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EVALUATION OF BIO STIMULANTS AND BIOFERTILIZERS ON QUALITY PARAMETERS IN FRENCH BEAN (*PHASEOLUS VULGARIS* L.)

Abhinandan Sood[1], Puja Rattan[2], Ashima Sharma[1], Amninder Kaur[1] and Deepika Sharma[1*]

[1]Faculty of Agriculture Sciences, D.A.V. University, Jalandhar-144 013, Punjab India

[2]Division of Vegetable Science, Sher-e-Kashmir University of Agricultural Sciences andTechnology of Jammu (J & K)- 180 009, India

*Corresponding author E-mail: dpkasharma44@gmail.com

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ABSTRACT

Biofertilizers and seaweed extracts play a crucial role in enhancing crop productivity and nutrient availability. The present study was conducted during the autumn season of 2023-2024 at the experimental farm of the Faculty of Agricultural Sciences, DAV University, Jalandhar. Green formulations of mycorrhiza and seaweed extracts were evaluated to study their effect on the growth, productivity, and quality of French bean (*Phaseolus vulgaris* L.). Significant outcomes from the study revealed that the integrated application of NPK + Mycorrhiza @ 5% germinates quickly (8.76 days), while application of 50% NPK + Seaweed @ 10% significantly reduced the time to first flowering (40.75 days), and 50% flowering (46.73). The treatment combination of 50% NPK + Seaweed @ 10% resulted in the highest value for growth parameters with respect to number of leaves (25.55) and branches per plant (9.58), maximum plant height (43.00), pod length (14.05), average pod weight (5.57), number of pods per plant (15.26), and overall pod yield per plant (80.61). Among the different biochemical parameters, highest total soluble solids (TSS) (7.67), chlorophyll content in leaves (0.86), and carotenoid content (0.156) were recorded when 50% NPK was combined with 10 % Mycorrhiza.

***Key words*: Seaweed extract, bio-stimulants, growth modulation, organic, french bean**

Introduction

French bean (*Phaseolus vulgaris* L.), also known as kidney bean is an annual legume crop which is grown for its tender pods, shelled beans and dry beans. India ranks first in area and production of French bean among Asian countries and occupies an area of 137.54 (000 ha) and average productivity of 9.96 MT/ha. In India, it is mostly grown in West Bengal, Andhra Pradesh, Jharkhand, Jammu and Kashmir and Himachal Pradesh. It is a major crop in Punjab which occupies an area of 1.9 (000 ha) with annual production of 1.9 (000 MT) and average productivity is 1.6 MT/ha Anonymous (2021). It is the most extensively grown bean in Punjab plains during autumn and spring because of its short duration nature with high nutritive value Dhaliwal (2012). French bean like other legumes, fixes atmospheric nitrogen and thereby improves soil fertility Adsule *et al.*, (1998). Due to the environmental and health concerns associated with use of inorganic fertilizers, there is a need to utilize the eco-friendly inputs like vermicompost, biofertilizer *viz.*, Phosphorus solubilizing bacteria (PSB), *Rhizobium* etc because of their cost effectiveness in vegetable cultivation.

Presently, the utilization of organic materials as fertilizers for crop production has received attention for sustainable crop productivity Tejada *et al.*, (2009) as they are economical as well as environmentally friendly. Organic substances hold great potential in crop production being source of rich nutrients with the ability to improve soil characteristics Moller (2009). Organic amendments act as source of nutrients with high organic matter that also increases the pod size along with the increase in microbial activity of the soil, with improvement in physical, chemical, and biological parameters of the soil Manivannan *et al.*, (2009). Organic manures thereby help to increase the population of soil microorganisms which influence the growth of plants against pathogens and provide growth hormones Agbedge and Ojeniyi (2009). Among different organic amendments, seaweed is an organic extract whose agricultural use as a plant bio-stimulant has been studied by various researchers Calvo *et al.,* (2014); Rouphael *et al.,* (2017); Singh *et al.,* (2016). Moreover, seaweed extract has been utilized in various vegetable crops for multifarious benefits like higher yield and foliar biomass, increase in antioxidants, and yield in broccoli, cucumber, egg plant, okra, onion, pepper, lettuce, respectively Lola-Luz *et al.,* (2014); Ahmed *et al.,* (2012); Crouch *et al.,* (1990); Dutta *et al.,* (2019); McGeary and Birkenhead (1984); Thirumaran *et al.,* (2009).

