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Response of Rajmah bean to different bio-enhancers under organic farming

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Abstract
A field investigation entitled "Response of Rajmah bean to different Bio-Enhancers under Organic Farming" was conducted in *kharif* season of 2024 at the Organic Farming Research and Training Centre, MPKV, Rahuri. The experiment consists of eleven treatments *viz.*, T_1: Absolute control, T_2: Water spray, T_3: Foliar spray of Cow urine @ 10%, T_4: Foliar spray of Vermiwash @ 10%, T_5: Foliar spray of Panchagavya @ 3%, T_6: Foliar spray of Chitosan @ 5%, T_7: Foliar spray of Amrutpani @ 5%, T_8: Foliar spray of Jeevamrut @ 10%, T_9: Foliar spray of Sea weed extract @ 2%, T_{10}: Foliar spray of Waste decomposer @ 25%, T_{11}: Foliar spray of Kunapajala 5%.
The experiment was laid out in Randomized Block Design (RBD) with three replications. The phule rajma variety seeds were line sown at spacing of 30 cm ×10 cm. At the time of sowing an application of the recommended dose of fertilizers (RDF) at 60:80:00 N:P_2O_5:K_2O kg ha^{-1}, integrated with vermicompost 2400 kg ha^{-1} and phosphate rich organic manure (PROM) 700 kg ha^{-1} as a basal dose and foliar sprays of different bio-stimulants were applied.
The results showed that growth attributing characters *viz*., plant height (48.14 cm), plant spread (34.39 cm), number of branches plant^{-1} (8.65) and dry matter (34.59 g) accumulation were recorded by application of T_6 Foliar spray of Chitosn @ 5% at 30 and 45 DAS. The treatment T_5 Foliar spray of Panchagavya @ 3% at 30 and 45 DAS and T_4 Foliar spray of Vermivash @ 20% spray at 30 and 45 DAS were found at par with treatment T_6 Foliar spray of Chitosan @ 5% at 30 and 45 DAS in respect of growth parameters.
As regards yield attributing characters *viz*., number of pods plant^{-1} (17.48), weight of pods plant^{-1} (21.87 g), number of seeds pod^{-1} (4.82), number of seeds plant^{-1} (80.54), weight of seeds plant^{-1} (20.71 g), seed yield (1802 kg ha^{-1}) and stover yield (2516 kg ha^{-1}) of rajmah bean were recorded significantly the highest under treatment T_6 Foliar spray of Chitosan @ 5% at 30 and 45 DAS. It was followed by and at par with other treatments T_5 Foliar spray of Panchagavya @ 3% at 30 and 45 DAS and T_4 Foliar spray of Vermivash @ 20% spray at 30 and 45 DAS.
A one-season experimental study can be concluded that an application of the recommended dose of fertilizers (RDF) at 60:80:00 N:P_2O_5:K_2O kg ha^{-1}, integrated with vermicompost 2400 kg ha^{-1} and phosphate rich organic manure (PROM) 700 kg ha^{-1} as a basal dose, along with foliar application of Chitosan @5% at 30 and 45 days after sowing (DAS), significantly enhanced yield-attributing parameters, seed yield, nutrient uptake, and economic returns of *kharif* rajmah bean cultivated on medium black soil.

Keywords: Bio-enhancers, chitosan, panchagavya, vermivash foliar sprays, Rajmah bean

1. Introduction
Rajmah bean (*Phaseolus vulgaris* L.) is known by several names, such as Kidney bean, navy bean, pinto bean, field bean, haricot bean, China bean, marrow bean, frijole, snap or string bean, wax bean, black bean, white bean, common bean. Over 14,000 cultivars of the common bean are recognized, with the International Center for Tropical Agriculture in Colombia serving as the primary repository for its germplasm (59). The Rajmah bean comprises 150-200 plant species, many of which are grown for food or as garden ornamentals (Adsule *et al.*, 1998) [1].
Beans are a diverse group of leguminous vegetables that are a major source of protein in the human diet. The Rajmah bean, also called the 'superfood,' 'grain of hope,' and 'meat of the poor' is a highly cherished pulse, known for its nutritional value and as a potential source of protein, minerals and carbohydrates. Rajmah bean is a significant leguminous crop that has gained considerable importance in agriculture due to its high nutritional protein content, with 1.7 per cent protein in fresh pods and 21.1 per cent in dried seeds, making it an affordable source of

high-quality protein (Alice *et al.*, 2018) [2].

