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Influence of Plant Spacing and Bio-fertilizers on Yield and Yield Attributing Characters of Rain-fed Soybean at Damazin in Blue Nile State, Sudan

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study had the objective of evaluating the effect of biofertilizers on the performance of soybean plants under different planting spacing. It was conducted during the summer seasons of 2018 and 2019at one site at Demonstration Farm of Damazin Agricultural Research Station, Sudan. The different plant spacing designated as D1, D2, and D3 (5, 10, and 15 cm between plants) under

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three types of bio-fertilizers as Rhizobacteria (B_1), Azotobacter (B_2), Bacillus (B_3) and control (B_0). The experiment was laid out in Randomized Complete Block design (RCBD) with three replications as split-plots trail. The result revealed that the improvement due to the application of fertilizers with wider, spacing D3 stimulated plant growth and caused an increase in dry matter accumulation and high leaf area and gave the higher number of pods and seeds/pod, particularly at inoculation with B1 and B2 bacteria. While sowing seeds inoculated with B1or B2 under closer spacing resulted in higher seed yield per unit area. To achieve optimum results in soybean variety Sudan 1, the crop may be sown in plant spacing of 10cm with inoculation seeds with B1or B2 to achieve a high plant population per unit area to obtain higher seed yield.

Keywords: Plant spacing; bio-fertilizers; soybean; leaf area and yield.

1. INTRODUCTION

"Soybean (*Glycine max* L.) is the most important commodity in the current international market and thus has a relevant effect on the food industry for people and animals worldwide" [1]. "Soybean 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" [2,3,4]. "In Sudan, soybean trials started as early as 1925 at Gezira Research Farm, where low yield was obtained. This low yield was attributed to a lack of adaptable cultivars to the Sudan agro-ecological conditions" [5]. "However, nutrient management is crucial for preserving a greater yield and soil fertility, among the many causes,causing low crop output" [6]. Also, the results reported by [7] illustrated that specific improvements can be achieved by changing the dose of the applied stimulus biofertilizers. "The highest numbers of pods with three grains were observed for two cultivars and the biofertilizer management, with productivity 15.3% higher than the control.Also, biofertilizer management and the soybean cultivars did not affect the seed protein content" [8]. Recently, [9] "reported that the highest yield and seed quality parameters were observed at the inoculated seeds with bacteria".

Soybean is a cash crop and has high yield potentiality under rain-fed conditions in the Blue Nile area, but the absence of recommended technologies for soybean under rain-fed conditions especially in nitrogen fixation, optimum plant population (spacing) and fertilization reflect unreal performance and productivity of soybean cultivars grown in Blue Nile State, which affected negatively the horizontal and vertical expansion of soybean in Blue Nile State. Keeping the above facts in consideration the present investigation was performed to evaluate the effects of Bio-fertilizer, and plant spacing on growth and grain yield of Soybean in the Blue Nile Area.

2. 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.A medium maturity cultivar of soybean namely, Sudan-1 (donated by Oil Seed Crops Research Department, Damazin Agricultural Research Station) was grown under three types of bio-fertilizers B_1,B_2, and B_3,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 control(B0), respectively) under three spacings between plants D1, D2 and D3 (spacing 5,10 and 15 cm between plants, respectively). The experiment was laid out in Randomized Complete Block design (RCBD) with three replications as split-plots trail. The main plots allotted spacing between plants and the sub-plots allotted for biofertilizers. The inoculation of the seeds was mixed with gum Arabic and water to coat themuntil they dryunder shade before sowing. The seeds were sown in the second week of July, in both seasons" [10].

2.1 Parameters Measured

2.1.1 Growth attributes

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

2.1.2 Leaf area index (LAI)

"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" by[11].

2.1.3 Dry weight per 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.

2.1.4 Number of nodules per plant

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

2.1.5 Yield attributes

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

Number of fruiting branches per plant, pods per plant, seeds per pod100-seed weight (g), also**,** harvest index was calculated as the ratio of grain yield to the total above-ground shoot biomass.

