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Genotypic Variation in Cowpea (*Vigna unguiculata* L.) for Rock Phosphate Use in Low Phosphorus Soils of Dry Sudan and Sahel Savannas of Niger and Nigeria, West Africa

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Abstract: Cowpea (*Vigna unguiculata* (L)) is a legume crop that provides food, feed and cash in dry areas of Sudan and Sahel environments of West African. Low availability of phosphorus is a major constraint to crop production by poor farmers. Farmers cannot afford to buy the soluble P fertilizer and use of local rock P may be an alternative. Efforts are being made to identify Cowpea genotypes with tolerance to low P and greater P use efficiency from local rock phosphate. Cowpea genotypes (>100) differing in morphology were examined at 2 P levels (0P, 90 kg P ha^{-1} as Rock Phosphate) in 2002. Wide apparent variation in grain yields was found. Grain yield in low P varied from 35 to 212% at both locations while in response to RP application it ranged from 30 to 219%. Based on the genotypes performance at low (0P) and high P (RP), genotypes were classified into the following groups: inherently low yielding at low and high P (Inefficient non responders), inherently high yielding at low and high P (Efficient responders), low yielding at low P but high yielding at high P (Inefficient responders), high yielding at low, but low yielding at high P (Efficient non responder) and inherently moderate yielding (Intermediate). In 2003, eight genotypes selected from the different tolerance and response groups were further examined in the screen house and field studies for growth characteristics related to tolerance to low P and response to applied RP. Application of RP, increased grain yield, shoots: root ratio and AMF infection of cowpea roots.

Key words: Tahoua rock phosphate · Cowpea varieties · Dry savannas · Low P soils · West africa

INTRODUCTION

Cowpea (*Vigna unguiculata* (L) Walp.) is an important grain legume crop providing food, feed and cash to many farmers in the dry savanna areas of West Africa. An additional attribute of the grain legume is its ability to fix nitrogen from the atmosphere and contribute to soil fertility restoration after residues decomposition [1]. Cowpea is mostly grown in low nutrient environment of the Sudano-Sahelian region of West Africa and low nutrient availability such as phosphorus (P) is a major constraint to cowpea production. Growth, nodulation and N_2-fixation of cowpea are hampered by phosphorus deficiency. Legumes like alfalfa [2], clover, common bean, cowpea [3] showed a high positive response to P supplementation. Study has so far been made to screen cowpea genotypes tolerant to low P soils or be efficient responder to applied RP in moist Savanna of West Africa [4]. The P use efficiency (PUE) [5] and relative P use efficiency (RPUE) have been established [6]. A strong correlation between the P use efficiency and the root fungus (Vesicular Abuscular Mycorrhizal) was pointed out in moist savanna of West Africa [4]. Root symbiosis with the AMF has been shown to enhance P absorption by increasing the effective root area [7]. Shoot: root ratio could be an indicator of the different cowpea genotypes being efficient responder or tolerant to low P soils. The objectives of this study were to identify cowpea genotypes that can access P not usually available to the average genotypes under low P condition (Tolerant genotypes or efficient non-responders) and the cowpea genotypes that respond to RP application (Efficient responder- genotypes).

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MATERIALS AND METHODS

Field Experiment: Field experiments were conducted over two consecutive years (2002 and 2003) at two locations at Minjibir (12°8.73'N, 8°39.97'E), Kano in the Sudan savanna of Nigeria and at Toumnia, Zinder (13°28.76'N, 9°.79'E) in the Sahel Savana of Niger Republic. The soils of the two selected sites were low in their available P content (2.1 and 0.7 mg P kg^{-1} Olsen at Minjibir and Toumnia, respectively. The average rain falls were 841.4 and 372.8 mm, respectively the first year and 430.3 mm at Toumnia and 1031.4mm at Minjibir the second year.

