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Full Length Research Paper

Effects of some physical and chemical characteristics of soil on productivity and yield of cowpea (*Vigna unguiculata* L. Walp.) in coastal region (Cameroon)

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Studies were conducted to assess the response of cowpea (*Vigna unguiculata* L. Walp) to some physical and chemical characteristics of soil in coastal region (Cameroon). The cowpea variety used in this trial was Tsacre, planted at a spacing of 80 cm × 80 cm. The experimental design was a randomized complete block comprising of five plots with three replicates. Productivity parameters (dry weight aerial parts, roots dry weight, abortion seeds rate, number of flowering per plant, flowering rate) and yield components (number of seeds per pod, number of pod per plant, grain yield, pod yield and weight of 1000 seeds) were determined. Soil samples were taken randomly from depths of 0 - 30 and 30 - 60 cm before seeds sowing. The results showed that the plot with the highest percentage of sand (71.80%), the lowest percentage of clay (21.00%) and silt (7.20%) and with the highest amount of organic matter (10.26%), exchange potassium (0.36 g Kg^{-1}), calcium (0.49 g Kg^{-1}) and magnesium (0.46 g Kg^{-1}) increased significantly ($P<0.05$) the dry weight aerial parts from 4291 to 7051 mg, the roots dry weight from 293 to 454 mg, the number of flowering per plant from 8.10 to 28.82 and the flowering rate from 47.75 to 93.33%. Similar results were obtained with yield components where the number of pod per plant increased from 5.90 to 16.12, the grain yield from 729.70 to 2381 Kg ha^{-1}, the pod yield from 1251.21 to 1679.21 Kg ha^{-1} and the weight of 1000 seeds from 81.70 to 145g. Results from this investigation showed that soil properties could influence cowpea growth, productivity and yield under Cameroon coastal growing conditions.

Key words: Cowpea, chemical composition, particle size distribution, productivity, yield.

INTRODUCTION

Legumes are important foodstuffs in the world especially in the tropical and subtropical regions (Gowda et al., 2000). The most prominent in the leguminosae family is cowpea (*Vigna unguiculata* L. Walp). Cowpeas are rich in protein, iron, starch, calcium, phosphorus and vitamins B, which make them excellent food even when eaten in small amount (Ebong, 1972). In west and central Africa, cowpea is second in importance after groundnuts, with Nigeria accounting for over 70% of the total world production (Sing et al., 2000). In Cameroon cowpea is the third most important legume food crop after groundnuts (*Arachis hypogaea*) and common beans (*Phaseolus vulgaris*) and is frequently intercropped with cereals (Taffouo et al., 2004). The most important beneficial attribute of this legume is its contribution to the soil nitrogen status through symbiotic nitrogen fixation, thereby enhancing soil fertility and reducing the need for N-fertilizer application (Martins et al., 2003). In Cameroon, where nearly 80% of the country's crop is produced, cowpea production is on the increase due to high demand from both the local and external markets, and many farmers in the rural area now grow cowpea for cash markets.

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Agriculture in Sub-saharan Africa is characterized by its poor productivity. Several factors related to soil fertility limit agricultural production. Many factors such as soil type, farmer's practices, crop residues and mineral fertilizers management influence crop yields (Bado et al., 2004). Among those factors, the texture and the chemical composition of soils remain a major constraint to crop production in large scale in tropical regions of Africa. The production of grain legumes is affected by the texture of soil and organic matter content richness (Nyabyenda, 2005). The influence of soil texture on organic matter decomposition indicate that the rate of decomposition and net mineralization depend on the accessibility of organic substrates to soils organisms (Hassink, 1992). Changing the texture through sand amendments increased the bulk densities of the soil (Mtambanengwe et al., 2004). Clay particles are believed to protect some of the more easily decomposable organic compounds from rapid microbial breakdown through encrustation and entrapment (Tisdall and Oades, 1982). The protective action by clays against organic matter degradation through the formation of complexes between metal ions associated with large clay surfaces and high CEC explains the effect of soil texture on organic matter decomposition (Giller et al., 1997). Fine textured soils (clays) often contain higher amounts of organic matter than sandy soils (Mtambanengwe et al., 2004).

