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Effects of biological, organic and chemical fertilizers on yield, hydration coefficient, cookability, and mineral composition of groundnut seeds

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A field experiment was carried out to investigate the effects of *Bradyrhizobium*, VA Mycorrhizal inoculation, phosphorus, nitrogen and chicken manure on yield, 100-seed weight, cookability, hydration coefficient and mineral composition of groundnut (*Arachis hypogaea*) seeds. The results showed that nitrogen, phosphorus and chicken manure treatments significantly ($p \leq 0.001$) increased yield, 100-seed weight, non-soakers, and hydration coefficient, in the absence of *Bradyrhizobium* and/or VA mycorrhizal inoculation. The results also showed that *Bradyrhizobium* and/or VA mycorrhizal inoculation significantly ($p \leq 0.05$) increased yield, 100-seed weight, cookability, hydration coefficient, P, Na, K, Cu and Mg contents. A positive correlation ($r = 0.87$–0.94) was observed between the hydration coefficient and cookability. Na, K and Cu content of seeds were significantly ($p \leq 0.05$) increased with N, P and manure treatments, whereas, the Mg percentage increased by N and P treatments and decreased when 0.01 mton manure were applied. The results of this investigation indicate that *Bradyrhizobium* and mycorrhizal inoculation are promising biological fertilizers because they are cheap, easy to handle and improve groundnut growth, yield and seed quality. © 1998 Elsevier Science Ltd. All rights reserved.

INTRODUCTION

Groundnut is an important oil crop in the Sudan. The crop makes a valuable contribution to the Sudan's economy. Nitrogen and phosphorus deficiency are considered as the major factors underlying low plant productivity in this country. The nitrogen demand of plants could be satisfied by nitrogen from the air fixed either industrially or biologically (Elsheikh and Osman, 1995). Phosphorus deficiency is probably the major limitation to the growth of legumes in many soils, and insufficient phosphorus levels in soil can limit nitrogen fixation (Salih *et al.*, 1986). Application of both mycorrhiza and rhizobia improves growth and yield of crops and this is attributed to the better utilization of phosphorus by the mycorrhiza, enhanced nodulation by *Rhizobium* and better N nutrition (Mahdi and Atabani, 1992).

In Sudan and other African countries, groundnut seeds are first soaked and cooked in water, sun dried and then roasted and consumed as such. Hydration coefficient is a very valuable attribute for both consumers and processors. It is a good indicator of seed quality because it plays a major role in defining the ability of the seeds to absorb water and, hence, become ready for the cooking process (Elmubarak *et al.*, 1988). Variation in cooking time of leguminous seeds has been known for a long time, and has been attributed to genetic and environmental factors, particularly climatic conditions and availability of nutrients in soil (Salih *et al.*, 1986).

Increasing population and the consequent increased demand for food production and food quality in the world, require that proposed agronomic strategies for improvement should, in general, avoid high input costs. Biofertilizers such as rhizobia and mycorrhiza, are steadily receiving increased attention and recognition from scientists. This could be attributed to the fact that they pose no ecological threats, usually have a longer-lasting effect and, if properly managed can out-yield recommended doses of chemical fertilizers (Mahdi and Atabani, 1992). The latter effect is of special importance for

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countries, like Sudan, with predominantly low-input agricultural systems of production.

Breeding programmes were started all over the world to improve seed quality of legumes. Fertilizer programmes were also established in the Sudan to serve the same purpose (Babiker *et al.*, 1995; Elsheikh and Elzidany, 1997). The objective of this study was to assess the possibility of improving the yield and seed quality of groundnut by nitrogen, phosphorus fertilizers and chicken manure in the presence of *Bradyrhizobium* and/or VA mycorrhizal fungi.

MATERIALS AND METHODS

Seeds, *Bradyrhizobium* and mycorrhizal strains

Seeds of the groundnut cultivar Ashford were supplied by the Ministry of Agriculture, Sudan. *Bradyrhizobium* sp. strain TAL 1000 was supplied by NifTAL Project, Paia, Hawaii, U.S.A. The strain was maintained at 4°C on yeast extract mannitol agar (YEMA) slopes. A locally-isolated VA mycorrhizal (*Glomus* sp.) strain from Shambat soil was used in this study. The VAM strain was multiplied and maintained in pot cultures of Sudan grass (Garawya *Sorghum bicolur* var. *sudanense*).