Cowpea genotypes were provided by the grain legume program of IITA, Ibadan, Nigeria, the Institute of Agricultural Research (IAR) Samaru, Zaria and the National Institute for Agronomic Research of Niger Republic (INRAN). A total of (> 100) cowpea genotypes were used for the field experimentation the first year. The design of the experiment was a strip-plot with 4 replications and two treatments (two P application levels and cowpea genotypes) was used [8]. Tahoua Rock P from Niger (90 kg P ha^{-1}) was the source of P applied by banding at 4 cm depth before planting. The rock P has the following characteristics: 28% P_2O_5, 1.5% CS, 43.9% CAO, 2.1% AL_2O_3, 13% F_2O_3, 1.6%MgO and 3.3% F [9]. Each cowpea genotype was grown in a single row of 4 meters long and four seeds were planted, thinned to two with 20 cm spacing between hills. The cowpea fields were sprayed and weeded according to standard agricultural practice. Plants were harvested at maturity for grain and fodder production.

In year 2, the spacing was 20 cm within the rows and 75 cm between rows. A strip plot design with 3 replications was used for the experiments [8]. The treatments were the 08-cowpea genotypes as vertical factor and two P levels (without P and 90 kg P ha^{-1} as RP) as horizontal factor. Each cowpea genotype was in a plot of 4 m x 3 m and received a basal application of 30 kg K ha^{-1} as muriate of potash. No N fertilizer, mycorrhizal fungi or *Bradyrhizobium* inoculums was applied. Five seeds were sown $hill^{-1}$ and the seedlings thinned to two a week after emergence. Fresh roots were collected in sampling vials at early pudding for AMF infection rate by the method of Giovanetti and Mosse [7].

The relative RP use efficiency (RRPUE) was calculated as: kg grain ha^{-1} in the RP source plot - kg grain in 0P plot)/ kg P ha^{-1} applied as the P source.

Screen House Experiment at IITA Kano: The river sand has pH of 6.4, organic carbon of 0.06 g kg^{-1}; CEC of 1.7 cmol kg^{-1}, Olsen P was 1.3 mg P kg $soil^{-1}$ and a total N of 0.021 g kg $soil^{-1}$. The river sand low in nutrients especially with very low was to see the response of cowpea to RP and this sand is closed to soils of study area. The characteristics of soil materiel used are as follows: The pH in water varied from 6.5 at Minjibir and in river sand to 7. 3 at Toumnia, the organic carbon (g kg $soil^{-1}$) varied from 0.061 in the river sand to 0.24.025 at Toumnia and Minjibir. The total N (g kg $soil^{-1}$) was 0.01 at M and T and 0.02 in the river sand. The available Olsen P (mg kg $soil^{-1}$) varied from 0.7 at Toumnia, 1.3 in the RS to 2.3 at M. The NH_4 Acetate extractable Cations (cmol kg^{-1}) for Ca varied 0.8-09 at T and M to 1.21 in the RS, 0.2-0.3, for K it varied from 0.04 in river sand to 0.1 at both T and M. for Na it varied from o.17 in RS to 0.4 at both T and M. The soils are sandy varying from 88%-91 at M and T respectively to 93% in RS.

A strip plot in a randomized complete block design with three replications was used. The treatments included 08 cowpea genotypes (Danila, Aloka, IT90K-277-2, IT98D-1399, TN256-87, IT97K-340-1, IT98K-476-8 and IAR-48) selected in the field at two locations in Niger and Nigeria in 2003 and two P levels (without P and 40 mg P kg^{-1} river sand as Rock P). The sand was air dried, sieved (< 2 mm screen) and weighed (3 kg sand pot^{-1}). A basal application of 60 mg K kg^{-1} sand as muriate of potash and 1 ml of micronutrient combination [10] kg^{-1} sand was applied to each pot at planting. The phosphorus source was the PNT at the rate of 40 mg P kg^{-1} sand where appropriate a week before planting as an incubation period. The seed were surface sterilized with 95% ethanol for 1 min and 3% hydrogen peroxide for 5 min and then rinsed with sterile water [10]. Five seeds of each genotype were sown in each pot and thinned to one plant pot^{-1} a week after emergence. All plants were harvested at 49 days after planting (DAP) and assessed for shoots and root dry matter, shoot to root ratio.

Statistical Analysis: All data generated from field and screen house studies were submitted to the Gen Stat package system for analysis of variances (ANOVA) [11]. Standard errors of means from the different experiments were computed to be able to differentiate between the different treatments means.

