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Response of Growth, Yield and Seed Quality of Guar (*Cyamopsis teteragonolopa L.*) to *Bradyrhizobium* Inoculations

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Abstract: *Bradyrhizobium* strains: ENRRI 16A, ENRRI 16C (Local) and strains TAL 169 and TAL 1371 (Introduced) were used to inoculate two guar cultivars namely, HFG-75 and Local, in split plot design with four replications in field experiment at two locations (ElAin and Abu-Habil, North Kordofan State-Sudan). The objective of the experiment was to study the effect of inoculation with *Bradyrhizobium* on yield attributes, proximate composition and minerals content of guar. *Bradyrhizobium* inoculation showed no significant ($p \leq 0.05$) effect on plant height (cm), number of fruiting branches/plant, number of pods/plant, 100-seed weight (g), grain yield and the yield kg/ha of the two guar cultivars grown at Abu-Habil. At ElAin site, inoculation with ENRRI 16C significantly ($p \leq 0.05$) increased the plant height (by 25%) and fruiting branches/plant (by 97%) of the two guar cultivars. Also, all treatments (except inoculation of HFG-75 with ENRRI 16A) considerably improved the 100-seed weight (g) of the tested cultivars compared to the control. The ash and protein contents of the tested guar cultivars at the two locations showed no response to inoculation by the four *Bradyrhizobium* strains. Also, the crude fibre content of guar seeds in the two sites did not responded to *Bradyrhizobium* inoculation, excluding the local cultivar treated with ENRRI 16C and TAL 1371 grown at Abu-Habil. The oil content for HFG-75 cultivar at the two locations showed positive response to inoculation with TAL 1371. The phosphorus content of the two cultivars, at both Abu-Habil and ElAin was notably increased due to inoculation. At ElAin site, inoculation did not influenced the phosphorus content except for HFG-75 treated with ENRRI 16C and local cultivar inoculated by TAL 169. Potassium content of the guar seeds from HFG-75 at the two locations as well as that for the local cultivar at ElAin demonstrated no response to inoculation. Inoculation with ENRRI 16C and TAL 169 significantly ($p \leq 0.05$) promoted the Na content of the local cultivar at Abu-Habil, whereas ENRRI 16A considerably increased Na content for HFG-75 at ElAin location. The calcium content of HGF-75 guar seeds was significantly ($p \leq 0.05$) enhanced due to inoculation with ENRRI 16C at Abu-Habil as well as treatment with ENRRI 16A, TAL 169 and TAL 1371 at ElAin. Conversely, Ca content of the local guar was not affected by inoculation. Magnesium content of HGF-75 cultivar at Abu-Habil was positively responded to *Bradyrhizobium* inoculation.

Key words: *Bradyrhizobium*, inoculation, guar, proximate composition, minerals content

INTRODUCTION

Guar (*Cyamopsis tetragonoloba* L.), member of the family fabaeace, is a drought-tolerant legume requiring 400-500 mm annual rainfall (Yousif, 1984). The legume showed the best growth in the United States with 900 mm (Francois *et al.*, 1990), performed well in areas with 400-900 mm of annual rainfall (Anon and Esser, 1975) and can be cultivated in regions with 300-500 mm annual rainfall (Mukhtar, 1981).

Guar has been well grown in wide range of soils. The most excellent performance is on the fertile medium to light sandy loam soil with pH values of 7.5-8 (Adam, 1995). Guar grows excellently on well drained soils with light to medium texture, pH value of 7.5-8 and

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temperature of 21-30°C at planting time (Tyagi *et al.*, 1982; Chapman and Pratt, 1961). Soil salinity significantly decreased nodulation, pod formation and yield of guar (Elsayed, 1994).

Guar is greatly valued because of its gum, which is characterized with high level of viscosity, hence used economically in mining, petroleum, tobacco, textile, cosmetics, pharmaceuticals and food industries (Burseglove, 1984; Duke, 1981).

Inoculation of guar with *Rhizobium* enhanced seed yield (Singh and Singh, 1989), number of nodules, nodules fresh weight, plant dry weight, nitrogen fixation and total nitrogen content (Mand *et al.*, 1991; Suman *et al.*, 1995). Although inoculation with different strains of *Bradyrhizobium* significantly improved shoot fresh and dry weight, number of pods and nodules, seed quality and yield (Elsheikh, 1993; Elsheikh and Ibrahim, 1999). Also inoculation of guar with *Rhizobium* on sandy loam soil elevated seed yield, seed gum and protein content (Brokwell and Bottmely, 1995).

In North Kordofan State-Sudan, no trials have yet been carried out to evaluate the response of guar to inoculation and its effect on seed quality. The present study was conduced to investigate the effect of inoculation with four bradyrhizobium strains on yield attributes, seed proximate composition and minerals content of two guar cultivars grown at two deferent locations in North Kordofan State-Sudan.

MATERIALS AND METHODS

Cultivars: Seeds of two guar cultivars (Local and HFG-75) supplied by the ministry of Agricultural and Forestry, Sudan.