Field experiment

The experiment was carried out at the Elrawakeeb Research Station during the 1995/1996 growing season in a factorial design with four replicates. The land was prepared by deep ploughing, harrowing and levelling. Then the area was ridged and divided into 3×4 m plots. Treatments used were:

1. Control (uninoculated).
2. Inoculated with *Bradyrhizobium* sp. strain TAL 1000.
3. Inoculated with VAM fungi *Glomus* sp.
4. Inoculated with both *Bradyrhizobium* sp. strain TAL 1000 and *Glomus* sp.

Each of these main treatments received the following sub-treatments:

(a) Control
(b) 20 kg N ha^{-1} (urea).
(c) 50 kg P_2O_5 ha^{-1} (super phosphate).
(d) 0.01 mton chicken manure ha^{-1}.

Sixteen treatments were set up with three replicates (a total of 48 plots). Chicken manure (composition %: 3.7 N; 2.7 P; 1.9 Ca; 0.7 Mg; 0.35 Na, and 2.7 K) treatments were applied 3 weeks before sowing to minimize harmful effects on germination. Nitrogen and phosphorus were applied at sowing. The inoculation with the *Bradyrhizobium* sp. and *Glomus* sp. (mycorrhiza) strains was carried out as previously described (Mahdi and Atabani, 1992). Three seeds of groundnut cultivar Ashford were placed in a hole on the top of the ridge with 20 cm spacing between holes and 70 cm between ridges. Plots were immediately irrigated after sowing and then, subsequently, irrigated at 7 day intervals.

100-seed weight and yield

At maturity, seeds were collected and the yield of each treatment was expressed on a square meter basis. The seeds were carefully cleaned and freed from dirt, stones, chips and other extraneous grain or dirt. From each sample, 100 seeds were counted randomly in triplicate and the weight was recorded. These seeds were weighed without shell and their weight was recorded.

Cookability test

Twenty grams of beans were processed in 200 ml of tap water in a Labconco apparatus at 110°C for 30 min. The sample was reweighed after processing. Cookability was calculated as follows:

$$\text{Cookability \%} = \frac{\text{Weight after processing} - \text{initial weight (20 g)}}{\text{Initial weight (20 g)}} \times 100$$

Hydration coefficient

For each treatment, 1000 seeds were selected at random and soaked in tap water at a ratio of 1 part to 4 parts of water for 16 h. The hydration coefficient percentage was calculated as follows:

$$\text{Hydration coefficient \%} = \frac{\text{Weight of soaked seeds}}{\text{Initial weight}} \times 100$$

Mineral composition of seeds

The seed minerals composition were determined in g kg^{-1}. The P was determined as described by Chapman and Pratt (1961). The dry ashing procedure (Walsh, 1980) was used for these determinations. Potassium and sodium were determined by using a flame photometer (Corning M400, UK) following the method of Chapman and Pratt (1961). Calcium, magnesium and copper were determined by atomic absorption spectrophotometry.

Statistical analysis

Each sample was analyzed in triplicate and the figures were then averaged. Data were assessed by analysis of variance (ANOVA). The Duncan multiple range test was used to separate means. Significance was accepted at $p \leq 0.05$.

RESULTS AND DISCUSSION

Effect of treatments on 100-seed weight and yield

All inoculation treatments significantly ($p \leq 0.001$) increased the yield and weight of seeds with shell and without shell (Table 1). The N, P and manure applications significantly increased the yield and weight of seeds with shell and without shell. There were no significant differences between N, P or manure treatments. The highest yield and weight of seeds with shell and without shell were observed when both *Bradyrhizobium* and *Glomus* mycorrhiza were applied (Table 1). The yields of groundnut were increased by more than 50%, 60% and 125% by rhizobial strain, VAM fungi and both rhizobial strain and VAM fungi, respectively, compared to uninoculated plants. Rahman *et al.* (1992) found that rhizobial inoculation increased the yield of groundnut by 145%. Direct inter-relationships between VAM fungi and root nodule bacteria are not known, but some researchers suggest that the processes of nodulation and nitrogen fixation require a high level of phosphorus in host tissues, and mycorrhizal fungi can effectively solve this problem (Hayman, 1986). Also *Bradyrhizobium* can influence VAM fungi as it was found that colonization by these fungi was increased significantly following the onset of nodulation. Giri (1993) found that the application of N fertilizer up to 25 kg N ha^{-1} increased the pod yield of groundnut.