RESULTS AND DISCUSSION

Field Experiment 2002

Genotypic Difference in Response to RP Application: Mean of more than 100 cowpea showed Genotypic differences in P use efficiency of field screened cowpea genotypes at (M) and (T) in based RP application, 2002 was analyzed: mean varied from 4 to 13 kg grain ha^{-1} per kg P applied. TN256-87 gave the highest (13) at Minjibir while IT90K-277-2 produced the lowest. Aloka performed well (10) at T while Danila used efficiently the PNT (10) at M.

The existence of a cowpea genotype x RP interaction in the 2002 field experiment indicated that cowpea genotypes differed in the relative performance in RP utilization.

This suggested that there might be differences among the cowpea genotypes with respect to P nutrition [12]. Cowpea genotypes were grouped based on grain, fodder and dual purpose production at low (0 P) and at high P (90kg ha^{-1} RP) using the classification scheme of [13] (Figs 1a, 1b, 2a and 2b). The different groups were: The Efficient non Responder (ENR) to P comprising the genotypes that performed in low P (0P) but were not responsive to RP applications; the efficient responders (ER) those which performed under RP condition; the inefficient responders (IR) or sensitive responders (S) comprising genotypes that did not perform under low P condition but responded well to RP application and the non-responders (INR) as these that performed poorly under both low and high P conditions. The result clearly suggested a number of cowpea genotypes that were good

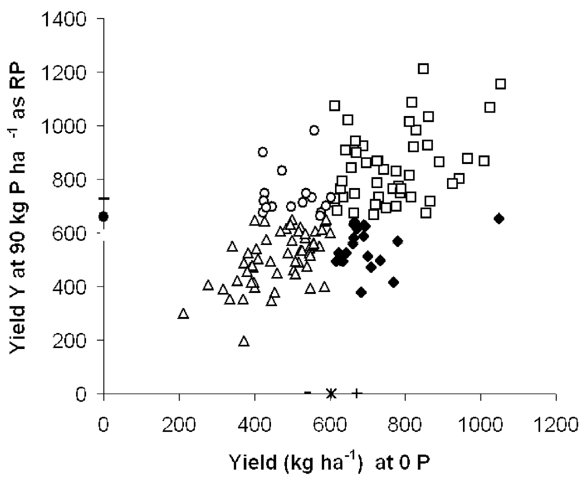

Fig. 1a: Relationship between low and high RP level for Cowpea grain production at Minjibir,Nigeria

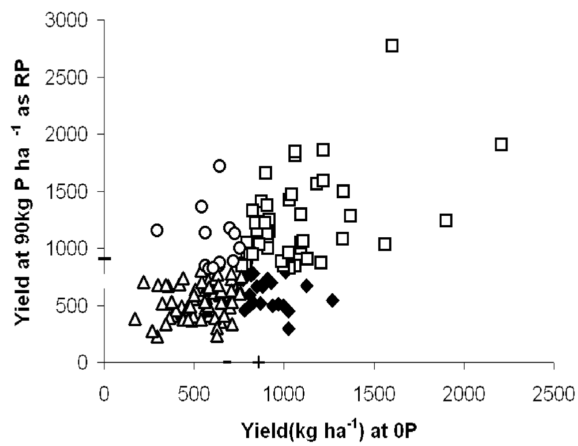

Fig. 2a: Relationship between low and high RP for fodder production at Minjibir,Nigeria

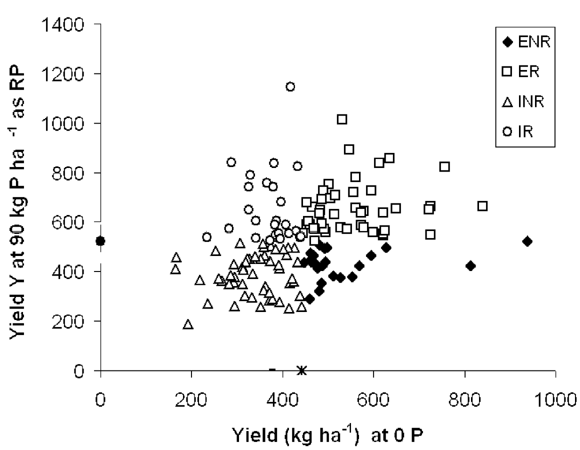

Fig. 1b: Relationship between low and high RP level for Cowpea grain production at Toumnia, Niger Republic

