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Response of Guar (*Cyamopsis teteragonolopa* L.) to Bradyrhizobium Inoculations in Semi-arid Environment

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Abstract Bio-fertilizers are environment friendly and protect the environment against the pollutant. Afield experiment was conducted in semi-arid environment "North Kordofan of Sudan" in rainy seasons (2008/09) to investigate the effect of inoculation of Bradyrhizobium on growth and yield of guar (*Cyamopsis teteragonolopa* L.) in gardoud soil. The treatments used were: un-inoculated control, inoculated with TAL169 and Hi12 (introduced), and other12 strains (Local Isolated Strains). The experiment was arranged in a randomized complete block design with three replications. Estimated Parameters were: fresh and dry weight of shoot and root, plant height, number of fruiting branches, number of nodules, number of pods per plant, 100-seed (g) and total seed yield (ton/ha). The results showed that, the Bradyrhizobium significant increased growth and yield attributes of guar.

Keywords Guar, Nodulation, Bradyrhizobium, Seed Yield

1. Introduction

Legumes are plants of the pea or bean family. The Leguminosae is one of the largest families of flowering plants with 18,000 species classified into around 650 genera [1]. This is just under a twelfth of all known flowering plants. The Leguminosae constitute one of humanity's most important groups of plants. Legumes are used as crops, forages and green manures. Many more legumes are local food plants. In addition to those legumes mainly cultivated for human consumption, many yield important fodders, green manures and forages, e.g., Lupinus (lupin), Medicago (alfalfa) and Trifolium (clover). Legumes are utilised for a variety of other purposes including timber, medicine, tannins and gums [2]. Guar, or cluster bean, (Cyamopsis tetragonoloba (L.) Taub) is a drought-tolerant annual legume grown principally in India and Pakistan. Also guar is cultivated in USA, Australia and Africa but in small areas. It can be eaten green like snap bean, feed to cattle or used as green manure [3]. Biological Nitrogen Fixation (BNF) is an efficient source of fixed N2 that plays an important role in land remediation. Interest in BNF has focused on the symbiotic systems of leguminous plants and rhizobia because these associations have the greatest quantitative impact on the nitrogen cycle. Deficiency in mineral N often limits plant growth and as such, symbiotic relationships have evolved between plants and a variety of N_2-fixing organisms. The symbiotically fixed N2 by the association between Rhizobium species and the legumes represents a renewable source of N for agriculture. Values estimated for various legume crops and pasture species are often impressive, commonly falling in the range of 200 to 300 kg N ha-1 per year. This underlines the significance of Rhizobium and legume symbioses as a major contributor to BNF. Nitrogen fixation, along with photosynthesis as the energy supplier, is the basis of the soil environment under a constant state of change and, as such, can be relatively stressful for both macro- and micro-organisms [4].

Inoculation of appropriate strains of rhizobia to legumes known to enhance yield, but both success and failures at field experiments have been documented [5]. Rhizobium inoculation of faba beans was reported to increase yield and protein content. The effect of inoculation with R. japonicum on nodulation, plant growth, and yield of diverse soybean [Glycine max (L.) Merr.] Cultivars was studied in Nigeria and Tanzania. Local cultivars from Nigeria and Indonesia nodulated with indigenous Rhizobium spp. in Nigeria. Inoculation with several strains of *R. japonicum* occasionally increased nodule mass of the local cultivars. Large increases in growth and yield were obtained when the cultivars were inoculated [6]. Inoculation with a selected

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rhizobium strain resulted in a significant increment in nodule number per plant, nodule dry weight and yield of Chickpea [7]. In sub-Saharan Africa, inoculation of soybean (Glycine max (L.) Merrill) with *Bradyrhizobium japonicum* increased yield from 500 to 1500 kg ha^{-1} [8]. The inoculated haricot bean in Sudan, showed that a local strain of Rhizobium significantly improved nodulation and usually increased the nitrogen content of plants. Also increases in seed yield were obtained ranging from 20–145 Per cent. Soil inoculation gave better early nodulation than seed inoculation, but the difference diminished in the later stages of plant growth [9]. Musa and Burhan [10] reported that Soybeans in the Gezira Scheme was a poor forage yielder with delayed nodulation and nitrogen fixation. Inoculation of groundnut genotypes with a very effective strain of Rhizobium increased nitrogen fixation and pod yield when the crops were grown in fields well populated with effective strains of Rhizobium [11]. The objective of this research study is to investigate the effect of inoculation with bradyrhizobium strains on growth and yield of guar crop.