Inocolum: Two locally isolated strains of *Bradyrhizobium* sp. (ENRRI 16A and ENRRI 16C) provided by Biofertilizers Department, Environment and natural Resources Institute, National Centre for Research, Khartoum, Sudan, in addition to another two introduced strains of *Bradyrhizobium* sp. (TAL 169 and TAL 1371) offered by NifTAL Project, Paia, Hawaii, USA. The strains were maintained at 4°C on Yeast Extract Mannitol Agar (YEMA) slopes.

Field experiment: The field experiment was conducted during 2006/07 cropping season in North Kordofan State, Sudan at two locations:

ElAin: 26 km North Elobeid city, longitude 30° 16' and 30° 21', latitude 12° 52' and 13° 3', soil with 53.4% sand, 15% silt, 31.6% clay, 0.04% N, 0.003% P, 0.4% O.C, 6.5 pH value and 0.1, 7.6, 1.25 and 0.25 meq/l K, Na, Ca and Mg, respectively.

Abu-Habil: 90 km South east Elobeid city, longitude 30° 38' 1, latitude 120 43' 18, soil with 84.9% sand, 2.0% silt, 13.1% clay, 0.02% N, 0.006% P, 0.3% O.C, 6.1 pH value and 0.14, 7.2, 1.45 and 0.55 meq/l K, Na, Ca and Mg, respectively.

The experiment was arranged in split plot design with four replications. The land was prepared by deep ploughing, harrowing and leveling. Then it was ridged and divided into 3.0 x 9.0 m plots.

Seeds were treated as follows:

- Inoculated with *Bradyrhizobium* sp. strains TAL 169 and TAL 1371 (Introduced).
- Inoculated with *Bradyrhizobium* sp. strains ENRRI 16A and ENRRI 16C (Local).
- Uninoculated (control).

Estimation of yield attributes: From each plot, after four weeks from sowing date, six plants were randomly taken to calculate the number of nodules.

At harvest, six plants were randomly obtained from each plot to estimate plant height (cm), number of fruiting branches/plant, number of pods /plant,100 seeds weight (g), grain yield (g) and yield (kg/ha).

Chemicals analysis: Proximate analysis: was determined according to (AOAC, 1984; AOAC, 1995).

Minerals: Samples were dry ashed (Walsh, 1980) as follows: in a digestion chamber about 1.0 g sample was acid-digested with diacid mixture (HNO_3:$HClO_4$, 5:1 v/v). The digested sample was dissolved in double–distilled water and filtered (whatman No.42). The filtrate was made to 50 ml with double-distilled water and was used for the determination of five minerals. Calcium and magnesium were determined by titration method as described by (Chapman and Pratt, 1961). Sodium and potassium were determined using flame photometer (CORING EEL, London, UK) according to (Baboo and Rona, 1995) method. Phosphorus was determined according to (Scheffer and Pajenkam, 1952) method.

Statistical analysis: Each sample was analyzed in triplicate and the figures were then averaged. Data were assessed by Analysis of Variance (ANOVA), (Snedecor and Cochran, 1987) using CRD and by Duncan's multiple range test with a probability $p \leq 0.05$ (Duncan, 1955).

RESULTS and DISCUSSION

Effect of *Bradyrhizobium* inoculation on yield attributes: *Bradyrhizobium* inoculation had no significant ($p \leq 0.05$) effect on plant height (cm), fruiting branches/plant, number of pods/plant and 100-seed weight (g) of the two guar cultivar grown at Abu-Habil location (Table 1). Although, inoculation with ENRRI 16A and ENRRI 16C slightly increased the plant height and the 100-seed weight of the HFG-75 cultivar, respectively. In addition the two guar cultivar grown at Abu-Habil showed nearly the same levels of yield attributes (Table 1).

Table 1: Response of plant height (cm), number of fruiting branches (branches/plant), number of pods (pods/plant) and 100-seed weight (g) of two cultivars of guar grown in Abu-Habil location to *Bradyrhizobium* inoculations

	Treatments					
Cultivar	Control	ENRRI 16A	ENRRI 16C	TAL 169	TAL 1371	Mean
Plant height (cm)						
HFG-75	54.50	75.30	60.20	66.71	59.65	62.42
Local	62.63	60.72	67.04	64.23	65.68	66.02
Mean	63.56	65.62	63.62	65.47	62.81	
Fruiting branches (branches/plant)						
HFG-75	6.00	6.50	6.50	6.00	4.50	5.90
Local	4.75	6.25	5.25	5.25	5.00	5.30
Mean	5.38	6.38	5.88	5.63	4.75	
Number of pods (pods/plant)						
HFG-75	34.25	41.75	44.75	34.25	41.25	39.25
Local	29.50	47.75	43.50	29.25	34.75	36.75
Mean	31.88	44.75	44.13	31.75	38.00	
100-seed weight (g)						
HFG-75	3.26	3.37	3.49	3.43	3.42	3.39
Local	3.27	3.41	3.36	3.45	3.52	3.40
Mean	3.26	3.39	3.43	3.44	3.47	