Phaseolus vulgaris L. (Family-Fabaceae), commonly known as Rajmah bean is a widely consumed food crop rich in carbohydrates and proteins, with medicinal properties. This plant contains a variety of compounds, including carbohydrates, proteins, saponins, phenolic acids, flavonoids and, tannins. The seeds of Rajmah bean exhibit anti-obesity and anti-urolithiatic properties. This review summarizes the phytochemistry and pharmacological effects of Rajmah bean. The plant, which contains a variety of chemical constituents, can be further explored for other pharmacological activities, as it is a commonly used food crop and its medicinal properties align with natural remedies (Devi *et al.*, 2020) [6].

According to FAOSTAT, global area of common beans in 2020 was 34.80 million hectares, with a production of 27.54 million tonnes. Asia is the largest producer, contributing 43.1 per cent of global bean production, followed by the Americas at 29.4 per cent and Africa at 25.5 per cent. The primary producers of common beans among major bean-producing regions include India, Myanmar, Brazil, the United States, Africa and China (Anonymous, 2023). [3]

The excessive use of chemical fertilizers and pesticides for high production is depleting soil fertility and putting food safety at risk. In the current situation, organic farming has become the backbone of India's rich agricultural heritage. Organic farming is the safest method for preserving soil fertility and public health. As a result, it can produce high-quality food without harming soil health, the environment, or compromising human health. Organic products encompass all types of food items, such as cotton, cosmetics, functional foods, body care products, tea, fruits, rice, pulses, honey, spices, coffee, oilseeds, cereals and herbal products (Mukherjee *et al.*, 2023) [13].

2. Materials and Methods

The experiment was carried out at the Organic Farming Research and Training Centre, located at Mahatma Phule Krishi Vidyapeeth, Rahuri. Rahuri is geographically located at a latitude of 19°57' North and between 74°32' and 74°10' East longitude, at an altitude of 511 meters above sea level. The region lies on the eastern side of the Western Ghats and is considered a rain shadow area. Climatically, it falls in a semi-arid zone, receiving an average annual rainfall of 407-619 mm over 15 to 45 rainy days.

The experiment consists of eleven treatments *viz.*, T_1: Absolute control, T_2: Water spray, T_3: Foliar spray of Cow urine @ 10%, T_4: Foliar spray of Vermiwash @ 10%, T_5: Foliar spray of Panchagavya @ 3%, T_6: Foliar spray of Chitosan @ 5%, T_7: Foliar spray of Amrutpani @ 5%, T_8: Foliar spray of Jeevamrut @ 10%, T_9: Foliar spray of Sea weed extract @ 2%, T_{10}: Foliar spray of Waste decomposer @ 25%, T_{11}: Foliar spray of Kunapajala @ 5%. These bio-stimulants were sprayed at the flowering and pod initiation stages of rajmah bean. The experiment was laid out in randomized block design (RBD) with three replications. The Phule rajma variety seeds were line sown at spacing of 30 cm x 10 cm.

The soil in the experimental area belongs to the Inceptisol order and has a clay loam texture. The topography of the experimental field is uniform and level. Representative initial soil samples were collected to evaluate the baseline soil fertility. These samples were thoroughly mixed to create a composite sample, which was then analyzed for both physical and chemical properties. The experimental soil had a clay loam texture and slightly alkaline reaction (pH 7.62), medium organic carbon content (0.52%) and an electrical conductivity of (0.33 dSm^{-1}). It was low in available nitrogen (169.98 kg ha^{-1}), low in available phosphorus (12.35 kg ha^{-1}) and very high in available potassium (379.87 kg ha^{-1}).