2. Materials and Methods

A field experiment was conducted during the seasons (2008/09) under rain fed, on in North Kordofan State, Sudan, latitude (11° 15 and 16° 30 N) and longitude (27° and 32° E).. The climate of the area is arid and semiarid zone. The soil has low fertility. Annual rainfall ranges between 350 – 500 mm. Average maximum daily temperatures varied between 30° and 35°C throughout the year [13]. Physio-chemical properties of gardud soils are shown in Table 1. The experiment was arranged in a randomized complete block design with three replications. The land was prepared and divided to plots 3.0 m x 2.0 m each. Treatments used were: un-inoculated control, inoculated with TAL169 and Hi12 (introduced), and other12 isolated strains (Local). Using local Guar cultivars (Local). The seeds supplied by the ministry of Agricultural and Forestry, Sudan. Seeds Inoculated by Twelve locally isolated strains of Rhizobium sp. (shown in Table 2) 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 Hi12) offered by NifTAL Project, Paia, Hawaii, USA. The strains were maintained at 4°C on Yeast Extract Mannitol Agar (YEMA) slopes. Sowing dates were on the July, 13th, 2013 for first season, and on 17th of July for second season. Ten inoculated seeds were put in a hole with space 40 cm between holes and 70 cm between rows immediately after rainfall. Thinning to three plants per hole two weeks later. Sampling began after four weeks from sowing date, and so every four weeks till harvesting. A sample of plants were taken from each plot to carry the parameters. Then placed in a paper bag and transported to the lab to estimate the following parameters:

1- Plant height (cm): Plant height (cm). Measured from the ground level to the tip of the plant.
2- Number of nodules/plant. Number of nodules was determined by counting the number of differential nodes of the main stem.
3- Shoot fresh weight (g)
4- Shoot dry weight (g): by weighed dry at 85°C for 24 hours to constant weight.
5- Root fresh weight (g)
6- Root dry weight (g): by weighed dry at 85°C for 24 hours to constant weight.
7- Number of pods per plant
8- 100-seed weight (g): 1000-seed weight (g) was determined by counting 1000-seeds at random from each lot of plot four times and weighed by a sensitive balance
9- Seed yield (tonlha):

$$Seed\ yield(t\ /\ ha)\ = \frac{Seed\ weig\ ht\ (t)\ of\ 7\ plant}{harvested\ \ plot\ \ area\ \ (m2)} \times 10000$$

The data of field experiments were analyzed statistically mainly for analysis of variance, using the statistical package SPSS and used Duncan [12] for mean separation.

Table 1. Monthly average of temperature and rainfall data during experiment period

Month	Temp. °C Mean		Rainfall (mm)
	Min.	Max.	
July	23.1	33.9	98.2
August	22.4	32.2	110.6
September	21,8	34.8	61.7
October	22.4	36.6	14.5

Source: Elobeid Research Station Observatory (2008)

Table 2. Some Physical and Chemical properties of the soil

Sand %	68.8
Silt %	8.0
Clay %	23.2
PH (paste)	7.30
Ece (dS/m)	0.34
Potassium (ppm)	12.82
Sodium (ppm)	13.79
Calcium (ppm)	10.79
Magnesium (ppm)	34.25
Phosphorus (mg/kg)	4.07
Nitrogen (%)	0.041
SAR	1.51

Source (Ibrahim, 2003)

Table 3. Rhizobium strain used in the study, their growth and sources

Strains	Source	Growth
H8	Local	Fast
H10	Local	Fast
H12	Local	Fast
H15	Local	Fast
Hi12	Introduced (USA*)	Fast
L6	Local	Fast
L7	Local	Fast
L10	Local	Fast
L11	Local	Fast
L14	Local	Fast
L15	Local	Fast
L18	Local	Fast
S3	Local	Fast
TAL169	Introduced (USA*)	Fast

*NifTAL is nitrogen fixation by tropical agricultural legume Project, University of Hawaii, USA.

