E-ISSN: 2618-0618
P-ISSN: 2618-060X

NAAS Rating (2025): 5.20
www.agronomyjournals.com
2025; 8(12): 817-820
Received: 13-09-2025
Accepted: 17-10-2025

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Effect of seed treatment and foliar spray with biochar on plant growth and seed yield of French bean (*Phaseolus vulgaris* L.)

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DOI: https://www.doi.org/10.33545/2618060X.2025.v8.i12l.4487

Abstract
French bean (*Phaseolus vulgaris* L.) is an important leguminous vegetable crop valued for its high nutritional content and economic importance. The present study was conducted during *Rabi* 2024-25 at the Postgraduate Research Block, College of Agriculture, University of Agricultural Sciences, Raichur, to evaluate the effect of seed treatment and foliar spray with biochar on the growth and yield of french bean. The experiment was laid out in a Randomized Complete Block Design with ten treatments replicated thrice, including control, seed treatments and foliar applications of biochar (300 and 500 mg/L), humic acid (2.5 mL/L) and their combinations, along with a common foliar spray of vegetable special @ 5 g/L. Growth and yield parameters were recorded at different crop stages. The results revealed that foliar spray of biochar @ 500 mg/L (T_5) significantly enhanced plant growth and yield attributes compared to the control. T_5 recorded maximum plant height at 30, 60 DAS and harvest (33.68, 46.33 and 40.18 cm, respectively), number of branches per plant (7.53), pod length (15.27 cm), and pod width (1.56 cm) higher than control. Early flower bud initiation (36.06 days), 50% flowering (41.66 days) and maturity (71.38 days) were observed in T_5, indicating accelerated phenological development. The same treatment recorded the highest number of clusters per plant (9.90), pods per plant (27.25), seeds per pod (6.40), and seed yield (901.00 g plot^{-1} and 19.06 q ha^{-1}) compared to the control (T_1, 754.66 g plot^{-1} and 17.00 q ha^{-1}). The study concludes that foliar application of biochar @ 500 mg/L effectively improves growth, earliness and yield of french bean, demonstrating its potential as a sustainable and efficient crop management practice.

Keywords: Biochar, foliar spray, French bean, growth and seed yield

Introduction
French bean (*Phaseolus vulgaris* L.), a member of the Fabaceae family, is an important leguminous vegetable crop known for its high nutritional value and global adaptability. It provides a rich source of protein, carbohydrates, vitamins, minerals and polyunsaturated fatty acids (Razvi *et al*., 2018) [6]. Immature pods are consumed as a vegetable, while mature pods serve as pulses. The crop, believed to have originated in Central and South America, is widely cultivated in India across states such as West Bengal, Andhra Pradesh, Jharkhand, Jammu and Kashmir, Himachal Pradesh and Punjab, covering 137.54 thousand hectares with an annual production of 1370.21 thousand metric tons and an average productivity of 9.96 t ha^{-1} (Kumar, 2024) [4].

French bean cultivars are broadly classified into bush and pole types. While bush types are preferred for ease of management, pole types perform better as off-season crops in the mid-hills of Himachal Pradesh, producing pods during the rainy season when market prices are favourable (Sharma *et al*., 2013) [10].

Biochar, produced through the controlled pyrolysis of organic materials such as crop residues, manure and wood at temperatures above 250 °C with limited oxygen, has recently gained attention as a soil amendment and seed priming agent. Rich in stable organic carbon, ash and essential nutrients, biochar can enhance soil fertility and plant growth. However, its quality and agronomic impact depend on the feedstock used and pyrolysis temperature, and it may contain undesirable compounds such as polyaromatic hydrocarbons or heavy metals (Solaiman *et al*.,

2012) [11].

Seed treatment and foliar application are cost-effective methods for improving germination, seedling vigour, nutrient uptake and crop protection (Barsa *et al*., 2005) [1]. Despite extensive studies on biochar use in soils, limited information exists regarding its potential as a seed treatment or foliar spray for enhancing plant establishment in french bean. Therefore, the present study was undertaken to evaluate the effect of seed treatment and foliar spray with biochar on the growth and yield establishment of french bean (*Phaseolus vulgaris* L.).

