RESEARCH ARTICLE **(Open Access)**

Evaluating Commercial Biological and Foliar Fertilizers Potentials in Cowpea Nutrient Uptake and Yield in Sahel Savanna of Niger Republic

CLEMENT ODON N'CHO

University of Man, BP 20 Man, Côte d'Ivoire

Abstract

Many Rhizobium, arbuscular mycorrhizal fungi and *Trichoderma* based inoculants on one hand, and foliar fertilizers on the other hand are commercially produced, mostly in developed countries, and available in sub-Saharan African markets. However, studies on cowpea (*Vigna unguiculata*) responses to these microbial and chemical products in the Sahel savanna agroecological zone do somewhat not exist. RACA6 (*Bradyrhizobium sp*.), Rhizatech (Arbuscular mycorrhizal fungi) and Eco-T (*Trichoderma harzianum*) were the microbial inoculants used either in single or combined application with two foliar fertilizers (Agroleaf high P and Agrolyser). The response of cowpea to rhizobial inoculant was not significant for shoot dry weight. *T. harzianum* slightly increased while Rhizatech and RACA6 decreased the shoot dry weight. P uptake was significantly improved by the biological and foliar fertilizers application. Direct application of P increased grain yield more than biofertilization. This study was aimed at getting an insight of microbiological fertilizer in cowpea production. Further attention could be given to how rapid and effective soil microbes could be selected.

Keywords: Arbuscular mycorrhizal fungi, *Trichoderma harzianum*, cowpea, Sahel savanna, foliage feeding, fertilizers.

1. Introduction

Cowpea is widely grown in Africa as a multipurpose crop [24]. It is the major indigenous African legume cash crop for farmers [12], and an important staple food in many countries in the world [16, 7]. Naturally tolerant to drought [6, 9] and a wide range of soil texture [16], cowpea can thrive on highly acid to slightly alkaline soils. By far, the role of cowpea in food security in dry savannah regions of developing countries is well determined [26].

With improved varieties, the production of cowpea is however constrained by edaphic and climatic conditions. Poor soil fertility and increasing soil nutrient deficiency notably phosphorus and nitrogen [24] constitute major limiting factors of cowpea production. Traditionally, fertilizer is applied to the soil to correct mainly macronutrient deficiency and increase crops growth. However, spraying of plant foliage with solution containing nutrients could effectively improve micronutrient and macronutrient status in the plant [14].

Present in large amounts in the soil, available phosphorus for plant uptake is most of the time low in sub-Saharan Africa. Phosphorus is very immobile because of its strong adsorption to aluminum and iron oxides and hydroxides [19, 5]. This process also reduces to 10-20% the proportion taken up by plant roots from added fertilizer P in the first year [20]. The application of inorganic P fertilizer is then an ineffective cost production; large amounts must be applied for the crops to meet their demand. To be available to plant, inorganic P needs to be desorbed or solubilized and organic P must be mineralized from pools of total soil P to release orthophosphate into the soil solution [18]. Through different mechanisms when interacting with plant roots, soil microorganisms play critical role in increasing available phosphate to plant uptake. A wide range of bacteria such as *Pseudomonas* [13, 15], *Bacillus* [27] and *Rhizobium* spp., actinomycetes and various fungi such as *Aspergillus* and *Penicillium* spp. [17] are involved in Phosphate solubilization. On the other hand, soil fungi such as arbuscular mycorrhizal fungi (AMF), by extending the root system, increase mobilization of orthophosphate

*Corresponding author: Clement Odon N'cho; E-mail: ncho_oc@yahoo.fr
(Accepted for publication March 20, 2018)
***ISSN**: 2218-2020, © Agricultural University of Tirana*

from soil P [17]. Due to their benefits in plant growth, specific soil microorganisms have been developed for use as commercial inoculants or biofertilizers [2, 17]. Apart from the fact that soil microorganisms increase plant P or other nutrient uptake, they provide lots of benefits to ensure good development to their host plant [5].

However, due to the fact that microorganisms could be influenced by environmental and biological factors, commercial microbial inoculants when applied could under-perform. As well, expected positive effects on crop growth and yield from foliar fertilization could be reduced by external environmental factors, plant physiological aspects and the solubility of the chemical contained in the solution.

Sahelian savanna is an important region of cowpea production where different varieties are cropped by smallholder farmers. Recently, improved cowpeas varieties bred by IITA are available. However, the response of those varieties to commercial rhizobial and fungal inoculants in smallholder farmers' conditions are somehow lacking. As well the potential of those varieties to be effectively fertilized by new formulations of foliar fertilizers have not been investigated. This study was therefore carried out to evaluate cowpea P and N uptake under microbial inoculants and foliar fertilizer application in smallholder farmer's field located in Sahelian agroecological zone.