Five selected plants were used for observation of the plant height. The plant height was recorded in cm from the ground level up to the tip of the stem with the help of a metric scale. Observations were started from 30, 45 and 60 DAS of five selected plants and were subsequently recorded at an interval of 14 days up to harvest. Plant spread (cm) was measured on five observation-tagged plants by measuring the maximum horizontal space occupied by the plant between the tips of two extreme leaves on either side of the plant at 30, 45, 60 DAS and at harvest. The mean plant spread was reported by averaging the plant spread of five observation plants. The number of branches was recorded periodically at 30, 45, 60 DAS and at harvest of five selected plants and an average number of branches was worked out and recorded. One representative plant from each plot was randomly selected and uprooted at the growth stage (30, 45, 60 DAS and at harvest) of one selected plant observation for dry matter studies. Roots were discarded for dry matter studies. First, plants were air-dried and kept in a hot air oven at 55±5°C until constant weight was obtained. On cooling the dry weight $plant^{-1}$ was recorded.

At harvest from five sampled plants were selected and tagged number of pods $plant^{-1}$, number of seeds pod^{-1} and number of seeds $plant^{-1}$ calculated separately. The weight of Pods $Plant^{-1}$ and weight of seeds $Plant^{-1}$ weighed on weighing balance separately at harvest.

The total seeds obtained from each observation plant were weighed separately on analytical weighing balance and the mean value was calculated for obtaining the weight of seeds $plant^{-1}$. The produce was dried in the sun for a week. After threshing, the seeds were cleaned of dried leaves, soil and other foreign material. The seed yield from net plot was recorded and then converted on a hectare basis by multiplying with the hectare factor. After removing the grain from the pods, the stalks along with the empty pods were dried in the sun. Upon drying, the weight of the bundle of stalk $plot^{-1}$ was recorded. The weight $plot^{-1}$ was transferred into a hectare basis by utilizing the hectare factor. Biological yield of crop is the total biomass put by a crop, and is calculated by summing up the seed yield straw yield. The Harvest index was calculated by using a formula.

$$\text{Harvesting index} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

The standard method of "Analysis of variance" was used for analyzing the data (Panse and Sukhatme, 1985) [15].

3. Results and Discussion

3.1 Plant Height (cm)

The plant height of rajmah bean was significantly higher in T_6 (Chitosan @ 5%) which is 43.14 cm and 48.14 cm at 45 and 60 DAS respectively. Whereas plant height of T_5 (Panchagavya @ 3%) 42.00 cm and 47.28 cm at 45 and 60 DAS respectively, also T_4 (Vermiwash @ 20%) 39.80 cm and 45.46 cm at 45 and 60 DAS respectively was found at par with superior treatments. The lowest height of rajmah bean 26.51cm and 32.51cm at 45 and 60 DAS respectively, was observed in the absolute control (No spray). Among the foliar application of various organic treatments, a significant plant height was seen in two foliar sprays of chitosan. This might be due to the presence of ample amounts of growth hormone substances like indole acetic acid, gibberellic acid and cytokinin that lead to growth enhancement. Similar findings were reported by Mondal *et al.* (2013) [10] and

Kumbhar and Devkumar (2016) [9].

Plant Spread (cm)

The plant spread of rajmah bean was significantly higher in T_6 (Chitosan @ 5%) 35.34 cm, 37.68 cm and 34.39 cm at 45,60 DAS and at harvest, respectively. Whereas the plant spread of T_5 (Panchagavya @ 3%) 34.20 cm, 36.36 cm and 32.97 cm at 45, 60 DAS and at harvest respectively and T_4 (Vermiwash @ 20%) 33.16 cm, 35.30 cm and 31.84 cm at 45, 60 DAS and at harvest respectively was found at par concerning the rest of treatments. The lowest plant spread of rajmah bean 26.18 cm, 26.85 cm and 23.89 cm, at 45, 60 DAS and harvest respectively was observed in the absolute control (No spray). The foliar application of Panchagavya is efficiently absorbed and translocated throughout the plant via the phloem. This could have triggered a physiological stimulus within the plant, potentially enhancing the production of growth-regulating cells in its cellular system. As a result, it may have promoted the growth and development of the rajmah bean plant, leading to increased plant height, leaf area index and overall plant spread. Similar findings were reported by Mondal *et al.* (2013) [11], Munji *et al.* (2010) [14] and Hatti *et al.* (2010) [7].

