landraces were used in this experiment: White Seed Coat (WSC), Black Seed Coat (BSC) and light Red Seed Coat (RSC). Seeds were provided by the breeding program of the Agronomic Institute for Research and Development (IRAD, Dschang). The experiment was in a randomized complete block design with four replicates. The plots measuring 4×4 m, comprised of four fertilizer application rates (0, 3, 6, 12 t ha^{-1}) each of Water Lettuce (WL) and Poultry Manure (PM) and four fertilization rates (0, 100, 150 and 200 kg ha^{-1}) each of N, P and K. The field was ridged 0.75 m apart with intra-row spacing of 0.40 m, three seeds were sown per hill and the seedlings thinned to one plant per hill 1 Week after Sowing (WAS) to give a population of 62500 plant ha^{-1} (Taffouo *et al*., 2008). The amendment in each case was applied 3 WAS. The water lettuce was collected from lakes around Douala while the poultry manure was provided by a commercial chicken production. Selected water lettuce and poultry manure chemical properties are shown in Table 1. Nitrogen was applied as urea (46% N), while phosphorus and potassium were applied as single superphosphate (7.9% P) and muriate of potash (49.8% K), respectively. Thiodan (endosulfan organochlorine insecticide) was applied as pre-emergence weed control measure and supplementary hoe-weeding was done at 4 and 8 WAS. Parameters assessed at harvest were plant dry weight, water content,

Table 1: Nutrient contents of water lettuce and poultry manure

	Nutrient concentration (g kg^{-1})					
Nutrient source	N	P	K	Ca	Mg	Na
Water lettuce	127.16	87.62	214.34	101.59	23.95	12.37
Poultry manure	21.76	8.74	11.22	13.80	6.23	2.67

plant height, total chlorophyll, number of pods per plant, number of seeds per pods, 1000 grain weight, grain and pod yields.

Soil, water lettuce and poultry manure sampling and analysis: Soil samples from 0-20 cm depth of the experimental site were taken to analysis physicochemical properties at the start of the experiment. Ten sub-samples were randomly taken and thoroughly mixed to make a composite sample which were air-dried and passed through a 2 mm sieve before analysis (Table 2). Water lettuce samples which were collected from lakes around Douala were washed with distilled water, pressed under blotting paper and their fresh weight recorded. Afterwards, the plant samples were air-dried, ground and sieved through a 2 mm sieve. Poultry manure was stored in an airtight container at 22°C for approximately 1 year before use. The following chemical analyses were done on the soil, water lettuce and poultry manure. Organic carbon (C) was determined by the wet oxidation procedure (Walkley and Black, 1934) and total Nitrogen (N) by micro-Kjeldahl digestion method. Magnesium (mg) was extracted using the Mehlich 3 method and determined by auto analyser (Technicon 2). The total and available soil Phosphorus (P) were determined by the method of Okalebo *et al.* (1993). Soil pH was measured potentiometrically in 1:2.5 soil: water mixture. Calcium (Ca), potassium (K) and sodium (Na) were determined by aflame photometer (JENWAY) as described by Taffouo *et al.* (2008).

Plant samples analysis: Plants were sampled at complete maturity, i.e. 12 WAS for dry weight, water content of aerial parts, plant height, total chlorophyll, number of pods per plant, number of seeds per pods, 1000 grain weight, grain and pod yield. Ten plants were randomly tagged per plot from which periodic measurement of plant height were made at 4, 8 and 12 WAS. Ten plants were also randomly chosen in each plot and their aerial parts cut at ground level and their fresh weight and water content recorded. A representative subsample of about 1000 g per plot was oven-dried at 70°C for 72 h for plant dry weight determination. Fresh pods were carefully removed from the soil and the number of seeds per pods was determined. Leaf chlorophyll content was determined from ten plants. Leaf tissues samples (2.0 g) were crushed in a mortar and tissues were homogenised using 80% acetone. The absorbance of the extract was then measured at 645 and 663 nm wavelengths for chlorophyll a and b, respectively (Arnon, 1949). Data are presented in term of mean (±SD). Multiple comparisons of several means were done using Analysis of Variance (ANOVA) and the post-hoc pairwise analysis was done using the Student-Newman-Keuls procedure. Multiple comparisons of data noted in experimental groups *versus* those recorded in the single control group were set up using the Dunnett's procedure (Sigma Stat software 2.03).

Table 2: Physicochemical properties of the soil taken from 0-20 cm depth of the experimental site in Douala, Cameroon

Properties	Mean	SEM
Clay (%)	14.20	1.20
Coarse sand (%)	27.90	2.10
Fine sand (%)	25.60	1.80
Coarse silt (%)	26.00	1.60
Fine silt (%)	6.30	0.50
Nitrogen (%)	0.32	0.01
Organic C (%)	0.75	0.05
Ratio C/N	2.34	0.02
Phosphorus (ppm)	4.60	0.10
Potassium (g kg^{-1})	0.25	0.02
Sodium (g kg^{-1})	0.07	0.01
Calcium (g kg^{-1})	0.23	0.01
Magnesium (g kg^{-1})	0.17	0.01
pH- water	6.45	0.10

RESULTS

Effects of water lettuce and poultry manure application on leaf water content: Leaf water content significantly ($p<0.01$) increased in all bambara groundnut cultivars with increasing Water Lettuce (WL) and Poultry Manure (PM) fertilization rates (Table 3). The highest value of 66.0% DW was observed in RSC landrace at the highest application rate (12 t ha^{-1}) of WL (Table 3). Moreover, the application of PM at 12 t ha^{-1} increased the leaf water content from 43.1 to 61.2% DW in RSC landrace (Table 3).