2. Materials and Methods

Experiment establishment

The experiment was carried out in the Sahel savanna agroecological zone covering the region of Maradi in the southern part of Niger Republic during 2011 cropping season. The planting material was the improved variety IT97K-499-35 of cowpea. It is a high yielding (estimated yield is 1. 6 t/ha) variety with medium seed size, semi-erect, semi-determinate, and early maturing variety. It is known to be resistant to *Striga* spp. in northern Nigeria [22, 23].

The microbial inoculants were constituted of two commercial fungi inoculants and one laboratory produced rhizobial inoculant (Table 1). RACA6 and Eco-T were used to inoculate the seeds while soil inoculation was done with Rhizatech. To inoculate the soil, 50 g of Rhizatech was thoroughly mixed with 500 g of soil. Sample of the mixture was introduced in the sowing holes before putting the seeds.

Table 1: Origins and content of the microbial products

Products	Origins	Types	Active microorganisms
RACA 6	IITA, Ibadan (Nigeria)	Laboratory	*Bradyrhizobium* sp.
Rhizatech	Dudutech Ltd., Kenya	Commercial	Spores and mycelia fragments of AMF
Eco-T	Plant Health Products (Pty) LTD, South Africa	Commercial	*Trichoderma harzianum* strain Rfai KRL AG2

Two foliar fertilizers (Agroleaf high P and Agrolyser) were sprayed under high pressure three times at 3, 6 and 8 weeks after planting (WAP). Agroleaf high P (NPK + micronutrients) and Agrolyser micronutrient fertilizer (10 micronutrients) are foliar fertilizer formulations produced by Scotts Company (Ohio, USA), and Cybernetics Ltd. (Nigeria), respectively.

Mineral soil applied fertilizers at the rate of 30 kg P_2O_5 ha^{-1} and 120 kg N ha^{-1} were applied with triple superphosphate (TSP, 46% P_2O_5) and urea (46% N), respectively. The application of TSP was done once at planting while urea was applied in three splits (at planting, 3 WAP and at flowering). The experiment was carried out in randomized complete block design with four replications representing four farmers field.

Sampling and data analysis

Before planting, soil samples were taken at depth of 0-15 cm for routine soil analysis in the Analytical Service Laboratory of the International Institute of Tropical Agriculture (IITA). At flowering, plant samples were taken to determine the shoot dry weight and N and P concentration. The shoots were oven-dried for 72 hours at 60 °C and dry weight was taken. The leaves and stems were ground separately. One volume of milled leaves and two volumes of stems
were mixed for the measurement of the shoot N and P contents [10].

The data recorded were submitted to analysis of variance with GLM Procedure in SAS version 9.2. Post ANOVA multiple means separation was conducted with Duncan's Multiple Range Test at $\alpha = 0.05$.

3. Results

Soil properties and cowpea shoot dry weight

The means of soil nutrient content of the experimental site at the beginning of the study is shown in Table 2. The soil was slightly acidic (pH = 6. 3) with an organic carbon content equal to 1.52 g $kg^{-1}$and ECEC mean value was 1.51 $Cmol_c$ kg^{-1}. Adaré's farm showed a slightly higher organic carbon (OC), N and ECEC than the other farms. Its Calcium content was about two times higher than the one of other farms. The textural class of the experimental sites was sandy soil.

The response of cowpea to the combined application of N and P (Reference treatment) gave the highest shoot dry weight with 23.07 g $plant^{-1}$ representing an increment of 118 % over the control (Figure 1). This was followed by TSP application (72 %) and RACA6 + TSP (60 %). Agroleaf high P and Eco-T increased shoot dry weight by 32 %, respectively.

Cowpea shoot N and P concentrations, grain yield and 100-seed weight

The application of the biological and chemical fertilizers did not have significant effect on cowpea shoot N concentration in Maradi. The co-inoculation of RACA6 + Rhizatech induced the greatest shoot N concentration representing a mean value of 30. 13 g kg^{-1}, as shown in Table 3. This was followed by TSP application with 30.03 g kg^{-1} and Rhizatech inoculation which gave 29.41 g kg^{-1}.