3.2 Number of branches plant^{-1}

The number of branches plant^{-1} of rajmah bean was significantly higher in T_6 (Chitosan @ 5%) 7.62 and 8.65 at 45 DAS and 60 DAS, respectively. Whereas the number of branches plant^{-1} of T_5 (Panchagavya @ 3%) 7.43 and 8.37, at 45 DAS and 60 DAS respectively, also T_4 (Vermiwash @ 20%) 6.64 and 8.27, at 45 DAS and 60 DAS respectively was found at par with the superior one. The lowest number of branches per plant in rajmah bean was recorded in the absolute control (no spray), with values of 3.75 and 3.09, at 45 DAS and 60 DAS, respectively. Among the various bio-enhancers applied as foliar sprays, two applications of Chitosan showed significant growth. This could be attributed to its rich content of growth-promoting substances such as auxins, amino acids, vitamins and essential nutrients including micronutrients and macronutrients like nitrogen, phosphorus and potassium which promote cell growth and multiplication, thereby enhancing shoot development and leaf foliage. The increase in the number of branches per plant may be attributed to the growth enzymes present in vermiwash, which stimulated rapid cell division and multiplication. Similar results were reported by Monirul *et al.* (2018) [12], Joshi *et al.* (2023) [8] and Sutar *et al.* (2019) [17].

3.3 Dry matter accumulation plant^{-1} (g)

The dry matter production plant^{-1} of rajmah bean was significantly higher in T_6 (Chitosan @ 5%) 18.36 (g), 39.72 (g) and 34.59 (g) at 45, 60 DAS and at harvest respectively. Whereas the number of branches plants^{-1} of T_5 (Panchagavya @ 3%) 17.36 (g), 38.74 (g) and 32.64 (g) at 45, 60 DAS and at harvest respectively, also T_4 (Vermiwash @ 20%) 16.28 (g), 37.03 (g) and 32.41 (g) at 45, 60 DAS and at harvest respectively was found at par with superior treatment. The lowest dry matter accumulation plant^{-1} (g) was observed in the absolute control (No spray) which was 11.12 (g), 29.53 (g) and 24.25 (g) at 45, 60 DAS and harvest, respectively. Similar findings were reported by Mondal *et al.* (2013) [10] and Munji *et al.* (2010) [14].

3.4 Yield attributes

The rajmah bean crop treated with T_6 (Chitosan @ 5%) demonstrated significantly superior yield attributing traits, including the number of pods plant^{-1} (17.48), pods weight plant^{-1} (21.87 g), number of seeds pod^{-1} (4.82), seed weight plant^{-1} (20.71 g), number of seeds plant^{-1} (80.54) and seed index (41.23) at harvest. T_5 (Panchagavya @ 3%) showed number of pods plant^{-1} (17.21), pods weight plant^{-1} (21.73 g), number of seeds pod^{-1} (4.67), seed weight plant^{-1} (19.43 g), number of seeds plant^{-1} (77.00) and seed index (41.17 g) at harvest, Also, T_4 (Vermiwash @ 20%) resulted into number of pods plant^{-1} (16.89), pods weight plant^{-1} (20.51 g), number of seeds pod^{-1} (4.51), seed weight plant^{-1} (19.37 g), number of seeds plant^{-1} (76.10) and seed index (40.57 g) at harvest. Both these treatments were at par with superior one. In contrast, the absolute control T_1 recorded the lowest yield attributes, with 13.07 pods plant^{-1}, pods weight of 11.97 g plant^{-1}, 3.20 seeds pod^{-1}, seed weight of 11.97 g plant^{-1} and 51.90 seeds plant^{-1} at harvest. The two foliar applications of bio-enhancers were carried out at the flowering (30DAS) and pod initiation stage (45DAS) of the rajmah bean crop.

3.5 Seed Yield (kg ha^{-1})

Seed yield (kg ha^{-1}) was significantly influenced by two foliar applications of different bio-enhancers at flowering and pod initiation stages. The seed yield of rajmah bean was significantly higher in T_6 (Chitosan @ 5%) (1802 kg ha^{-1}) at harvest. Whereas the seed yield of T_5 (Panchagavya @ 3%) (1654 kg ha^{-1}) at harvest, T_4 (Vermiwash @ 20%) (1621 kg ha^{-1}) were found at par with the superior one. The lowest seed yield of rajmah bean was observed in the absolute control (956 kg ha^{-1}). Similar findings were presented by Joshi *et al.* (2023) [8], Choudhary *et al.* (2021) [5] and Mondal *et al.* (2013) [11].

