



RESEARCH ARTICLE

Yield and quality enhancement of French bean (*Phaseolus vulgaris*) genotypes by using bio-priming agents

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Abstract

A vast variability in French bean's genotypes is available in the Uttarakhand which is very crucial as far as concern of farmer's income. The eco-friendly bio-priming techniques have a potential to enhance the yield and quality of these genotypes. In the present study eight genotypes were collected from different regions of Uttarakhand and used to study the effect of different bio priming on their growth, yield and seed quality parameters. Two bio-priming treatment includes *Pseudomonas fluorescence* with *Trichoderma viride* (T₁) and *Aconitum heterophyllum* (T₂) along with a control (T₀). The findings show that the growth, yield and quality parameters significantly influenced by the treatments applied. The treatment T₁ shows significantly higher growth and yield characters than T₂ and T₀. The minimum days to 50 % field emergence and flowering were recorded with genotype Harshil rajma (V₂). The Chakrata rajma (V₇) perform best for number of pods per plant, seed yield per plant and seed yield per plot among all other genotypes. Among the seed quality parameter, the highest value of germination per cent (95.16), seedling length (21.81 cm), seedling dry weight (0.80 g), vigour index-I (2075.44) and vigour index-II (76.12) were recorded with treatment T₁ and minimum with treatment T₀. Among the genotypes, the Chakrata rajma gives the maximum germination per cent (91.55), seedling length (22.01 cm), seedling dry weight (0.83 g), vigour index-I (2015.01) and vigour index-II (75.98) than all other genotypes. Overall, in the present study, it can be concluded that the eco-friendly seed priming treatment of genotype Chakrata rajma with *Pseudomonas fluorescence* with *Trichoderma viride* is best to receive sustainable higher economic output in Dehradun region.

Keywords: bio-priming; microbial inoculants; seed quality; seed yield; vigour

Introduction

French bean (*Phaseolus vulgaris* L.) is an important leguminous vegetable cultivated globally, valued both for its tender green pods and nutritious dry seeds. It originated in Southern Mexico and Central America (1) and is now extensively produced and consumed across India. French bean is nutritionally rich, containing 21.1 % protein, 69.9 % carbohydrates and essential minerals, making it an affordable and high-quality dietary component (2). Being a leguminous crop, it also contributes to soil fertility by fixing atmospheric nitrogen through symbiotic association with *Rhizobium* spp. (3). Despite its nutritional and agronomic significance, French bean production in Uttarakhand faces challenges due to unfavourable climatic conditions, poor soil quality and cultivation of low-yielding varieties (4). Evaluation of diverse genotypes is therefore crucial for identifying lines with superior adaptability, higher yield potential and tolerance to biotic and abiotic stresses. Genotypic characterization provides a foundation for breeding programs aimed at developing improved cultivars, thereby ensuring both production and nutritional security (5, 6). Seed quality plays a decisive role in crop establishment and yield potential. In this context, seed modification technologies are gaining importance. Among them, seed priming particularly biopriming has emerged as an eco-friendly technique to enhance germination, seedling vigour

and resilience against stresses (7). Biopriming involves controlled hydration of seeds with beneficial microorganisms such as *Trichoderma* and *Pseudomonas* spp., which promote seedling growth, suppress seed- and soil-borne pathogens and improve productivity as well as storability of seeds (8). The present study was undertaken to evaluate the effect of seed biopriming on the growth, yield and quality of French bean, with the aim of establishing sustainable strategies to improve seed health and crop productivity, particularly under the challenging agro-climatic conditions of mountainous regions.

Materials and Methods

Experimental site and seed material

The present study was conducted in two growing seasons 2023-2024 and 2024-2025 by following Factorial Randomized Block Design (FRBD) in the department of seed science and technology, School of Agricultural Sciences, Shri Guru Ram Rai University, Dehradun, Uttarakhand which is situated in the north-western sector of the Himalayas at an altitude of 450 m above mean sea level (MSL). The sowing was done in a special spot of 2.0 x 2.0 m with spacing 45 x 15 cm between rows and plants, respectively.