	LSD 0.05			
Treatments	Plant height (cm)	Fruiting branches (branches/plant)	Number of pods (pods/plant)	100-seed weight (g)
Guar Genotype	6.42	0.58	23.69	0.120
Strains	15.45	2.16	20.61	0.224
Interaction	16.24	2.27	21.67	0.240

Table 2: Response of plant height (cm), number of fruiting branches (branches/plant), number of pods (pods/plant) and 100-seed weight (g) of two cultivars of guar grown in ElAin location to *Bradyrhizobium* inoculations

	Treatments					
Cultivar	Control	ENRRI 16A	ENRRI 16C	TAL 169	TAL 1371	Mean
Plant height (cm)						
HFG-75	52.48	60.18	64.17	65.44	54.27	59.31
Local	53.65	61.75	68.70	63.12	62.98	62.04
Mean	53.06b	60.96ab	66.34a	64.28ab	58.62ab	
Fruiting branches (branches/plant)						
HFG-75	5.50	6.75	8.25	7.25	5.75	6.7
Local	4.25	6.00	6.75	6.25	5.25	5.7
Mean	4.88b	6.38ab	7.50ab	6.75ab	5.50ab	
Number of pods (pods/plant)						
HFG-75	35.00	44.25	68.75	65.00	47.00	52.00
Local	27.75	51.25	55.00	54.00	41.00	45.80
Mean	31.38b	47.75ab	61.88a	59.50ab	44.00ab	
100-seed weight (g)						
HFG-75	3.26	3.39	3.42	3.51	3.54	3.42
Local	3.14	3.41	3.45	3.34	3.50	3.37
Mean	3.20b	3.40ab	3.43a	3.43a	3.52a	

	LSD 0.05			
Treatments	Plant height (cm)	Fruiting branches (branches/plant)	Number of pods (pods/plant)	100-seed weight (g)
Guar Genotype	3.01	1.01	16.26	0.08
Strains	11.43	2.07	28.48	0.15
Interaction	12.01	2.18	20.94	0.16

As presented in Table 2, inoculation with ENRRI 16C, at ElAin site, significantly ($p \leq 0.05$) increased the plant height (by 25%) and fruiting branches/plant (by 97%) of the two guar cultivars. Also, strain TAL 169 significantly ($p \leq 0.05$) enhanced the plant height of just HFG-75 cultivar. Comparable findings were previously reported (Stafford and Seiher, 1986; Yadava and Manju, 1985). The four *Bradyrhizobium* strains failed to affect the number of pods /plant of the two cultivars. On the other hand, all treatments (except inoculation of HFG-75 with

Table 3: Response of grain yield (g/plant) and yield (kg/ha) of two cultivars of guar grown in Abu-Habil and ElAin locations to *Bradyrhizobium* inoculations

	Treatments					
Cultivar	Control	ENRRI 16A	ENRRI 16C	TAL 169	TAL 1371	Mean
Grain yield (g/plant), Abu-Habil						
HFG-75	6041.00	9.19	9.74	7.84	7.62	8.16
Local	8.07	9.43	8.21	6.58	7.62	7.98
Mean	7.24	9.31	8.97	7.20	7.62	
Grain yield (g/plant), ElAin						
HFG-75	7.17	10.23	13.98	15.52	11.16	11.61
Local	6.69	11.39	11.98	11.42	9.71	10.24
Mean	6.93	10.81	12.98	13.47	10.44	
Yield kg/ha, Abu-Habil						
HFG-75	124.28	191.68	216.30	174.18	169.23	175.13
Local	120.73	209.43	187.40	146.15	169.23	179.79
Mean	155.50	200.55	201.85	160.17	169.23	
Yield 2 kg/ha, ElAin						
HFG-75	159.23	227.33	31023.00	344.78	248.08	257.93
Local	148.73	253.15	266.13	253.85	215.78	227.53
Mean	153.98	240.24	288.18	299.31	231.93	

	LSD 0.05			
Treatments	Grain yield 1 (g/plant)	Grain yield 2 (g/plant)	Yield 1 kg/ha	Yield 2 kg/ha
Guar Genotype	3.06	3.59	58.13	79.56
Strains	4.96	6.65	107.20	147.70
Interaction	5.21	6.99	112.70	155.30

ENRRI 16A) considerably improved the 100-seed weight (g) of the tested cultivars compared to the control. The yield attributes of the two cultivars showed significantly ($p \leq 0.05$) similar responses to inoculation with *Bradyrhizobium* strains. However, manipulation with ENRRI 16C notably elevate the plant height of the local cultivar and the fruiting branches/plant of the HFG-75 cultivar matched to the corresponding treatments. Besides, TAL 169 strain remarkably promoted the 100-seed weight of HFG-75 guar compared to the local one (Table 2) Current results were in good agreement with previous studies (Ibrahim *et al*., 2010; Ibrahim, 1997; Singh and Singh, 1989).