2.2 Statistical Analysis

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

3. RESULTS AND DISCUSSION

Analysis of variance showed significant differences due to spacing (D) and biofertilizer(B)and their interactions on dry weight, leaf area (LAI), and number of nodules in both seasons. The higher dry weight was observed in inoculation soybean seeds with B2 bacteria at D1 and D2spacing in both seasons as compared with other treatments (Fig. 1). Also, the same trend was observed on LAI in the second season while in the first season, inoculation seeds with B3 resulted in higher LAI values under the three spacing treatments (Fig. 2). The higher number of nodules were recorded when inoculation seeds with bacteria B3 under narrow spacing D1as compared with related treatments (Fig. 3). Sowing Soybeans at D2 spacing slightly increased number of fruit branches as compared with D1and D3 particularly when modulated with B1bacteria in the two seasons(Table 1).The wider spacing D3 gave a higher number of pods and seeds/pod particularly at inoculation with B1 and B2 bacteria in both seasons (Table 2). Moreover, the higher 100-seed weight (12.71,13.20 g) were recorded in D3 spacing while there were none significant differences in 100-seed weight between the bacteria inoculation treatments under every spacing treatment (Table 2). Sowing soybeans at closer spacing resulted in higher seed yield per unit area while wider spacing gave lesser seed yield (kg/ha) in both seasons (Table 2). Inoculation of soybean seeds with B1 significantly increased seed yield as compared with relative treatments. In this regard, sowing seeds inoculated with B1or B2 under closer spacing resulted in higher seed yield per unit area in both seasons (Table 2). The same trends were observed in harvest index character in both seasons (Table 2).

In this study, the increased in LAI and dry weight due to sowing seeds in wider spacing was agreed with results reported by [12] who stated that the highest values of LA, and dry weight of soybean plants significantly increased as plant density decreased. Also, the increase in growth characteristics due to the low plant population might be attributed to the fact that in the wider space, the individual plants did not face competition for moisture and nutrient supply. Application of biofertilizers can make nutrients available to soybean plants might result in higher leaf area leading to increased dry matter this could explain the results of the current study where inoculation of soybean seeds with bacteria result in an increase of plant growth characteristics i.e. dry weight, leaf area and number of nodules as reported by [13,8]. Also, the application of biofertilizers (bacillus and azotobacter) resulted in a higher number of branches, pods/plant, and number of seeds/pod. These findings were in accordance with those results reported by [14] in the number of branches, pods/plant and seeds/pod. Moreover, the increase of these yield components might result in an increased of seed yield and high 100-seed weight and consequently increased harvest index. This could be agreed with a previous study conducted by [15,16,17]. On the other hand, the higher number of pods and seeds/pod and 100-seed weight in wider spacing indicated the ability of Soybean to compensate for low plant population. These results were also in close conformity with the findings of [18,19]. Furthermore, sowing seeds inoculated with B1or B2 under closer spacing resulted in higher seed yield per unit area; this might be due to in increasing of plant growth and yield attributing characters resulting from the same treatment. The obtained results were in accord with those stated by [20].