Bio-priming agents

The mother cultures of two bio-priming agents *i.e.* *Pseudomonas fluorescens*, *Trichoderma viride* and *Aconitum heterophyllum* were procured from the Biotechnology laboratory, SGRR University, Dehradun. These cultures were further maintained on the artificial growing media in the Department of Seed Science and Technology, SGRR University, Dehradun, which is used as priming agent. The French bean seeds for priming were selected based on their initial physical quality (seed colour, no physical damage) and were sterilized with 1.5 % solution of sodium hypochlorite by soaking in the solution for 5 min. After that seeds were washed three times by using sterilized distilled water and kept for drying in sterilized blotting paper at room temperature (9). After drying, seeds were bio primed by immersion in the suspension of *Pseudomonas fluorescens* + *Trichoderma viride* and *Aconitum heterophyllum* for 1 hr. All the seeds were shade dried to bring down the moisture to the initial level after that the treated seeds used for sowing.

Treatments

Two priming agents were used in the current study *Pseudomonas fluorescens* and *Trichoderma viride* (T₁) and *Aconitum heterophyllum* (T₂) along with control (T₀). In the current research eight genotypes were collected from various regions of Uttarakhand *viz.*, white rajma (V₁), Harshil rajma (V₂), Munsyari rajma (V₃), Chitkabri rajma (V₄), Red rajma (V₅), Tehri rajma (V₆), chakrata rajma (V₇) and chitra rajma (V₈) collected from Srinagar, Uttarkashi, Champawat, Rudraprayag, Nainital, Tehri Garhwal, Dehradun and Chamoli respectively. The bio-priming agents and eight genotypes were used for experimental work and replicated thrice in FRBD

Observations recorded

Several growths (50 % field emergence, height of the plant (30 days after sowing and at harvest) and days to pod harvest) yield (pods per plant, dry pod weight (g), pod yield per plant (g), seedling length (cm), number of seeds per pod, seed yield/pod and seed yield/plant g) and seed quality parameters were recorded to assess the effect of bio priming on French bean genotypes. The seed quality test was conducted by using the guidelines of International Seed Testing Association. The seed quality parameters like germination, seedling length, seedling weight, vigour index were recorded during the investigation.

Statistical analysis

The mean data collected from the field and laboratory was subjected to statistical analysis. The data were analysed by using statistical program SPSS.

Results and Discussion

Growth and yield parameters

The present study revealed that the minimum days to field emergence were recorded under treatment T₁ (8 days) while maximum days of 50 % flowering were taken with control (12 days). Genotypes V₂ (8 days) and V₇ (8 days) were found to have early emergence, which shows that they were intrinsically vigorous and sensitive to microbial inoculants. The seedling sprouting process in legumes was promoted by the inoculum with rhizobacteria (10). After the optimum DAS of 30, treatment T₁ resulted in the highest plant height of 40.68 cm and higher height of 52.33 cm upon harvest which showed the effectiveness of *P. fluorescens* and *T. viride* in vegetative growth promotion. Among genotypes V₄ (38.79 cm), V₈ (39.01 cm) had a high height at 30 days post-sowing, but at harvest, V₃ (51.22 cm) followed by V₇ (50.55 cm) were longer and gave an indication of the possible interaction between the genotype and treatment in their height expression. Microbial inoculation is responsible for increased plant height and biomass of French bean (11).

The days to 50 % flowering with treatment T₁ (47 days) had the least while with control (T₀) having the highest at 55 days, which was approximately 18.17 % higher than T₁. The genotype V₂ (49.61 days) followed by V₇ (50.23 days) were found to have reduced flowering since they were adapted to shortened growth periods. The treatments had a beneficial effect on parameters contributing to yield (Table 1). A comparable effect, which referred to the fact that microbial consortia facilitated the enhanced yield of pulse crops (12). The trait pods/plant also show a positive significant effect by both Treatments where again, T₁ had the most pod count per plant (38.92) compared to T₀ (27.52) which was 29.29 % lower than T₁. Whereas, genotype V₃ had the highest pod count per plant (37.18), which proved that microbial inoculants have a significant effect on reproductive performance (Table 2). The use of *Trichoderma* had a great impact on improving the pod count and reproductive characteristics of legumes (13). The researchers found out that the

Table 1. Effect of bio-priming agents on growth and yield of French bean genotypes