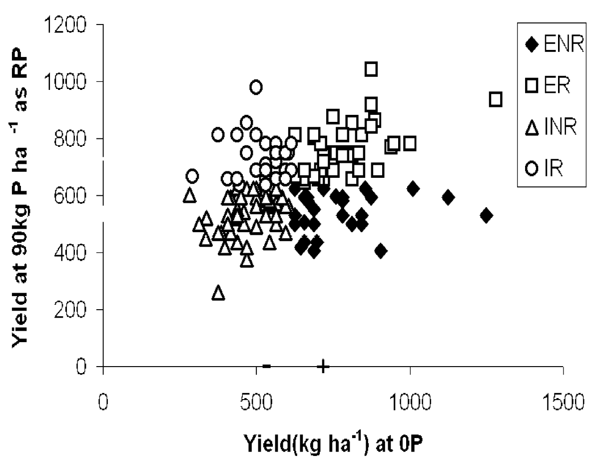

Fig. 2b: Relationship between low and high RP for fodder production at Toumnia, Niger Republic

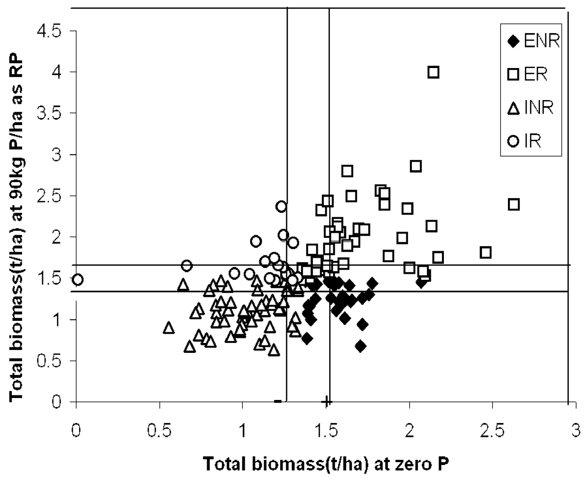

Fig. 3a: Total above ground biomass(t/ha) to RP application at Minjibir 2002

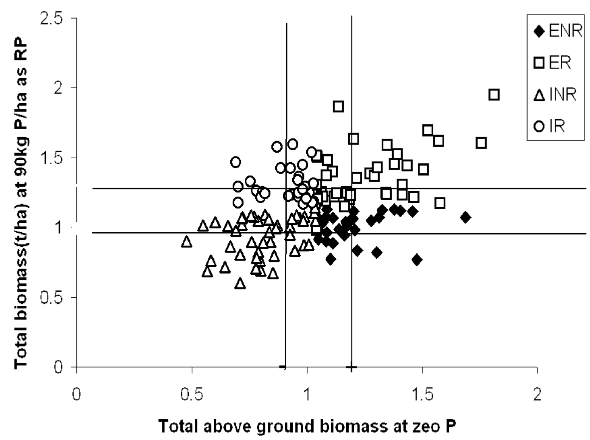

Fig. 3b: Total above ground biomass(t/ha) to RP application at Toumnia 2002

in grain production (IT90K-277-2, IT97K-340-1, IT98K-476-8); then some were good fodder producer (Danila, Aloka, IT98K-476-8, TN256-87, IT98D-1399) and yet other genotypes were of dual-purpose production because they gave both grain and fodder (TN256-87, IT98K-476-8, IAR-48 and IT98D-1399). 08-cowpea genotypes were selected based on the grain at low P (0P) or at high P (PNT) for further study. Genotype such as TN256-87 was recorded as responder. Danila, IT98D-1399 and Aloka belonged to the same group of inefficient responder. In comparison to the soils from the two locations, the grain production at Minjibir (658 kg ha^{-1}) was higher than that at Toumnia (522.2 kg ha^{-1}) when RP was added. TN256-87 was efficient responder at both locations. IT98K-476-8 was tolerant at Minjibir, while it was efficient responder at Toumnia.

