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Growth and Yield Responses of Cowpea (*Vigna unguiculata* (L.) Walp) Genotypes to Nitrogen Fertilizer (NPK) Application in the Southern Guinea Savanna Zone of Nigeria

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Abstract: The effects of compound fertilizer (NPK) application on growth and yields of cowpea genotypes were investigated in a field study at the Teaching and Research Farm of the University of Ilorin, Ilorin in the Southern guinea savanna zone of Nigeria. The study was designed as a series of factorial experiments in split-plot arrangements with four replications and were carried out in the late cropping seasons (August to December) of 2002 to 2004. Ten cowpea genotypes were evaluated at fertilizer levels ranging from 0 to 300 kg fertilizer (NPK) ha^{-1} (equivalent to 0-0-0 to 60-30-30 kg N-P-K ha^{-1}). Results show that fertilizer application resulted in significant improvement in plant height, number of leaves per plant and reduced days to flowering, but no significant effect on total number of flowers produced. Application of fertilizer resulted in significant decreases in nodule production. Yield components and grain yield were significantly enhanced by the application of fertilizer at 150 kg ha^{-1} (i.e., 30 kg N, 15 P_2O_5 and 15 K_2O ha^{-1}), but significant fertilizer×genotype effect indicated differential genotype responses to fertilizer application which may have significant practical implications for field production. It was therefore concluded that the application of fertilizer to cowpea is beneficial although in small quantity and genotype dependent.

Key words: Cowpea genotypes, growth, yield responses, fertilizer (NPK) application

INTRODUCTION

Cowpea is an important food grain legume for over 200 million people in the dry savanna of tropical Africa. It is particularly important in West Africa with over 9.3 million metric tonnes of annual production (Oritz, 1998). The grain is a good source of human protein, while the haulms are valuable source of livestock protein (Fatokun, 2002). It is also a source of income for many smallholder farmers in sub-Saharan Africa and contributes to the sustainability of cropping systems and soil fertility improvement in marginal lands through provision of ground cover and plant residue, nitrogen fixation and suppressing weed. However, despite its great importance, grain yield of cowpea crop is low, around 300 kg ha^{-1} (Cardoso *et al*., 1995; Leite *et al*., 1997). Compared with many other crops, the cowpea has received little attention from plant breeders and a large efforts needs to be made to break the yield barriers and if cowpea production is to keep pace with the other crops, especially cereals, its yield potential must be improved (Anonymous, 2004).

In Nigeria, 80% of the cowpea produced is grain mainly in the savanna zone of the country (FAO, 1999). A wide range of seed yields have been recorded for cowpeas but are generally low. Among factors responsible for the low yields are low soil fertility, as most tropical soils are deficient in essential nutrients particularly N and P (Jones and Wild, 1975). Traditionally, soil fertility in West Africa have been maintained through fallow. However, in Nigeria, intensive cropping is gradually replacing the traditional shifting cultivation that is associated with long fallow and hence low crop yield. The steady decline in food production due to reduced length of fallow on land has prompt farmers to amend soil with different materials (organic and inorganic) in order to enhance plant growth and increase yield (Adepetu, 1997). It has been suggested that organic manure should be used in place of chemical fertilizer to avoid long-term negative effects of chemical fertilizer on the soil (Parr *et al*., 1990). However, organic manure is usually required in large quantity to sustain crop production and may not be available to the small scale farmers (Nyathi and Campbell, 1995), hence, the need for inorganic fertilizer. The positive effect of the application of inorganic fertilizers on crop yields and yield improvement have been reported (Carsky and Iwuafor, 1999). Although, cowpea symbiotically fixes nitrogen, plant dependent on symbiotically fixed N may well suffer from temporary N deficiency during the seedling growth once the cotyledonary reserves have been exhausted. Usually prior to the onset of symbiotic N fixation, cotyledonary reserves are mobilized during hypocotyl

