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Combination Influences of NPK Fertilizers and *Bradyrhizobium* Inoculation on the Yield, Chemical Constituents and Guaran Production of Guar (*Cyamopsis tetragonoloba*, Taub.) Plant

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Abstract At the Experimental Farm (Ghazala Farm) of the Agric. Fac., Zagazig University, Egypt, two field experiments were conducted through the two successive summer seasons in 2019 and 2020. This was an effort to improve the guar plant's yield and productivity. The experiment was set up as a split-plot design with NPK fertilization as the main plot and bio-fertilization as the sub-plot. The *Bradyrhizobium* spp. inoculation rates were (0.0, 200 and 400 g/feddan), while the NPK fertilization levels were (0.0, 75, 100, and 125% of recommended level). Ammonium sulphate (20.5% N) at 200 kg/feddan, calcium super phosphate (15.5% P₂O₅) at 200 kg/feddan, and potassium sulphate (48% K₂O) at 100 kg/feddan were the NPK fertilization recommended rates (RR). The obtained results showed that, in comparison to control and the other levels under study, guar plants fertilized with 125% RR significantly increased yield components as well as total carbohydrates content, and NPK percentages in seeds and guaran production. Additionally, compared to the control and lowest inoculation rates of *Bradyrhizobium*, the maximum inoculation rate (400 g/feddan) considerably recorded the highest values of all the aforementioned parameters. The majority of the study's findings demonstrated that fertilized guar plants with 125% RR of NPK fertilization, together with 400 g/feddan of *Bradyrhizobium* inoculation rate, might aid to improve guar plant (*Cyamopsis tetragonoloba* Taub.) yield, chemical constituents and guaran production.

Keywords. *Cyamopsis tetragonoloba*, Bio-fertilization, NPK, yield, Guaran and carbohydrates.

1. Introduction

Guar or cluster bean, also known as *Cyamopsis tetragonoloba*, is widely used in guar gum products, food additives, and thickeners. Guar is a multi-purpose legume crop that is primarily grown in the summer. It is drought-tolerant, used as green manure, animal feed, and to extract gum for a variety of industrial uses [1]. The first well-known product of the guar plant, guaran gum, is derived from the endosperm. Guaran gum, which makes up 19–43% of the entire seed's endosperm and forms a viscous gel in acidified alcohol, also, it is present in substantial amounts in the spherical endosperm [2].

Due to their roles in protein synthesis, photosynthesis, carbohydrate metabolism, enzyme activity, nitrogen fixation, and nucleic acid metabolism, the nutrients nitrogen, phosphorous, and potassium (N, P,



and K) are necessary for the growth and development of plants [3-5]. Moreover, the application of NPK fertilization at 6:3:3 rates resulted in the highest values for *Salvadora persica* plant growth attributes, root parameters, and greenness level [6]. According to [7], utilizing NPK fertilization at (7:20:30) level treatment increased herb fresh and dry yield per plant compared to control (untreated basil plants).

One method of converting elemental nitrogen into a form that plants can use is through biological nitrogen fixation [8]. Bradyrhizobium strains' ability to fix nitrogen through the development of effective root nodules makes nitrogen fertilizers more accessible [9]. In addition, [10] discovered that Bradyrhizobium inoculation and phosphorus supplementation, either alone or together, had a favorable impact on growth, grain yield, leaf chlorophyll content, and nitrogen fixation. Additionally, [11] found that for plant development and chemical contents (plant height, leaves per plant, pigment content, and total carbohydrate percentage) of two dill genotypes, bio-fertilizer and 100% chemical fertilizer were the best nutrition treatments.

The main goal of the current study was to examine the effects of various NPK fertilizer levels, *Bradyrhizobium* rates, and their combinations on the yield and chemical constituents of guar plants especially guaran and NPK percentages.

2. Materials and Methods

At the Experimental Farm (Ghazala Farm) of the Agriculture Faculty, Zagazig University, Egypt, two field experiments were conducted throughout the course of the two summers that followed in 2019 and 2020. This study looked at how different levels of Bradyrhizobium (0.0, 200, and 400 g/feddan), NPK fertilization (0.0, 75, 100, and 125% recommended rate), and their combinations affected the yield components, percentages of NPK and total carbohydrates in seeds and guaran production of guar (*Cyamopsis tetragonoloba*, Taub.) plant.