Materials and Methods

The field experiment was carried out at the Postgraduate Research Block (New Area), College of Agriculture, University of Agricultural Sciences, Raichur, during *Rabi* 2024-25. The site is located in the North-Eastern Dry Zone (Zone-2) of Karnataka at 16°15′ N latitude, 77°00′ E longitude and an altitude of 406.97 m above mean sea level. The region has a semi-arid climate with an average annual rainfall of 722 mm. The experimental soil belongs to the Vertisol class (medium deep black soil) and is clayey in texture with 21.12% sand, 21.57% silt and 59.48% clay, having a bulk density of 1.29 g cm^{-3}. Prior to the experiment, a composite soil sample was collected from a depth of 0-30 cm, air-dried, sieved through a 2 mm mesh and analyzed for physico-chemical properties using standard methods. The soil was slightly alkaline (pH 8.13) with an electrical conductivity of 0.53 dS m^{-1}, low in organic carbon (0.46%) and available nitrogen (232.15 kg ha^{-1}), medium in available phosphorus (23.33 kg ha^{-1}) and high in available potassium (378.80 kg ha^{-1}). Seeds of french bean (*Phaseolus vulgaris* L.) variety 'Arka Arjun' were obtained from ICAR-Indian Institute of Horticultural Research, Hessaraghatta, Bengaluru, Karnataka. The field experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications and ten treatments including control, seed treatment, foliar sprays of biochar @ 300 and 500 mg/L, humic acid @ 2.5 mL/L and their combinations, foliar spray with vegetable special @ 5 g/L common for all treatments. The seeds were treated with biochar @ 140 g/kg + PSB 30 g/kg + *Trichoderma* @ 3 g/kg + *Rhizobium* @ 30 g/ kg using starch (1%) as adhesive material then the seeds will be dried to the original moisture content before sowing. The foliar spray solution was prepared as per the treatment by dissolving in a known quantity of water and sprayed to the crop at 45 and 60 DAS.

Plant height was measured from the base to the tip of five randomly selected plants at 30, 60, and harvest days after sowing (DAS) for each treatment, and the mean was expressed in centimeters. The number of branches per plant was recorded by counting branches on the main and primary stems of the same plants. Days to flower stalk initiation, 50% flowering, and maturity were noted from sowing to respective stages. Pod length and diameter were measured from pods of five tagged plants, and the mean values were calculated. The number of clusters per plant, pods per plant, and seeds per pod were recorded from five randomly selected plants, and their means were computed. Seed yield per plot and per hectare was calculated from the total seed weight of each plot and expressed in grams per plot and quintals per hectare, respectively. A random sample of 100 seeds from the produce of each replication was weighed to record 100-seed weight in grams.

Results and Discussion

Plant height showed significant variation among treatments at all growth stages, with the foliar spray of biochar @ 500 mg/L (T_5) recording the maximum height at 30 DAS (33.68 cm), 60 DAS (46.33 cm) and harvest (40.18 cm), representing 49.0%, 31.5% and 47.4% increases, respectively, over the control (T_1) in Table 1. The superior performance of biochar-treated plants is attributed to enhanced nutrient uptake, improved photosynthesis, and better physiological activity, as reported by Byan and El-Shimi (2021) [3] and Shahzadi *et al*. (2025) [9]. The number of branches per plant was significantly higher in T_5 (7.53) compared to the control (6.40) in Table 2, reflecting improved apical dominance regulation and enhanced auxin-cytokinin balance. Pod length (15.27 cm) and pod width (1.56 cm) were also highest in T_5, showing 15.3% and 13.0% increases over control (Table 2), respectively, owing to improved cell elongation, carbohydrate translocation and nutrient utilization (Udayakumar *et al*., 2019; Bashanday *et al*., 2025) [12, 2]. Biochar foliar application advanced flowering and maturity, with T_5 recording earliest flower bud initiation (36.06 days), 50% flowering (41.66 days) and maturity (71.38 days) in Table 3, indicating accelerated phenological development through improved nutrient availability and hormonal balance (Mahadule *et al*., 2019; Semida *et al*., 2019) [5, 7]. The highest number of clusters (9.90), pods per plant (27.25) and seeds per pod (6.40) were recorded in T_5 (Table 4), significantly exceeding control values (6.83, 18.08 and 4.70, respectively), due to enhanced reproductive node formation and nutrient supply (Sethi *et al*., 2023) [8]. Maximum seed yield was also obtained in T_5 (901.00 g $plot^{-1}$ and 19.06 q ha^{-1}) compared to the control (754.66 g $plot^{-1}$ and 17.00 q ha^{-1}) in Table 5, attributed to improved photosynthetic efficiency, nutrient cycling, and assimilate partitioning to pods. These results collectively confirm that foliar application of biochar @ 500 mg/L effectively enhances growth, yield attributes and productivity of french bean through improved nutrient availability and physiological efficiency.