Effects of water lettuce and poultry manure application on growth and yield parameters: Application of water lettuce and poultry manure affected plant dry weight and plant height of bambara groundnut landraces (Table 3). Application of WL at 12 t ha^{-1} significantly ($p<0.001$) increased the plant dry weight of WSC landrace from 27.1 to 45.4 g $plant^{-1}$ (Table 3). The highest increase in plant height (from 21.6-41.0 cm) was recorded in BSC landrace under WL treatment at 12 t ha^{-1} (Table 3). The application of PM positively influenced the growth parameters studied in all cultivars with increasing fertilization rates (Table 3). Plant dry weight and plant height were considerably increased from 29.5 to 52.2 g $plant^{-1}$ and 17.8- 32.8 cm, respectively in RSC cultivar when PM was applied at 12 t ha^{-1} (Table 3).

The yield parameters of bambara groundnut landrace were positively influenced by application of WL and PM 12 WAS (Table 4). For the landraces, the number of pods per plant, the number of seeds per pods, the 1000 grain weight, the pod yield and grain yield were increased with

Table 3: Effects of water lettuce and poultry manure fertilization rates on growth parameters and total chlorophyll concentrations (mg g^{-1}) of Bambara groundnut landraces (12 WAS)

			Growth parameters			
Bambara groundnut landraces	Nutrient sources	Treatments (t ha^{-1})	Leaf water content (% DM)	Dry weight (g $plant^{-1}$)	Plant height (cm)	Foliar chl (a+b) (mg g^{-1}) FW
White seed coat (WSC)	Water lettuce	0	51.7±0.8	27.1±0.4	17.9±1.1	35.9±1.1
		3	55.4±1.2*	31.2±1.2*	21.3±1.2*	40.1±1.4*
		6	58.3±2.1*	34.8±0.7*	24.1±1.3*	43.0±1.5*
		12	61.4±1.5*	45.4±1.3*	28.0±1.4*	49.1±1.4*
	ANOVA $F_{(3,16)}$		20.11 **	61.39 **	19.21 **	75.32 **
	Poultry manure	0	47.5±1.7	28.1±0.3	15.3±1.2	25.2±0.8
		3	51.4±1.7*	39.2±1.1*	24.2±1.8*	34.6±1.2*
		6	60.3±0.9*	43.8±1.9*	27.0±1.3*	35.2±1.1*
		12	61.8±2.3*	45.4±0.6*	28.8±1.5*	46.1±1.6*
	ANOVA $F_{(3,16)}$		95.65 **	106.11 **	14.25 **	56.47 **
Black seed coat (BSC)	Water lettuce	0	53.6±0.6	29.3±0.7	21.6±1.1	18.9±0.5
		3	62.3±0.9*	42.9±1.0*	30.2±2.7*	24.9±0.7*
		6	63.7±1.4*	43.2±0.9*	32.2±1.2*	25.5±0.6*
		12	64.7±2.0*	44.3±1.0*	41.0±2.1*	27.9±0.7*
	ANOVA $F_{(3,16)}$		124.14 **	213.34 **	147.22 **	98.21 **
	Poultry manure	0	49.2±0.5	28.9±0.6	18.4±1.7	21.5±0.4
		3	56.9±1.2*	31.3±1.3*	24.0±2.1*	27.8±1.6*
		6	60.9±1.1*	38.1±1.8*	28.4±1.5*	28.1±0.7*
		12	66.1±3.1*	47.2±1.6*	31.2±1.3*	37.8±1.6*
	ANOVA $F_{(3,16)}$		55.24 **	111.2 **	85.44 **	101.22 **
Light red seed coat (RSC)	Water lettuce	0	42.1±0.7	30.2±0.2	16.3±1.1	18.2±0.2
		3	47.9±1.7*	33.4±0.4*	21.6±1.6*	23.8±0.7*
		6	54.2±1.5*	37.9±0.9*	24.2±1.2*	25.3±0.5*
		12	66.0±1.9*	49.1±0.4*	26.4±2.0*	28.8±0.7*
	ANOVA $F_{(3,16)}$		81.32 **	101.78 **	23.01 **	46.37 **
	Poultry manure	0	43.1±0.9	29.5±0.5	17.8±1.4	23.5±0.7
		3	50.8±1.5*	41.1±1.4*	27.6±1.2*	38.1±1.9*
		6	52.3±1.0*	45.5±1.1*	30.1±2.6*	44.6±1.6*
		12	61.2±1.9*	52.2±1.6*	32.8±2.1*	46.5±1.2*
	ANOVA $F_{(3,16)}$		53.29 **	232.18 **	78.56 **	221.13 **

n = 10, Based on Dunnett's test, *,**Significant at p<0.05 and p<0.01, respectively, Values are Mean±SE

increasing WL and PM f application rates (Table 4). Application of WL fertilizer significantly (p<0.001) increased the number of pods per plant and the 1000 grain weight from 19.03-43.10 and 1.43-2.63 kg, respectively in RSC landrace at 12 t ha^{-1}. On the other hand, there was significant increase in the number of seeds per pod from 2.07-4.74 in WSC landrace while the highest increase values of grain yield and pod yield (from 5.82-9.84 and 7.30-11.94 t ha^{-1}, respectively) were recorded in BSC landrace at 12 t ha^{-1} under WL application (Table 4). PM applied at 12 t ha^{-1} showed greater increase in the number of pods per plant, the number of seeds per pods, the 1000 grain weight, the grain yield and the pod yield from 21.22-49.20; 1.53-5.65; 1.53-2.57 kg, 7.25-13.13 t ha^{-1} and 5.50-10.21 t ha^{-1}, respectively in RSC cultivar (Table 4).