Table 2*: Soil chemical and physical properties in Maradi at beginning of the experiment*

Farmers	Units	Adaré	Oumarou	Bakoye	Issoufou	Maradi
pH(H_2O) 1:1		6.2	7.3	6.3	5.4	6.3
OC	g kg^{-1}	2.09	1.76	1.22	1.00	1.52
N	g kg^{-1}	0.13	0.08	0.10	0.03	0.09
Mehlich P	mg kg^{-1}	8.95	9.91	4.79	2.64	6.57
Ca	mg kg^{-1}	1.18	0.81	0.76	0.55	0.83
Mg	mg kg^{-1}	0.46	0.50	0.31	0.19	0.36
K	mg kg^{-1}	0.16	0.23	0.11	0.10	0.15
Na	mg kg^{-1}	0.16	0.17	0.17	0.17	0.17
Exch. Acidity	$Cmol_c$ kg^{-1}	0.00	0.00	0.00	0.00	0.00
ECEC	$Cmol_c$ kg^{-1}	1.95	1.71	1.35	1.02	1.51
Zn	$Cmol_c$ kg^{-1}	2.52	1.69	1.36	0.53	1.52
Cu	$Cmol_c$ kg^{-1}	2.91	1.94	2.43	1.46	2.19
Mn	$Cmol_c$ kg^{-1}	16.66	9.30	17.96	12.98	14.22
Fe	$Cmol_c$ kg^{-1}	45.00	39.00	33.00	33.00	37.50
Sand	g kg^{-1}	904	904	904	904	904
Silt	g kg^{-1}	12	12	32	32	22
Clay	g kg^{-1}	84	84	64	64	74

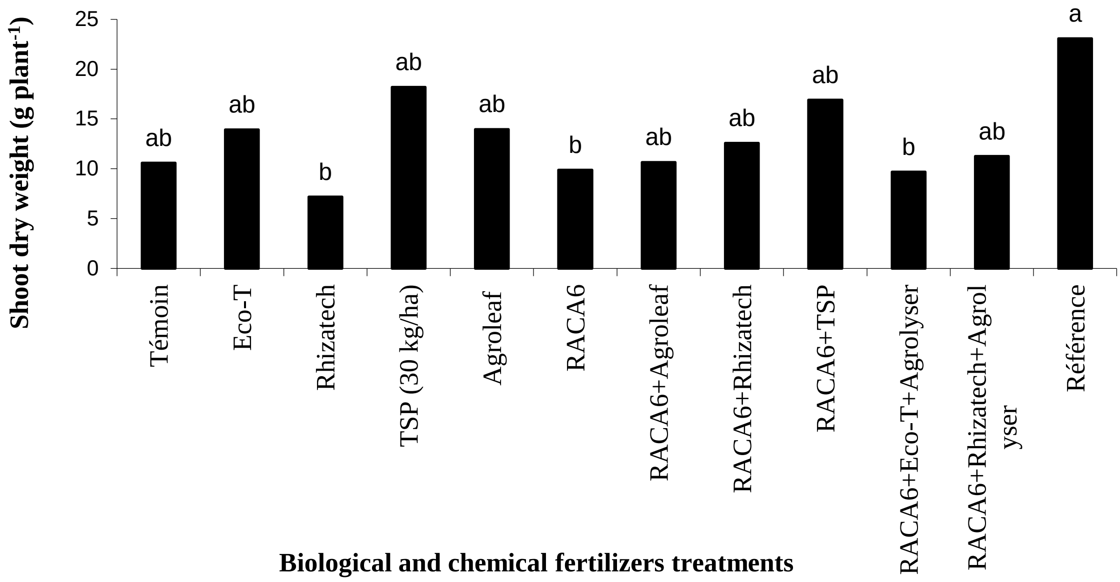

Figure 1: Effect of biological and chemical fertilizers on cowpea shoot biomass production at 8 WAP in Maradi (Treatment bars with the same letters are not statistically different according to Duncan's test at P = 0.5).

Table 3: Effect of biological and chemical fertilizers on cowpea shoot N and P concentration at 8 WAP in Maradi

Treatments	Shoot N concentration		Shoot P concentration	
	Means (g kg^{-1})	Relative response (%)	Means (g kg^{-1})	Relative response (%)
Control	26.98	-	1.81	-
Eco-T	26.3	-3	1.96	8
Rhizatech	29.41	9	2.49	38
TSP (30 kg ha^{-1})	30.03	11	2.96	64
Agroleaf	28.51	6	2.34	29
RACA6	27.73	3	2.22	23
RACA6 + Agroleaf	27.56	2	1.95	8
RACA6 + Rhizatech	30.13	12	2.86	58
RACA6 + TSP	28.18	4	2.63	45
RACA6 + Eco-T + Agrolyser	29.2	8	2.11	17
RACA6 + Rhizatech + Agrolyser	26.95	0	2.15	19
Reference (120 N + 30 P kg ha^{-1})	25.5	-5	2.69	49