The recommended NPK fertilization rate (RR) was 200 kg/feddan (0.42 hectare) of ammonium sulphate (20.5% N), 200 kg/feddan of calcium super phosphate (15.5% P₂O₅), and 100 kg/feddan of potassium sulphate (48% K₂O). According to [12], physical and chemical examination of the experimental soil at a depth of 0–30 cm (average of both seasons) is shown in Table 1.

Table 1. Physical and chemical properties of experimental farm soil (average of both seasons).

Physical analysis												Soil texture		
Clay (%)			Silt (%)			Coarse sand (%)						Loamy		
43.70			31.90			24.40								
Chemical analysis														
pH	E.C. (dsm ⁻¹)	Soluble cations (m.mol/l)						Soluble anions (m.mol/l)			Available (ppm)			
		Ca ⁺⁺	Mg ⁺⁺	Na ⁺	Fe	Zn ⁺⁺	Mo ⁺⁺	Cl ⁻	HCO ₃ ⁻	SO ₄ ^{- -}	N	P	K	
7.80	1.56	2.10	2.80	0.90	0.30	1.65	1.42	3.40	4.08	1.30	155	89	73	

2.1. Experimental Units and Guar Cultivation

The experimental unit has a 14.70 m² (3.50 4.20 m) surface area and six ridges. Each ridge measured 3.50 metres long by 60 cm wide. Under surface irrigation, there were 30 cm between hills in the ridge. For the 2019 and 2020 growing seasons, the guar seeds were planted in the experimental units on October 12 and 16, respectively. Then it started irrigating right away. After perfect germination at 15 days after sowing, seeds were trimmed to two plants per hill.

2.2. Experimental Design

Three replicates of the split-plot design were used to set up the current experiment. There were four NPK fertilization levels in the main plots. The subplots, however, were eligible for three Bradyrhizobium rates. There were 12 combination treatments as a result of the main factor and the sub factor combined.

2.3. *Treatments Application*

Before planting, *Bradyrhizobium* was infected onto guar seeds. Arabic gum 20% was utilized as the glue. Before seeding, the inoculated seeds were allowed to air dry in a shaded area for about an hour. Additionally, three equal levels of different nitrogen and potassium fertilizer levels were added to the soil 35, 60, and 85 days after guar seeds were sown. When preparing the soil, several phosphorus applications were made. Every suggested agricultural procedure for cultivating guar plants was followed as necessary.

2.4. *Recorded Data*

2.4.1. *Yield Components*

The yield components represented as number of pods per plant, seed yield/plant (g), and seed yield/feddan (kg) were noted at the harvesting stage (after 160 days from the sowing date).

2.4.2. *Chemical Constituents*

At the end of the experiment, total carbohydrates, total nitrogen, total phosphorus, and potassium percentage in guar seeds were determined in accordance with [12].

2.4.3. *Guaran Production*

Guaran (galactomannan) percentage was determined in guar seeds according to the method described by [13]. However, total guaran percentage was multiplied by the weight of seeds per plant to get the amount of guaran present in each plant (g) and feddan (kg).

2.5. *Statistical Analysis*

According to [14], the current research's collected data were examined. At the 5% level of probability, means were differentiated using the least significant difference (L.S.D.). Using Statistix version 9's computer application, the means were compared [15].

3. **Results and Discussion**

3.1. *Seed Yield Components*

According to the data in Table 2, all NPK fertilization treatments significantly increased the number of pods per plant, seed yield per plant (g) and seed yield per feddan (kg) compared to control in both seasons. In general, increasing NPK fertilization levels from 75 to 125% RR in the two tested seasons was associated with a steady rise in the recorded yield and its components. Additionally, compared to control and the lowest rate under research, utilizing the maximum rate of *Bradyrhizobium* produced the highest values in guar yield components. For a 125% RR over the control (unfertilized plants), the gains in pod production per plant were around 30.35 and 44.35%, as well as in seed output per plant about 27.43 and 35.26%, in the first and second seasons, respectively. In most cases, both seasons saw a considerable rise in the yield components and chemical elements of guar (*Cyamopsis tetragonoloba*) in all combinations of NPK fertilization level and *Bradyrhizobium* rate treatments. In comparison to the control treatment (unfertilized plants without *Bradyrhizobium* inoculation), the increases in seed yield/feddan (kg) for the combination of NPK fertilization at 125% RR + *Bradyrhizobium* at 400 g/feddan were approximately 38.33 and 52.59% in the first and second seasons, respectively.