3.6 Stover Yield (kg ha^{-1})

Stover yield (kg ha^{-1}) was significantly influenced by two foliar applications of different bio-enhancers at flowering and pod initiation stages. The stover yield of rajmah bean was significantly higher in T_6 (Chitosan @ 5%) (2516 kg ha^{-1}) at harvest. Whereas the stover yield of T_5 (Panchagavya @ 3%) (2467 kg ha^{-1}) at harvest, also T_4 (Vermiwash @ 20%) (2392 kg ha^{-1}) was found at par with the superior treatment. The lowest stover yield of rajmah bean was observed in the absolute control (1558 kg ha^{-1}). The application of bio-enhancers in the current experiment enhanced leaf area, allowing greater solar radiation capture, which boosted photosynthesis and consequently improved all growth parameters, including plant height, number of branches per plant and dry matter accumulation, ultimately resulting in a higher straw yield. Similar results were obtained by Joshi *et al.* (2023) [8].

Biological Yield (kg ha^{-1})

Biological yield (kg ha^{-1}) was significantly influenced by two foliar applications of different bio-enhancers at flowering and pod initiation stages. The biological yield of rajmah bean was significantly higher in T_6 (Chitosan @ 5%) (4318 kg ha^{-1}) at harvest. Whereas the biological yield of T_5 (Panchagavya @ 3%) (4013 kg ha^{-1}) at harvest, also T_4 (Vermiwash @ 20%) (3976 kg ha^{-1}) was found at par with the superior treatment. The lowest biological yield of rajmah bean was observed in the absolute control (2514 kg ha^{-1}). Similar results were obtained by Joshi *et al.* (2023) [8].

3.7 Harvest Index (%)

Harvest index of rajmah bean as merely impacted by foliar application of different bio- enhancers during the *Kharif* season, 2024-2025. The mean harvest index of rajmah bean was 38.59

per cent during the experiment. Different foliar spray of bio-enhancers had little to no effect on the results relating to the rajmah bean harvest index (%). The range was between 41.73 to 34.39 per cent for the *Kharif* rajmah bean crop. Similar findings were presented by Chande *et al.* (2021) [4], Mondal *et al.* (2013) [10] and Raut *et al.* (2022) [16].

Table 1: Periodical growth attributes of rajmah bean as influenced by foliar application of different bio-enhancers:

Tr. No.	Treatment	Plant height (cm)			Plant spread (cm)				No. of branches plant^{-1}			Dry matter (g) plant^{-1}			
		30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS	At harvest	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS	At harvest
T_1	Absolute control	19.04	26.51	32.51	16.66	26.18	26.85	23.89	3.05	3.75	5.09	3.80	11.12	29.53	24.25
T_2	Water spray	22.85	29.10	36.41	21.06	29.11	30.75	28.86	3.11	4.47	5.47	4.87	14.50	34.65	26.27
T_3	Foliar spray of Cow urine @ 10%	25.18	35.58	42.66	22.27	31.23	33.29	30.09	4.24	5.33	6.59	5.38	15.78	36.08	30.07
T_4	Foliar spray of Vermiwash @ 20%	27.41	39.80	45.46	23.24	33.16	35.30	31.84	5.40	6.64	8.27	6.08	16.28	37.03	32.41
T_5	Foliar spray of Panchagavya @ 3%	27.60	42.00	47.28	23.60	34.20	36.36	32.97	5.71	7.43	8.37	6.23	17.36	38.74	32.64
T_6	Foliar spray of Chitosan @ 5%	28.78	43.14	48.14	23.81	35.34	37.68	34.39	5.75	7.62	8.65	7.36	18.36	39.72	34.59
T_7	Foliar spray of Amrut pani @ 5%	24.93	34.30	41.11	21.75	31.14	33.10	30.00	4.08	5.22	6.45	5.29	15.59	35.93	29.73
T_8	Foliar spray of Jeevamrut @ 10%	26.38	38.12	43.36	22.59	32.19	34.56	30.57	4.85	6.34	7.27	5.59	16.15	36.22	31.18
T_9	Foliar spray of Sea weed extract @ 2%	26.05	37.50	43.12	22.51	31.45	34.41	30.37	4.25	6.21	6.66	5.41	16.01	36.16	30.23
T_{10}	Foliar spray of Waste decomposer @ 25%	24.18	32.72	40.66	21.72	30.52	32.59	29.37	3.26	4.75	6.15	5.03	15.57	35.05	28.89
T_{11}	Foliar spray of Kunapajala @ 5%	23.34	30.07	38.84	21.17	30.43	31.76	29.32	3.20	4.63	5.81	4.98	15.55	34.73	27.48
	S.E m ±	1.90	1.66	1.59	2.77	0.93	0.98	0.89	0.84	0.36	0.42	0.50	0.71	1.08	1.01
	C.D. at 5%	N.S.	4.91	4.70	N.S.	2.76	2.90	2.63	N.S.	1.07	1.26	N.S.	2.11	3.21	2.99
	General Mean	25.06	35.35	41.78	21.85	31.36	33.33	30.15	4.26	5.67	6.80	5.45	15.66	35.80	29.79