The beneficial effects of seaweed extract on overall growth, yield and quality parameters with different agronomic and horticultural crops have been reported Battacharyya *et al.,* (2015); Kumar *et al.,* (2020). The beneficial effects of seaweed extracts refer to the presence of plant macro and micronutrients, betaines and betaine analogues proteins, secondary metabolites, vitamins (including vitamin precursors), polysaccharides, phenolic compounds, phytohormones like auxins, cytokinins, GAs, ABAs and brassinosteroids and osmolytes, Rayirath *et al.,* (2009); Stirk *et al.,* (2014); Wang *et al.,* (2009). Seaweed extract thereby boosts the antioxidant properties in soil with increase in organic carbon content and thereby makes more nutrients available towards plants Kasim *et al.,* (2016). Seaweed extracts thereby improve the soil health by increasing the water holding capacity and aeration of soil, promoting growth of the plant with higher soil microbial activity Moore *et al.,* (2004). These bioactive compounds boost the quality and productivity of the majority of the crops. Thus, keeping in view, the present investigation was planned to study the efficacy of organic amendments i.e. seaweed extract and biofertilizers on growth, yield and quality of french bean.

Material and Methods

The field experiment was carried out during the autumn season of 2022-2023 at Experimental Farm of Faculty of Agricultural Sciences, DAV University, Sarmastpur, Jalandhar (Punjab) with the aim to study efficiency of biofertilizer and seaweed extract french bean (*Phaseolus vulgaris* L.).

The climate of the experimental site was mainly sub-tropical in nature with cool winter and long and hot summers with mean annual rainfall that varies from 1060-1110 mm (approx.) of which about 75 per cent is received during June to September months of the year. The experiment was carried out in a Factorial Randomized Block Design (FRBD) with two different varieties *i.e.* Falguni and Serengeti, with eight treatments and three replications. Seeds of cultivar *i.e* Falguni and Serengeti were sown in the month of September 2023.

The experimental field was prepared for the sowing of french bean varieties *i.e.* Falguni and Serengeti. The field was ploughed to a fine tilth with disc plough and subsequently light ploughing was done with cultivator followed by harrowing and planking. The required area for sowing of the varieties was marked and about 48 plots were prepared. The seeds of different varieties *i.e.* Falguni and Serengeti were planted at a spacing of 45 cm × 15 cm in a field area of 416 m². Each experimental plot measured around 6m². Organic amendments were then applied manually to individual plots as per the treatment schedule. The first irrigation was carried out two days after sowing. Weed management was performed manually at 15–20-day intervals to reduce competition for moisture, nutrients, and space, while also enhancing the soil aeration and thereby maintaining the plot hygiene. Fruits from each plot were harvested manually at the green, tender, and marketable stage. Also, immediately after each picking, the fruits were weighed and later subjected to further observations and analysis.

Observations recorded

Five plants were randomly selected and permanently tagged from each plot for recording various growth, yield, and quality parameters from the experimental field. All observations were consistently recorded from these tagged plants, as per the methodology outlined below:

Growth and yield parameters

The different growth parameters were recorded that included days to germination, days to first flowering, days to 50% flowering, plant height, number of branches per plant, and number of leaves per plant. Days to germination, days to first flowering, date of sowing, days to the appearance of first flower, days to 50% flowering were recorded. Plant height was measured at the harvesting stage from the base to the apex of five randomly tagged plants per plot using a meter scale, and the average height was recorded in centimetres. The number of primary branches per plant was determined by counting the branches on the same five plants, and the mean value was calculated. The total number of leaves per plant was counted at final harvest from five randomly selected plants in each plot, and the average was recorded.