3.2. *Chemical Constituent*

Data listed in Tables 3 and 4 reveal that, total carbohydrates, total nitrogen, total phosphorus and potassium percentages significantly increased by utilizing any NPK fertilization levels compared to unfertilized guar plants in both seasons. In general the highest values in this regard were achieved when guar plants fertilized with NPK at 125 % RR compared to the other ones under study in 1st and 2nd

seasons. Moreover, inoculated guar seeds with *Bradyrhizobium* gave the highest values concern total carbohydrates and NPK percentages compared to control (un-inoculated plants) in both seasons. The plants that received *Bradyrhizobium* at 400 g/feddan and were fertilized with NPK at 125% RR had the highest results in this area in both seasons, followed by the combination treatment of plants that received *Bradyrhizobium* at 200 or 400 g/feddan and either 125 or 100% RR of NPK in the 1st and 2nd seasons, respectively.

Table 2. Effect of NPK fertilization level (A) and *Bradyrhizobium* inoculation rate (B) and their interaction (A×B) treatments on number of pods/plant, seed yield /plant (g) and seed yield /feddan (kg) of guar plants during the two seasons of 2019 and 2020.

NPK fertilization level (% RR*)	Bradyrhizobium inoculation rate (g/feddan)							
	0.0	200	400	Mean (A)	0.0	200	400	Mean (A)
	2019 season				2020 season			
	Number of pods /plant							
0.0	84.33	89.22	92.67	88.74	78.89	81.11	87.33	82.44
75	86.89	95.44	101.11	94.48	81.56	85.89	93.11	86.85
100	92.66	99.89	116.33	102.96	98.55	110.56	122.00	110.37
125	103.55	118.44	125.00	115.67	107.44	121.67	127.88	119.00
Mean (B)	91.86	100.75	108.78		91.61	99.81	107.58	
LSD at 5%	A= 1.00	B= 1.12	A×B= 2.08		A= 2.22	B= 1.37	A×B= 3.14	
	Seed yield /plant (g)							
0.0	6.04	6.17	6.61	6.27	5.73	6.02	6.46	6.07
75	6.18	6.73	7.01	6.64	5.99	6.32	6.86	6.39
100	6.20	7.22	8.16	7.19	6.14	7.95	8.38	7.49
125	7.42	8.19	8.36	7.99	7.64	8.25	8.74	8.21
Mean (B)	6.46	7.08	7.54		6.38	7.14	7.61	
LSD at 5%	A= 0.19	B= 0.17	A×B= 0.33		A= 0.07	B= 0.10	A×B= 0.18	
	Seed yield /feddan (kg)							
0.0	282.03	287.94	308.47	292.81	267.40	281.09	301.47	283.32
75	288.56	314.07	327.29	309.97	279.69	294.78	320.14	298.20
100	289.49	337.09	380.65	335.74	286.69	371.00	391.07	349.59
125	346.12	382.20	390.14	372.82	356.69	385.16	408.03	383.29
Mean (B)	301.55	330.32	351.64		297.62	333.01	355.18	
LSD at 5%	A= 8.93	B= 7.75	A×B=15.46		A=3.32	B= 4.67	A×B= 8.31	

* Recommended rate (RR): Ammonium sulfate (20.5% N) at 200 kg/feddan, calcium super phosphate (15.5%P₂O₅) at 200 kg/feddan and potassium sulfate (48 % K₂O) at 100 kg / feddan.

These results coincided with those found by [16] on some medicinal Apiaceae, [17] on medicinal plants, [7] on basil and [6] on *Salvadora persica* plants regard NPK fertilization effect. In the same time, [18] pointed out that soybean inoculated with an adequate amount of *Bradyrhizobium japonicum* gave optimal growth and development and maximize yield components.