3. Results and Discussion

3.1. Growth Attributes

Inoculation of guar genotype with local and introduced rhizobium strains significantly ($p \leq 0.05$) effect the most growth and yield attributes studied (Table 4. 5 and 6). Inoculation increased plant height (Table 4). The strains H10, H8, L10, L11, L18, L6 and L7 increased plant height by 6%, 8%, 31%, 4%, 38%, 15% and 26% respectively (Table 4). Similar were reported by Ibrahim, et al, [20] that inoculation enhanced plant height of guar and. Inoculation of guar genotype with rhizobium strains significantly ($p \leq 0.05$) increased shoot fresh weight. While inoculation with strains H10, H12, H8, L10, L18 and L7 significantly ($p \leq 0.05$) increased the shoot fresh weight by 2%, 71%, 59%, 45%, 7% and 55% respectively (Table 5).

The results of effect of inoculation on shoot dry weight are represented in Table 4. Rhizobium inoculation significantly ($p \leq 0.05$) increased shoot dry weight when guar genotype inoculated with. The inoculation with strains H12, H8, L10, L6 and L7 increased shoot dry weight respectively by 4%, 60%, 50%, 1% and 61%. the findings were on line with the results of Elhassan et al, [19] mentioned that The inoculation of faba bean with rhizobium strain TAL 1400 constantly resulted in severe increments in the fresh and dry weights of shoot, root, nodules, number of nodules, nodule dry weight, grain yield and N2 fixation. Inoculation with local and introduced strains significantly ($p \leq 0.05$) affected the root fresh weight. Inoculation with. Inoculation with strains H10, H12, H8, L10, L18, L6, L7 and S3 increased root fresh weight by 112%, 133%, 95%, 87%, 262%, 29%, 16% and 41% respectively (Table 5). These results were similar with Idris et al., [16] showed that shoot and root fresh weights, number of leaves, plant height and pod number of guar were increased by inoculation and nitrogen fertilization. Inoculation of rhizobium strains significantly increased root dry weight (Table 5). Treatments. Whereas inoculation with strains H12, H8, L10, L18, L7 and S3 increased root dry weight respectively by 81%, 54%, 72%, 9%, 63% and 181% respectively. These are in agreement with Hatice et al, [17] that Bacterial inoculations significantly increased root and shoot dry weights compared to the un-inoculated control of chickpeas. The inoculation with rhizobium strains increased number of nodules per plant (Table 4). While strains H10, H12, H15, H8, Hi12, L11, L14, L15, L18, L6, L7, S3 and TAL169 increased nodules number ($p \leq 0.05$) by 79%, 47%, 37%, 26%, 77%, 17%, 4%, 19%, 56%, 33%, 79% and 17% respectively compared to un-inoculated treatment. These findings supported the findings of Hassan and Abdelgani [18] who demonstrated that the inoculation of rhizobium strains increased nodules number with faba bean.

Table 4. Effect of Rhizobium inoculation on plant height (cm), number of fruiting branches per plant and number of nodules per plant of gaur crop

Treatments	Plant height (cm)	Number of fruiting branches	Number of nodules
Control	23.7bcde	1.56a,b,c,d	1.94a
H10	22.8bcd	1.4abcd	4.2de
H12	20.1abc	1.4abcd	3.3bcd
H15	19.5ab	1.1ab	2.2ab
H8	28.6de	1.2abc	3.2bcd
Hi12	23.2bcde	1.1abc	2.7abc
L10	29.9e	2.1bcd	2.1a
L11	28.3de	1.4abcd	3.5cde
L14	19.1ab	2.2cd	2.6abc
L15	21.1abc	2.4d	2.2ab
L18	28.5de	2.0abcd	2.4ab
L6	26.8cde	1.8abcd	3.6cde
L7	21,8abcd	1.3abc	2.5abc
S3	20.6abc	1.4abcd	4.3e
TAL169	15.1a	1.0a	2.4ab

Means in each column having the same latter's are not significantly different at 0.05 level of probability, according to the Duncan s Multiple Range Test.