As shown in Table 3, the four *Bradyrhizobium* strains used insignificantly ($p \leq 0.05$) increased the grain yield as well as the yield kg/ha of the two cultivars at Abu-Habil location compared to the uninoculated control without significant differences between the two cultivars. The same was observed at ElAin site excepting that ENRRI 16C and TAL 169 significantly ($p \leq 0.05$) enhanced the grain yield as well as the yield kg/ha of HFG-75 cultivar. Though, HFG-75 inoculated with TAL169 demonstrated considerably higher yield kg/ha than the respective local cultivar. These findings were in harmony with earlier reports (Ibrahim *et al*., 2010; Singh and Singh, 1989). Moreover, inoculation was found to be positively correlated with grain yield of some legumes crops such as fenugreek (Abdelgani *et al*., 2003), hyacinth bean (Abdel-Hafeez, 2001) and faba bean (Abdelmula *et al*., 1995). Present results for yield were in contrast with other legumes such as faba bean (Elsheikh, 1993); ground nut (Mohammed Zein, 1996) and fenugreek (Abdelgani *et al*., 2003). However, environmental and biotic factors such as inoculation, the presence and quality of indigenous rhizobial population, soil nitrogen content, soil physiochemical constraints and climatic conditions are important factors in determining the yield of crops. These factors together with the suitability of the inoculums strain(s) determine success in inoculation programs specifically (Singleton *et al*.,1992).

Effect of *Bradyrhizobium* inoculation on seed proximate composition: As shown in Table 4, inoculation by *Bradyrhizobium* strains insignificantly ($p \leq 0.05$) affected the seed moisture content at Abu-Habil location, excluding inoculation of the local cultivar with TAL 169. In contrast, at ElAin site (Table 5), the seed moisture content was significantly ($p \leq 0.05$) increased due to treatments (except for local cultivar with TAL 169). HFG-75 cultivar manipulate by ENRRI 16C and TAL 169 strains at Abu-Habil showed significantly higher moisture contents compared to the respective local cultivar, whereas the remaining treatments demonstrated significantly similar moisture contents. On the other hand, the same cultivar inoculated with TAL 169 and TAL 1371 at ElAin contained considerably higher moisture matched up to the related local cultivar. However, moisture content of guar seeds was reported to be influenced by the relative humidity of surrounding atmosphere at the time of harvest and during storage (Elsheikh, 2001; Elsheikh and Ibrahim, 1999).

The ash content of the tested guar cultivars at the two locations showed no response to inoculation by the four *Bradyrhizobium* strains. Regarding the oil content, only

Table 4: Response of seed moisture (%), ash (%) and oil (%) of two cultivars of guar grown in Abu-Habil to *Bradyrhizobium* inoculations

	Treatments					
Cultivar	Control	ENRRI 16A	ENRRI 16C	TAL 169	TAL 1371	Mean
Moisture (%)						
HFG-75	5.03	4.67	5.70	4.73	4.03	4.83
Local	5.20	5.53	4.20	3.20	4.57	4.45
Mean	5.12	5.10	4.50	3.97	4.30	
Ash (%)						
HFG-75	2.83	4.33	4.17	4.17	3.83	3.87
Local	3.67	5.00	2.83	2.83	3.33	3.53
Mean	3.25	4.67	3.50	3.50	3.58	
Oil (%)						
HFG-75	1.33	2.67	2.67	3.33	3.76	2.73
Local	2.17	3.17	2.83	4.00	3.00	3.03
Mean	1.75	2.92	2.75	3.67	3.33	

	LSD 0.05		
Treatments	Moisture (%)	Ash (%)	Oil (%)
Guar Genotype	0.98	1.61	0.16
Strains	1.78	1.63	2.38
Interaction	1.87	1.71	2.51

Table 5: Response of seed moisture (%), ash (%) and oil (%) of two cultivars of guar grown in ElAin to *Bradyrhizobium* inoculations

	Treatments					
Cultivar	Control	ENRRI 16A	ENRRI 16C	TAL 169	TAL 1371	Mean
Moisture (%)						
HFG-75	6.50	6.83	6.67	7.40	6.83	6.85
Local	6.50	6.83	6.67	6.33	6.50	6.57
Mean	6.50	6.83	6.67	6.87	6.67	
Ash (%)						
HFG-75	3.50	3.33	3.50	3.50	3.67	3.50
Local	3.67	3.50	3.33	3.67	3.50	3.53
Mean	3.58	3.42	3.42	3.58	3.58	
Oil (%)						
HFG-75	1.67	4.50	2.17	1.50	4.83	2.93
Local	2.33	3.33	3.17	1.83	5.33	3.20
Mean	2.00	3.92	2.67	1.67	5.08	

	LSD 0.05		
Treatments	Moisture (%)	Ash (%)	Oil (%)
Guar Genotype	0.052	0.240	1.72
Strains	0.057	0.390	3.05
Interaction	0.600	0.399	3.21

inoculation of HFG-75 cultivar by TAL 1371 at the two locations resulted in a positive response (Table 4, 5).