Effects of N, P and K fertilization on growth and yield parameters: Plant dry weight and plant height parameters were positively influenced by N, P and K applications in all bambara groundnut landrace (Fig. 1). Significant increase in plant dry weight was observed in all landraces at 100 kg ha^{-1} N, P or K treatments (Fig. 1b). However, BSC landrace had relatively higher dry weight accumulation at 100 kg ha^{-1} P fertilization than WSC and RSC (Fig. 1b). The application of N, P and K at different rates (100, 150 and 200 kg ha^{-1}) significantly increased the plant height compared to the control (0 kg ha^{-1}) in all landraces (Fig. 2). The highest values of plant height were recorded in WSC landrace at 100 kg ha^{-1} P application and also at 100 kg ha^{-1} K treatments (Fig. 2b).

Application of N fertilizer had a positive effect on agronomic parameters of all bambara groundnut cultivars (Table 5). It significantly (p<0.01) improved the number of pods per plant, the number of seeds per pod, the 1000 grain weight, the grain yield and the pod yield of all landraces (Table 5). The highest increase of 16.96-39.20, 1.02-1.49, 5.11-7.49 and 5.22-7.77 t ha^{-1} were observed in the number of pods per plant, the number of seeds per pod, the grain yield and the pod yield, respectively in RSC landrace at 100 kg ha^{-1} under N

Table 4: Effects of water lettuce and poultry manure fertilization rates on yield components of bambara groundnut landraces (12 WAS)

			Yield components				
Bambara groundnut landraces	Nutrient source	Treatments (t ha^{-1})	No. of pods per plant	No. of seeds per pod	1000 grain weight (kg)	Grain yield (t ha^{-1})	Pod yield (t ha^{-1})
White seed coat (WSC)	Water lettuce	0	20.51±2.42	2.07±0.02	1.49±0.30	5.85±0.04	7.25±0.07
		3	25.00±3.21*	2.56±0.07*	2.01±0.06*	7.04±0.03*	10.44±0.03*
		6	33.40±2.45*	3.66±0.16*	2.06±0.04*	7.56±0.05*	10.94±0.05*
		12	44.00±4.32*	4.74±0.10*	2.09±0.05*	8.58±0.06*	11.08±0.03*
	ANOVA		285.23	157.11	85.10	187.56	235.41
	$F_{(3,16)}$		***	***	**	***	***
	Poultry manure	0	23.45±2.35	2.09±0.03	1.37±0.02	7.70±0.02	7.09±0.03
		3	28.40±4.51*	3.71±0.08*	2.01±0.01*	8.11±0.03*	11.42±0.02*
		6	40.00±2.64*	3.75±0.06*	2.12±0.05*	8.27±0.01*	11.60±0.03*
		12	46.04±4.12*	5.77±0.06*	2.25±0.07*	8.61±0.03*	12.00±0.04*
	ANOVA		304.89	155.44	311.75	129.21	174.26
	$F_{(3,16)}$		***	***	**	***	***
Black seed coat (BSC)	Water lettuce	0	23.12±2.12	2.01±0.01	1.45±0.01	5.82±0.04	7.30±0.05
		3	29.20±2.49*	3.54±0.09*	2.12±0.02*	8.27±0.01*	10.57±0.03*
		6	32.00±1.58*	4.61±0.14*	2.21±0.05*	8.38±0.03*	10.68±0.04*
		12	45.60±4.03*	5.70±0.05*	2.24±0.03*	9.84±0.03*	11.94±0.05*
	ANOVA		192.31	186.71	264.13	285.01	104.69
	$F_{(3,16)}$		***	***	**	***	***
	Poultry manure	0	20.65±2.34	2.05±0.02	1.41±0.02	8.01±0.03	7.60±0.03
		3	27.20±4.36*	4.59±0.07*	2.06±0.04*	8.38±0.02*	9.13±0.04*
		6	31.20±3.03*	4.61±0.15*	2.11±0.02*	9.21±0.05*	10.98±0.03*
		12	46.20±5.92*	5.73±0.09*	2.14±0.12*	10.05±0.06*	11.96±0.06*
	ANOVA		310.14	225.10	196.21	123.54	384.99
	$F_{(3,16)}$		***	***	**	***	***
Light red seed coat (RSC)	Water lettuce	0	19.03±2.84	2.02±0.02	1.43±0.03	7.75±0.04	5.76±0.06
		3	25.40±2.77*	3.45±0.29*	2.30±0.02*	8.09±0.02*	8.42±0.03*
		6	39.20±3.71*	3.62±0.19*	2.58±0.01*	8.14±0.03*	8.56±0.05*
		12	43.10±3.90*	4.69±0.13*	2.63±0.03*	9.24±0.04*	9.12±0.06*
	ANOVA		405.55	321.02	297.23	166.42	318.14
	$F_{(3,16)}$		***	***	**	***	***
	Poultry manure	0	21.22±2.01	1.53±0.01	1.53±0.01	7.25±0.01	5.50±0.01
		3	26.40±1.84*	2.31±0.08*	2.31±0.02*	7.72±0.02*	5.82±0.01*
		6	42.0±4.12*	4.57±0.08*	2.47±0.01*	11.46±0.03*	9.44±0.04*
		12	49.20±5.70*	5.65±0.15*	2.57±0.01*	13.13±0.04*	10.21±0.08*
	ANOVA		254.68	257.24	307.78	98.52	211.65
	$F_{(3,16)}$		***	***	**	***	***