Effect of Applied RP on Root, Shoot Dry Matter, Biomass and Differential Response in Pots: In general, all cowpea genotypes responded to RP application. The mean response varied from 0.114 to 0.382 g pot^{-1} at 0P and from 0.117 to 0.464 g pot^{-1} under R P for the root, while it varied from 0.934 to 1.155 g pot^{-1} for the shoot from low to RP application. The cowpea genotypes were basically grouped for their high growth under low P (0P), their sensitive or response under high P (RP). Under 0P condition Danila the local genotype was observed at the bottom and under RP condition, the cowpea genotypes: Danila and Aloka suggesting the RP application improved the root development and P uptake of the local genotypes. On the other hand, under 0P condition IT97K-340-1, was observed to get highest shoot dry weight while under high P conditions, genotype IT97K-340-1 was recorded to be on top (Table 1). The result suggests that the IT97K-340-1 was efficient responder because of it performance at both low and high P conditions. The low organic carbon of 0.06 g kg^{-1} of the river sand might have likely contributed to the P problem in the area as shown by Agboola [14].

The biomass was generally increased and varied from 1.164 to 1.377 g pot^{-1} from 0P to RP application. Danila showed relative response to RP (Table 1). The relative cowpea genotypes response varied from -2.98 % to 126.91 %.

Effect of RP on Shoot: Root Ratios in Pot: In comparing the genotypes for shoot: root ratio, the following genotypes responded the same way under 0P condition by giving similar shoot: root ratio (6): IT97K-340-1, Aloka, TN256-87; the second group gave 5 as shoot: root ratio and included IT98D-1399, Danila and IAR-48 (Table 2). IT97K-340-1 was recorded with high shoot to root ratio under low P conditions in this pot experiment. TN256-87 gave the highest shoots-to-root ratio (5.81) under zero P and the value was higher than the overall mean shoot-to-root ratio under zero P and therefore the belowground biomass was higher than the above ground biomass. The more relevant criterion for the response group was the relative response to RP compared to the control without P. A relative increase of 100% of the RP on IT98K-476-8 compared to the control without P showed that genotype as responsive. Also, Genetic differences have been

Table 1: Effect of applied P sources on total biomass (g pot^{-1}), relative cowpea response and on root and shoot dry matter in pots

		90RP	90RP		90RP		90RP
Genotypes	0P	Bms	% Diff	0P	RDWg	0P	SDWg
IT90K-277-2	0.564	0.950	68.44	0.124	0.173	0.441	0.777
97K-340-1	1.943	1.585	-18.43	0.295	0.195	1.648	1.390
98K-1399	0.744	0.846	13.71	0.141	0.158	0.603	0.688
98K-476-8	0.827	1.218	47.28	0.210	0.189	0.617	1.029
ALOKA	1.339	1.199	-10.46	0.251	0.209	1.088	0.989
DANILA	0.628	1.425	126.91	0.114	0.260	0.515	1.164
IAR-48	0.813	1.230	51.29	0.220	0.254	0.593	0.976
TN256-87	1.308	1.269	-2.98	0.191	0.172	1.117	1.097
Means	1.164	1.377		0.230	0.222	0.934	1.155
SE (P)	0.119				0.026		0.137
SE (PXG)	0.501				0.094		0.446

G, Genotypes; Bms, Biomass; %Diff, percentage relative response compared to 0P

Table 2: Effect of RP on shoot: root ration in pot and field experiment

	Minjibir			Toumnia			Pot		
	--------------------			---------------------			----------------------------		
Cowpeas	0P	90RP	Rmk	0P	90RP	Rmk	0P	90RP	Rmk
				Shoot-to-root ratio					
ALOKA	9	12	Shoot	19	24	Shoot	6	6	Shoot/root
TN256-87	14	14	Shoot/root	16	14	Root	6	8	Shoot
DANILA	12	12	Shoot/root	13	13	Shoot/root	5	5	Shoot/root
IT98D-1399	13	8	Root	12	11	Root	5	4	Root
IT98K-476-8	10	9	Root	9	8	Root	3	6	Shoot
IAR-48	5	4	Root	8	13	Shoot	5	5	Shoot/rot
Means	10	10		13	13		4	5	
SE □ (P) M = 1							SE ± (P) = 1		
SE □ (PXC) M = 3							SE ± (PXC) = 2		
SE □ (P) T = 1									
SE □ (PXC) T = 5									

reported in common beans for root to shoot ratio [15] and for cowpea grown in moist savanna of Nigeria [4]. P efficient genotypes should have root to shoot ratio as reported by Yan *et al.* [16].