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elongation in cowpea and cotyledons are usually shed one or two days from emergence. It has thus been recognized and demonstrated that application of a small quantity of nitrogen fertilizer enhances early vegetative growth (Dart *et al.*, 1977). Burries (1959), stated that nitrogen has a stimulating effect on root activity and rooting pattern of the crop. It has also been reported that available nitrogenous compound allowed seedlings to make a good start before nitrogen fixation has a chance to occur. Other workers have shown that plants given inorganic N during vegetative periods were much larger by the onset of flowering than those dependent on symbiotic N fixation (Minchin *et al.*, 1981). Such plants also had more branches and produced many peduncles resulting in greater number of pods, seeds and significantly larger yields. There are many reported studies on the effects of P application on growth and yield of cowpea (Owolade *et al.*, 2006; Kolawole *et al.*, 2002; Okeleye and Okelana, 1997), there is darth of information on the effects of N fertilizer on growth and yield of cowpea in Nigeria. However, it has been reported elsewhere that the main limiting nutrients for legume production in the tropics are N and P (Fox and Kang, 1977). This study was therefore designed to evaluate the growth and yield responses of cowpea genotypes to NPK fertilizer under field conditions.

MATERIALS AND METHODS

The study was conducted at the Teaching and Research Farm of the University of Ilorin, Ilorin, in the Southern guinea savanna zone of Nigeria (latitude 8° 29' N and longitude 4° 35' E) at 310 m above sea level. The soil of the experimental site is a plinthustalf (USDA Soil Survey Staff, 1975) with sandy texture in the upper 60 cm. The annual rainfall of Ilorin is on the range of 1000-1200 mm. The field experiments were carried out during the late cropping seasons (August-December) of 2002, 2003 and 2004. Prior to land preparation of ploughing, harrowing and ridging, a composite soil sample of the experimental plot was taken and analyzed for its physico-chemical properties including particle size distribution, pH (in 1:1 soil: water) using glass electrode pH meter, exchangeable cations, total nitrogen, available P (Bray-1) and organic matter, all determined according to methods described by Tel and Hagarty (1984).

The study was designed as a set of factorial experiments in split-plot arrangements with four replications. The first trial in 2002 evaluated three cowpea genotypes (TVX 3636, IT90K-102, IT84-124) at three levels of fertilizer (0, 150 and 300 kg ha^{-1} (equivalent to 0-0-0, 30-15-15, 60-30-30 kg N-P_2O_5-K_2O ha^{-1}) application. The second experiment in 2003 investigated two genotypes (IT89KD-256, IR-48) at five fertilizer levels (0, 75, 150, 225, 300 kg ha^{-1}) (equivalent to 0-0-0, 15-7.5-7.5, 30-15-15, 45-22.5-22.5 and 60-30-30 kg N-P_2O_5-K_2O ha^{-1}), while the third trial in 2004 studied the responses of five cowpea genotypes (IT97K-356-1, IT97K-499-38, IT98K-491-4, IT99K-1122, IT00K-901-5) to three levels of fertilizer as in experiment 1. The fertilizer application was made at 2 weeks after planting (WAP) in each of the experiments as band application using a compound fertilizer NPK 20-10-10.

In each experiment, the plot size was 30 m^2 consisting of four ridges 1.5 m apart and each ridge 5 m long. Planting was done at 30 cm intra row spacing and two seeds per hole. Other cultural practices included weed control achieved by initial application of a tank mixture of codal 400 EC (200 g metolachlor, 200 g prometryn per litre) and stomp 500 E (500 g pendimethalin per litre) at 5 and 1 L ha^{-1}, respectively. This was followed by hand weeding with the traditional hoe at the onset of flowering. Insect pests were controlled using an insecticide, karate 2.5 EC (25 g lambda-cyhalothrin per litre) sprayed at 5 ml L^{-1} of water in a knapsack sprayer. Spraying started at the commencement of flowering and continued at weekly intervals until pod maturity.