n = 10, Based on Dunnett's test, ******Significant at $p<0.05$, $p<0.01$ and $p<0.0001$, respectively, Values are Mean±SE

Table 5: Effect of N fertilization rates on yield parameters of bambara groundnut landraces (12 WAS)

		Yield components				
Bambara groundnut landraces	Treatment (kg ha^{-1})	No. of pods per plant	No. of seeds per pod	1000 grain weight (kg)	Grain yield (t ha^{-1})	Pod yield (t ha^{-1})
White seed coat (WSC)	0	21.52±1.53	1.05±0.02	0.32±0.02	5.12±0.04	6.21±0.05
	100	38.01±2.12*	1.38±0.02*	1.00±0.01*	6.26±0.06*	7.72±0.04*
	150	31.80±3.83*	1.14±0.01*	0.68±0.02*	5.70±0.04*	6.67±0.02*
	200	28.49±1.43*	1.20±0.02*	0.53±0.02*	5.57±0.03*	6.54±0.03*
	ANOVA	86.65	75.26	114.02	75.12	45.92
	$F_{(3,16)}$	**	**	***	***	**
Black seed coat (BSC)	0	17.25±1.21	1.01±0.02	0.27±0.01	4.92±0.04	5.33±0.05
	100	30.80±3.75*	1.32±0.01*	0.54±0.03*	6.06±0.02*	7.39±0.07*
	150	24.44±2.36*	1.22±0.04*	0.53±0.01**	5.54±0.03*	6.41±0.05*
	200	25.40±2.30*	1.19±0.03*	0.40±0.02*	5.33±0.04*	6.10±0.06*
	ANOVA	236.29	341.11	158.41	175.23	76.23
	$F_{(3,16)}$	***	**	***	***	***
Light red seed coat (RSC)	0	16.95±1.02	1.02±0.01	0.39±0.03	5.11±0.4	5.22±0.03
	100	39.20±3.20*	1.49±0.04*	1.01±0.02*	7.49±0.06*	7.77±0.05*
	150	21.20±1.92*	1.22±0.03*	0.68±0.02*	5.43±0.05*	5.85±0.03*
	200	18.60±2.04*	1.16±0.04*	0.60±0.01*	5.34±0.03*	5.74±0.04*
	ANOVA	465.44	122.13	92.17	155.42	345.88
	$F_{(3,16)}$	***	**	***	***	***

n = 10, Based on Dunnett's test, ******Significant at $p<0.05$, $p<0.01$ and $p<0.0001$, respectively, Values are Mean±SE

