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INTERACTIVE EFFECTS OF BIO-FERTILIZERS AND PLANT *GLYCINE MAX* L POPULATION ON TWO SOYBEAN (.) CULTIVARS PERFORMANCE IN SOUTH-EASTERN SUDAN

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ABSTRACT

In order to estimate effect of bio-fertilizers x genotype × plant population interaction on soy bean performance, an experiment was conducted for two successive summer seasons (2018 and 2019) at Demonstration Farm of Damazin Agricultural Research Station in Damazin, Blue Nile State, South-eastern Sudan.Two cultivars of soybean namely,Sudan-1(V1) and Sudan-2(V1) inoculated with [Rhizobacteria (B1), Azotobacter (B2) and Bacillus(B3), and without bacteria as control(B0), respectively] under three plant population (D1≡ 210000, D2≡110000 and D3≡70000 plants/ha). The experiment was laid out in (RCBD) with three replications as split-split-plots trail. The traits of dry matter, leaf area, number of nodules, branches, pods per plant, seeds in pod, 100- seed-weight, seeds and straw yield were studied**.** The results revealed that, the interaction between of plant population and bio-fertilizer with genotypes showed significant effects on the most of these traits. The highest leaf area (8.97,9.98), seeds yield (967.22 and 986.22 kg/ha), HI (36.17 and 36.67) recorded when sowing seeds of V_1 at higher density D_1inoculated with B1 ($V_1 \times D_1 \times B_1$)in both seasons. Also, the heavier dry weights (0.95 and 0.92 kg), higher 100-seed weight (15.49 g), seeds/pod (7.48) were observed in $V_1 \times D_3 \times B_1$ treatment. The superiority of the above two interaction treatments, it was noted that the Sudan-1 genotype and bio-fertilizer (B1) ranked first in all traits of the seed yield and its components.

Keywords: Plant population, Bio-fertilizers, soybean, dry matter, nodules, 100-seed weight and yield attributes

INTRODUCTION

The soybean (*Glycine max* L.) is an annual herbaceous plant of Leguminosae. It is an important legume cultivated worldwide and due to the high biological value of protein it is considered the most important protein plant in the world (Abeje et al, 2024; Chen et al,1992,Tarekegn and Kibret. 2017).Yield increase emanating from plant density was mainly due to the increase in seed number per area rather than increased yield per plant. Earlier researchers (Andrade *et al*., 2002; Cox and Cherney ,2011; Herbert, 1984) reported that, individual soybean plants compensated dry matter as spacing increased. While in low plant densities there was accumulated more dry matter than higher plant density. Also, Caliskan *et al*., (2007) stated that, increasing plant density may increase light interception. Recently, Israilov *et al* (2023) concluded that, the highest yield and seed quality parameters were observed at the inoculated seeds with bacteria. The beneficial effects of phosphate solubilizing bacteria on crop productivity have been widely described but the use of PSB as bio-fertilizer is scarcely documented in soy bean **(**Rodriguez and Fragra,1999).

Further, Obid *et al*., (2016) showed that, several bacterial species like phosphate solubilizing bacteria (PSB) improving the plant growth and yield of crops. The greater dry biomass for both cultivars when increasing bio fertilizer doses application (Abeje et al., 2024;Bacilieri et al, 2023) concluded that, nodulation and grain yield can be affected by a relationship between P-solubilizing and Rhizobium bacteria. Also, recently Maftu'ah et al, (2022) reported that, application of biofertilizer e.g. N-fixing bacteria symbiotic and nonsymbiotic, P-solubilizing bacteria gave the highest soybean yields. Moreover, efforts are now underway in Sudan to encourage the cultivation of oil seed crops to meet the domestic need as well as to earn the foreign exchange Consequently, among different factors, cultivars (yield stability) emerges at a serious threat to low productivity of oil crops for farmers in Blue Nile state for the past few years (Khidir,1997). Further, Ngalamu et al. (2013) reported a significant difference among different genotypes of soybean pertaining to plant height, number of branches, number of pods per plant, number of seeds per pod, 1000-grain weight and seed yield.

Therefore, the best option for soybean, yield improvement and yield stability under bio-fertilizer application is using specific high yielding soybean cultivars grow in adequate plant population. However, the knowledge regarding comparative effectiveness of different PGPRs in improving the performance of different genotypes of soybean is lacking. Today, there are no recommended technologies of plant density/ha and nitrogen fixation (Bacteria strains) in soybean under rain-fed sector in Blue Nile State in Sudan. In view of the above reasons it was imperative to conduct experiment involving two soybean cultivars with regard to their response to three types of bacteria (bio-fertilizer) under three plant populations in order to obtain the potential seed yield of these cultivars. Therefore, this study aims to examine the effect of Bio-fertilizers, and Plant density on Growth and grain yield of two Soybean cultivars in Blue Nile Area, Sudan.