It is clear that seeds protein content of the two guar cultivars at Abu-Habil location (Table 6) as well as that of the local cultivar at ElAin (Table 7) was not subjective to *Bradyrhizobium* inoculation; this could be probably due to deficiency of fixed nitrogen, to be transformed to the seeds, in the nodules. Conversely, protein content of HFG-75 cultivar at ElAin showed significant ($p\leq0.05$) deterioration, except inoculation with TAL 169 (Table 7).

The crude fibre content of guar seeds in the two locations (Table 6 and 7) did not responded to *Bradyrhizobium* inoculation, excluding the local cultivar treated with ERRI 16C and TAL 1371 grown at Abu-Habil location which gained noticeably elevated fibre content compared to control. Similar results were formerly reported (Khatta *et al.*, 1988). It is well known that the crude fibre is an important constituent of human food and animal feed and it is needed in a reasonable proportion as it gives the bulk to the diet and helps in movement of food through the digest (Abdelgani, 1997). Usually, the carbohydrate content in the seeds of legumes crops tend to decrease with *Rhizobium* inoculation (Elsheikh, 1993).

The total carbohydrate content of guar seeds in the two locations (Table 6 and 7) was not affected by *Bradyrhizobium* inoculation, except for the HFG-75 cultivar inoculated with ENRRI 16A grown at Abu-Habil location which attained distinctly higher carbohydrate content compared to control.

Table 6: Response of seed fiber (%), protein (%) and carbohydrates of two cultivars of guar grown in Abu-Habil to *Bradyrhizobium* inoculations

Cultivar	Treatments: Control	ENRRI 16A	ENRRI 16C	TAL 169	TAL 1371	Mean
Fiber (%)						
HFG-75	8.63	9.60	8.23	7.97	8.53	8.59
Local	7.87	8.67	9.40	7.23	9.33	8.50
Mean	8.25	9.13	8.82	7.60	8.93	
Protein (%)						
HFG-75	24.37	30.17	28.43	22.87	29.37	27.04
Local	30.50	31.37	26.10	32.23	27.00	29.44
Mean	27.43	30.77	27.27	27.55	28.18	
Carbohydrate (%)						
HFG-75	57.80	48.57	50.80	56.93	50.57	52.93
Local	50.93	46.30	54.63	50.50	52.77	51.03
Mean	54.37	47.43	52.72	53.72	51.67	

Treatments	LSD 0.05: Fiber (%)	Protein (%)	Carbohydrate (%)
Guar Genotype	1.08	4.33	4.36
Strains	1.42	9.25	8.08
Interaction	1.49	9.73	8.49

Table 7: Response of seed fiber (%), protein (%) and carbohydrates of two cultivars of guar grown in ElAin to *Bradyrhizobium* inoculations

Cultivar	Treatments: Control	ENRRI 16A	ENRRI 16C	TAL 169	TAL 1371	Mean
Fiber (%)						
HFG-75	9.70	9.90	9.00	10.90	11.37	10.17
Local	9.00	10.10	9.10	9.57	9.33	9.42
Mean	9.35	10.00	9.05	10.23	10.35	
Protein (%)						
HFG-75	39.23	33.23	31.63	39.83	35.30	35.85
Local	35.03	37.50	35.60	39.13	35.00	36.45
Mean	37.13b	35.37bc	33.62c	39.48a	35.15bc	
Carbohydrate (%)						
HFG-75	39.40	42.20	43.70	36.87	37.33	39.90
Local	43.47	38.73	42.23	39.47	40.33	40.85
Mean	41.43	40.47	42.97	38.17	38.83	

Treatments	LSD 0.05: Fiber (%)	Protein (%)	Carbohydrate (%)
Guar Genotype	1.37	3.18	3.28
Strains	2.05	3.40	7.39
Interaction	2.16	4.71	7.77

Effect of *Bradyrhizobium* inoculation on minerals content: In this study, at Abu-Habil, inoculation with the locally isolated strains *Bradyrhizobium* (ENRRI 16A and ENRRI 16C) significantly ($p \leq 0.05$) increased the phosphorus content for the seeds of HFG-75 cultivar, while insignificantly ($p \leq 0.05$) elevated that for the local one. Interestingly, the introduced strains (TAL 169 and TAL 1371) of *Bradyrhizobium* insignificantly enhanced the phosphorus of HFG-75 seeds, but immaterially reduced that of the local cultivar. However, the treated HFG-75 cultivar showed significantly ($p \leq 0.05$) higher phosphorus content compared to their corresponding local cultivar (Table 8). In contrast, at ElAin site (Table 9), inoculation did not influenced the phosphorus content of either the HFG-75 cultivar (excluding ENRRI 16C) nor the local one (except TAL 169).