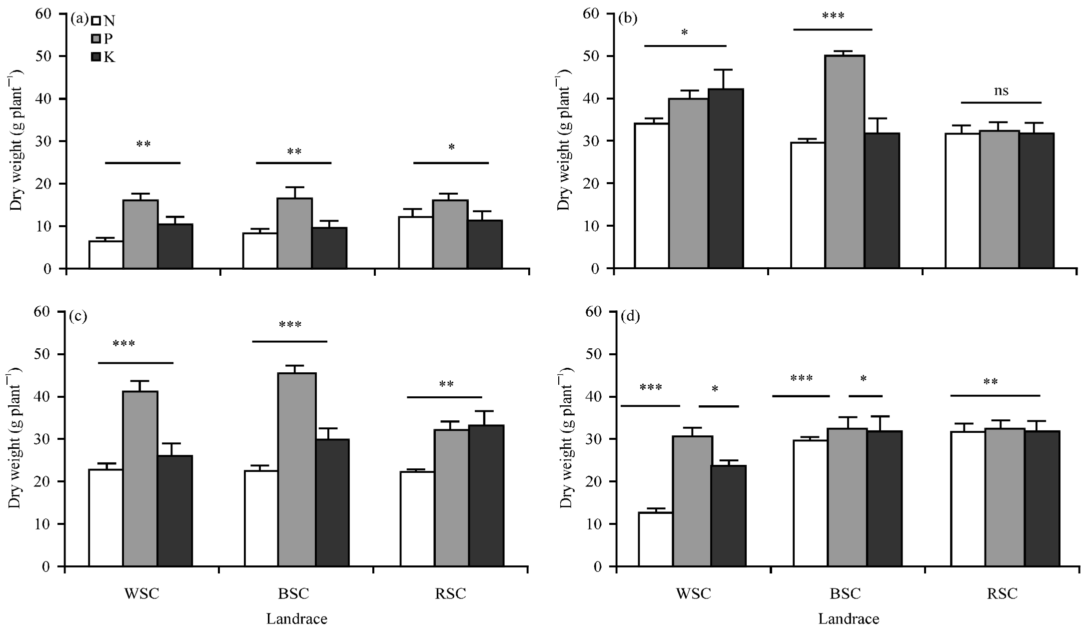

Fig. 1(a-d): Effect of different N, P and K fertilizer rates on the dry weight (g plant^{-1}) of bambara groundnut landraces: WSC: White seed coat, BSC: Black seed coat and RSC: Light red seed coat, treated with (a) 0 kg (control), (b) 100 kg, (c) 150 kg and (d) 200 kg fertilizer ha^{-1}, n = 10, The bars indicate standard errors of the mean, *p≤0.05, **p≤0.01, ***p≤0.001, ns: Not significant

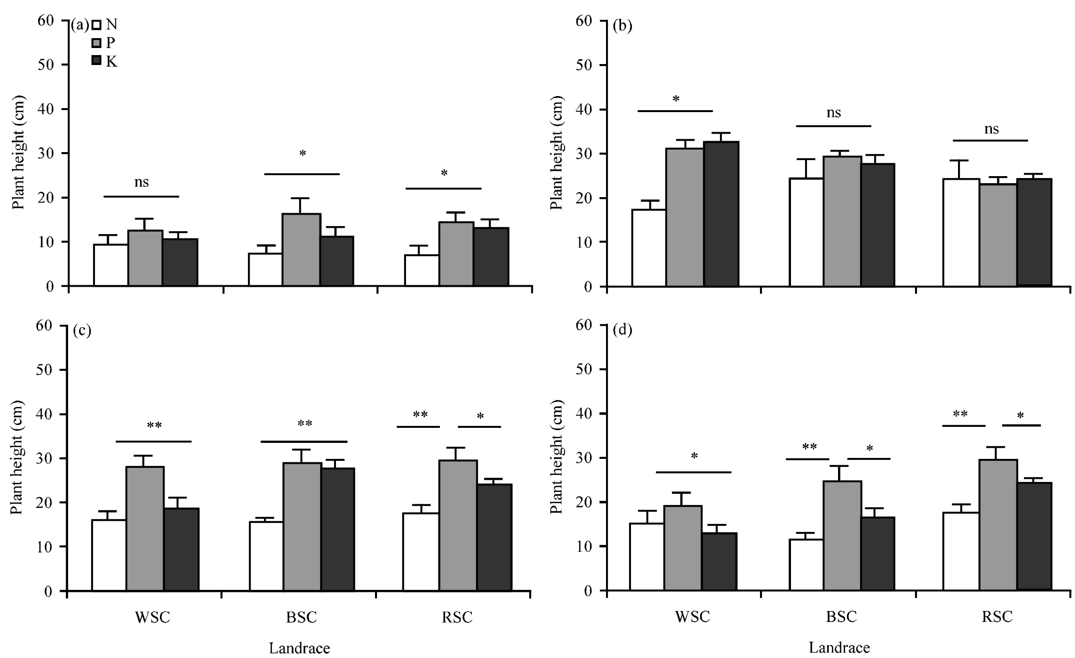

Fig. 2(a-d): Effect of different N, P and K fertilizer rates on the plant height (cm) of bambara groundnut landraces, WSC: White seed coat, BSC: Black seed coat and RSC: Light red seed coat treated with, (a) 0 kg (control), (b) 100 kg, (c) 150 kg and (d) 200 kg fertilizer ha^{-1}, n = 10, the bars indicate standard errors of the mean. *p≤0.05, **p≤0.01, ***p≤0.001, ns: Not significant application (Table 5). The supply of N at 100 kg ha^{-1} significantly ($p<0.001$) increased the 1000 grain weight from 0.32-1.00 kg in WSC landrace (Table 5).

The P rates significantly ($p<0.001$) increased yield parameters in all bambara groundnut cultivars (Table 6). The RSC landrace had the highest increase from 1.03-1.74, 0.27-1.31 kg and 4.21-8.63 t ha^{-1} in the number of seeds per pods, the 1000 grain weight and the grain yield, respectively when P was applied at 100 kg ha^{-1} (Table 6). On the other hand, the highest increases of 20.11-37.60 and 5.06-9.06 t ha^{-1} in BSC were observed under 100 kg ha^{-1} P for the number of pods per plant and the pod yield, respectively (Table 6).

Number of pods per plant, number of seeds per pod, weight of 1000 grains, grain yield and pod yield of all bambara groundnut landraces were also affected significantly ($p<0.001$) by K applications (Table 7). Application of K fertilizer at 100 kg ha^{-1} improved the number of pods per plant, the grain yield and the pod yield from 15.23-27.80, 4.03-7.57 and 4.57-8.51 t ha^{-1}, respectively in WSC cultivar (Table 7). On the other hand, the highest increase (from 14.72-25.80) was recorded in BSC at 100 kg ha^{-1} for number of seeds per pod while RSC landrace was observed to have relatively higher 1000 grain weight increase (from 0.37-0.95 kg) than both landraces under K fertilization (Table 7).