Plant data collection included growth parameters of plant height, number of branches, number of leaves, nodule production and dry matter yield, all taken at 50% flowering. Total number of flowers produced per plant was also recorded. At pod maturity, yield components including peduncles per plant, number of pods per plant, number of seeds per pod, seed size and shelling percentage were taken. All data collected were subjected to the analysis of variance following the split-plot model using Genstat 5.32 statistical package. Significant means were separated by the Duncan's Multiple Range Test at 5% probability level.

RESULTS AND DISCUSSION

The physico-chemical properties of the soil samples of the experimental site (Table 1) show that the soil was sandy loam, low in total N (4.7 g kg^{-1}) and available

Table 1: Physico-chemical properties of the soil of the experimental site

Soil characteristics	Value
Sand (%)	73.00
Silt (%)	20.00
Clay (%)	7.00
pH (H_2O)	5.90
Total N (g kg^{-1})	4.70
Bray 1 P (mg kg^{-1})	4.50
Ca (cmol kg^{-1})	1.20
Mg (cmol kg^{-1})	0.90
Na (cmol kg^{-1})	0.17
K (cmol kg^{-1})	0.28

Table 2: Effects of genotype and fertilizer (NPK) applications on growth parameters of cowpea at 50% flowering stage in 2002

Treatments	Plants height (cm)	Branches /plant (No.)	Leaves /plant (No.)	Nodules /plant (No.)	Dry matter (g plant^{-1})	Days to flowering (DAP)	Flowers plant (No.)
Genotype							
TVX 3636	20.210b	5.20a	24.20a	12.10a	24.790b	42.0a	25.40a
IT90K-120-6	29.430a	5.20a	26.60a	11.70ab	36.080a	39.0b	27.60a
IT84-124	21.050b	4.70b	27.20a	7.40b	33.110a	41.0a	26.50a
SED	2.477	0.13	2.71	2.34	2.616	1.1	2.43
Fertilizer Level (kg N-P-K ha^{-1})							
0-0-0	22.760b	5.00a	25.40a	16.90a	29.450a	43.0c	25.50a
30-15-15	26.000a	5.00a	25.80a	9.00b	31.220a	40.0b	28.30a
60-30-30	25.920a	5.00a	26.80a	5.30b	33.320a	37.0a	29.10a
SED	1.681	0.26	2.74	2.03	3.890	1.3	2.64

Values followed by the same letter(s) in each column are not significantly different by the Duncan's Multiple Range Test at 5% probability level

Table 3: Effects of genotype and fertilizer (NPK) applications on growth parameters of cowpea at 50% flowering stage in 2003

Treatments	Plants height (cm)	Branches /plant (No.)	Leaves /plant (No.)	Nodules /plant (No.)	Dry matter (g plant^{-1})	Days to flowering (DAP)	Flowers plant (No.)
Genotype							
IT89KD-256	46.210b	13.50b	19.0b	13.10b	36.70a	35.0a	22.0a
IR-48	59.120a	15.60a	27.0a	18.50a	40.50a	43.0b	20.0a
SED	0.900	0.39	0.9	2.18	2.55	0.1	0.2
Fertilizer Level (kg N-P-K ha^{-1})							
0-0-0	51.030c	13.80c	20.0c	25.70a	26.50b	39.0b	21.0a
15-7.5-7.5	52.350b	13.60c	23.0b	22.50a	30.40b	40.0b	21.0a
30-15-15	53.540b	14.40b	26.0a	12.80b	36.90a	42.0b	21.0a
45-22.5-22.5	52.00b	14.40b	25.0a	8.20c	38.70a	37.0a	22.0a
60-30-30	54.410a	16.60a	26.0a	5.10d	40.80a	36.0a	21.0a
SED	0.961	0.64	1.0	1.23	3.10	0.5	0.6

Values followed by the same letter(s) in each column are not significantly different by the Duncan's Multiple Range Test at 5% probability level

Table 4: Effects of genotype and fertilizer (NPK) applications on growth parameters of cowpea at 50% flowering stage in 2004