Potassium content of the guar seeds from HFG-75 at the two locations as well as that for the local cultivar at ElAin demonstrated no response to inoculation (Table 8 and 9). On the other hand, at Abu-Habil site, treatments considerably decreased the potassium content of the local cultivar (Table 8).

Bradyrhizobium strain ENRRI 16A significantly ($p \leq 0.05$) decreased Na content of HGF-75 in Abu-Habil site, but considerably increased it at ElAin location. However, the remaining strains did not influenced Na content of HGF-75 cultivar at the two sites. Inoculation with ENRRI 16C and TAL 169 significantly ($p \leq 0.05$) promoted the Na

Table 8: Response of seed phosphorous (%), potassium (mg/100 g) and sodium (mg/100 g) of two cultivars of guar grown in Abu-Habil to *Bradyrhizobium* inoculations

	Treatments					
Cultivar	Control	ENRRI 16A	ENRRI 16C	TAL 169	TAL 1371	Mean
Phosphorus (%)						
HFG-75	0.39	0.65	0.66	0.65	0.54	0.58
Local	0.47	0.48	0.48	0.37	0.37	0.44
Mean	0.43	0.57	0.57	0.51	0.45	
Potassium (mg/100 g)						
HFG-75	27.10	27.77	29.60	29.33	28.10	28.38
Local	29.83	26.17	27.45	25.97	26.70	27.23
Mean	28.45	26.97	28.53	27.65	27.40	
Sodium (mg/100 g)						
HFG-75	5.20	4.20	5.37	4.93	4.60	4.86
Local	4.80	4.77	6.07	5.83	4.93	5.28
Mean	5.00	4.48	5.72	5.38	4.77	

	LSD 0.05		
Treatments	Phosphorus (%)	Potassium (mg/100 g)	Sodium (mg/100 g)
Guar Genotype	0.09	1.22	0.26
Strains	0.21	3.37	0.82
Interaction	0.22	3.54	0.86

Table 9: Response of seed phosphorous (%), potassium (mg/100 g) and sodium (mg/100 g) of two cultivars of guar grown in ElAin to *Bradyrhizobium* inoculations

	Treatments					
Cultivar	Control	ENRRI 16A	ENRRI 16C	TAL 169	TAL 1371	Mean
Phosphorus (%)						
HFG-75	0.40	0.45	0.21	0.41	0.44	0.39
Local	0.55	0.53	0.39	0.27	0.38	0.42
Mean	0.48	0.49	0.30	0.34	0.41	
Potassium (mg/100 g)						
HFG-75	26.73	27.10	27.20	26.70	27.20	26.99
Local	26.93	28.00	26.83	27.63	26.83	27.25
Mean	26.83	27.55	27.02	27.17	27.02	
Sodium (mg/100 g)						
HFG-75	6.07	12.00	6.23	5.93	6.83	7.41
Local	6.63	5.77	6.27	5.93	8.40	6.60
Mean	6.35	8.88	6.25	5.93	7.62	

	LSD 0.05		
Treatments	Phosphorus (%)	Potassium (mg/100 g)	Sodium (mg/100 g)
Guar Genotype	0.26	0.710	3.96
Strains	0.24	1.197	5.26
Interaction	0.25	1.260	5.12

content of the local cultivar at Abu-Habil, whereas ENRRI 16A and TAL 1371 exerted no effect. The same cultivar at ElAin, showed no response to inoculation (Table 8 and 9). Improvement of Na content due to inoculation was earlier reported (Elsheikh and Ibrahim, 1999; Elsheikh, 1993).

The calcium content of HGF-75 guar seeds was significantly ($p \leq 0.05$) enhanced due to inoculation with ENRRI 16C at Abu-Habil as well as treatment with ENRRI 16A, TAL 169 and TAL 1371 at ElAin. Conversely, Ca content of the local guar was not affected by inoculation with the four strains at both Abu-Habil and ElAin locations (Table 10). Former report (Gumma, 1999) confirmed that inoculation notably increased calcium content of guar. Also, improved calcium, potassium and sodium contents of groundnut seeds due to *Bradyrhizobium* inoculation was previously reported (Mohammed Zein, 1996).

Magnesium content of HGF-75 cultivar at Abu-Habil was significantly ($p \leq 0.05$) increased due to inoculation by ENRRI 16C and TAL 169 strains, but insignificantly ($p \leq 0.05$) get higher owing to treatment with ENRRI 16 A and TAL 1371. Magnesium content of the guar seeds from the local cultivar at the two locations as well as that for HGF-75 cultivar at ElAin showed no reaction to inoculation (Table 10).