Present study showed that application rates above 100 kg ha^{-1} N, P or K led to a decline in yield in all the bambara groundnut landraces compared to the optimum 100 kg ha^{-1} N, P or K fertilization (Table 7).

Table 6: Effect of P fertilization rates on yield parameters of bambara groundnut landraces (12 WAS)

Bambara groundnut landraces	Treatments (kg ha^{-1})	Yield components: No. of pods per plant	No. of seeds per pod	1000 grain weight (kg)	Grain yield (t ha^{-1})	Pod yield (t ha^{-1})
White seed coat (WSC)	0	21.21±1.08	1.01±0.02	0.61±0.01	5.11±0.03	5.21±0.04
	100	34.00±3.39*	1.64±0.04*	1.10±0.02*	8.10±0.06*	8.78±0.06*
	150	29.06±2.21*	1.63±0.03*	1.05±0.01*	8.06±0.05*	8.16±0.08*
	200	27.00±2.17*	1.39±0.06*	0.78±0.02*	5.72±0.03*	5.88±0.05*
	ANOVA	195.25	73.22	40.78	198.76	352.41
	$F_{(3,16)}$	***	***	***	***	***
Black seed coat (BSC)	0	20.11±1.32	1.13±0.02	0.35±0.01	4.81±0.03	5.06±0.04
	100	37.60±4.15*	1.77±0.05*	1.02±0.02*	8.58±0.07*	9.06±0.07*
	150	32.20±3.11*	1.74±0.04*	0.93±0.03*	7.95±0.05*	8.69±0.04*
	200	26.20±32.81*	1.54±0.02*	0.72±0.02*	5.19±0.04*	5.93±0.05*
	ANOVA	221.23	246.57	193.17	357.04	171.34
	$F_{(3,16)}$	***	***	***	***	***
Light red seed coat (RSC)	0	17.22±1.45	1.03±0.04	0.27±0.04	4.21±0.03	4.65±0.05
	100	29.20±3.10*	1.74±0.03*	1.31±0.01*	8.63±0.06*	7.61±0.05*
	150	26.01±2.34*	1.62±0.03*	1.21±0.03*	8.23±0.04*	7.08±0.08*
	200	24.60±2.21*	1.34±0.05*	0.74±0.02*	5.88±0.05*	5.46±0.05*
	ANOVA	362.14	321.45	111.47	84.36	125.18
	$F_{(3,16)}$	***	***	***	***	***

n = 10, Based on Dunnett's test, ******Significant at $p<0.05$, $p<0.01$ and $p<0.0001$, respectively, Values are Mean±SE

Table 7: Effect of K fertilization rates on yield components of bambara groundnut landraces (12 WAS)

Bambara groundnut landraces	Treatments (kg ha^{-1})	Yield components: No. of pods per plant	No. of seeds per pod	1000 grain weight (kg)	Grain yield (t ha^{-1})	Pod yield (t ha^{-1})
White seed coat (WSC)	0	15.23±1.05	1.02±0.01	0.43±0.03	4.03±0.02	4.57±0.04
	100	27.80±2.14*	1.38±0.05*	1.03±0.03*	7.57±0.05*	8.51±0.07*
	150	25.00±1.29*	1.16±0.04*	0.78±0.03*	6.05±0.03*	6.80±0.04*
	200	24.02±1.92*	1.13±0.02*	0.60±0.01*	5.32±0.03*	5.80±0.03*
	ANOVA	153.55	96.75	162.47	351.48	271.39
	$F_{(3,16)}$	***	**	***	***	***
Black seed coat (BSC)	0	14.72±1.03	1.09±0.02	0.23±0.04	3.95±0.03	4.11±0.04
	100	25.80±2.46*	1.67±0.06*	0.51±0.01*	5.97±0.04*	6.47±0.05*
	150	23.10±2.82*	1.32±0.03*	0.49±0.01*	4.97±0.05*	5.16±0.06*
	200	21.91±1.38*	1.16±0.05*	0.40±0.01*	4.17±0.04*	4.73±0.03*
	ANOVA	223.10	312.49	432.28	194.35	306.99
	$F_{(3,16)}$	***	***	**	***	***
Light red seed coat (RSC)	0	14.32±1.08	1.02±0.03	0.37±0.01	3.88±0.02	4.11±0.04
	100	24.80±1.59*	1.29±0.05*	0.95±0.06*	6.65±0.04*	7.19±0.06*
	150	21.04±2.01*	1.27±0.03*	0.47±0.05*	5.16±0.03*	5.60±0.05*
	200	20.10±1.91*	1.16±0.01*	0.33±0.02*	4.22±0.04*	4.92±0.03*
	ANOVA	76.24	74.58	147.8	387.94	268.41
	$F_{(3,16)}$	***	**	***	***	***

n = 10, Based on Dunnett's test, ******Significant at $p<0.05$, $p<0.01$ and $p<0.0001$, respectively, Values are Mean±SE