Crop yields in large parts of Kenya had been low due to declining soil fertility as a result of soils impoverishment in organic matter content and low reserves of nitrogen, phosphorus and some trace elements (Ayuke et al., 2004). Nitrogen and phosphorus are the most limiting nutrients to crop production and high costs of inorganic fertilizers limit their sufficient use by majority of the smallholder farmers in Sub-saharan Africa (Mugwe et al., 2004). Mineral absorption is largely influenced by the availability of soil mineral nutrients content which in turn affects the chemical composition of the plants (Juma and Van Averbeke, 2005). In tropical regions of Africa, as soon as the vegetative cover is removed and land intensively cropped with grain crops, the soil's physical, chemical and biological properties are readily degraded (Sanchez et al., 1997). Changes in soil properties and their effects on maize productivity following *Sesbania sesban* and *Cajanus Cajan* improved fallow systems in Eastern Zambia (Chirwam et al., 2004). Soil organic matter plays an important role in maintaining physical, chemical and biological properties of the soil, and therefore the crop productivity and yield (Micheni et al., 2004). Enhancement and maintenance of soil productivity through the improvement of soil organic matter and minerals elements is one of the essential aspects for sustained agricultural production systems in Sub-saharan Africa (Bunting, 1992). This is particularly important if the physical and chemical properties of soils are previously known.

Therefore, the major objective of the present investigation is to assess how particle size distribution and chemical composition of soil influence cowpea production in coastal region of Cameroon.

MATERIALS AND METHODS

Study site

The field experiment was carried out at the research farm of the University of Douala - Cameroon (03° 40' - 04° 4' N and 9° 16' - 09° 52' E, 13 m above sea level). According to Din et al. (2008), the climate of Douala is uniform and is described as a particular equatorial type called "camerounian" marked by lengthy rainy season (at least nine months), abundant rainfall (about 4000 mm per annum), high and stable average annual temperatures (26.7°C). The main relative air humidity remains high throughout the year with a mean value of 82.6% (Dibong et al., 2008).

Methods

A randomised complete block design comprising of five plots (P1, P2, P3, P4 and P5) replicated three times was used, with plots of 7.5 × 7 m. Soil samples were taken from three different locations at two depth intervals (0 - 30 and 30 - 60 cm), within each plot. One composite sample was prepared for each 0 - 30 and 30 - 60 cm depths, and they were analysed for physical and chemical properties. The cowpea variety used in this trial was Tsacre, planted at a spacing of 80 × 80 cm (Taffouo et al., 2008). This is the most preferred variety at the study site (Taffouo et al., 2008). In the field conditions, dry weight aerial parts, roots dry weight, abortion seeds rate, number of flowering per plant, flowering rate, number of seeds per pod, number of pod per plant, grain yield, pod yield and weight of 1000 seeds were measured in each plot. The trials were carried out in dry season in pure culture without fertilization. Water was carried out once per week at a rate of 20 Lm^{-2} (Taffouo et al., 2008).

Analysis of soils samples

Soil samples were taken from five different plots at two depths intervals (0 - 30 and 30 - 60 cm). Five composite samples prepared from 0 - 30 and 30 - 60 cm depths within five plots were analyzed in the laboratory. The parameters analysed included (i) particle size distribution by the method of Davidson (1955), (ii) organic carbon was measured by the procedure of Walkley and Black (1934), (iii) exchangeable potassium, calcium and magnesium of the soil using the procedure of Jackson (1958), (iv) total nitrogen content by the method of Kjeldahl (AOAC, 1980), (v) phosphorus uptake by the method of proportioning colorimetric starting from the nitrochlorhydric solution of ashes (Stuffins, 1967), (vi) soil pH was measured by the procedure of Bates (1954), while (vii) potassium content was determined using flame photometer (Jenway) (Prevel et al., 1984).