Field Experiment, 2003: In order to further screen for P use efficiency, the selected cowpea genotypes were further screened under field conditions. P use efficiency of the selected cowpea genotypes were further investigated based on some candidate mechanisms such as root infection by AMF, Shoot: root ratio.

Effect of RP on Shoot: Root Ratios in the Field at Minjibir and Toumnia: One of the most commonly observed effects of nutrient deficiency on plant development is a decrease in the shoot: root ratio [17]. The shoot: root ratio was not increased at both locations but it was higher at Toumnia (13) than Minjibir (10) (Table 2). There was variation among the cowpea genotypes: At Minjibir the shoot to root ratio showed that some cowpea genotypes developed more shoot than root e.g.: IT90K-277-2 while other genotypes developed more root and these included: IT98D-1399, IT98K-476-8 and IAR-48 and that explained the mechanism by which those genotypes acquire the soil P. Other genotypes developed both shoot and root because they gave the same shoot to root ratio and these regrouped: TN256-87 and Danila. At Toumnia the same pattern was observed the local genotype Aloka from the Sahel gave more shoot than root; Danila from the Sudan savanna produced both shoot and root while the improved genotypes IT98D-1399 and IT98K-476-8 gave more root than shoot. The cowpea genotypes were grouped based on high or low shoot: root ratio at low P (0P) or RP application.

With regards to RP effects on the shoot: root ratio in the field, the group of cowpea genotype with high shoot: root ratio under low P condition at both locations was: IT98D-1399 and IT98K-476-8. Another group was observed under RP supply at both sites and included Aloka. The last group was the genotypes that provided high shoot: root ratio under both low and high P conditions and among those genotypes Danila was recorded at both sites. At Minjibir, the genotype TN256-87 had the highest shoot to root ratio of (14) followed by IT98D-1399 (13) and Danila (12) under low P conditions. At Toumnia, Aloka local was recorded with the highest shoot to root ratio under RP condition. The results suggest that high shoot: root ratio means increase in aboveground biomass beyond below ground biomass. This result indicated that the cowpea genotype IT98K-476-8 was tolerant at both locations because it gave higher shoot to root ratios under low P conditions (Table 2). Genetic differences have been reported in common beans for root to shoot ratio [15] in this work the shoot to root ratio was examined and results indicate significant effect (P<. 001) among field grown cowpea genotypes at both Toumnia and Minjibir. Shoot to root ratio was one of the mechanisms explaining the variability of cowpea genotypes response to P-application [18]. Deficiency in P results in a shift of dry matter allocation in favor of root growth [19].

Effect of P on the Grain Yield Variability and RP Use Efficiency of Selected Cowpea Genotypes in the Field at Minjibir and Toumnia, 2003: The grain is the most important part of the mature cowpea, which provides food protein for the urban and rural poor in West Africa [20] and a source of cash to farmers.

P application increased the grain yield at both locations. The genotypes IT98D-1399 (2170 kg ha^{-1}) and IT98K-476-8 (2067 kg ha^{-1}) were recorded as highest under low P conditions at Minjibir but the highest grain yield of 1535 kg ha^{-1} for TN256-87 at Toumnia, under low P conditions was recorded (Table 3). The cowpea genotypes were classified in P efficient and inefficient at both sites based on high mean at low or high P. At Minjibir the P inefficient were those responding to RP addition and included: Danila, IAR-48, 97K-813-21, 98K-476-8 and while at Toumnia those were: IT97K-340-1, Danila, 98D-1399 and 98K-476-8. On the other hand the P efficient genotypes included genotypes such as IT98D-1399 and IT99K-826-119 at Minjibir while at Toumnia those P efficient genotypes included: IT97K-813-21, TN256-87, IT99K-826-119, Aloka. The grain legume and P fertilization system is influenced by the initial soil P status as shown by Raij [21]. He had therefore suggested that soil testing for P could prove to be an effective aid in making decision about rates of fertilizer to apply. Grain yield production due to P compared to control without P could be further explained by the relative P use efficiency in the two sources of P. This suggested that cowpea like pigeon pea and soybean have an external P requirement [22].