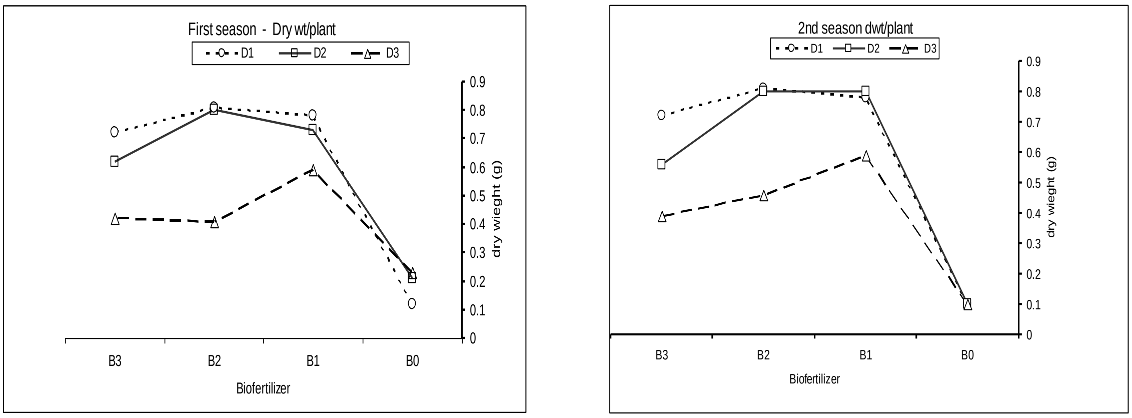

Fig. 1. Dry weight soybean plant due to interactive effects of spacing andbio-fertilizer in 2018 and 2019seasons

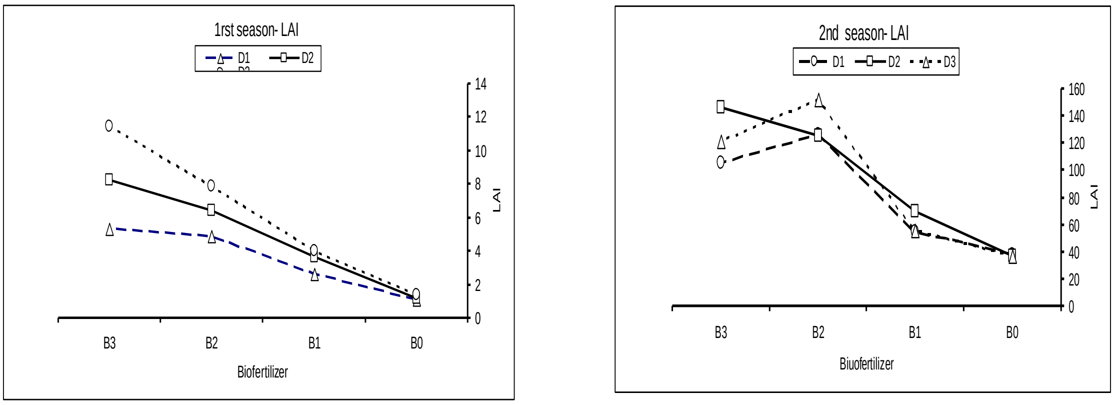

Fig. 2. LAI of soybean plant due to interactive effects of spacing and bio-fertilizer in 2018 and 2019 seasons

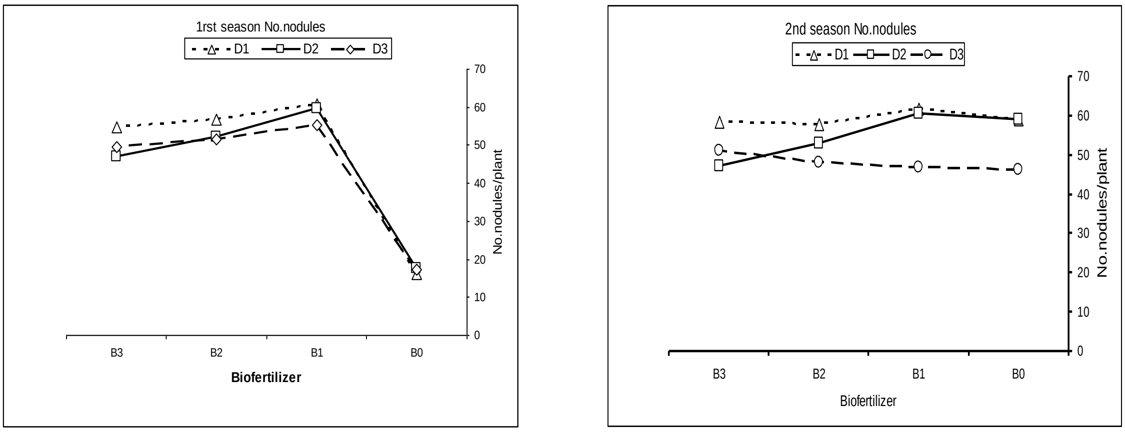

Fig. 3. No. of nodules/plant due to interactive effects of spacing and bio-fertilizer in the 2018 and 2019 seasons