Treatments	DfE	PH	PHH	DFf	NPP	DPH	SPP	YPP (Kg)	YPL (Kg)	TW
T ₀	12.23	31.58	43.05	55.79	27.52	101.31	165.17	0.188	0.549	19.92
T ₁	8.10	40.68	52.33	47.65	38.92	94.99	233.53	0.197	0.668	37.52
T ₂	9.47	36.07	47.56	52.03	33.98	98.11	203.88	0.195	0.612	33.58
CD 5 %	0.08	0.11	0.10	0.08	0.081	0.06	0.495	N/A	0.065	1.69
V ₁	11.56	36.10	44.90	53.92	25.37	100.51	152.22	0.179	0.491	24.33
V ₂	8.18	33.60	48.73	48.23	36.84	96.03	221.08	0.207	0.676	33.50
V ₃	8.90	36.64	51.22	49.61	37.18	94.73	223.10	0.205	0.650	34.40
V ₄	11.32	38.79	44.91	53.46	32.98	99.43	197.88	0.173	0.558	27.98
V ₅	10.85	33.37	47.27	54.29	32.29	100.66	193.75	0.170	0.552	28.41
V ₆	10.35	35.78	45.43	52.55	30.44	99.01	182.67	0.184	0.593	28.15
V ₇	8.57	35.57	50.55	50.23	38.64	95.96	231.87	0.217	0.738	34.73
V ₈	9.75	39.01	48.16	52.21	34.05	98.74	204.33	0.212	0.622	31.20
CD 5 %	0.139	0.188	0.165	0.134	0.133	0.112	0.809	N/A	0.106	2.76

DfE: Days to 50 % field emergence, PH: Plant height (30 DAS), PHH: Plant height at harvest (cm), DFf: Days to 50% flowering, NPP: Number of pods/plant, DPH: Number of days to pod harvest, SPP: Number of seeds/plant, YPP: Yield/plant, YPL: Yield/plot, TW: Test Weight.

T₀ Control; T₁ *Pseudomonas fluorescens*+*Trichoderma viride*; T₂ *Aconitum heterophyllum*; V₁ white rajma; V₂ Harshil rajma; V₃ Munsyari rajma; V₄ chitkabri rajma; V₅ Red rajma; V₆ tehri local; V₇ Chakrata rajma; V₈ chitra rajma

Table 2. Effect of bio-priming agents on seed quality parameters of different French bean genotypes

Treatments	Germination %	Root length (cm)	Shoot length (cm)	Seedling length (cm)	Seedling fresh weight (g)	Seedling dry weight	Vigour index-I	Vigour-II
T ₀	76.87	5.37	10.61	15.99	1.16	0.54	1229.15	41.50
T ₁	95.16	8.28	13.52	21.81	1.30	0.80	2075.44	76.12
T ₂	90.75	7.59	12.83	20.43	1.40	0.79	1854.02	71.69
CD 5 %	0.366	0.19	0.19	0.38	0.012	0.058	13.33	0.021
V ₁	82.77	5.46	10.70	16.17	1.65	0.72	1338.39	59.59
V ₂	90.33	8.01	13.25	21.27	1.64	0.65	1921.31	58.71
V ₃	90.88	7.83	13.07	20.91	1.79	0.80	1900.30	72.70
V ₄	85.00	6.65	11.89	18.55	1.21	0.61	1576.75	51.85
V ₅	85.11	6.17	11.41	17.59	1.32	0.66	1497.08	56.17
V ₆	87.11	6.98	12.22	19.21	1.14	0.63	1673.38	54.87
V ₇	91.55	8.38	13.62	22.01	1.92	0.83	2015.01	75.98
V ₈	88.00	7.16	12.40	19.58	1.97	0.75	1723.04	66.00
CD 5%	0.598	0.31	0.31	0.62	0.047	0.09	37.19	0.05

T₀ Control; T₁ *Pseudomonas fluorescens*+*Trichoderma viride*; T₂ *Aconitum heterophyllum*; V₁ *white rajma*; V₂ *Harshil rajma*; V₃ *Munsiyari rajma*; V₄ *chitkabri rajma*; V₅ *Red rajma*; V₆ *tehri local*; V₇ *Chakrata rajma*; V₈ *chitra rajma*

use of biofertilizers (*Trichoderma* spp.) led to a significant improvement in the seed weight of chickpea and French bean (14). Seed yield is a complex character contributed by various parameters. The seeds yield per plant and seed yield per plot was recorded maximum with treatment T₁ and with genotype Chakrata rajma (V₇). The higher yield with this genotype is mainly due higher performance of yield contributing parameters like seed yield per plant with this genotype (15). The test weight which is an indicator of the grain quality recorded a significant difference with treatments. The highest test weight of 34.73 g was recorded in V₂. The lowest test weight was measured in with genotype V₁ (24.331 g). These responses were also reported by other researchers who explain that the efficacy of inoculants depends on host genotype, rhizosphere conditions and compatibility of microbes (15).