Yield parameters included pod length, average pod weight, number of pods per plant, pod yield per plant, and pod yield per plot. Pod length was measured using a ruler on marketable pods harvested from five tagged plants per plot, and the average was recorded in centimeters. Average pod weight was calculated by weighing the harvested pods using a digital balance at each picking and computing the mean weight in grams. The number of pods per plant was counted from each picking and averaged. Pod yield per plant was obtained by summing the total pod weight from each tagged plant across all pickings and expressing the result in grams. Total pod yield per plot was recorded in kilograms, and the mean was calculated to assess the overall productivity of each treatment.

Quality parameters

Different quality parameters, namely chlorophyll content, carotenoid content, and total soluble solids (TSS), were measured.

Chlorophyll content in leaves (mg/g)

The chlorophyll content of leaves was determined from fresh leaf samples at 40 days after sowing. The leaf sample were washed with distilled water and dried with blotting paper. Out of this, 100 mg fresh leaves were ground well by mortar and pestle with 5 ml of 80 per cent acetone and centrifuged at 2000 rpm for 10 minutes and filtered through Whatman filter paper No.1. Volume of supernatant was made to 10 ml with 80 % acetone. The resultant intensity of colour was measured on Spectronic-20 at Absorbance (A) of 652 nm. Total chlorophyll content was calculated with the help of following formula and expressed in mg/g fresh weight of leaves (Arnon, 1949).

$$\text{Total chlorophyll (mg/g) tissue} = 20.2\,(A645) + 8.02\,(A663)$$

$$\text{Chlorophyll A (mg/g) tissue} = 12.7\,(A663) + 2.69\,(A645)$$

$$\text{Chlorophyll B (mg/g) tissue} = 22.9\,(A645) - 4.68\,(A663)$$

Total carotenoid content (mg/g)

The Beer-Lambert Law was used to calculate the carotenoid content, which is compared to standard absorbance value. 50 mg fresh leaf material from randomly selected leaf was used. The material was then taken into test tubes to which 10 ml acetone was added. Mix the solution well and thereby keep it in a dark place for 24 hours to allow the carotenoids to dissolve into the solvent.

TSS (Total Soluble Solid)

Total soluble solids were calculated with the help of refractometer. Juice of the selected sample were taken and thereby filtered with the help of dropper, the juice was being dropped on the refractometer, and as the refractive light passes and TSS along with temperature appeared, the value was recorded.

Results

Growth Parameters

The experimental results showed significant variation in growth and developmental parameters across treatments and varieties. T3 (NPK + Mycorrhiza @5%) recorded the earliest germination (8.76 days), statistically similar to T4 (8.83 days), while the control (T1) exhibited the slowest germination (14.00 days). Among varieties, Serengeti (V2) germinated faster (10.70 days) than Falguni (V1, 11.43 days). The interaction T2 × V2 showed the quickest germination (8.43 days), while T1 × V1 was the slowest (14.23 days), likely due to improved early root development and nutrient uptake facilitated by mycorrhiza. In terms of flowering, T6 (50% NPK + Seaweed @10%) promoted the earliest first flowering (40.75 days) and 50% flowering (46.73 days), whereas T1 delayed flowering (47.92 and 54.41 days, respectively). V2 flowered earlier than V1, and the interaction T6 × V2 was the earliest (40.20 and 46.16 days), in contrast to T1 × V1, which was the latest (47.92 and 54.80 days), indicating seaweed's influence through cytokinin activity and enhanced hormonal balance. For vegetative growth, T6 and T5 resulted in the maximum number of leaves (25.55 in T6) and branches (9.58 in T5), while T1 again had the lowest values (18.50 leaves and 6.20 branches). Serengeti (V2) consistently showed better growth than Falguni (V1), with T6 × V2 and T5 × V2 achieving the highest leaf and branch counts, respectively. Regarding plant height, T6 produced the tallest plants (43.00 cm), followed by T5, while the shortest plants were observed in T1 (35.80 cm). Between varieties, V2 (39.31 cm) was taller than V1 (38.75 cm), and the interaction T6 × V2 recorded the maximum height (43.40 cm), with T1 × V1 being the shortest (35.07 cm). These findings clearly demonstrate the beneficial effects of mycorrhiza and seaweed extract, which enhanced seed germination, early flowering, and vegetative vigor by improving nutrient absorption, stimulating hormonal activity, and promoting better root and shoot development. The effects of different treatments and varieties on the growth parameters, including days to germination, days to first flowering, days to 50% flowering, number of leaves, number of branches, and plant height was recorded and presented in Table 1.