3.2. Yield Attributes

Rhizobium strains significantly ($p \leq 0.05$) increased number of pods per plant as shown in Table 6. Inoculation with strains Treatments H10, H12, H8, Hi12, L10, L14, L6, L7 and S3 significantly increased number of pods per plant compared to other strains and control by 27%, 28%, 11%, 34%, 13%, 15%, 55% and 9% respectively. Comparable results were reported by Ibrahim et al, [20] in guar. Inoculation of guar with local and introduced strains had significant effect ($p \leq 0.05$) on number of pods in both sites. On the other site the inoculation of guar genotype with strains H8, L10, L14 and L7, significantly increased the number of pods by 5%, 66% and 61% respectively. These results were found to be on the same line with those obtained by Gomaa and Mohamed [3]. Rhizobium inoculation had no significant ($p \leq 0.05$) effect on 100-seed weight (g) of the guar (Table 6). While strain H15 increased 100-seed weight by 2.34%. These findings are in line with finding of Ibrahim et al [21] and Elsheikh et al, [22]. Inoculation of guar genotype with rhizobium strains significantly ($p \leq 0.05$) increased the final seed yield (ton ha^{-1}). Whereas treatments H8, Hi12, L10, L11, L14, L15, L18, L6, L7, S3 andTAL169 increased the final yield by 9%, 5%, 34%, 6%, 49%, 53%, 6%, 15%, 47%, 40% and 18% respectively, compared to un-inoculated one (Table 5). These results supported the findings of Ibrahim *et al* [14] and Bhuiyan [15] in Chickpea.

Table 5. Effect of Rhizobium inoculation on shoot fresh weight (g), shoot dry weight, and root fresh and dry weight (g) of gaur crop

Treatments	Shoot fresh weight (g)	Shoot dry weight (g)	Root fresh weight (g)	Root dry weight (g)
Control	2.1bc	0.5ab	0.3abc	0.1a
H10	2.4b,c	0.7ab	0.3abc	0.1a
H12	2.2bc	0.6ab	0.3abc	0.1a
H15	1.5ab	0.5ab	0.3abc	0.1a
H8	7.0d	2.2d	0.7d	0.3b
Hi12	1.9ab	0.6ab	0.3abc	0.1a
L10	1.9ab	0.5ab	0.2a	0.1a
L11	3.0c	0.9b	0.4c	0.1a
L14	2.3bc	0.7ab	0.3abc	0.1a
L15	2.2bc	0.6ab	0.3abc	0.1a
L18	1.2a	0.4a	0.2a	0.1a
L6	2.3bc	0.7ab	0.3abc	0.1a
L7	2.2bc	0.7ab	0.3abc	0.1a
S3	2.2bc	0.6ab	0.2a	0.1a
TAL169	1.7ab	0.6ab	0.2a	0.1a

Means in each column having the same latter's are not significantly different at 0.05 level of probability, according to the Duncan s Multiple Range Test.

Table 6. Effect of Rhizobium inoculation on 1000-seed weight (g) and seed yield (ton/ha) of gaur crop

Treatments	Number of pods per plant	1000-seed weight (g)	Seed yield (ton/ha)
Control	8.6c,d	3.4a	1.63a
H10	7.6a,b,c	3.1a	1.77ab
H12	7.3a,b,c	3.0a	4.09c
H15	6.1a,b,c	3.5a	3.95c
H8	9.0c,d	3.1a	3.07abc
Hi12	1.5a	3.4a	1.51a
L10	14.2d	3.0a	3.06abc
L11	3.7a,b,c	3.0a	2.75bc
L14	4.1a,b,c	3.4a	2.41abc
L15	3.0a,bc	3.1a	2.71abc
L18	8.2bcd	3.4a	3.89c
L6	8.6cd	3.4a	4.12c
L7	13.8d	3.1a	3.36bc
S3	4.8abc	3.1a	1.54a
TAL169	1.8ab	3.0a	3.86c

Means in each column having the same latter's are not significantly different at 0.05 level of probability, according to the Duncan s Multiple Range Test.

4. Conclusions

The results indicated that inoculation of guar with Bradyrhizobium (local and introduced strains) produced greater growth and seed yield in all inoculation treatments. So as a result inoculation of guar crop with Bradyrhizobium is recommended for similar conditions with this study.

REFERENCES

[1] Polhill, R.M. and Raven, P.H. (eds) 1981. Advances in Legume ystematics. Royal Botanic Gardens, Kew.

[2] Duranti, M. 2006. Grain legume proteins and nutraceutical properties. Fitoterapia, 77, 67–82.

[3] Gomaa, A. M., Mohamed, M. H. 2007. Application of Bio-Organic Agriculture and its effect on guar (Cyamopsis tetragonoloba L.) Root Nodules, Forage, Seed Yield and Yield Quality, World Journal of Agricultural Sciences, 3(1), 91-96.

[4] Mohammadi, K. S., Yousef, G. H., Khalesro, S.; Majidi, M. 2012. Effective factors on biological nitrogen fixation. African Journal of Agricultural Research, 7(12), 1782-1788.