Table 1. Means of No. fruit branches, pods /plant, and No. of seeds/pod due to the interactive effects of spacing and bio- fertilizer in the 2018 and 2019 seasons

Treatments	No. of fruit branches		No. of pod/plant		No. of seeds/pod	
	2018	2019	2018	2019	2018	2019
D1	7.04	4.79	48.41	54.29	4.47	2.48
D2	7.83	5.63	48.41	54.68	4.06	2.54
D3	6.56	6.21	60.88	68.14	4.73	2.58
$LSD_{0.05}$	-	0.66	5.34	5.02	-	0.03
B0	6.37	5.40	31.58	50.40	2.59	2.50
B1	7.87	3.39	60.37	62.52	5.56	2.53
B2	7.37	6.10	62.38	64.53	4.97	2.53
B3	6.97	5.44	56.53	58.68	4.56	2.27
$LSD_{0.05}$	1.55	0.58	3.91	4.11	0.31	0.05
D1B0	6.37	5.40	31.80	50.40	2.59	2.50
D1B1	7.50	3.75	51.22	50.03	5.69	2.46
D1B2	7.63	5.15	67.12	59.27	4.99	2.46
D1B3	6.67	4.87	45.30	47.45	4.63	2.52
D2B0	6.37	5.40	31.80	50.40	2.59	2.50
D2B1	8.97	6.37	60.08	62.23	4.96	2.53
D2B2	8.23	5.65	50.43	52.58	4.55	2.49
D2B3	7.73	5.08	51.33	53.48	4.14	2.63
D3B0	6.37	5.40	31.13	50.40	2.59	2.50
D3B1	7.13	5.92	69.82	75.30	6.04	2.60
D3B2	6.25	7.50	69.60	71.75	5.37	2.64
D3B3	6.50	6.37	72.97	75.12	4.90	2.56
$LSD_{0.05}$	1.95	1.09	7.92	7.92	-	0.08

Table 2. Means of 100-seed weight(g), Seed yield(kg/ha), and Harvest index due to interactive effects of spacing and bio-fertilizer in the 2018 and 2019 seasons

Seasons	100-seed weight (g)		Seed yield(kg/ha)		HI Harvest index	
treatments	2018	2019	2018	2019	2018	2019
D1	12.45	12.45	649.07	574.32	27.91	36.12
D2	12.70	12.45	556.33	490.60	25.13	33.73
D3	12.71	13.20	466.94	387.86	26.09	34.23
$LSD_{0.05}$	-	0.58	52.53	38.65	1.26	1.11
B0	10.83	13.04	326.39	0.33	23.00	23.66
B1	13.38	13.25	681.91	698.28	25.55	29.11
B2	13.25	12.53	633.82	634.80	28.08	29.19
B3	13.02	12.11	587.68	603.63	25.99	26.82
$LSD_{0.05}$	0.88	0.58	52.62	38.91	2.63	2.38
D1B0	10.83	13.04	320.83	0.33	23.16	53.66
D1B1	13.36	13.23	740.44	754.92	30.71	31.21
D1B2	13.13	11.99	798.33	796.53	30.47	31.81
D1B3	12.49	11.55	736.57	754.51	27.27	27.73
D2B0	10.83	13.04	329.17	0.33	22.27	53.66
D2B1	13.49	12.62	725.28	757.90	26.85	27.85
D2B2	13.27	12.36	577.83	589.62	26.58	27.58
D2B3	13.21	12.16	593.06	614.57	24.80	25.81
D3B0	10.83	13.04	329.17	0.33	23.80	53.66
D3B1	13.28	13.91	580.00	582.04	27.91	28.16
D3B2	13.35	13.22	525.28	518.24	27.18	28.18
D3B3	13.35	12.63	433.33	450.83	25.51	26.93
$LSD_{0.05}$	-	-	94.66	69.91	-	-

4. CONCLUSION

Hence it is concluded that, for achieving optimum results in soybean variety Sudan 1, the crop may be sown in plant spacing of 10cm with inoculation seeds with B1or B2 to achieve high plant population per unit area to obtain higher seed yield.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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