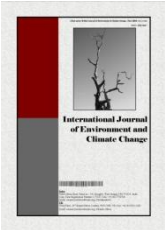

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Influence of Biofertilizers and Foliar Application of Seaweed (*Kappaphycus alvarezii*) Extract on Growth of Sorghum (*Sorghum bicolor* L.)

Mohammed Ali Dalwale [a*], Rajesh Singh [b] and Geshu Singh [b]

[a] Department of Agronomy, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, India.
[b] Department of Agronomy, NAI, SHUATS, Prayagraj, Uttar Pradesh, India.

Author's contributions

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

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ABSTRACT

In *the Kharif* season 2021, the field trial was conducted at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (UP), India. The experiment aims to reduce the impact of harmful chemical amendments in agro-ecosystems. The experiment was conducted in Randomized Block Design with ten treatments, including control with different biofertilizers, *viz*., *Azospirillum* sp. 25 g/kg seeds + 5% seaweed, *Azospirillum* sp. 25 g/kg seeds + 10% seaweed, *Azospirillum* sp. 25 g/kg seeds + 15% seaweed, PSB 25 g/kg seeds + 5% seaweed, PSB 25 g/kg seeds + 10% seaweed, PSB 25 g/kg seeds + 15% seaweed, *Azospirillum* sp., PSB: 25, 25 g/kg seeds + 5% seaweed, *Azospirillum* sp., PSB: 25, 25 g/kg seeds + 10% seaweed, *Azospirillum* sp., PSB: 25, 25 g/kg seeds + 15% seaweed including control i.e., application of 80: 40:40 kg NPK (farmer's practice) were replicated thrice. The results revealed dual inoculation by *Azospirillum* sp. 25 g/kg seeds and PSB 25 g/kg seeds, along with the foliar application of 10% seaweed at 30-50-70 DAS, significantly increased the growth parameters of sorghum *viz*., plant height (164.07 cm), number of leaves (12.47) dry matter accumulation (116.59 g), absolute growth rate (1.21 g/plant/day), crop growth rate (40.33 g/m^2/day) and leaf area (332.33 cm^2).

Keywords: Sorghum; seaweed; Azospirillum sp.; phosphate solubilizing bacteria; growth.

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[a]M.Sc. Scholar;*
[b]Assistant Professor,
**Corresponding author E-mail: dmdali123@gmail.com;*

ABBREVIATIONS

sp. : *species;*
DAS : *Days After Sowing;*
Ha : *hectare;*
m^2 : *square meter;*
g : *gram;*
kg : *kilogram;*
PSB : *Phosphate Solubilizing Bacteria;*
NPK : *Nitrogen Phosphorous Potassium;*
SEd ± : *Standard Error of difference;*
SE(m) ± : *Standard Error of mean;*

1. INTRODUCTION

Sorghum is generally cultivated as a rainfed crop in India during *the Kharif* and *rabi* seasons (92% of the area). Maharashtra is the state where the most sorghum is cultivated and produced in India. It is the fifth most important cereal crop. Sorghum is high in vitamins and has high protein content, accounting for a significant portion of dietary fiber intake. The 100 g of grains contains 10.4 g of proteins, 1.9 g of fats, 72.6 g of carbohydrates, 1.6 g of crude fiber, 25 g of calcium, and 3.5 g of fat, only 0.6 g of saturated fat. Sorghum is a drought-tolerant crop that is ideal for dry climates. The use of chemical fertilizers is inevitable in agriculture due to fulfilling the demand of the growing population; however, the priority to supply food in an eco-friendly manner will have to lessen the impact of chemical fertilizers in the agroecosystem. The use of biofertilizers can be effective for farmers to increase productivity. Biofertilizers enhance plant development by adding nutrients through natural biological processes. “It has been claimed that extracts of *Kappaphycus alvarezii* and *Gracilaria edulis* can improve nutrient absorption. This might be due to the presence of organic compounds and natural chelating agents in sap, such as mannitol, which mobilize and fixed nutrients to the plant in effective form” [1].