Table 10: Response of seed calcium and magnesium (mg/100 g) of two cultivars of guar grown in Abu-Habil and ElAin to *Bradyrhizobium* inoculations

	Treatments					
Cultivar	Control	ENRRI 16A	ENRRI 16C	TAL 169	TAL 1371	Mean
Calcium (mg/100 g), Abu-Habil						
HFG-75	123.73	136.30	245.70	194.73	120.60	164.21
Local	108.67	138.50	181.33	183.13	143.53	151.03
Mean	116.20	137.40	213.50	188.93	132.07	
Magnesium (mg/100 g), Abu-Habil						
HFG-75	109.33	142.30	183.47	200.43	182.87	163.68
Local	154.80	118.57	157.27	156.47	138.17	145.05
Mean	132.07	130.43	170.37	138.45	160.52	
Calcium (mg/100 g), ElAin						
HFG-75	114.67	210.13	198.90	231.00	252.23	201.39
Local	184.03	252.13	246.40	251.83	216.13	230.11
Mean	149.35	231.13	222.65	241.42	234.18	
Magnesium (mg/100 g), ElAin						
HFG-75	178.47	211.17	230.40	214.87	178.77	202.73
Local	211.47	177.07	168.00	173.10	214.10	188.75
Mean	194.97	194.12	199.20	193.98	196.43	

	LSD 0.05			
Treatments	Calcium (mg/100 g), Abu-Habil	Magnesium (mg/100 g), Abu-Habil	Calcium (mg/100 g), ElAin	Magnesium (mg/100 g), ElAin
Guar Genotype	16.78	26.12	103.20	50.44
Strains	97.33	73.68	91.45	107.70
Interaction	102.3	77.46	96.14	113.20

Conclusion: ENRRI 16 A strain significantly ($p \leq 0.05$) improved total carbohydrates and phosphorus contents of HFG-75 cultivar grown at Abu-Habil location as well as the Na and Ca contents of the same cultivar grown at ElAin site.

ENRRI 16C strain considerably enhanced the plant height, number of the fruiting branches and 100-seed weight of the tested cultivars grown at the two locations; grain yield and yield (Kg/ha) for HFG-75 at ElAin; fibre and Na contents of the local cultivar at Abu-Habil as well as P, Ca and Mg contents of HFG-75 at Abu-Habil site.

TAL 169 strain markedly elevated the plant height, 100-seed weight, grain yield, yield (Kg/ha) and Ca content for HFG-75 grown at ElAin site as well as the 100-seed weight and Na content of the local cultivar at ElAin and Abu-Habil, respectively. The same strain significantly ($p \leq 0.05$) increased the Mg content of HFG-75 at Abu-Habil location.

TAL 1371 notably promoted the 100-seed weight of the two cultivars at ElAin, ash content of HFG-75 at the two locations, fiber content of the local cultivar at Abu-Habil and Ca content of HGF-75 at ElAin.

REFERENCES

Abdelgani, M.E., E.A.E. Elsheikh and N.O. Mukhtar, 2003. Effect of *Rhizobium* inoculation and chicken manure fertilization on growth, nodulation and yield of fenugreek (*Trigonella foenumgraecum* L.), University of Khartoum J. Agric. Sci., 11: 28-39.

Abdelgani, M.E., 1997. Effect of *Rhizobium* on nitrogen fixation, yield and seed quality of fenugreek (*Trigonella foeum graecuml*). Ph.D (Agric.) Thesis. University of Khartoum, Sudan.

Abdel-Hafeez, M.E., 2001. Effect of partially acidulate phosphate rocks and triple superphosphate and their combinations on growth, mineral composition and yield of wheat. Ph.D (Agric.) Thesis, University of Sudan for Science and Technology, Sudan.

Abdelmula, A.A., A.H. Abdalla and F.A. Salih, 1995. Phenotypic and genotype correlation of some characters in faba bean (*Vicia faba* L.). University of Khartoum J. Agric. Sci., 1: 20-31.

Adam, M.E., 1995. Aspects of guar mechanical harvesting. MSc. (Agric.) Thesis, University of Khartoum, Sudan.

Anon, K. and A.S. Esser, 1975. New guar varieties. Tex. Agric. Exp. Stn. Leaflet, pp: 13-56.

AOAC, 1984. Association of officials' analytical chemist official methods of analysis, 14th Edn., Washington DC.

AOAC, 1995. Official Methods of Analysis of the Association of Official Analytical Chemists. W. Horwitz (Ed.), 16th Edn., Association of Official Analytical Chemists, Washington, DC.

Baboo, R. and N.S. Rona, 1995. Nutrient uptake and yield of cluster bean (*Cyamopsis tetragonoloba*) as influenced by nitrogen, phosphorous and seed rate. In. J. Agron., 40: 482-485.

Brokwell, J. and P.J. Bottmely, 1995. Recent advances in inoculant technology and prespects for the future. Soil Biol. Biochem., 27: 683-697.

Burseglove, J.W., 1984. *Cyamopsis tetragonoloba* (L.) Taubert, cluster bean uses. Tropical crops Dicot. Longman Scientific and Technical Copublished in the U. S. A John Wiley and Sons. Inc Publish. New York, USA., pp: 255.

Chapman, H.D. and P.F. Pratt, 1961. Method of analysis for soil, plant and water, University of California.