Yield Parameters

The results indicated significant differences in pod characteristics and yield across treatments and varieties (Table 2). T6 (50% NPK + Seaweed @10%) produced the longest pods (14.05 cm), while T1 (control) recorded the shortest (9.63 cm).

Table 1: Effect of biofertilizer, seaweed extract, and varieties on growth parameters.

Treatment	Days to germination (Days)	Days to First Flowering (Days)	Days to 50% Flowering (Days)	No. of Leaves /Plant	No. of Branches /Plant	Plant Height (cm)
T1 (Control)	14.00	47.92	54.41	18.50	6.20	35.80
T2 (NPK)	9.06	45.55	52.16	20.26	7.28	37.18
T3 (NPK + Mycorrhiza @5%)	8.76	43.18	49.15	23.90	8.38	39.61
T4 (NPK + Seaweed @5%)	8.83	42.78	48.91	23.35	8.83	38.79
T5 (50% NPK + Mycorrhiza @10%)	10.98	41.33	47.36	24.75	9.16	40.71
T6 (50% NPK + Seaweed @10%)	11.01	40.75	46.73	25.55	9.58	43.00
T7 (Mycorrhiza @15%)	12.95	44.88	51.26	22.50	8.15	38.75
T8 (Seaweed @15%)	12.93	44.80	50.71	21.50	8.20	38.45
CD (5%)	0.24	0.22	0.21	0.38	0.22	0.39
SE(d)	0.12	0.10	0.10	0.18	0.10	0.19
Varieties						
V1 (Falguni)	11.43	44.22	50.72	22.26	7.97	38.75
V2 (Serengeti)	10.70	43.35	49.46	22.81	8.47	39.31
CD (5%)	0.12	0.11	0.10	0.19	0.11	0.19
SE(d)	0.06	0.05	0.05	0.09	0.05	0.09

Among varieties, Serengeti (V2) had longer pods (12.46 cm) than Falguni (V1, 11.80 cm), with the T6 × V2 interaction showing the maximum pod length (14.50 cm) and T1 × V1 the minimum (9.40 cm), likely due to the elongation effect of seaweed-derived phytohormones. T6 also resulted in the highest number of pods per plant (15.26), compared to T1 (9.43 pods). V2 again outperformed V1, and the interaction T6 × V2 had the most pods (15.44), while T1 × V1 had the fewest (9.14), indicating phosphorus-induced improvements in pod formation. In terms of average pod weight, T6 showed the heaviest pods (5.57 g) and T1 the lightest (3.07 g). V2 (4.41 g) was superior to V1 (4.02 g), and the T6 × V2 combination recorded the maximum weight (5.88 g), while T1 × V1 was the lowest (2.91 g), reflecting enhanced assimilate partitioning from seaweed biostimulants. For pod yield, T6 achieved the highest yield per plant (80.61 g) and per plot (3.66 kg), followed by other treatments, with T1 recording the lowest (48.11 g and 1.06 kg, respectively). Serengeti (V2) again surpassed Falguni (V1), and the interactions T6 × V1 and T6 × V2 yielded the maximum per plant (81.83 g) and per plot yield (3.80 kg), respectively, while T1 × V1 was the lowest (46.43 g, 1.02 kg). Overall, seaweed application significantly enhanced yield-related traits through improved nutrient availability and physiological efficiency (Table 2).