Effect of treatments on hydration coefficient and cookability

The hydration coefficient and cookability percentage of groundnut seed were significantly ($p \leq 0.05$) increased with all inoculation treatments (Table 2). The N, P and manure application significantly ($p \leq 0.05$) improved the hydration coefficient, and the manure was the most effective fertilizer. Nitrogen application did not affect the cookability %, whereas the P and manure treatments significantly decreased it (Table 2). A highly positive linear correlation was observed between the hydration coefficient and cookability with the following equations:

(1) Uninoculated	$Y = 10.5X - 0.35$	$r = 0.87$
(2) *Bradyrhizobium*	$Y = 11.8X - 0.42$	$r = 0.90$
(3) VA mycorrhiza	$Y = 14.0X - 1.00$	$r = 0.88$
(4) *Bradyrhizobium* + VA mycorrhiza	$Y = 15.9X - 0.30$	$r = 0.94$

where Y is the hydration coefficient, and X is the cookability.

Hydration coefficient is a very valuable parameter for both consumer and processor. Low hydration coefficient indicates that the seeds are not capable of absorbing water efficiently (Ali *et al.*, 1988). The hydration coefficient of different varieties of faba bean was found to be in the range from 181.4 to 206.3% (Elmubarak *et al.*, 1988). Legumes, in general, gave more than double initial weight after soaking (Ali *et al.*, 1988). In this investigation, all treatments significantly increased the hydration coefficient. Salih and Khairi (1990) found

Table 1. Effect of nitrogen phosphorus and chicken manure on yield and 100 seed weight of groundnut seeds either uninoculated or inoculated with TAL 1000 and/or VAM

Treatment	Yield (kg ha^{-1})	Seeds with shell (g)	Seeds without shell (g)
Uninoculated			
Control	222.2 ($\pm$5.6)^a	61.34 ($\pm$1.060)^a	41.61 ($\pm$0.080)^a
20 kg N ha^{-1}	316.7 ($\pm$7.2)^b	96.96 ($\pm$1.070)^b	48.18 ($\pm$0.050)^b
50 kg P_2O_5 ha^{-1}	311.1 ($\pm$9.7)^b	96.84 ($\pm$0.035)^b	47.25 ($\pm$0.900)^b
0.01 mton manure ha^{-1}	283.3 ($\pm$8.7)^b	97.37 ($\pm$0.060)^b	47.80 ($\pm$0.910)^b
TAL 1000			
Control	333.3 ($\pm$7.4)^a	92.92 ($\pm$0.045)^a	47.35 ($\pm$0.150)^a
20 kg N ha^{-1}	416.7 ($\pm$6.3)^b	96.94 ($\pm$0.075)^b	56.58 ($\pm$0.080)^b
50 kg P_2O_5 ha^{-1}	440.5 ($\pm$8.7)^b	97.21 ($\pm$0.080)^b	57.86 ($\pm$0.315)^b
0.01 mton manure ha^{-1}	400.0 ($\pm$5.1)^b	97.36 ($\pm$0.070)^b	57.45 ($\pm$0.065)^b
VAM			
Control	357.9 ($\pm$3.8)^a	91.47 ($\pm$0.070)^a	47.34 ($\pm$0.190)^a
20 kg N ha^{-1}	436.9 ($\pm$6.7)^b	96.57 ($\pm$0.080)^b	53.75 ($\pm$0.817)^b
50 kg P_2O_5 ha^{-1}	441.7 ($\pm$7.4)^b	95.58 ($\pm$0.040)^b	53.63 ($\pm$0.080)^b
0.01 mton manure ha^{-1}	443.7 ($\pm$8.1)^b	95.74 ($\pm$1.200)^b	52.54($\pm$0.500)^b
TAL 1000 + VAM			
Control	500.0 ($\pm$10.4)^a	96.92 ($\pm$0.035)^a	54.85 ($\pm$0.800)^a
20 kg N ha^{-1}	572.2 ($\pm$7.6)^b	100.48 ($\pm$0.030)^b	57.19 ($\pm$0.800)^b
50 kg P_2O_5 ha^{-1}	568.3 ($\pm$6.8)^b	99.26 ($\pm$0.080)^b	57.52 ($\pm$1.080)^b
0.01 mton manure ha^{-1}	570.7 ($\pm$4.7)^b	101.44 ($\pm$0.055)^b	56.47 ($\pm$0.816)^b

Values are means ($\pm$SD). Means not sharing a common superscript in a column (for each of the four main treatments) are significantly different at $p \leq 0.05$ as assessed by Duncan's multiple range test.