MATERIALS AND METHODS

An experiment was conducted for two successive summer seasons (2018 and 2019) at one site at Demonstration Farm of Damazin Agricultural Research Station (Lat. 11º 47´ N, long. 31º 21´ E, 492 m *asl*), Damazin, Blue Nile State, Sudan.Two medium maturity cultivars of soybean namely, Sudan-1(V1) and Sudan-2 (V1) which (donated by Oil Seed Crops Research Department, Damazin Agricultural Research Station) were grown under application of three types of bio-fertilizers B_1,B_2 and B_3, and B_0 as control. These bio-fertilizers were obtained from the institute of Ecology and natural Resource (Khartoum, Sudan) corresponding to [Rhizobacteria (B1), Azotobacter (B2) and Bacillus(B3), and without bacteria as control(B0), respectively] under three plant densities D1, D2 and D3 (spaces between plants 5cm≡ 210000, 10cm ≡110000 and 15cm ≡ 70000 plants/ha, respectively). The experiment was laid out in Randomized Complete Bock design (RCBD) with three replications as split-split-plots trail. The main plots allotted to cultivars, sub-plots allotted for plant density population treatments and the sub-sub-plots allotted for bio-fertilizers. The inoculated of the seeds were mixed with gum Arabic and water to coat them until they dry under shade before sowing. The seeds were sown in the second week of July in both seasons.

Parameters measured

Growth attributes

Five plants were randomly selected and tagged in each sub-plot to determine the following growth parameters:

Leaf area (LA)

The Leaf area index, which expresses the ratio of leaf surface area to the ground area occupied by the crop, was calculated using the formula suggested (Watson and Watson,1953).

Dry weight plant (g)
Five plants from each sub-plot were collected to determine shoot dry weight. Plants were then oven- dried and subsequently determined using a precision balance.

Number of nodules per plant
The total number of nodes present on the main stem was counted and recorded per plant.

Yield attributes
The two inner ridges in each sub sub- plot were used for the determination of the following yield components:

Number of pods per plant, seeds per pod, 100-seed weight (g), seeds yield (kg/ha), straw yield (kg/ha) also**,** harvest index was calculated as the ratio of grain yield to the total above ground shoot biomass.

Statistical Analysis
Data were statistically analyzed according to the analysis of variance (ANOVA) for RCBD design of split plot trial using a computer soft ware package (Statistix 10). Mean comparisons were worked out by Duncan's Multiple Range Test (DMRT) at 5% level of probability.

RESULTS AND DISCUSSION
SowingV_1 variety at medium density $D_2$when inoculated with bacteria with B_1 and B_2 significantly increased the dry weight of soy bean plants which were score heavier dry weights(0.95 and 0.92 kg) in first and second seasons, respectively (Table1). The leaf area values (8.97, 9.98) were recorded when sowing V_1 at higher density with inoculation with B_1 bacteria in first and second season, respectively. While the highest leaf area values (8.47, 9.07) were observed due to application $D_1B_1$and D_2B_3treatments at sowing V_2 variety in second season (Table1).The higher number of nodules were observed when Sowing V_1 at medium D2 density with inoculation with $B_1$and B_3as comparing with number of nodules observed when sowing variety V2 under the interactive (B×D) treatments in the two seasons (Table1). Inoculation seeds of V_1 with B1,B2 and B3incerased number of pods per plant particularly at lower density D3as compared with number of pods achieved at sowing V2 at higher density under all inoculation treatments (Table 2).The differences in number of seeds per pod ranged between(2.41,to7.48)for variety V1while the number ranged from 2.42 to 5.1 for variety V_2. The high number of seeds/pod(7.48, 6.69, 5.15, 5.10) where observed in D_3B_1, D_3B_2, D_1B_2, and D_1B_2 treatments, respectively in the first season (Table2). Sowing V_1at higher density $D_1$with inoculation with B_1 bacteria significantly gave the higher 100-seed weight (13.66g) in first season while the highest values (15.49, 14.31 g) of this character were observed when sowing V_1at lower density D3 inoculated with $B_1$and B_2in the second season (Table2). The higher seed yield(967.22 and 986.22 kg/ha)where recorded when sowing seeds of V_1 at higher density D_1inoculated with B1in both seasons as compared with relative treatments(Table3). For straw yield per unit area showed the same trend of aforementioned trait for $V_1×D_1×B_1$ treatment (Table3). The highest HI values (36.17 and 36.67) was observed for $V1×D_1×B_1$ V_1in first and second season, respectively (Table3). Planting density is one of the main factors that plays an important role on growth of any crop, So that planting density is one of the main factors that have an important role on growth, yield performance of soybean. The significant increase in leaf area of sowing V1 at closer spaces under application of B1 biofertilizer in this study might be due to the fact that, inoculation seeds with symbiotic N fixers might have increased nodulation and the concentration of nutrients efficient and healthy strain of Rhizobium which in turn resulted in greater of atmosphere N in soil for use by the plant and consequently resulting in to the better growth as reported by (Mena *et al*, 2023).