[5] Kannaiyan, S. 2002. Biotechnology of Biofertilizers, Narosa Publishing House, New Delhi, India.

[6] Pulver, E. L., Brockman, F., Wien, H. C. 1982. Nodulation of Soybean Cultivars with Rhizobium spp. and their Response to Inoculation with *R. Japonicum*, 22 (5), 1065-1070.

[7] El hadi, E. A., Elshiekh, E. A. E. 1999. Effect of Rhizobium inoculation and nitrogen fertilization on yield and protein content of six chickpea (Cicer arietinum L.) cultivars in marginal soils under irrigation. Nutrient Cycling in Agroecosystems, 54 (1), 57-63.

[8] Cummings, S. P. 2005. The role and future potential of nitrogen fixing bacteria to boost productivity in organic and low-input sustainable farming systems, School of Applied Sciences, Ellison Building, University of Northumbria, Newcastle-upon-Tyne, NE1 8ST, UK, Environmental Biotechnology, (1)1, 1-10.

[9] Habish, H. A., Ishag, H. M. 1974. Nodulation of Legumes in the Sudan III. Response of Haricot Bean to Inoculation. Experimental Agriculture, 10, 45-50.

[10] Musa, M. M., Burhan, H. 0. 1974. The relative performance of forage legumes as rotational crops in the Gezira. Exp. Agric. 10,131-140.

[11] McDonald, D. 1985. Proceedings of the Regional Groundnut Workshop for Southern Africa 26-29 March 1984, Lilongwe, Malawi, Sponsored by International Development Research Centre (IDRC) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Patancheru P.O., Andhra Pradesh 502324, India.

[12] Duncan, D.M. 1955. Multiple range and multiple F-test. economics. F.A.O range management expert. Borno.

[13] El Naim, A. M.; Eldouma, M A; Ibrahim E A; Moayad, M B Z. 2011. Influence of Plant Spacing and Weeds on Growth

and Yield of Peanut (Arachis hypogaea L) in Rain-fed of Sudan. Advances in life Sciences, 1(2), 45-48.

[14] Ibrahim, Khalid A. (1998): The effect of Bradyrhizobium inoculation on yield and seed quality of guar (Cyamopsis tetragonoloba L.). M.sc. thesis, Faculty of Agriculture, University of Khartoum, Sudan.

[15] Bhuiyani. M.A.H., D. Khanam, M.F. Hossain, Ahmed M.S. 2008. Effect of Rhizobium Inoculation and Yield of Chickpea in Calcareous Soil. Bangladesh, J. Agri. Res., 33 (3), 549-554.

[16] Idris, S. A., Babiker, H., Mukhtar, N. O. 2000. Influence of inoculation, N and P fertilization on nodulation, growth and yield of guar (Cyamopsis tetragonoloba L.) Sudan. Journal of Science. and Technology. PP 48-65.

[17] Hatice, O., Caner, K. and Erdal, E. 2010. Effects of rhizobium strains isolated from wild chickpeas on the growth and symbiotic performance of chickpeas (Cicer arietinum L.) under salt stress. Turk J Agric., 34, 361-371.

[18] Hassan, M. A., Abdelgani, M. E. 2009. Effect of Microbial Biofertilization on Nodulation, Nitrogen and Phosphorus Content and Forage Yield of Lablab Bean (Lablab purpureus L.). Am.-Eurasian J. Sustain. Agric., 3(4), 829-835.

[19] Elhassan, G. A. Abdelgani, M. E. Awad G. O. 2010. Potential Production and Application of Biofertilizers in Sudan, Pakistan Journal of Nutrition. 9 (9), 926-934.

[20] Ibrahim, K A; Elsheikh; E A; El Naim, A. M. 2011. The effects of Bradyrhizobium inoculation on yield and yield components of hyacinth bean (Dolichos hyacinth L.). Australian Journal of Basic and Applied Sciences, 5(6), 303-310.

[21] Ibrahim, K A; Elsheikh, E A; El Naim, A. M. 2011. Effect of Bradyrhizobium Inoculation on Yield and Yield’s components of Soybean (Glycine max (L.)) Grown in Sudan. Australian Journal of Basic and Applied Sciences, 5(7), 793-799.

[22] Elsheikh, E. A. E., Ibrahim, K. A. 1999. The effect of Bradyrhizobium inoculation on yield and seed quality of guar (Cyamopsis tetragonoloba L.). Food Chemistry, 65(2), 183-187.