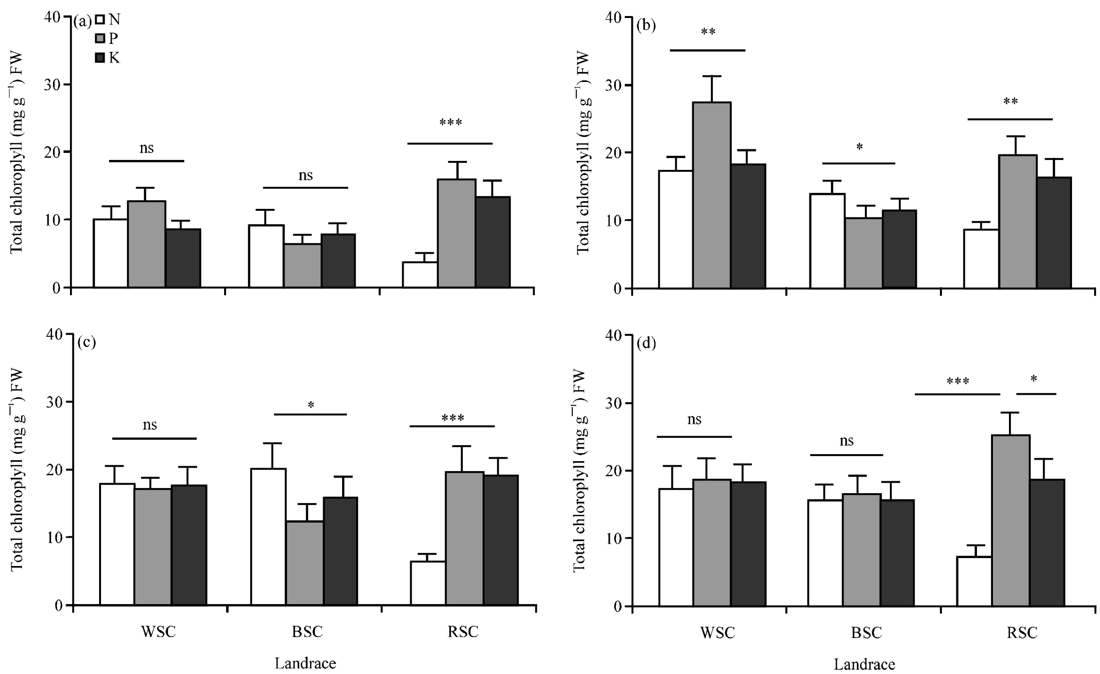

Fig. 3(a-d): Effect of different N, P and K fertilizer rates on the total chlorophyll (mg g^{-1}) fresh weight of bambara groundnut landraces, WSC: White seed coat, BSC: Black seed coat and RSC: Light red seed coat treated with, (a) 0 kg (control), (b) 100 kg, (c) 150 kg and (d) 200 kg fertilizer ha^{-1}, n = 10, the bars indicate standard errors of the mean. *$p \leq 0.05$, **$p \leq 0.01$, ***$p \leq 0.001$, ns: Not significant

Total chlorophyll content as affected by organic and inorganic fertilizers application: Total chlorophyll content was significantly ($p<0.01$) increased in all bambara groundnut landraces with increasing WL and PM fertilization rates 12 WAS (Table 3). Application of WL and PM at 12 t ha^{-1} enhanced the chlorophyll content in RSC from 18.2-28.8 and 23.5-46.5 (mg g^{-1}) fresh weight, respectively.

Application of N, P or K at different fertilization rates significantly ($p<0.001$) increased the total chlorophyll content of all bambara groundnut landraces (Fig. 3). The highest increase was observed in WSC landrace at 100 kg ha^{-1} P compared to the control (Fig. 3b).

DISCUSSION

Effects of water lettuce and poultry manure application on leaf water content: Leaf water content was significantly increased in all bambara groundnut cultivars with increasing rates of WL and PM fertilization. Similar results were found in leaves of *Salix sericea* (Lower and Orians, 2003). According to Hossner and Juo (1999), the beneficial effect of organic nutrient is to improve soil structure and increase water holding capacity. Physiologically, the uptake of nutrients depends on water availability (Marschner, 1986). Mineral nutrients are delivered from the root to the shoot along the transpiration stream and therefore soil water deficits can limit nutrient transport simply by reducing the volume of water that moves into the plant (Kramer and Boyer, 1995). Consequently, we expected that water and nutrient availability of organic fertilizer would interact to influence plant growth and yield performance. We found that increasing nutrient application to bambara groundnut landraces increased water content of aerial parts, suggesting that application of WL and PM fertilizers enhances the ability of bambara groundnut to uptake water or to conserve water internally. According to Hossner and Juo (1999), organic fertilizer is the energy source for soil fauna and microorganism, which are the primary agents that manipulate the decomposition and release of mineral nutrients in soil ecosystems.

Effects of water lettuce and poultry manure application on growth and yield parameters: The present study showed that WL fertilization greatly increased dry weight, plant height, number of pods per plant, number of seeds per pod, 1000 grain weight, pod yield and grain yield of all bambara groundnut landraces. Similar outcomes were obtained earlier on several landraces (Hairiah and Noordwijk, 1989; Ayuke *et al*., 2004; Nziguheba *et al*., 2004; Marschner and McNeill *et al*., 2011). It is well established that WL has a higher N, P and K concentrations and undergoes rapid mineralization (Sridhar, 1986; Edema *et al*., 2007; Rahman *et al*., 2011). According to Hossner and Juo (1999), the organic matter increases the capacity of the soil to buffer changes in pH, enhances the Cation Exchange Capacity (CEC), reduces phosphate fixation and serves as a reservoir for secondary nutrients and micronutrients. The growth and yield differences among treatments and landraces have been related to N, P and K availability to crops and release patterns by organic residues (Hairiah and Noordwijk, 1989; Kilinc *et al*., 2005; Edema *et al*., 2007; Leconte *et al*., 2011). According to Ayuke *et al*. (2004), the variation observed among landraces was due to the fact that in the organic residues treatments, nutrient availability depended on nutrient concentration and release in synchrony with crop needs. In this study, The highest plant growth and yield obtained in the WL fertilizer at 12 t ha^{-1} could be attributed to the nutrients being readily available from the WL fertilizer.