The greater dry matter resulted from V1D2B1 and V1D2B2 interaction treatment scould be due to role of these two bacteria`s activities and low competition in low plant density and gentic make up of V1. The supporting evidence were reported by Herbert, (1984); Cox and Cherney (2011) who concluded that, individual soybean plants compensated dry matter as spacing increased. While inoculation seeds with symbiotic N fixers and P-solubilizing bacteria might have increased the concentration of nutrients and consequently dry matter increased as reported by Bacilieri et al, (2023); Abeje et al., (2024). The increase in growth characters in this study, may explain the increase in yield attributing traits .i.e. number of branches and pods per plant which were gave more and heavier seeds per pod particularly in wider spaces for V1variety. Also, inoculation seeds of V1 that sowing in closer spaces significantly increased seeds an straw yield per unit area. This could be attributed to the great leaf area values and role of bio-fertilizers in this treatment. The results of present study are also in close conformity with those of Obid *et al*., (2016) ; Maftu'ah et al, (2022) ; zveushe *et al* , (2023) who concluded that, inoculation with N-fixing bacteria or p-Solublizing bacteria as increased seeds and straw yield of soybeans genotypes which were differ in their biomass and seeds weight. Another supporting finding is that, Phosphate solubilizing bacteria led to increased absorption of other elements by increasing the ability to access phosphorus and thereby can increase crop yield (Mahfouz and Sharaf, 2007).

It is concluded that seeds inoculation with biofertilizer (B1, B2 or B3) is an effective approach in enhancing the growth and yield of soybean. The superiority of the ($V_1 \times D_1 \times B_1$, ($V_1 \times D_3 \times B_1$)) two interaction treatments, it was noted that the Sudan-1 genotype and bio-fertilizer (B1) ranked first in all traits of the seed yield and its components.

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Table 1: Means of dry weight/plant(g), LAI and No. of nodules/plant due to interactive effects of variety, density and bio fertilizer in 2018 and 2019 seasons.

Treatments	Seasons	Dry weight (kg)		LAI		No of Nodules	
		2018	2019	2018	2019	2018	2019
V1	D1B0	0.06	0.09	4.07	5.16	20.00	65.00
	D1B1	085	0.80	8.97	9.98	72.67	73.87
	D1B2	0.82	0.82	7.77	8.90	71.33	72.33
	D1B3	0.87	0.87	8.40	9.00	64.33	65.33
	D2B0	0.19	0.09	4.07	5.16	24.33	65.00
	D2B1	0.95	0.95	7.90	8.70	70.67	71.67
	D2B2	0.92	0.92	6.83	8.50	60.67	61.67
	D2B3	0.63	0.63	7.47	9.00	74.67	48.67
	D3B0	0.28	0.79	4.07	5.16	24.33	65.00
	D3B1	0.78	0.78	6.20	6.73	49.67	50.67
	D3B2	0.52	0.52	6.20	5.73	48.00	49.00
	D3B3	0.61	0.61	6.13	6.13	48.67	49.67
V2	D1B0	0.18	0.07	4.97	5.16	12.33	53.00
	D1B1	0.60	0.60	7.93	8.47	49.00	50.00
	D1B2	0.70	0.70	7.20	7.27	42.33	43.33
	D1B3	0.57	0.57	6.90	7.67	45.00	46.00
	D2B0	0.23	0.07	4.97	4.16	11.00	53.00
	D2B1	0.63	0.63	6.73	7.27	48.67	49.67
	D2B2	0.80	0.83	7.38	8.21	43.50	44.50
	D2B3	0.60	0.61	7.93	9.07	46.00	47.00
	D3B0	0.17	0.07	5.13	4.16	11.00	53.00
	D3B1	0.40	0.40	6.73	8.07	41.00	42.00
	D3B2	0.30	0.30	6.07	6.47	44.33	45.33
	D3B3	0.32	0.32	6.50	6.67	45.00	46.00
	$LSD_{0.05}$	-	-	-	1.85	27.87	5.00