Statistical analysis

The data obtained were subjected to Analysis of Variance (ANOVA). Significant differences between particle size distribution, chemical composition and productivity and yield of cowpea cultivar were compared using Duncan Multiple Range Test (DMRT).

Table 1. Effects of some physical characteristics of soil on productivity of cowpea cultivar (values are mean ±SE).

Plots	Particle size distribution(%)			Productivity parameters				
	Clay	Sand	Silt	Dry weight aerial parts (mg)	Roots dry weight (mg)	Abortion seeds rate (%)	Number of flowering per plant	Flowering rate (%)
P1	24.85 a	56.15 b	19.00 a	4291±62 c	293±12c	55.85 a	8.10±0.70 c	47.75 c
P2	21.00 a	71.80 a	7.20 b	7051±75 a	454±17 a	56.07 a	28.82±0.74 a	93.33 a
P3	24.50 a	66.20 ab	9.30 b	6508±57 ab	433±11 ab	56.29 a	21.70±0.57 ab	79.77 ab
P4	25.15 a	60.35 b	16.50 a	5542±87 b	415±15 b	54.52 a	15.70±0.63 b	67.42 b
P5	25.55 a	57.20 b	14.25 a	5042±37 bc	395±13 bc	54.13 a	13.81±0.64 b	56.71 bc
Mean	24.21	62.34	13.25	5686.8	398	55.37	17.63	68.99
S.E.	1.84	6.58	4.92	1109.09	62.62	0.98	7.92	18.12
CV (%)	7.60	10.56	37.13	19.50	15.73	1.76	44.93	26.26

Means followed by the same letter within a column do not differ significantly, Duncan's multiple range test at 5% level.

Table 2. Effects of some physical characteristics of soil on yield of cowpea cultivar (values are mean ± SE).

Plots	Particle size distribution (%)			Yield components				
	Clay	Sand	Silt	Number of seeds per pod	Number of pod per plant	Grain Yield (Kg ha^{-1})	Pod yield (Kg ha^{-1})	Weight of 1000 seeds (g)
P1	24.85 a	56.15 b	19.00 a	12.71±0.52 a	5.90±0.35 b	729.70±5.17 c	1251.21±13.45 bc	81.70±0.26 c
P2	21.00 a	71.80 a	7.20 b	12.25±0.42 a	16.12±0.51 a	2381.32±42.70 a	1679.21±14.75 a	145.90±0.17a
P3	24.50 a	66.20 ab	9.30 b	11.31±0.48 a	14.24±0.22 a	2240.98±30.11 ab	1520.36±25.68 ab	128.60±0.13 ab
P4	25.15 a	60.35 b	16.50 a	10.73±0.53 a	10.41±0.15 ab	1845.23±18.56 b	1472.62±10.16 b	115.55±0.15 b
P5	25.55 a	57.20 b	14.25 a	10.45±0.67 a	6.06±0.31 b	1432.97±25.31 bc	853.25±7.33 c	101.60±0.25 bc
Mean	24.21	62.34	13.25	11.49	10.55	1726.04	1355.33	114.67
S.E.	1.84	6.58	4.92	0.98	4.65	668.45	319.69	24.64
CV (%)	7.60	10.56	37.13	8.52	44.07	38.72	23.58	21.48

Means followed by the same letter (s) in each column are not significantly different (p = 0.05), using Duncan's multiple range test (DMRT).

RESULTS AND DISCUSSION

Effects of some physical characteristics of soil on productivity and yield of cowpea cultivar