Table 4: Effect of treatments on grain yield and 100-seed dry weight of cowpea in Maradi

Treatments	Grain yield		100-seed weight	
	Means (g $plant^{-1}$)	Relative Response (%)	Means (g)	Relative Response (%)
Control	7.08	-	14.67	-
Eco-T	6.58	-7	14.82	1
Rhizatech	6.27	-11	16.04	9

TSP (30 kg ha^{-1})	10.91	54	15.1	3
Agroleaf	8.64	22	14.35	-2
RACA6	7.4	5	15.46	5
RACA6+Agroleaf	5.8	-18	15.65	7
RACA6+Rhizatech	6.95	-2	15.43	5
RACA6+TSP	9.43	33	15.15	3
RACA6+Eco-T+Agrolyser	7.21	2	15.18	3
RACA6+Rhizatech+Agrolyser	6.82	-4	14.93	2
Reference (120 N + 30 P kg ha^{-1})	17.78	151	16.33	11

4. Discussion

The experiment was carried out to evaluate the effect of microbial inoculants and foliar fertilizers on cowpea growth and yield. The result of soil analysis showed that their characteristics constitute constraints to crop production. This observation was also noticed by [1] in its study. Sandy soils are very permeable and vulnerable to wind erosion. This low capacity of water retention weakens the soil conditions to promote plant growth. In addition, the variation between farmers soil nutrient content is source that could influence.

Differently the applied biofertilizer effect on cowpea growth. In fact, Farmers' farm as factor had significant ($P < 0.05$) effect on shoot dry weight with a CV = 38. 70 %.

Cowpea is promiscuous to indigenous *Rhizobium* of sub-Saharan Africa. Therefore, cowpea could meet its N requirement through BNF in presence of effective strains [21] and overcome inorganic N fertilizer application especially when P is available [11]. The potential of N_2-fixation of cowpea, under efficient soil fertility management, is estimated to 88 kg N ha^{-1} [3]. Moreover, [4] identified new varieties could fix up to 182 kg N ha^{-1}. Dissimilarly, the result from Maradi agroecological zone showed irresponsive behavior of cowpea to Rhizobium inoculation. The promiscuity of cowpea to indigenous rhizobia constitutes a challenge to rhizobial inoculation technology to improve its yield. Less is known about the profile of effectiveness of the tropical indigenous rhizobia in cowpea grain yield improvement. Less or non-efficient numerous indigenous rhizobia could present a competition barrier, block inoculant strains to nodulate cowpea plant and thereby cause inoculation failure. Similar findings were observed by [25] where cowpea failed to respond to rhizobial inoculation. The performance of inoculant strains was inversely related to the indigenous rhizobial population. Furthermore, due to the Sahelian sandy acid soil of the Maradi zone with low organic matter (Table 1), (micro)biological activities could be limited. In addition, the soil could be deficient in some BNF essential nutrient such as Mo, P, etc. This is supported by what was observed by [8] in groundnut production and confirmed possible micronutrient deficiency. Application of P fertilizer increased groundnut pod while combined application of P and Mo fertilizers increased pod yield by 21 – 86 % compared to P application alone. Therefore, grain legume like cowpea hardly meets their N requirement through BNF in poor deficient soil. Likewise, AMF inoculation was not beneficial for cowpea IT97K-499-35 shoot dry weight and grain yield production. In contrary, plants treated with *T. harzianum* produced relatively higher shoot dry weight compared to the control. Sahel savanna soils are poor with low P content which could limit efficiency of AM fungi or plant growth promoting microorganisms used in agriculture. The short length of growth period and the irregularity of the rain during this period do not favor strong biological activity; therefore, survival of introduced microorganisms could be seriously affected.

5. Conclusions

The observations from this study showed that the response of cowpea variety IT97K-499-35 to mycorrhizal inoculation in shoot dry weight production was less significant than P application. As well, rhizobial inoculation with P application did not overcome the grain yield of combined N and P application. Further studies are needed to select effective and compatible soil microorganisms to improve cowpea yield in the Sahel savanna.

6. Acknowledgement

I gratefully acknowledge Bill and Melinda Gates Foundation which provided full grant to conduct this study through COMPRO I project. All my gratitude to the Soil microbiology laboratory staff and field technicians, International Institute of Tropical Agriculture, Ibadan, Nigeria. I also thank our collaborators from INRAN-Maradi who were in part responsible for the trial management.

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