Treatments	Plants height (cm)	Branches /plant (No.)	Leaves /plant (No.)	Nodules /plant (No.)	Dry matter (g plant^{-1})	Days to flowering (DAP)	Flowers plant (No.)
Genotype							
IT97K-356-1	35.50b	4.60abc	42.60a	15.50ab	33.60ab	38.0a	39.20a
IT97K-499-38	42.40a	4.90a	32.90b	16.20ab	35.90a	39.0a	27.00b
IT98K-491-4	35.10b	4.20bc	34.10b	13.60b	30.00b	43.0b	24.30bc
IT99K-1122	36.40ab	4.40abc	34.30b	17.40ab	31.10ab	48.0c	19.80c
IT00K-901-5	37.60ab	4.10c	31.90b	19.30a	34.10ab	41.0ab	25.20b
SED	3.45	0.30	2.30	2.60	2.50	1.5	2.34
Fertilizer Level (kg N-P-K ha^{-1})							
0-0-0	34.70b	4.00a	34.90a	20.00a	30.50b	45.0b	27.10a
30-15-15	37.70ab	4.50a	34.70a	14.90a	35.80a	42.0a	27.00a
60-30-30	39.80a	4.50a	36.00a	6.50b	32.50b	39.0a	28.50a
SED	1.85	0.20	1.40	3.55	1.60	1.7	2.16

Values followed by the same letter(s) in each column are not significantly different by the Duncan's Multiple Range Test at 5% probability level

P (4.5 mg kg^{-1}) both of which values were below the critical levels (Aune and Lai, 1995). Klinkinberg and Higgins (1968) have characterized the savanna as highly leached ferruginous ultisols low in O.M., N and P but high in K content derived from the base complex.

Although cowpea is known to obtain most of its nitrogen requirements through symbiotic fixation of the atmospheric nitrogen, the importance of the externally applied N to its growth and grain yields have been reported elsewhere by various workers (Dart *et al.*, 1977; Sinclair and Dewit, 1976). The results of this study showed that the application of fertilizer (NPK) improved growth parameters (Table 2-4). Dart *et al.* (1977) had reported that application of a small quantity of nitrogen (20 kg N ha^{-1}) enhanced early vegetative growth as obtained in the present study. This may be due to the stimulating effect of nitrogen on root activity and rooting pattern (Burries, 1959).

The results of the present study showed that plant height, number of leaves per plant and plant dry matter at 50% flowering were highest with the highest level of fertilizer applied. This was in line with the observation of Minchin *et al.* (1981) who found that plants given inorganic nitrogen during vegetative period were much larger by the onset of flowering than those dependent on symbiotic N fixation. However, nodulation was

Table 5: Effects of genotype and fertilizer (NPK) application on yield parameters and grain yield of cowpea in 2002

Treatments	Peduncle/ plant (No.)	Pods/ plant	Seeds/pod (No.)	100 seeds weight (g)	Shelling (%)	Grain yield (t h^{-1})
Genotype						
TVX 3636	12.10b	17.50b	8.30b	21.50a	81.40a	1.230b
IT90K-102-6	13.70ab	20.10b	9.70ab	22.80a	78.10b	1.390a
IT84-124	16.40a	26.20a	10.80a	16.40b	64.80c	1.020b
SED	1.44	1.92	0.70	1.45	1.22	0.055
Fertilizer level (kg N-P-K ha^{-1})						
0-0-0	13.30b	19.70b	9.20b	18.80b	72.80b	1.120b
30-15-15	14.80a	22.10a	11.10a	24.50a	76.20a	1.340a
60-30-30	14.10ab	21.30ab	8.50b	23.70a	75.30ab	1.190b
SED	0.97	1.16	0.39	2.07	1.69	0.032

Values followed by the same letter(s) in each column are not significantly different by DMRT at 5% probability level

Table 6: Effects of genotype and fertilizer (NPK) application on yield parameters and grain yield of cowpea in 2003