Table 2. Effect of nitrogen, phosphorus and chicken manure on hydration coefficient and cookability of groundnut seeds either uninoculated or inoculated with TAL 1000 and/or VAM

Treatment	Hydration coefficient (%)	Cookability (%)
Uninoculated		
Control	131.45 (±1.250)[a]	9.97 (±0.190)[b]
20 kg N ha^{-1}	145.55 (±1.000)[b]	10.08 (±0.110)[b]
50 kg P_2O_5 ha^{-1}	145.99 (±0.980)[b]	9.14 (±0.400)[a]
0.01 mton manure ha^{-1}	150.16 (±0.900)[c]	9.11 (±0.141)[a]
TAL 1000		
Control	143.00 (±0.150)[a]	11.15 (±0.230)[b]
20 kg N ha^{-1}	146.43 (±0.315)[b]	11.28 (±0.200)[b]
50 kg P_2O_5 ha^{-1}	145.79 (±0.816)[b]	10.28 (±0.445)[a]
0.01 mton manure ha^{-1}	150.05 (±1.000)[c]	10.09 (±0.074)[a]
VAM		
Control	145.01 (±1.000)[a]	12.80 (±0.400)[b]
20 kg N ha^{-1}	147.29 (±1.080)[b]	12.78 (±0.200)[b]
50 kg P_2O_5 ha^{-1}	145.78 (±1.000)[b]	10.13 (±0.100)[a]
0.01 mton manure ha^{-1}	148.95 (±0.550)[c]	10.34 (±0.245)[a]
TAL 1000 + VAM		
Control	142.69 (±0.800)[a]	15.57 (±0.180)[b]
20 kg N ha^{-1}	145.51 (±0.880)[b]	15.52 (±0.120)[b]
50 kg P_2O_5 ha^{-1}	145.33 (±1.000)[b]	14.89 (±0.150)[a]
0.01 mton manure ha^{-1}	150.51 (±0.816)[c]	14.79 (±0.167)[a]

Values are means (±SD). Means not sharing a common superscript in a column (for each of the four main treatments) are significantly different at $p \leq 0.05$ as assessed by Duncan's multiple range test.

that the hydration coefficient of faba bean was affected by locality, harvesting time and genotype.

In this investigation, cookability increased significantly ($p \leq 0.05$) by all inoculations and N fertilizer treatments, and it ranged from 9.1–15.6. Elmubarak *et al.* (1988) showed the cookability of faba bean ranged from 11.5–33%. Cooking time, taste texture, smell, appearance and after-taste are considered to be the most important parameters that affect cooking quality. Permeability of the seed coat is an important factor in hard-seed-coatedness. This condition affects hydration of the seed and may double the cooking time (Williams and Nakkoul, 1983). Cookability is known to be affected by soaking time, type of water, time of cooking, environmental factors, location and time of harvesting (Salih *et al.*, 1986; Elmubarak *et al.*, 1988). The positive correlation between cookability and hydration coefficient could be attributed to the absorbing capability of the groundnut seeds which consequently assist cooking.

Effect of treatments on seed chemical composition

Inoculation with *Bradyrhizobium* and/or VA mycorrhiza significantly ($p \leq 0.05$) increased the seed contents of P, Na, K, Cu and Mg (Table 3). Mycorrhizal and/or phosphorus treatments significantly ($p \leq 0.001$) increased the seed phosphorus content compared to other treatments. Mycorrhizal inoculation was reported to improve the phosphorus uptake by plants (Hayman, 1986). Sodium, Cu and K content of seeds were significantly ($p \leq 0.05$) increased with N, P and manure treatments. The Mg percentage increased by N and P treatments and decreased when 0.01 mton manure were applied. The seed contents of Na, K, Cu, and Mg were increased by inoculation, Na and K increased by fertilization; P responded variably to fertilization. However, the seed Ca content did not show any pattern in

Table 3. Effect of nitrogen, phosphorus and chicken manure on mineral composition (g kg^{-1}) of groundnut seeds either uninoculated or inoculated with TAL 1000 and/or VAM