Results on the productivity performance of cowpea showed that the particle size distribution of the plot with high sand texture (66.20 and 71.80%) and lower silt texture (7.20 and 9.30%) improved significantly values of dry weight aerial parts, roots dry weight, number of flowering per plant and flowering rate (Table 1) and had also a slight positive effect on number of pod per plant, grain yield, pod yield and weight of 1000 seeds of cowpea except for a number of seeds per pod (Table 2). Our data on crop yields and productivity were in agreement with previous findings in which various reporters (Bado et al., 2004; Ossom and Rhykerd, 2007) found that particles size fractions, pH and exchange acidity influenced plant growth, productivity and yield during the cropping season. Several researchers showed that the texture of soil remain a major constraint to crop production in large scale in tropical Africa. In this way, Nyabyenda (2005) reported that the production of grain legumes had been low due to declining soil fertility as a result of soils impoverishment in organic matter content and corresponding texture. According to Sanchez et al. (1997) as soon as the vegetative cover is removed and land intensively cropped with grain crops, the soil's physical and biological properties are readily degraded. There was no significant (p = 0.05) difference in abortion seeds rate between clay, sand and silt texture of soil. Our results also showed that the amount of clay fractions (21.00 to 25.55%) were high than silt fractions (Table 1). The protective action by clay against organic matter degradation through the formation of complexes between metal ions associated with large clay surfaces and high CEC explains the effect of soil texture on organic matter decomposition (Giller et al., 1997). According to Micheni et al. (2004) the soil organic matter plays an important role in maintaining physical, chemical and biological properties of the soil, and therefore the crop productivity and yield.

Table 3. Effects of chemical composition of soil on productivity of cowpea cultivar (values are mean ± SE).

Plots	Elements	Chemical composition (g Kg^{-1})	Productivity parameters				
			Dry weight aerial parts (mg)	Roots dry weight (mg)	abortion seeds rate (%)	Number of flowering per plant	Flowering rate (%)
P1	Nitrogen (%)	0.20 ns					
	Available phosphorus	0.006 ns					
	Exchangeable potassium	0.15*					
	Exchangeable calcium	0.21*	4291 ± 62	293 ± 12	55.85	8.10 ± 0.70	47.75
	Magnesium	0.10*					
	Organic matter (%)	1.62*					
	pH-water	4.91 ns					
P2	Nitrogen (%)	0.18 ns					
	available phosphorus	0.008 ns					
	Exchangeable potassium	0.36*					
	Exchangeable calcium	0.49*	7051 ± 75	454 ± 17	56.07	28.82 ± 0.74	93.33
	Magnesium	0.46*					
	Organic matter (%)	10.26*					
	pH-water	4.89 ns					
P3	Nitrogen (%)	0.19 ns					
	available phosphorus	0.008 ns					
	Exchangeable potassium	0.25*					
	Exchangeable Calcium	0.39*	6508 ± 57	433 ± 11	56.29	21.70 ± 0.57	79.77
	Magnesium	0.37*					
	Organic matter (%)	7.82*					
	pH-water	4.93 ns					
P4	Nitrogen (%)	0.17 ns					
	available phosphorus	0.006 ns					
	Exchangeable potassium	0.20*					
	Exchangeable calcium	0.33*	5542 ± 87	415 ± 15	54.52	15.70 ± 0.63	67.42
	Magnesium	0.27*					
	Organic matter (%)	5.15*					
	pH-water	4.90 ns					
P5	Nitrogen (%)	0.19 ns	5042 ± 37	395 ± 13	54.13	13.81 ± 0.64	56.71
	available phosphorus	0.007 ns					
	Exchangeable potassium	0.17*					
	Exchangeable calcium	0.27*					
	Magnesium	0.18*					
	Organic matter (%)	3.02*					
	pH-water	4.91 ns					
	ANOVA	*	**	**	ns	*	*

*, ** significant at p = 0.05 and 0.01, respectively; ns = non significant.

Effects of chemical composition of soil on productivity and yield of cowpea cultivar

The results of this study highlighted the importance of soil mineral nutrients concentration of the study area on productivity and yield of cowpea. The dry weight aerial parts, roots dry weight, number of flowering per plant and flowering rate of cowpea were affected by the quality and

Table 4. Effects of chemical composition of soil on yield of cowpea cultivar (values are mean± SE).