Treatments	Peduncle/ plant (No.)	Pods/ plant	Seeds/pod (No.)	100 seeds weight (g)	Shelling (%)	Grain yield (t h^{-1})
Genotype						
IT89KD-256	14.10b	21.0b	10.30a	17.810a	81.90a	1.310a
IR-48	15.70a	23.0a	9.30b	17.450a	82.80a	1.290a
SED	1.24	0.60	0.50	0.191	3.17	0.116
Fertilizer level (kg N-P-K ha^{-1})						
0-0-0	12.30b	19.0b	8.20b	17.700a	79.90a	1.050c
15-7.5-7.5	12.80b	19.0b	10.50a	17.510a	81.30a	1.210b
30-15-15	14.10a	21.0b	11.50a	17.690a	85.60a	1.340ab
45-22.5-22.5	15.00a	24.0a	10.90a	17.520a	82.00a	1.410a
60-30-30	14.30a	26.0a	10.60a	17.700a	83.00a	1.480a
SED	0.77	0.90	0.68	0.285	2.59	0.139

Values followed by the same letter(s) in each column are not significantly different by the DMRT at 5% probability level

Table 7: Effects of genotype and fertilizer (NPK) application on yield parameters and grain yield of cowpea in 2004

Treatments	Peduncle/ plant (No.)	Pods/ plant	Seeds/pod (No.)	100 seeds weight (g)	Shelling (%)	Grain yield (t h^{-1})
Genotype						
IT97K-356-1	21.30a	28.60a	7.20b	20.200a	83.30ab	1.052a
IT97K-499-38	15.70b	20.70b	9.30a	17.000b	78.70ab	0.937a
IT98K-491-4	14.40b	19.80b	8.80ab	19.000a	85.70a	1.089a
IT99K-1122	13.60b	16.00b	10.40a	16.000b	74.80b	0.793a
IT00K-901-5	15.00b	19.30b	8.50ab	19.000a	78.90ab	1.048a
SED	2.44	3.09	0.93	0.110	4.98	
Fertilizer level (kg N-P-K ha^{-1})						
0-0-0	19.30b	20.60b	8.60a	18.000a	79.10a	0.916b
30-15-15	24.80a	22.10a	8.90a	18.000a	79.70a	1.020a
60-30-30	23.10a	21.40ab	8.90a	18.000a	81.70a	1.020a
SED	0.77	0.90	0.23	0.006	4.79	

Values followed by the same letter(s) in each column are not significantly different by the DMRT at 5% probability level

significantly reduced by successive application of NPK fertilizer from 0-0-0 to 60-30-30 kg N-P-K ha^{-1} (Table 2-4). These results were in line with the reports of the earlier workers who showed that application of N fertilizer three weeks after emergence depressed nodule numbers (Rhodes, 1981; Ofori, 1973; Tewari, 1965). Similarly, Graham and Scott (1984) reported that nodulation in cowpea was inhibited by nitrogen fertilizer application at rates greater than 30 kg ha^{-1}. In the same vein, Eriksen and Whitney (1984) showed that even though the application of nitrogen fertilizer at flowering promoted vegetative dry weight, it decreased nodule dry weight.

The results of this study also suggest that nodulation decreased with increasing P application contrary to the report of earlier workers that the application of fertilizer P increased the number and dry matter of nodules (McLaughlin *et al.*, 1990). Other workers also reported that P stimulates root and plant growth, initiates nodule formation as well as influences the general efficiency of the rhizobium-legume symbiosis (Abdel-Wahab *et al.*, 1994; Luyindula *et al.*, 1994), thereby optimizes the biological nitrogen fixation (BNF) system of legume (Norman *et al.*, 1995). The results suggest an antagonistic effect of readily available N on these functions of P, thereby indicating that application of P may not optimize the BNF in the presence of readily available N in the soil.