As was previously mentioned, NPK fertilization and *Bradyrhizobium* inoculation each individually increased the yield components and chemical components of the guar plant; however, when combined, they may have the greatest impact, resulting in more pods per plant and the heaviest seed yield per plant and per feddan. Moreover, a suitable supply of NPK is in demand for optimum growth and yield output [3-5].

Table 3. Effect of NPK fertilization level (A) and *Bradyrhizobium* inoculation rate (B) and their interaction (A×B) treatments on total carbohydrates percentage and total nitrogen percentage of guar plants during the two seasons of 2019 and 2020.

NPK fertilization level (% RR*)	Bradyrhizobium inoculation rate (g/feddan)							
	0.0	200	400	Mean (A)	0.0	200	400	Mean (A)
	2019 season				2020 season			
	Total carbohydrates percentage in seeds							
0.0	16.15	16.41	16.63	16.40	16.02	17.26	17.49	16.92
75	16.28	17.24	17.43	16.98	16.63	17.14	17.62	17.13
100	17.16	17.60	17.86	17.54	17.06	17.76	18.23	17.69
125	18.03	18.63	20.19	18.95	17.75	18.33	19.08	19.39
Mean (B)	16.91	17.47	18.03		16.87	19.63	18.11	
LSD at 5%	A= 0.22	B = 0.27	A×B= 0.49		A= 0.18	B= 0.17	A×B= 0.33	
	Total nitrogen percentage in seeds							
0.0	2.747	2.840	2.910	2.832	2.660	2.687	2.770	2.706
75	2.823	2.867	2.950	2.880	2.697	2.750	2.850	2.766
100	2.877	3.010	3.200	3.029	2.823	3.140	3.207	3.057
125	2.953	3.233	3.317	3.168	2.883	3.117	3.280	3.093
Mean (B)	2.850	2.988	3.094		2.766	2.923	3.027	
LSD at 5%	A=0.081	B=0.029	A×B=0.094		A=0.032	B=0.034	A×B=0.064	

* Recommended rate (RR): Ammonium sulfate (20.5% N) at 200 kg/feddan, calcium super phosphate (15.5% P₂O₅) at 200 kg/feddan and potassium sulfate (48 % K₂O) at 100 kg / feddan.

3.3. Guaran Production

The data in Table 5 demonstrate that, in both seasons, utilizing NPK fertilization treatments at high levels (100 and 125% RR) considerably enhanced guaran percentage, guaran yield per guar plant (g), and per feddan (kg), compared to control and the lowest level (75% RR). In general, guaran production rose as NPK levels were raised, reaching its maximum when 125% of the recommended dose was used (RR). In addition, compared to un-inoculated seeds, the production of guaran was significantly enhanced by all *Bradyrhizobium* rate treatments (control). In comparison to control and the other study rates, using 400 g/feddan of *Bradyrhizobium* significantly increased guaran percentage, guaran yield per guar plant, and per feddan of guar. These results hold true in the 2019 and 2020 seasons. The combination treatment between NPK fertilization at 125% RR and *Bradyrhizobium* at 400 g/feddan significantly increased guaran production compared to control and the other ones under study in both seasons. In addition, increasing *Bradyrhizobium* rates under each NPK fertilization level gradually increased guar growth parameters.

Table 4. Effect of NPK fertilization level (A) and *Bradyrhizobium* inoculation rate (B) and their interaction (A×B) treatments on total phosphorus and potassium percentages in seeds of guar plants during the two seasons of 2019 and 2020.

NPK fertilization level (% RR*)	<i>Bradyrhizobium</i> inoculation rate (g/feddan)							
	0.0	200	400	Mean (A)	0.0	200	400	Mean (A)
	2019 season				2020 season			
Total phosphorus percentage in seeds								
0.0	0.503	0.517	0.553	0.524	0.507	0.530	0.547	0.528
75	0.520	0.527	0.570	0.539	0.517	0.543	0.557	0.539
100	0.540	0.567	0.587	0.564	0.537	0.583	0.607	0.576
125	0.560	0.593	0.610	0.588	0.550	0.570	0.613	0.578
Mean (B)	0.531	0.551	0.580		0.528	0.557	0.581	
LSD at 5%	A=0.007	B=0.004	A×B=0.010		A=0.012	B=0.006	A×B=0.015	
Potassium percentage in seeds								