Plots	Elements (g Kg^{-1})	Chemical composition	Yield components				
			Number of seeds per pod	Number of pod per plant	Grain Yield (Kg ha^{-1})	Pod yield (Kg ha^{-1})	Weight of 1000 seeds (g)
P1	Nitrogen (%)	0.20 ns	12.71 ± 0.52	5.90 ± 0.35	729.70 ± 5.17	1251.21 ± 13.45	81.70 ± 0.26
	available phosphorus	0.006 ns					
	Exchangeable potassium	0.15*					
	Exchangeable Calcium	0.21*					
	Magnesium	0.10*					
	Organic matter (%)	1.62*					
	pH-water	4.91 ns					
P2	Nitrogen (%)	0.18 ns	12.25 ± 0.42	16.12 ± 0.51	2381.32 ± 42.70	1679.21 ± 14.75	145.90 ± 0.17
	available phosphorus	0.008 ns					
	Exchangeable potassium	0.36*					
	Exchangeable Calcium	0.49*					
	Magnesium	0.46*					
	Organic matter (%)	10.26*					
	pH-water	4.89 ns					
P3	Nitrogen (%)	0.19 ns	11.31± 0.48	14.24 ± 0.22	2240.98 ± 30.11	1520.36 ± 25.68	128.60 ± 0.13
	available phosphorus	0.008 ns					
	Exchangeable potassium	0.25*					
	Exchangeable Calcium	0.39*					
	Magnesium	0.37*					
	Organic matter (%)	7.82*					
	pH-water	4.93 ns					
P4	Nitrogen (%)	0.17 ns	10.73±0.53	10.41 ± 0.15	1845.23 ± 18.56	1472.62 ± 10.16	115.55 ± 0.15
	available phosphorus	0.006 ns					
	Exchangeable potassium	0.20*					
	Exchangeable Calcium	0.33*					
	Magnesium	0.27*					
	Organic matter (%)	5.15*					
	pH-water	4.90 ns					
P5	Nitrogen (%)	0.19 ns	10.45 ± 0.67	6.06 ± 0.31	1432.97 ± 25.31	853.25 ± 7.33	101.60 ± 0.25
	available phosphorus	0.007 ns					

Table 4. Contd.

Exchangeable potassium	0.17*					
Exchangeable calcium	0.27*					
Magnesium	0.18*					
Organic matter (%)	3.02*					
pH-water	4.91 ns					
ANOVA	*	ns	*	**	**	*

*, ** significant at p = 0.05 and 0.01, respectively; ns = non significant.

accumulation of mineral nutrients in the soil of study area (Table 3). Similar results were observed in the yield component as number of pod per plant, grain yield, pod yield and Weight of 1000 seeds of cowpea (Table 4). The plot with high values of exchangeable bases potassium, magnesium, calcium and organic matter improved significantly some productivity and yield parameters of cowpea (Tables 3 and 4). Ayuke et al. (2004) showed that crop yields in a large part of Kenya was low due to declining soil fertility as a result of soils impoverishment in organic matter content and low reserves of some trace elements. The importance of soil organic matter in stabilizing soil has been well documented (Tisdall and Oades, 1983; Chaney and Swift, 1984). It is believed that the soils of arid, semiarid and coastal contain sufficient exchange potassium (exchange with NH_4^+) and K^+ bearing minerals able to release enough K^+ to meet crop requirements (Rezaei and Movahedi, 2009). Ossom and Rhykerd (2007) found that soil chemical properties influenced plant growth, and development, as well as the concentrations of various mineral nutrients at the end of the cropping season. In the other hand productivity and yield parameters were not significantly influenced by nitrogen and phosphorus in the soil of study site (Tables 3 and 4). Ojiem et al. (2000) reported that legumes have potential to improve soil nutrients status through biological nitrogen fixation and incorporation of biomass into the soil as green manure. Some food and fodder legumes are known for nitrogen fixing ability, however their establishment with P fertilizers enhances nodulation and hence fixation of atmospheric nitrogen (Masinde and Omolo, 2007).

Conclusion

Results from this investigation show that soil properties could influence cowpea growth, productivity and yield. The obtained results indicated that sand texture and supply soil with organic matter and mineral nutrients as potassium, calcium and magnesium could be recommended to increase significantly cowpea productivity and yield under Cameroon coastal growing environment conditions and the other corresponding conditions.

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