The RP use efficiency (RPUE) varied from 5 to 30 kg grain ha-1 kg P ha-1 and it was higher at Minjibir than Toumnia. An improved cowpea genotype (TN256-87) from the Sahel area gave 13 as RPUE at Toumnia while it gave 7 at Minjibir. Likewise another improved genotype from the Sudan gave 30 as RPUE at Minjibir and 5 at Toumnia. The local genotype Aloka from Sahel gave 9 as RPUE at Toumnia but 6 at Minjibir while the local genotype Danila from Sudan savanna gave 17 as RPUE at Minjibir and 8 at Toumnia (Table 3). That indicates the adaptation of the genotypes to their locations.

Effect of RP on Relative Rp Use Efficiency (RRPUE) in the Field at Minjibir and Toumnia: The relative P use efficiency varied generally from -5.5 to 9.6 kg grain kg^{-1} P applied across the locations and the RRPUE was positive at Minjibir and negative at Toumnia(Table 4).

Table 3: Effect of P on the grain yield variability and RP use efficiency of selected cowpea Genotypes in the field at Minjibir and Toumnia, 2003

	Mijibir			Toumnia		
	0P	RP	RPUE	0P	RP	RPUE
Genotypes	kg ha^{-1}					
TN256-87	735	668	7	1535	1177	13
IAR-48	911	1782	20	1349	1447	16
ALOKA	321	509	6	841	831	9
DANILA	1278	1494	17	647	692	8
IT97K-340-1	BG	BG		633	1024	11
IT98D-1399	2170	1756	20	517	555	6
IT98K-476-8	2067	2705	30	319	419	5
Means	962	1099		762	741	

SE ± (P) M=110
SE ± (PXC) M=406
SE ± (P) T=95
SE ± (PXC) T=285

Table 4: Effect of P on relative RP use efficiency of cowpea genotypes in the field

Cowpeas	Minjibir RP kg ha^{-1}	Toumnia RP kg P ha^{-1}
IT97K-340-1	BG	4.3
IT98D-1399	-4.6	0.4
IT98K-476-8	7.1	1.1
ALOKA	2.1	0.0
DANILA	2.4	0.5
IAR-48	9.7	1.1
TN256-87	-0.7	-4.0
Means	1.5	-0.2

SE ± (P) M=4.2
SE ± (PXC) M=12.5
SE ± (P) =3.5
SE ± (PXC) =9.5

Table 5: Effect of P on the selected genotypes AMFIR* in the field

	Minjibir		Toumnia	
	0P	RP90	0P	RP90
Cowpeas	% AMFIR			
IAR-48	14	8	20	13
TN256-87	15	8	19	15
ALOKA	4	8	16	15
IT90K-277-2	19	12	15	11
IT98D-1399	20	10	14	23
IT98K-476-8	21	20	13	11
DANILA	11	13	11	15
IT97K-340-1	BG	BG	8	29
Means	12	9	16	15

SE ± (P) M = 1
SE ± (PXC) M = 3
SE ± (P) T = 1
SE ± (PXC) T = 5
AMFIR, Arbascular Mycorrhiza Fungi Infection Rate

The improved cowpea genotype IAR-48 gave the highest 9.7 as RRPUE at Minjibir and 1.1 at Toumnia. Also, the improved cowpea genotype IT98K-476-8 gave 7.1 as RRPUE at Minjibir and 1.1 at Toumnia. The local genotype Danila gave 2.4 RRPUE at Minjibir and 0.5 at Toumnia.