In this experiment, PM amendment had a positive effect on the plant dry weight, plant height, the number of pods per plant, the number of seeds per pod, the 1000 grain weight, the pod yield and grain yield of all bambara groundnut landraces. This is in agreement with the results obtained by Perkins (1964), Boateng *et al*. (2006) and Lv *et al*. (2011). According to Waldrip *et al*. (2011), the incorporation of poultry manure into soil promoted transformation and mineralization of less-labile inorganic and organic P into labile-P_i in the rhizosphere, which resulted in higher root P concentrations and higher total P uptake by plant.

Effects of N, P and K fertilization on growth and yield parameters: The result of the present work showed that the dry weight, the plant height, the number of pods per plant, the number of seeds per pod, the 1000 grain weight, the grain and pod yield of all bambara groundnut landraces were significantly increased by N, P or K fertilization rates. Similar observations were reported by other researchers on various species but the reported optimum rates at which growth and yield were maximized varied widely (Nkoa *et al*., 2001; MMhango *et al*., 2008; Anyanzwa *et al*., 2010; Bado *et al*., 2010; Shehu *et al*., 2010; Tauro *et al*., 2010; Bala *et al*., 2011). This could be attributed to differences in nutrient inputs by the fertilizers and differences in nutrient demand by the crops (Hossner and Juo, 1999). According to Christianson and Vlek (1991), N, P and K are key elements in the production of leafy vegetables as they enhance yield by promoting cell division and expansion in leaves and root development. Studies carried out by Manu *et al*. (1991) revealed that nitrogen is among the limiting nutrients for cereals and food legumes production. Adequate supply of nitrogen is beneficial for carbohydrate and protein metabolism that promotes cell division and enlargement resulting in higher yield (Shehu *et al*., 2010). Similarly, supply of P is usually associated with increased root density and proliferation, which aid in extensive exploration and supply of nutriments and water to the growing plant, resulting in increased growth and yield traits, thereby ensuring more seed and dry matter yield (Maiti and Jana, 1985). Jakobsen (1985) related positive effects of P nutrition on plant growth to increased photosynthesis, root growth and nodulation. The supply of K gave substantial increase in plant growth and yield of bambara groundnut landraces. According to Amtmann *et al*. (2006), K is the most abundant inorganic cation in plants, comprising up to 10% of plant dry weight and is vital for various functions in the plant as photosynthesis, osmoregulation and transpiration.

Present study showed that application rates above 100 kg ha^{-1} N, P or K let to a decline in yield in all the bambara groundnut landraces compared to the optimum 100 kg ha^{-1} N, P or K fertilization. A negative response of plants to excess macronutrients has been explained theoretically by the energy plants use to transform and remove excess osmotic solutes associated with macronutrients accumulation, energy which otherwise would have been used for growth (Nkoa *et al*., 2001).

Total chlorophyll content as affected organic and inorganic fertilizers application: Total chlorophyll content was significantly increased in all bambara groundnut cultivars with increasing organic (WL and PM) and inorganic (N, P and K) fertilization rates. According to Sridhar (1986) and Kilinc *et al*. (2005), plant parts of WL and PM have higher macro elements and trace element contents. Maiti and Jana (1985) demonstrated that the supply of P is usually associated with increased root density and proliferation which aid in extensive exploration and supply of nutrients and water to the growing plant parts, resulting in increased growth and total chlorophyll, thereby ensuring more seed and dry matter yield. Nitrogen is a component of chlorophyll. When N is deficient, leaves will contain relatively little chlorophyll and thus tend to be chlorotic and pale green in color (Edema *et al*., 2007). K is an important macronutrient for plants, which carries out vital functions in metabolism, growth and stress adaptation (Taffouo *et al*., 2010b). In many plants, a decrease in chlorophyll level under K deficiency has been reported (Taffouo *et al*., 2010a, b). According to Amtmann *et al*. (2006), a lack of K will impede the establishment of H^+ gradients, inhibit the activity of photosynthetic enzymes and disturb source-sink transport of sugars which have an impact on rates of photosynthesis.

CONCLUSION

The response of three bambara groundnut landraces to organic and mineral fertilizers differed significantly with respect to most growth and yield parameters. The RSC showed better growth and yield than WSC and BSC landraces in this condition revealing a greater response of this landrace to organic and mineral fertilization. RSC landrace can be considered as an important companion crop for the development of smallholder agriculture in coastal region of Cameroon. In this experiment, the best fertilization rates for growth and yield of all bambara groundnut landraces were 12 t ha^{-1} under WL and PM amendments and 100 kg ha^{-1} N, P or K when mineral fertilization was applied. WL and PM can be considered as a valuable fertilizer and can serve as a suitable alternative to chemical fertilizer in coastal region of Cameroon.

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