Quality Parameters

Significant variations in quality parameters were observed among treatments and varieties, with T5 (NPK + Mycorrhiza @10%) consistently outperforming others. It recorded the highest total soluble solids (TSS) at 7.67°Brix, while the lowest was observed in T1 (5.11°Brix). Among varieties, Serengeti (V2) showed superior TSS (6.61°Brix) compared to Falguni (V1, 6.34°Brix). The interaction T5 × V2 resulted in the maximum TSS (7.88°Brix), statistically comparable to T6 × V2 (7.74°Brix), whereas the lowest was in T1 × V1 (5.10°Brix). Chlorophyll content also followed a similar trend, with T5 recording the highest total chlorophyll (0.86 mg/100g), chlorophyll A (0.354 mg/100g), and chlorophyll B (0.515 mg/100g). T6 was statistically on par for total chlorophyll (0.82 mg/100g) and chlorophyll A (0.352 mg/100g), while T1 consistently showed the lowest pigment concentrations. Serengeti (V2) again outperformed Falguni (V1), and interactions T5 × V2 and T6 × V1 exhibited the highest chlorophyll content, while T1 and T2 in both varieties were the lowest performers. Similarly, carotenoid content was highest in T5 (0.156 mg/100g), followed by while the lowest values were seen in T1 (0.080 mg/100g) and T1 × V1 (0.078 mg/100g). The superior performance of T5, particularly in combination with V2, can be attributed to the positive influence of mycorrhiza in enhancing nutrient uptake, sugar synthesis, and pigment biosynthesis. Table 3 summarizes the effects on quality parameters, including total soluble solids (TSS), total chlorophyll, chlorophyll A, chlorophyll B, and carotenoid content.

Discussion

The results provide significant insights into optimizing cultivation practices, with interpretations, comparisons to existing literature, and future implications discussed below. Salma *et al.*, (2014) who detected a 5% increase in the germination percentage and a decrease of 1.28 days in the average emergence speed in response to the

Table 2: Effect of Biofertilizer, Seaweed Extract, and Varieties on Yield Parameters.

Treatment	Pod Length (cm)	No. of Pods/Plant	Avg. Pod Weight (g)	Pod Yield/Plant (g)	Pod Yield/Plot (kg)
T1 (Control)	9.63	9.43	3.07	48.11	1.06
T2 (NPK)	10.46	10.71	3.45	52.96	1.25
T3 (NPK + Mycorrhiza @5%)	12.50	13.29	4.26	66.66	2.10
T4 (NPK + Seaweed @5%)	13.03	13.98	4.71	72.43	2.52
T5 (50% NPK + Mycorrhiza @10%)	13.56	14.65	5.33	79.48	3.40
T6 (50% NPK + Seaweed @10%)	14.05	15.26	5.57	80.61	3.66
T7 (Mycorrhiza @15%)	11.76	12.01	3.56	63.05	1.48
T8 (Seaweed @15%)	12.08	12.60	3.76	65.41	1.66
CD (5%)	0.22	0.18	0.13	1.09	0.08
SE(d)	0.11	0.08	0.06	0.53	0.04
Varieties					
V1 (Falguni)	11.80	12.52	4.02	65.40	2.05
V2 (Serengeti)	12.46	12.96	4.41	66.78	2.24
CD (5%)	0.11	0.09	0.06	0.54	0.04
SE(d)	0.05	0.04	0.03	0.26	0.02

extraction of *S. vulgare* in two bean cultivars are in accordance with our results. Lukiwati and Simanungkalit (2002); Jalaluddin (2005); Avis *et al.*, (2008) also studied the effect of VAM (*Glomus mossae*) on growth and productivity of legumes and recorded its significant influence when compared with non-mycorrhizal plants. The rapid germination observed with Mycorrhiza aligns with Fidelibus *et al.*, (2000), who noted enhanced root colonization and nutrient uptake in legumes. Salma *et al.*, (2014) reported a 5% increase in bean germination with seaweed extracts, supporting the earliness in T3 and T4. The early flowering induced by T6 corroborates Wightman and Thimann (1980), who linked seaweed's cytokinins to floral induction, and O'Dell (2003), who observed similar effects in vegetables. Vegetative growth improvements in T5 and T6 are consistent with Temple *et al.*, (1988), who reported increased leaf and branch counts in beans with kelp extracts, and Thirumaran *et al.*, (2009), who noted enhanced growth in cluster beans with seaweed liquid fertilizers. Yield enhancements in T6 mirror Rathore *et al.*, (2008), who attributed increased pod numbers in legumes to seaweed's phosphorus and calcium content, and Arioli *et al.*, (2015), who linked improved soil structure to higher nutrient uptake. The pod length increase aligns with Sethi and Adhikary (2008), who reported longer vegetable fruits with 1% seaweed foliar sprays. Quality improvements, particularly TSS and chlorophyll, support Mikiciuk *et al.*, (2019), who noted higher sugar content in Mycorrhiza-treated plants. The results of the study of total chlorophyll content of mycorrhizal applications showed that all mycorrhizal applications can increase the total chlorophyll content. Similar results with the

Table 3: Effect of Biofertilizer, Seaweed Extract, and Varieties on Quality Parameters.