Most yield parameters and consequently the grain yield were significantly increased by the application of NPK fertilizer at rate equivalent to 30-15-15 kg N-P-K ha^{-1} (Table 5-7). These results agree with the report of Minchin *et al.* (1981) who showed that plants given

Table 8: Simple linear correlation coefficients of grain yield and growth and yield parameters

Grain yield Vs	r
Plant height	0.653**
Branches per plant	0.675**
Leaves per plant	0.272
Nodules per plant	0.070
Peduncles per plant	0.341
Dry matter at 50% flowering	0.324
Pods per plant	0.378*
Seeds per pod	0.008
Pod weight	0.773**
Shelling percentage	0.755**

*, **denote effects significant at 5 and 1% probability level, respectively

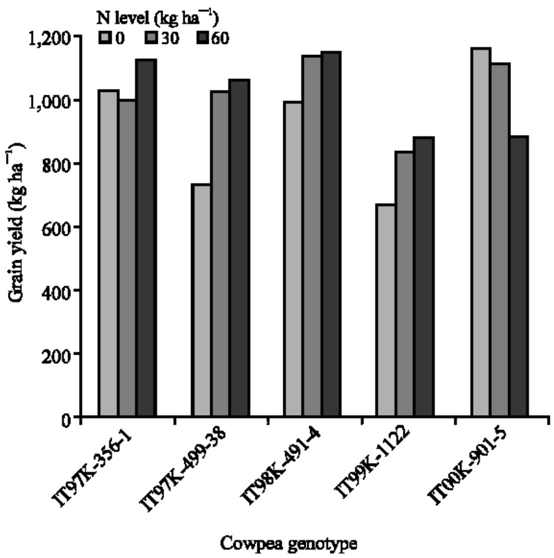

Fig. 1: Interactive effects of cowpea genotype and N fertilizer on grain yield

inorganic nitrogen fertilizer had more branches, produced many peduncles and so greater number of pods, seeds and significantly larger grain yields than those dependent on symbiotic nitrogen fixation. The results show that the application of 300 kg NPK fertilizer ha^{-1} (an equivalent of 60-30-30 kg N-P-K ha^{-1}) depressed most of the yield parameters and grain yield when compared with the application of 150 kg (30-15-15 kg N-P-K ha^{-1}). This was also similar to the report of Njobdi (1990) who showed that 20 kg N ha^{-1} of nitrogen fertilizer was the best level for high grain yield while the application of 40 kg N ha^{-1} depressed flowering and reduced grain yield, although vegetative growth was significantly increased.

The results of the interactive effects of cowpea genotype by fertilizer application observed in 2004 presented in Fig. 1 showed differential genotype responses to fertilizer application. The results show that while IT97K-356-1 showed no appreciable response to fertilizer application at any level, grain yields in IT97K-499-38, IT98K-491-4 and IT99K-1122 increased with increased fertilizer application with a net increase of 41.1, 15.7 and 31.6%, respectively at the highest level of fertilizer applied. However, the application of NPK fertilizer resulted in progressive decreases in grain yield, resulting in a final yield loss of 24% with the application of 300 kg NPK fertilizer ha^{-1} in IT00K-901-5. These results were in consonance with the report of Tayo (1980) who showed significant differences in varietal responses of cowpea to fertilizer application. This has significant implication for fertilizer management in cowpea production, as fertilizer requirement may vary with different genotypes. It is therefore imperative that fertilizer need of each genotype should be determined prior to large scale field application.

Grain yield was found to be positively correlated ($p<0.01$) with parameters such as plant height, number of branches per plant, number of pods per plant, pod weight and shelling percentage (Table 8). These parameters were significantly improved by the application of nitrogen fertilizer and hence significant increase in grain yield. The importance of plant height as a function of yield had been reported for other crops (Abayomi, 1992; Blum *et al*., 1989). It has therefore been suggested that the final plant height may be taken as a simple integral measure of growth response to moisture and nutrient stress (Blum *et al*., 1989). From the results of the present study and reports from elsewhere in the literature, it can be concluded that the application of inorganic fertilizer to cowpea is beneficial, although may be in small quantity (equivalent of 30-15-15 kg N-P-K ha^{-1}). The results of this study also showed that there may be differential genotype response to fertilizer application, hence the need to determine the fertilizer requirement of the individual genotypes before applying to field production.

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