Treatment	P	Na	Ca	K	Mg	Cu
Uninoculated						
Control	7.83 (±0.11)[a]	2100 (±18)[a]	1670 (±10)[a]	6300 (±20)[a]	4220 (±20)[b]	10.2 (±0.10)[a]
20 kg N ha^{-1}	8.20 (±0.10)[b]	3050 (±17)[b]	2330 (±20)[d]	7770 (±18)[b]	7620 (±25)[d]	12.0 (±0.10)[b]
50 kg P_2O_5 ha^{-1}	11.7 (±0.11)[c]	3070 (±20)[b]	1870 (±10)[c]	7800 (±26)[b]	6300 (±28)[c]	11.5 (±0.12)[b]
0.01 mton manure ha^{-1}	8.50 (±0.12)[b]	4720 (±13)[c]	1830 (±18)[b]	7820 (±25)[b]	3820 (±21)[a]	11.8 (±0.10)[b]
TAL 1000						
Control	8.0 (±0.09)[a]	2550 (±10)[a]	2000 (±10)[b]	6720 (±25)[a]	6200 (±20)[b]	10.7 (±0.12)[a]
20 kg N ha^{-1}	9.67 (±0.12)[b]	2900 (±11)[b]	2070 (±18)[c]	7470 (±28)[b]	9070 (±25)[d]	12.7 (±0.11)[b]
50 kg P_2O_5 ha^{-1}	12.0 (±0.11)[c]	3000 (±18)[b]	1930 (±13)[a]	7500 (±25)[b]	7350 (±18)[c]	12.1 (±0.10)[b]
0.01 mton manure ha^{-1}	9.50 (±0.10)[bc]	4850 (±10)[c]	2000 (±13)[b]	7450 (±27)[b]	5650 (±20)[a]	12.0 (±0.11)[b]
VAM						
Control	10.7 (±0.16)[a]	2850 (±10)[a]	1900 (±12)[b]	6600 (±28)[a]	7530 (±20)[b]	10.8 (±0.13)[a]
20 kg N ha^{-1}	10.3 (±0.08)[a]	4050 (±12)[b]	2230 (±10)[c]	7350 (±21)[b]	8750 (±25)[d]	12.2 (±0.12)[b]
50 kg P_2O_5 ha^{-1}	12.3 (±0.09)[c]	4080 (±10)[b]	1930 (±10)[b]	7320 (±20)[b]	8030 (±21)[c]	12.0 (±0.11)[b]
0.01 mton manure ha^{-1}	10.8 (±0.15)[b]	5930 (±25)[c]	1730 (±13)[a]	7450 (±21)[b]	4400 (±20)[a]	12.2 (±0.10)[b]
TAL 1000 + VAM						
Control	11.8 (±0.11)[a]	3330 (±18)[a]	1970 (±18)[a]	7180 (±18)[a]	7680 (±25)[b]	11.8 (±0.10)[a]
20 kg N ha^{-1}	11.8 (±0.12)[a]	4170 (±15)[b]	2100 (±18)[b]	7750 (±20)[b]	8580 (±23)[d]	13.3 (±0.12)[b]
50 kg P_2O_5 ha^{-1}	15.5 (±0.14)[c]	4070 (±20)[b]	1970 (±13)[a]	7750 (±21)[b]	8220 (±28)[c]	13.3 (±0.11)[b]
0.01 mton manure ha^{-1}	12.8 (±0.09)[b]	5080 (±14)[c]	2070 (±13)[b]	7650 (±28)[b]	7420 (±25)[a]	13.3 (±0.10)[b]

Values are means (±SD). Means not sharing a common superscript in a column (for each of the four main treatments) are significantly different at $p \leq 0.05$ as assessed by Duncan's multiple range test.

response to fertilization. Kawai and Yamamoto (1986) reported that inoculation with VAM increased plant development through supply of some elements such as Ca and Mg. Giri (1993) reported that application of $25\,kg\,N\,ha^{-1}$ to groundnut increased crop uptake of K, Ca and Mg. Several minerals such as Ca, Fe, K, Mo, Na and P are essential for human and animal health. Knowledge about their level in different raw foods will provide information on the nutritional adequacy of diets. Other minerals, such as Cu, Se and Zn though essential, have a limited range between required and toxic levels.

Proper fertilization programmes, focusing on bio-fertilization should be implemented to improve the productivity of food legumes and thereby increase total food production, improve the supply of good quality proteins in the diet of people who largely depend on food legume crops, and improve seed quality. The latter implies processing, consumer, nutritional value and export quality. This investigation also calls food scientists to allow for the previous agronomic treatments, the history of the seeds, their origin, and certification, before starting their experiments, analysis or interpreting their data.

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