Table 2: Means No. of pods/plant, No. of seeds/pod and 100-seed weight (g) due to interactive effects of variety, density and bio fertilizer in 2018 and 2019 seasons

TreatmentsSeasons		No.of pods/plant		No.of seeds/pod		100-seed weight (g)	
		2018	2019	2018	2019	2018	2019
V1	D1B0	35.33	56.00	2.64	2.48	11.97	13.05
	D1B1	56.83	59.13	5.97	2.41	13.66	13.30
	D1B2	71.40	73.70	4.8	2.48	13.36	12.78
	D1B3	44.80	47.10	4.10	2.56	12.12	11.91
	D2B0	35.33	56.00	2.64	2.48	11.67	13.05
	D2B1	63.60	65.90	5.93	2.55	13.49	12.73
	D2B2	52.53	54.83	4.28	2.49	13.46	12.45
	D2B3	45.40	47.70	4.74	2.67	12.94	12.16
	D3B0	34.00	56.00	2.64	2.48	11.97	13.05
	D3B1	67.70	76.67	7.48	2.62	13.39	15.49
	D3B2	72.65	74.95	6.69	2.65	13.69	14.31
	D3B3	75.20	77.50	4.92	2.58	13.46	12.45
V2	D1B0	28.27	44.80	2.54	2.52	10.00	13.04
	D1B1	45.60	40.93	2.42	2.50	13.05	13.16
	D1B2	62.83	64.83	5.10	2.44	12.89	11.21
	D1B3	45.80	47.80	5.15	2.48	12.87	11.19
	D2B0	28.27	44.80	2.54	2.52	10.00	13.04
	D2B1	56.57	58.57	3.98	2.52	13.49	12.50
	D2B2	48.33	50.33	4.82	2.48	13.09	12.28
	D2B3	57.27	59.27	3.53	2.59	13.47	12.15
	D3B0	28.27	44.80	2.54	2.52	10.00	13.04
	D3B1	71.93	73.93	4.60	2.58	13.17	12.34
	D3B2	66.55	68.55	4.05	2.63	13.02	12.13
	D3B3	70.73	72.73	4.89	2.56	13.24	12.82
	$LSD_{0.05}$	-	-	1.21	-	-	1.27

Table 3: Means Seed yield (kg/ha), Straw yield (kg/ha) and Harvest index (HI due to interactive effects of variety, density and bio fertilizer in 2018 and 2019 seasons.

TreatmentsSeasons		Seed yield(kg/ha)		Straw yield(kg/ha)		Harvest index(HI)	
		2018	2019	2018	2019	2018	2019
V1	D1B0	320.00	441.33	1.41	0.73	21.02	25.25
	D1B1	967.22	986.22	2.88	0.99	36.17	36.67
	D1B2	896.17	915.67	1.77	0.90	34.20	34.70
	D1B3	851.11	870.11	1.92	0.88	28.42	29.92
	D2B0	336.67	383.33	1.41	0.59	21.02	25.25
	D2B1	761.67	772.67	2.08	0.72	29.40	30.09
	D2B2	666.78	677.78	1.94	0.64	25.88	27.38
	D2B3	663.89	674.89	1.92	0.79	25.06	26.56
	D3B0	336.67	375.33	1.41	0.31	23.66	25.25
	D3B1	520.56	529.09	2.12	0.40	24.45	25.95
	D3B2	475.56	484.09	1.83	0.48	29.48	30.98
	D3B3	449.44	427.98	2.00	0.45	27.82	29.32
V2	D1B0	321.67	361.34	1.29	0.32	25.29	22.07
	D1B1	513.67	523.61	2.46	0.51	25.43	25.93
	D1B2	700.00	677.39	2.14	0.37	26.75	28.91
	D1B3	622.22	620.91	2.16	0.49	26.71	25.54
	D2B0	371.67	354.34	1.29	0.32	23.51	22.07
	D2B1	688.89	743.13	2.22	0.33	24.31	24.81
	D2B2	488.89	501.46	2.26	0.61	27.27	27.77
	D2B3	522.22	554.24	2.06	0.46	24.56	25.06
	D3B0	321.67	335.34	1.29	0.32	23.51	22.08
	D3B1	639.44	634.98	2.30	0.47	31.54	30.38
	D3B2	575.00	552.39	2.21	0.32	24.88	25.38
	D3B3	447.22	473.68	1.82	0.49	23.37	24.54
	$LSD_{0.05}$	197.40	117.51	-	0.45	6.76	7.67