Treatment	TSS (°Brix)	Total Chlorophyll (mg/100g)	Chlorophyll A (mg/100g)	Chlorophyll B (mg/100g)	Carotenoid (mg/100g)
T1 (Control)	5.11	0.49	0.029	0.027	0.080
T2 (NPK)	5.44	0.59	0.223	0.273	0.092
T3 (NPK + Mycorrhiza @5%)	6.74	0.76	0.340	0.421	0.143
T4 (NPK + Seaweed @5%)	6.62	0.67	0.338	0.341	0.136
T5 (50% NPK + Mycorrhiza @10%)	7.67	0.86	0.354	0.515	0.156
T6 (50% NPK + Seaweed @10%)	7.43	0.82	0.352	0.477	0.150
T7 (Mycorrhiza @15%)	6.46	0.65	0.321	0.333	0.109
T8 (Seaweed @15%)	6.36	0.61	0.315	0.295	0.106
CD (5%)	0.14	0.13	0.09	0.05	0.02
SE(d)	0.06	0.06	0.04	0.02	0.01
Varieties: V1 (Falguni)	6.34	0.65	0.281	0.333	0.11
V2 (Serengeti)	6.61	0.72	0.287	0.338	0.12
CD (5%)	0.07	0.06	0.04	0.02	0.01
SE(d)	0.03	0.03	0.02	0.01	0.01

application of mycorrhiza have been observed by Muhammad *et al.,* (2021) in *Glycine max*; Youssef *et al.*, (2017) in snap bean Amin *et al.*, (2020) in common bean; El-Sherbeny *et al.,* (2022) in onion. Carotenoid enhancements in T5 are consistent with Hart *et al.*, (2015), who reported higher pigment levels in Mycorrhiza-treated tomatoes. Varietal differences between Serengeti and Falguni align with genotypic variations in French bean performance. These findings suggest that integrating biofertilizers and seaweed extracts with reduced chemical fertilizers can enhance French bean cultivation sustainably. The superior performance of T5 and T6 indicates potential for reducing NPK dependency by up to 50%, lowering costs and environmental impact while maintaining or improving yields. The consistent outperformance of Serengeti (V2) highlights the importance of selecting high-performing varieties for specific agroecological conditions. Future research should explore optimal Mycorrhiza and seaweed concentrations across diverse climates and soil types to refine application protocols. Long-term studies could assess the cumulative effects on soil health and microbial activity, further supporting sustainable agriculture. Additionally, scaling these practices to commercial farms could improve farmer livelihoods and food security, particularly in regions reliant on legume crops. Investigating the molecular mechanisms behind seaweed and Mycorrhiza's effects could also guide the development of tailored biostimulants for legumes.

Conclusion

This study advocated the significant potential of biofertilizers and different seaweed extracts in enhancing the growth, yield, and quality of French bean (*Phaseolus vulgaris* L.). Among different treatments, T5 (50% NPK + Mycorrhiza @10%) and T6 (50% NPK + Seaweed @10%) consistently outperformed other treatments. These results highlighted the efficacy of combining bio stimulants with reduced dependence on chemicals to optimize the nutrient uptake, stimulate floral initiation, and thereby enhance the pod development. Serengeti (V2) consistently outperformed Falguni (V1), indicating genetic advantages in responsiveness to bio stimulants. This study thereby emphasis on the synergy that reduces the reliance on synthetic fertilizers and thereby offering a sustainable approach to French bean cultivation. Future research should focus on optimizing bio stimulant concentrations across diverse agroecological conditions and assessing long-term soil health impacts.

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