Acidic soils with a high pH buffering capacity provide an ideal environment for RP dissolution. Results reported by Bado [23] indicated that the PUE of the unreactive KPR (Rock phosphate) on an acidic soil (pH in H_2O=5) is similar to the PUE of water soluble TSP [9]. In the irrigated system, the PUE of RP was often higher than the soluble fertilizer Triple super phosphate (TSP) (INRAN, 1988) because the RP get solubilized in irrigated soil and the other being leached. Similarly, the genotype IT98K-476-8 performed well under rock P situation at Minjibir while IT97K-340-1 gave higher RPUE at Toumnia.

The data has revealed that Relative P use efficiency depends on the P, the cowpea genotypes and this compliment the earlier observation by Bationo and Anan Kumar [6]. These observations revealed that a variety such as IAR-48 would not produce high grain yield under low P conditions.

Effect of RP on Cowpea Genotypes Root AMF Infection Rate: Mechanism such as mycorrhizal symbiosis has been proposed to explain the P efficiency of crop plants [24]. RP suppressed AMF infection in more than 60% of the field grown cowpea genotypes and infection varied from 1 to 29% at both Minjibir and Toumnia (Table 5) and colonization varied with cowpea genotypes. Aloka local was at part in that, AMF was not affected by the P application (8% infection in RP plot higher than the control (4%) at Minjibir and 15% infection in RP at Toumnia) and IT97K-340-1 gave high AMF infection rate (29%) under Rock P compare to the control. The genotype IT98K-476-8 was observed to have the largest proportion of its root colonized AMF (21%) at Minjibir, while IT97K-813-21 had the highest AMF infection rate (24%) at Toumnia (Table 5). At Minjibir RP increased the %AMF colonization (compared to control) of the genotype IT98K-476-8 by 20%, Aloka by 8% and Danila by 13%. P tolerance was probably related to the high infection of AMF as seen with the genotype IT97K-813-21 with 17% infection rate under low P at Minjibir compared to 13% under rock P condition. Similarly, the genotype IT98K-476-8 was 21% root infected under low P at Minjibir compared to 20% infection rate under RP condition. At Toumnia, IAR-48 was 20% root infected under low P compared to 16% under RP conditions. This explains somehow the mechanism behind the RP tolerance.

At Toumnia RP increased the %AMF colonization (compared to control without P) of IT97K-340-1 by 29%, IT98D-1399 by 23%, (Table 5). These results are in contrast to the reduction of root infection by AMF resulting from addition of rock P in cowpea cv. Pale Green [25]. Similarly, Heckman and Angle [26] examined 15 soybean genotypes for colonization by a heterogeneous field population of AM fungi at two P levels and found that colonization varied significantly with cultivars. Root colonization by AMF is accompanied by the development of a network of fine extraradicl hyphae, which increases the absorption rate of slow-diffusing nutrient, mainly P, from the soil to the plant [27]. Therefore, AMF might play a critical role in low-input inorganic systems of Minjibir and Toumnia due to their function in linking plant and soil processes. The AMF colonization is positively related (r = 0.47) to RPUE in this study as observed by Sanginga *et al.* [4]. AMF colonization is therefore one of the mechanisms that may explain the variation among cowpeas genotypes in low P soils as suggested by other workers [4, 25]. The application of RP increase in AMF infection suggests that RP improved the AMF colonization of 3 cowpea genotypes (IT98K-476-8, Aloka and Danila) at both locations. AMF has formerly been shown to improve the utilization of sparingly soluble P of RP of varying origins [28]. Vanlauwe *et al.* [29] also had the same report on mucuna and lablab. This increase could be as a result of RP having low reactivity [9] on AMF colonization. Young *et al.* [30] hypothesized that the fungus produced compounds that dissolved rock phosphate. Furthermore, AMF can increase P uptake by host plants [31], which is another criterion that can explain the P use efficiency by cowpea genotypes.

CONCLUSION

Wide differences between cowpea genotypes were obtained for grain, P- use efficiency and AMF infection rate and shoot-to-root ratio parameters. The cowpea genotypes differed widely in their P requirement for growth and AMF infection rate. Genotype like IT97K-476-8, IT98D-1399 and IAR-48 with high RPUE and high shoot-to-root ratio under RP condition in the fields are to be used for low P- soils. Local genotypes such Danilla and Aloka are to be used for low P- soils with some R P application.

The possibility to use low reactive Rock P in combination with selected improved P-efficient genotypes exists from this study.

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