Seed quality parameters

Among the seed quality parameters, the germination (%) was recorded maximum within treatment T₁ (95.16), followed by T₂ (90.75), while minimum germination % was recorded in T₀ (76.875). The genotypes also vary significantly for germination and maximum germination per cent was recorded with genotype V₇ (91.55), followed by V₃ (90.88) and minimum germination per cent was recorded with V₁ (82.77) (Table 2). The improvement in germination under bio-inoculated treatments may be due to microbial enhancement of seed metabolic activity, secretion of growth-promoting hormones and improvement of rhizosphere conditions that favour rapid seedling emergence. Similar reports were made by (11) in French bean and (16) in legumes, where microbial inoculation significantly improved germination over untreated controls.

The maximum seedling length was recorded with treatment T₁ (21.81 cm) and minimum with T₀ (5.37 cm). Probably this was because of the microbial production of auxin, siderophores and phosphate-solubilizing activity that leads to favourable increase of root length in legumes when inoculated with *Trichoderma* (13). Regarding the shoot length treatments T₁ (13.52 cm) was greater than T₂ (12.83 cm), which was further greater than T₀ (10.61 cm). The results showed that V₇ possessed the highest shoot length. V₁ record the shortest length of shoots at 10.70 cm. Other genotypes had a medium length of the shoot namely V₄ (11.89) V₆ (12.22) and V₈ (12.40) (Table 2). The growth effect caused by the genotype and addition of microbial inoculants can be attributed to better nutrient

absorption and the growth of cells and shoots through the synthesis of growth hormones (17).

The highest fresh weight was recorded (1.30 g) with treatment T₁ and minimum with treatment T₀ i.e. 1.16 g. The improved fresh and dry weight treatment is a sign of effective translocation of assimilates and a high vigour of seedlings (Table 2). The microbial inoculants enhanced the growth of biomass in French bean seedlings (13). The genotype Chakrata rajma (V₇) gives the maximum fresh and dry weight of seedlings among all other genotypes. This might be because of the potential of genotype shows in prevailing environmental condition. The Vigour Index-I and II show significant variation with treatments. The highest vigour index-I and II was recorded with the treatment T₁ (2075.44 and 76.12, respectively) and minimum with treatment T₀ (1229.15 and 41.50, respectively). *P. fluorescens* and *T. viride* (T₁) inoculated simultaneously always did superiorly compared to control and *A. heterophyllum* (T₂) in regard to germination, seedling growth and measures of vigour. The enhanced microbial synergy efficacy is accredited to the effectiveness of nutrient absorption systems, hormone production and the ability to endure stress. Plant extracts contain the antioxidants, secondary and Osmo protectants which stimulate early seed metabolism and enhance resistance to oxidative stress, therefore explaining the enhanced germination and vigour control (18, 19). Similar outcomes were noted with the extracts of moringa and turmeric that both increased germination and stress tolerance (20, 21). However, effects of growth promotion on the long term are not observable in extracts with phytotoxicity in high concentration through the alkaloids, unlike the microorganisms that live in the rhizosphere (22). Although T₂ showed moderate benefits, microbial inoculants (T₁) showed better results and this explains the substantial future of their application in seed priming in a sustainable manner. Among the genotypes, the genotype Chakrata rajma (V₇) perform best in terms of vigour index-I and vigour index-II. The chakrata rajma gives 33.58 % higher vigour index-I than genotype V₁, which shows minimum vigour index-I. This higher vigour might be because of the genotypic character which shows the best result under ideal germinating condition (23).

Conclusion

The present research found that the bio-inoculant-based intervention with the use of *P. fluorescens* and *T. viride* (T₁) enhanced the growth, yield and the quality of the seeds of French bean significantly than other interventions. The genotype of Chakrata rajma performed most of the metrics among the genotypes obtained in various regions of Uttarakhand. Thus, it is concluded that, for sustainable higher yield and quality seeds production, the eco-friendly bio-priming of French bean seeds with *P. fluorescens* and *T. viride* by using genotype Chakrata rajma is recommended for the farmers of this region.

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Authors' contributions

AT carried out the manuscript writing and data collection. GC carried out research plan of work along with the drafted the manuscript and corresponding work. AD participated in manuscript writing. PB participated in data collection. S carried out the statistical Analysis. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: The Authors do not have any conflict of interest to declare.

Ethical issues: None

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