0.0	2.670	2.737	2.833	2.747	2.743	2.827	2.857	2.809
75	2.683	2.830	2.947	2.820	2.747	2.803	2.980	2.843
100	2.800	2.927	3.093	2.940	2.853	2.997	3.073	2.974
125	2.820	3.093	3.183	3.032	2.910	3.127	3.217	3.084
Mean (B)	2.743	2.897	3.014		2.813	2.938	3.032	
LSD at 5%	A=0.047	B=0.034	A×B=0.073		A=0.074	B=0.061	A×B=0.124	

* Recommended rate (RR): Ammonium sulfate (20.5% N) at 200 kg/feddan, calcium super phosphate (15.5%P₂O₅) at 200 kg/feddan and potassium sulfate (48 % K₂O) at 100 kg / feddan.

Additionally, the NPK nutrients are essential for respiration, osmotic control, transpiration, photosynthesis and other processes [19]. Moreover, Applying basil plant with NPK fertilizer produced the highest active ingredients contents [20]. As was previously noted, both NPK fertilization and bio-fertilization treatments (each separately) boosted guaran output. However, when combined, these treatments may maximize their effects, resulting in the highest guaran yield per feddan and higher guaran yield per plant.

Conclusions

To improve the guar seed yield, chemical constituents, and guaran production it is advised to fertilize and inoculate guar with a sufficient NPK level as well as Bradyrhizobium strains. In addition, fertilization with NPK at 125% RR and 400 g Bradyrhizobium /feddan was the most effective treatment for improving seed yield and guaran output and the percentages of seed carbohydrates and NPK in *Cyamopsis tetragonoloba* plant.

Table 5. Effect of NPK fertilization level (A) and Bradyrhizobium inoculation rate (B) and their interaction (A×B) treatments on guaran percentage, guaran yield /plant (g) and guaran yield /feddan (kg) of guar plants during the two seasons of 2019 and 2020.

NPK fertilization level (% RR*)	Bradyrhizobium inoculation rate (g/feddan)							
	0.0	200	400	Mean (A)	0.0	200	400	Mean (A)
	2019 season				2020 season			
	Guaran percentage							
0.0	24.52	25.06	25.45	25.01	26.47	26.50	26.79	26.59
75	24.81	25.72	26.36	25.63	25.81	27.03	27.12	26.65
100	25.21	26.32	27.03	26.19	25.90	27.10	27.63	26.88
125	26.33	27.30	28.45	27.36	26.25	28.19	29.23	27.89
Mean (B)	25.22	26.10	26.82		26.11	27.20	27.69	
LSD at 5%	A= 0.17	B= 0.15	A×B= 0.29		A= 0.24	B= 0.20	A×B= 0.40	
	Guaran yield /plant (g)							
0.0	1.48	1.55	1.68	1.57	1.51	1.60	1.73	1.61
75	1.53	1.73	1.85	1.70	1.55	1.70	1.86	1.70
100	1.56	1.90	2.20	1.89	1.59	2.16	2.31	2.02
125	1.95	2.24	2.38	2.19	2.01	2.32	2.55	2.29
Mean (B)	1.63	1.85	2.03		1.66	1.95	2.11	
LSD at 5%	A= 0.05	B= 0.04	A×B= 0.09		A= 0.02	B= 0.03	A×B= 0.06	
	Guaran yield /feddan (kg)							
0.0	69.14	72.13	78.50	73.25	70.79	74.47	80.76	75.34
75	71.60	80.78	86.27	79.55	72.20	79.60	86.82	79.54
100	72.98	88.77	102.89	88.21	74.26	100.5 3	108.0 4	94.28
125	91.13	104.34	110.99	102.15	93.64	108.5 7	119.2 6	107.16
Mean (B)	76.21	86.50	94.66		77.72	90.79	98.72	
LSD at 5%	A= 2.26	B= 2.09	A×B= 4.09		A= 1.04	B= 1.47	A×B= 2.67	

* Recommended rate (RR): Ammonium sulfate (20.5% N) at 200 kg/feddan, calcium super phosphate (15.5%P₂O₅) at 200 kg/feddan and potassium sulfate (48 % K₂O) at 100 kg / feddan.

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