2. MATERIALS AND METHODS

The trial was conducted at Crop Research Farm during *the Kharif* season of 2021, Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj (U.P), India, which is situated at 25° 39' 42" N latitude, 81° 67' 56" E longitude and 98 m altitude above the mean sea level. The soil of the experiential plot was sandy loam, nearly neutral in pH (7.7), low in organic carbon (0.57%), available nitrogen (230 kg), and available phosphorous (32.10 kg), and available potassium (346 kg). The crop was sown on 20th July 2021 using the variety NTJ-5. The trial was carried out in a randomized block design, which includes three replications and a total of ten treatments *viz*., T1: Control 80:40:40 kg NPK (Farmer's Practice), T2: *Azospirillum* sp. 25 g/kg seeds + 5% seaweed, T3: *Azospirillum* sp. 25 g/kg seeds + 10% seaweed, T4: *Azospirillum* sp. 25 g/kg seeds + 15% seaweed, T5: PSB 25 g/kg seeds + 5% seaweed, T6 PSB 25 g/kg seeds + 10% seaweed, T7: PSB 25 g/kg seeds + 15% seaweed T8: *Azospirillum* sp., PSB: 25, 25 g/kg seeds + 5% seaweed, T9: *Azospirillum* sp., PSB: 25, 25 g/kg seeds + 10% seaweed, T10: *Azospirillum* sp., PSB: 25, 25 g/kg seeds + 15% seaweed. The details of treatment combinations are mentioned in Table 1. The nutrients applied to all treatments are urea, single super phosphate (SSP), and muriate of potash (MOP) by the soil. For each plot, full doses of phosphorous and potassium were administered basal, half doses of nitrogen (urea) were also applied as basal dose, and the remaining half dose of N was top-dressed at 30-35 DAS. The growth parameters were recorded from randomly selected five tagged plants in each treatment at intervals of 20,40,60,80 DAS and the harvest stage. Statistical analysis was performed, and the mean was compared at a 5% probability level of significance.

Table 1. Details of treatment combinations

Treatment No.	Treatment Combinations
T1	Control, 80:40:40 kg NPK (Farmer’s Practice)
T2	*Azospirillum* sp. 25 g/kg seeds + 5% seaweed at 30, 50, 70 DAS
T3	*Azospirillum* sp. 25 g/kg seeds + 10% seaweed at 30, 50, 70 DAS
T4	*Azospirillum* sp. 25 g/kg seeds + 15% seaweed at 30, 50, 70 DAS
T5	PSB 25 g/kg seeds + 5% seaweed at 30, 50, 70 DAS
T6	PSB 25 g/kg seeds + 10% seaweed at 30, 50, 70 DAS
T7	PSB 25 g/kg seeds 15% seaweed at 30, 50, 70 DAS
T8	*Azospirillum* sp. + PSB: 25+25 g/kg seeds + 5% seaweed at 30, 50, 70 DAS
T9	*Azospirillum* sp. + PSB: 25+25 g/kg seeds +10% seaweed at 30, 50, 70 DAS
T10	*Azospirillum* sp. + PSB: 25+25 g/kg seeds + 15% seaweed at 30, 50, 70 DAS

3. RESULTS AND DISCUSSION

3.1. The Influence of Biofertilizers and Foliar Application of Seaweed on Growth Parameters

The Influence of biofertilizers and foliar application of seaweed on growth parameters of sorghum are presented in Table 8.

3.1.1 Plant height

The findings resulted that the treatment with dual inoculation of *Azospirillum* sp. and PSB along with a foliar spray of 10% seaweed at 30-50-70 DAS recorded maximum plant height (164.07 cm). "Plant height grows as a result of increased biological activity of auxins and cytokinin's, which lengthen internodes and promote cell division" [2].

3.1.2 Number of leaves per plant

The results revealed that the highest number of leaves per plant (12.47) was reported with dual inoculation of *Azospirillum* sp. and PSB and foliar application of 10% seaweed at 30-50-70 DAS, which was superior to the treatments.

3.1.3 Dry matter accumulation

The results recorded that significantly highest plant dry matter accumulation (116.59 g) was found with dual inoculation of *Azospirillum* sp. and PSB along with the foliar application of 10% seaweed at 30-50-70 DAS was higher over the treatments. The presence of biologically active cytokinin, which promotes cell division, boosts the physiological response of crop dry matter [3]. "Foliar application of sea weed sap also enhanced nutrient mobilization division and thereby resulted in dry matter production" [4]. It could be because of enhanced nitrogen and phosphorus availability, which promotes more significant vegetative growth and result in larger sorghum seed and stover yields. Similar findings were reported by Singh et al. [5].

3.1.4 Absolute growth rate

At 80-100 DAS, significantly highest absolute growth rate (1.21 g/plant/day) was observed by dual inoculation of *Azospirillum* sp. and PSB along with foliar application of 10% seaweed at 30-50-70 DAS which was superior over the treatments [6-8].

3.1.5 Crop growth rate

At 80-100 DAS, significantly highest crop growth rate (40.339 g/m^2/day) has been recorded with dual inoculation by *Azospirillum* sp. and phosphate solubilizing bacteria (PSB) along with the foliar application of 10% seaweed at 30-50-70 DAS over control (only RDF). It might be due to better availability of nutrients during the crop growth period by the action of biofertilizers and seaweed [9-11].