Duncan, D.M., 1955. Multiple range and multiple F-test. Biometrics, 11: 1-420.

Duke, J.A., 1981. *Cyamopsis tetragonoloba* (L.) Taubert. Handbook of legumes of world economic importance.

Elsayed, M.E., 1994. The influence of locality and genotype on quality aspects of faba bean (*Vicia faba* L.) cultivars. M.Sc. (Agric.) Thesis, University of Khartoum, Sudan.

Elsheikh, E.A.E., 2001. Effect of inoculation with *Rhizobium* on the seed chemical and physical properties of legumes. Aspects Applied Biol., 63: 151-163.

Elsheikh, E.A.E. and K.A. Ibrahim, 1999. The effect of *Bradyrhizobium* inoculation on yield and seed quality of guar (*Cyamobsis tetragonoloba* L. (Taub). Food Chem., 65: 183-187.

Elsheikh, E.A.E., 1993. Soil Microbiology (in Arabic) Khartoum University Press.

Francois, L.F., T.J. Donovan and E.V. Maas, 1990. Salinity effect on emergence, vegetative growth and seed yield in guar. Agron. J., 82: 587-592.

Gumma, A.A.H.A., 1999. effect of inoculation, nitrogen fixation and phosphorous fertilization on growth and yield of three guar (*Cyamobsis tetragonoloba* L.) Cultivars under irrigation, M.Sc. Thesis university of Khartoum, Sudan.

Ibrahim, K.A., K.H. Suliman and A.A. Abdalla, 2010. Influence of inoculation with some *Bradyrhizobium* strains on yield attributes, seed proximate composition and minerals content of guar (*Cyamopsis teteragonolopa L.*) grown in Sudan. Austr. J. Basic Applied Sci., 4: 808-816.

Ibrahim Khalid, A., 1997. Effect of *Bradyrhizobium* on growth, nodulation, yield and seed quality of guar (*Cyamopsis tetragonoloba* (L.)Taub), M.Sc, (Agric). Thesis, University of Khartoum, Sudan.

Khatta, V.K., N. Kumar and Gupta, 1988. Chemical composition and amino acid profile of four varieties of guar *(Cyamopsis tetragonoloba*) seed. India J. Anim. Nutr., 5: 325-326.

Mand, S., B.N. Dahiya and K. Lakshmin Aryana, 1991. Nodulation, nitrogen fixation and biomass yield by slow and fast growing cowpea rhizobia in guar under different environments. Annu. Biol., 7: 31-37.

Mohammed Zein, E.M., 1996. Effect of *Bradyrhizobium* and Vesicular Arbuscular Mycorrhizal (VAM) inoculation on symbiotic properties, yield and seed quality of groundnut, M.Sc. (Agric.) thesis, university of Khartoum, Sudan.

Mukhtar, H.A., 1981. Report on guar production and economics. F.A.O range management expert. Borno project. Maidnguri, Nigeria, pp: 1-6.

Scheffer, R. and H.P. Pajenkam, 1952. (G) Phosphate-bestimmung in Pflanzenashennach Molydbean-Vanidate-method e. Z P flanzenernach. Dueng. Bodenk, 3623: 8.

Singh, R.V. and R.R. Singh, 1989. Effect of nitrogen, phosphorous and seed rate on yield, nutrient uptake and water use of guar under dry land conditions. In. J. Agron., 34: 53-56.

Singleton, P.W., B.B. Bohlool and P.L. Nakao, 1992. Legumes response to rhizobial inoculation in the tropics, myths and realities. In: Myths and Sciences of Soils of the Tropics (soil science society of America and America society of Agronomy). Special publication N. 29. 888 A. Madison USA., pp: 135-155.

Snedecor, G.W. and W.G. Cochran, 1987. Statistical methods, 7th Edn., Iowa State University Press, Ames, IA, USA.

Stafford, R.E. and G.J. Seiler, 1986. Path coefficient analysis of yield components in guar. Field Crop Res., 14: 171-179.

Suman-Mor, R.C. Dongra and S.S. Dugeja, 1995. Effect of adhesive on rhizobial survival, distribution, nodulation and nitrogen fixation in summer and winter legumes. In. J. Microbiol., 35: 115-120.

Tyagi, C.S., R.S. Paroda and G.P. lodhi, 1982. Seed production technology for guar. In. Farming, 32: 7-10.

Walsh, L.M., 1980. Instrumental methods for analysis of soil and plant tissues. 2nd Edn., Soil Sci. Soc. Am. Madison, WI.

Yadava, R.B.R. and U. Manju, 1985. Influence of growth retardant (B- Nine) on growth, flowering, fruiting and seed yield on guar (*Cyamopsis tetragonoloba* (L. Taub) plants under pot culture. In. J. Plant Physiol., Vol. 18.

Yousif, Y.H., 1984. Guar Agronomy, Shambat research station. Annual report. Soba research unit (S.R.U), pp: 3-4.