Table 1: Effect of seed treatment and foliar spray on plant height at 30 DAS, 60 DAS and at harvest of french bean

Treatment	Plant height (cm)		
	30 DAS	60 DAS	At harvest
T_1 - Control	22.60	35.23	27.25
T_2 - Seed treatment	23.04	38.35	32.12
T_3 - Foliar spray of humic acid @ 2.5 mL/L	26.22	40.77	35.32
T_4 - Foliar spray of biochar @ 300 mg/L	27.27	41.41	36.18
T_5 - Foliar spray of biochar @ 500 mg/L	33.68	46.33	40.18
T_6- T_2 + foliar spray of biochar @ 300 mg/L	25.18	39.12	34.65
T_7 - T_2 + foliar spray of biochar @ 500 mg/L	25.71	39.61	34.92
T_8 - T_2 + foliar spray of humic acid @ 2.5 mL/L	23.99	38.97	34.32
T_9 - T_2 + foliar spray of biochar @ 300 mg/L + humic acid @ 2.5 mL/L	23.73	38.92	33.92
T_{10} - T_2 + foliar spray of biochar @ 500 mg/L + humic acid @ 2.5 mL/L	23.05	38.71	33.45
Mean	25.44	39.71	34.23
S.Em. ±	1.60	1.62	1.78
CD @ 5%	4.78	4.82	5.29

Legend: Foliar spray of vegetable special @ 5g/L from T_1 to T_{10} except T_3 at 45 DAS and 60 DAS.
Seed treatment (T_2): Biochar @ 140 g/kg + *Trichoderma* @ 3 g/kg + *Rhizobium* @ 30 g/kg + PSB @ 30 g/kg + adhesive material (starch, 1%).

Table 2: Effect of seed treatment and foliar spray on number of branches, pod length and pod width of french bean

Treatment	Number of branches	Pod length(cm)	Pod width(cm)
T_1 - Control	6.40	13.24	1.38
T_2 - Seed treatment	6.40	13.28	1.42
T_3 - Foliar spray of humic acid @ 2.5 mL/L	6.73	13.98	1.45
T_4 - Foliar spray of biochar @ 300 mg/L	7.36	14.13	1.47
T_5 - Foliar spray of biochar @ 500 mg/L	7.53	15.27	1.56
T_6- T_2 + foliar spray of biochar @ 300 mg/L	6.63	13.92	1.43
T_7 - T_2 + foliar spray of biochar @ 500 mg/L	6.66	13.94	1.44
T_8 - T_2 + foliar spray of humic acid @ 2.5 mL/L	6.60	13.74	1.43
T_9 - T_2 + foliar spray of biochar @ 300 mg/L + humic acid @ 2.5 mL/L	6.60	13.46	1.43
T_{10} - T_2 + foliar spray of biochar @ 500 mg/L + humic acid @ 2.5 mL/L	6.46	13.29	1.42
Mean	6.73	13.82	1.44
S.Em. ±	0.23	0.21	0.02
CD @ 5%	0.69	0.63	0.06

Legend: Foliar spray of vegetable special @ 5g/L from T_1 to T_{10} except T_3 at 45 DAS and 60 DAS.
Seed treatment (T_2): Biochar @ 140 g/kg + *Trichoderma* @ 3 g/kg + *Rhizobium* @ 30 g/kg + PSB @ 30 g/kg + adhesive material (starch, 1%).

Table 3: Days to 1st flower bud initiation, 50 per cent flowering and maturity as influenced by seed treatment and foliar spray of french bean

Treatment	Days to 1st flower bud initiation	Days to 50 per cent flowering	Days to maturity
T_1 - Control	39.72	45.00	76.05
T_2 - Seed treatment	39.06	44.00	75.71
T_3 - Foliar spray of humic acid @ 2.5 mL/L	36.76	43.00	73.38
T_4 - Foliar spray of biochar @ 300 mg/L	36.72	43.00	72.71
T_5 - Foliar spray of biochar @ 500 mg/L	36.06	41.66	71.38
T_6- T_2 + foliar spray of biochar @ 300 mg/L	37.39	43.66	75.05
T_7 - T_2 + foliar spray of biochar @ 500 mg/L	37.06	43.33	73.38
T_8 - T_2 + foliar spray of humic acid @ 2.5 mL/L	37.52	43.33	75.05
T_9 - T_2 + foliar spray of biochar @ 300 mg/L + humic acid @ 2.5 mL/L	38.06	43.87	75.38
T_{10} - T_2 + foliar spray of biochar @ 500 mg/L + humic acid @ 2.5 mL/L	38.72	42.92	76.05
Mean	37.70	43.37	74.41
S.Em. ±	0.56	1.02	0.87
CD @ 5%	1.68	3.03	2.59