3.1.6 Leaf area (cm^2)

At 80 DAS, significantly highest Leaf area (332.33 cm^2) has been recorded with dual inoculation by *Azospirillum* sp. and phosphate solubilizing bacteria (PSB) along with the foliar application of 10% seaweed at 30-50-70 DAS over control (only RDF).

Table 2. ANOVA of plant height (cm) at 80 DAS

Source	D.F.	SS	MSS	Cal. F	TAB F(5%)	TAB F(1%)
Treatment	9	828.40	92.04	34.58	S	S
Replication	2	2.65	1.32	0.50		
Error	18	47.92	2.66			
Total	**29**	**878.96**				

Table 3. ANOVA of number of leaves at 80 DAS

Source	D.F.	SS	MSS	Cal. F	TAB F(5%)	TAB F(1%)
Treatment	9	8.32	0.92	2.95	S	NS
Replication	2	1.60	0.80	2.55		
Error	18	5.65	0.31			
Total	**29**	15.57				

Table 4. ANOVA of dry matter accumulation (g) at 80 DAS

Source	D.F.	SS	MSS	Cal. F	TAB F(5%)	TAB F(1%)
Treatment	9	1390.65	154.52	127077.61	S	S
Replication	2	0.02	0.01	7.91		
Error	18	0.02	0.00			
Total	**29**	**1390.69**				

Table 5. ANOVA of absolute growth rate (g/g/day) at 80-100 DAS

Source	D.F.	SS	MSS	Cal. F	TAB F(5%)	TAB F(1%)
Treatment	9	0.48	0.05	533.15	S	S
Replication	2	0.00	0.00	2.53	NS	NS
Error	18	0.00	0.00			
Total	29	0.48				

Table 6. ANOVA of crop growth rate (g/m^2/day) at 80-100 DAS

Source	D.F.	SS	MSS	Cal. F	TAB F(5%)	TAB F(1%)
Treatment	9	531.34	59.04	533.15	S	S
Replication	2	0.56	0.28	2.53	NS	NS
Error	18	1.99	0.11			
Total	**29**	**533.90**				

Table 7. ANOVA of leaf area (cm^2) of sorghum 80 DAS

Source	D.F.	SS	MSS	Cal. F	TAB F(5%)	TAB F(1%)
Treatment	9	3283.63	364.85	48438.32	S	S
Replication	2	0.04	0.02	2.67	NS	NS
Error	18	0.14	0.01			
Total	**29**	**3283.81**				

Table 8. Influence of biofertilizers and foliar application of seaweed on growth parameters of sorghum

	Growth parameters (80DAS)					
Treatment Combinations	**Plant height (cm)**	**No. of leaves per plant**	**Dry matter accumulation (g)**	**Absolute growth rate (g/plant/day) 80-100 DAS**	**Crop growth rate (g/m^2/day) 80-100 DAS**	**Leaf area (cm^2)**
1. Control (Farmer's Practice)	130.47	10.87	65.27	0.760	25.322	293.36
2. *Azospirillum* sp. 25 g/kg seeds + 5% seaweed	127.20	11.33	81.35	1.049	34.967	302.36
3. *Azospirillum* sp. 25 g/kg seeds + 10% seaweed	138.21	11.20	81.64	1.084	36.139	310.37
4. *Azospirillum* sp. 25 g/kg seeds + 15% seaweed	138.92	11.73	81.37	1.110	36.983	311.47
5. PSB 25 g/kg seeds + 5% seaweed	139.17	11.40	82.69	1.132	37.728	313.56
6. PSB 25 g/kg seeds + 10% seaweed	139.72	11.13	82.58	1.139	37.967	315.52
7. PSB 25 g/kg seeds + 15% seaweed	135.93	12.13	81.55	1.185	39.500	316.38
8. *Azospirillum* sp. + PSB 25+25 g/kg seeds + 5% seaweed	142.61	11.87	90.33	1.196	39.878	325.38
9. *Azospirillum* sp. + PSB 25+25 g/kg seeds +10% seaweed	146.35	12.47	92.39	1.210	40.339	332.33
10. *Azospirillum* sp. + PSB 25+25 g/kg seeds + 15% seaweed	139.64	10.73	84.37	1.199	39.978	320.33
F test	S	S	S	S	S	S
S.Em (±)	0.94	0.32	0.02	0.006	0.192	0.05
S.Ed (±)	1.33	0.46	0.03	0.01	0.27	0.07
CD (P=0.05)	2.80	0.96	0.06	0.017	0.571	0.15

4. CONCLUSION

Finally, based on the results of this experiment, it can be recommended that sorghum be sown with dual inoculation of *Azospirillum* sp. and PSB along with the foliar spray of 10% seaweed at 30-50-70 DAS to get higher growth parameters of sorghum.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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