Legend: Foliar spray of vegetable special @ 5g/L from T_1 to T_{10} except T_3 at 45 DAS and 60 DAS.
Seed treatment (T_2): Biochar @ 140 g/kg + *Trichoderma* @ 3 g/kg + *Rhizobium* @ 30 g/kg + PSB @ 30 g/kg + adhesive material (starch, 1%).

Table 4: Effect of seed treatment and foliar spray on number of clusters per plant, number of pods per plant and number of seeds per pod of french bean

Treatment	Number of clusters per plant	Number of pods per plant	Number of seeds per pod
T_1 - Control	6.83	18.08	4.70
T_2 - Seed treatment	7.26	18.52	4.86
T_3 - Foliar spray of humic acid @ 2.5 mL/L	9.33	24.49	5.23
T_4 - Foliar spray of biochar @ 300 mg/L	9.53	26.38	5.33
T_5 - Foliar spray of biochar @ 500 mg/L	9.90	27.25	6.40
T_6- T_2 + foliar spray of biochar @ 300 mg/L	8.86	22.29	5.03
T_7 - T_2 + foliar spray of biochar @ 500 mg/L	9.26	23.18	5.13
T_8 - T_2 + foliar spray of humic acid @ 2.5 mL/L	8.66	21.02	5.03
T_9 - T_2 + foliar spray of biochar @ 300 mg/L + humic acid @ 2.5 mL/L	8.40	19.85	4.93
T_{10} - T_2 + foliar spray of biochar @ 500 mg/L + humic acid @ 2.5 mL/L	7.96	18.97	4.96
Mean	8.60	22.00	5.16
S.Em. ±	0.40	0.65	0.27
CD @ 5%	1.19	1.95	0.81

Legend: Foliar spray of vegetable special @ 5g/L from T_1 to T_{10} except T_3 at 45 DAS and 60 DAS.
Seed treatment (T_2): Biochar @ 140 g/kg + *Trichoderma* @ 3 g/kg + *Rhizobium* @ 30 g/kg + PSB @ 30 g/kg + adhesive material (starch, 1%).

Table 5: Effect of seed treatment and foliar spray on seed yield per plot (g) and seed yield per hectare (q) of french bean

Treatment	Seed yield per plot (g)	Seed yield per hectare (q)
T_1 - Control	754.66	15.97
T_2 - Seed treatment	803.33	17.00
T_3 - Foliar spray of humic acid @ 2.5 mL/L	872.00	18.45
T_4 - Foliar spray of biochar @ 300 mg/L	885.00	18.73
T_5 - Foliar spray of biochar @ 500 mg/L	901.00	19.06
T_6- T_2 + foliar spray of biochar @ 300 mg/L	855.00	18.09
T_7 - T_2 + foliar spray of biochar @ 500 mg/L	858.00	18.15
T_8 - T_2 + foliar spray of humic acid @ 2.5 mL/L	850.00	17.98
T_9 - T_2 + foliar spray of biochar @ 300 mg/L + humic acid @ 2.5mL/L	842.00	17.82
T_{10} - T_2 + foliar spray of biochar @ 500 mg/L + humic acid @ 2.5 mL/L	838.00	17.73
Mean	845.90	17.90
S.Em. ±	26.17	0.55
CD @ 5%	77.77	1.64

Legend: Foliar spray of vegetable special @ 5g/L from T_1 to T_{10} except T_3 at 45 DAS and 60 DAS.
Seed treatment (T_2): Biochar @ 140 g/kg + *Trichoderma* @ 3 g/kg + *Rhizobium* @ 30 g/kg + PSB @ 30 g/kg + adhesive material (starch, 1%).

Conclusion

Foliar sprays of biochar @ 500 mg/L, significantly enhances French bean on plant growth. These treatments improved key growth and yield parameters such as plant height, number of branches, pod length, pod width, hastening flowering, maturity, number of clusters and pods per plant, number of seeds per pod and seed yield compared to the control.

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