Note: 1. Soil application at the time of sowing as basal dose.
2. Two foliar sprays given at flowering and pod initiation stage.

Table 2: Yield attributing characters, yield and harvest index as influenced by foliar application of different bio- enhancers

Tr. No	Treatment	No. of pods plant^{-1}	Weight of pods plant^{-1} (g)	No. of seeds pods-1	No. of seeds plant^{-1}	Weight of seed plant^{-1} (g)	100 seed weight (g)	Yield (kg ha^{-1})			Harvest index (%)
								Seed	Stover	Biological yield	
T_1	Absolute control	13.07	11.97	3.20	51.90	11.97	33.88	956	1558	2514	38.02
T_2	Water spray	14.15	14.74	3.54	52.08	13.94	34.67	1168	1873	3041	38.40
T_3	Foliar spray of Cow urine @ 10%	15.55	17.54	4.16	64.53	16.55	36.23	1303	2165	3468	37.89
T_1	Foliar spray of Vermiwash @ 20%	16.89	20.51	4.51	76.10	19.37	40.57	1621	2392	3976	40.76
T_5	Foliar spray of Panchagavya @ 3%	17.21	21.73	4.67	77.00	19.43	41.17	1654	2467	4013	41.21
T_6	Foliar spray of Chitosan @ 5%	17.48	21.87	4.82	80.54	20.71	41.23	1802	2516	4318	41.73
T_7	Foliar spray of Amrut pani @ 5%	15.47	17.49	4.14	64.11	16.26	36.20	1273	2120	3393	37.51
T_8	Foliar spray of Jeevamrut @ 10%	16.26	18.34	4.31	70.41	17.44	38.41	1423	2255	3678	38.68
T_9	Foliar spray of Sea weed extract @ 2%	16.04	18.23	4.22	66.98	17.34	38.38	1412	2202	3711	38.04
T_{10}	Foliar spray of Waste decomposer @ 25%	15.39	17.30	4.10	64.05	16.02	35.25	1243	2010	3614	34.39
T_{11}	Foliar spray of Kunapajala @ 5%	14.88	15.58	4.04	57.19	14.57	35.19	1202	1976	3178	37.82
	S.E m ±	0.47	0.66	0.14	1.62	0.92	1.87	64.74	78.05	11.90	-
	C.D. at 5%	1.40	1.95	0.43	4.77	2.72	N.S.	190.99	23.02	35.10	-
	General Mean	15.67	17.75	4.15	65.90	16.69	37.38	1368	2139	3536	38.59

Note: 1. Soil application at the time of sowing as basal dose.
2. Two foliar sprays given at flowering and pod initiation stage.

4. Conclusion

Among the different bio-enhancers T_6 (Chitosan @ 5%) recorded significantly higher growth parameters, yield and quality parameters i.e. plant height, plant spread, no. of branches plant$^{-1,}$ dry matter plant^{-1}, days to 50% flowering, days to maturity, no. of pods plant$^{-1,}$ weight of pods plant^{-1}, no. of seeds pod$^{-1,}$ weight of seed plant $^{-1}$, no. of seeds plant$^{-1,}$ 100 seed index, grain yield, stover yield and protein content. Where as treatment, T_5 Panchagavya @ 3% and Treatment T_4 Vermiwash @ 20% found at par with superior treatment.

Among the different bio-enhancers T_6 (Chitosan @ 5%) recorded significantly improves soil properties and availability of nutrients i.e. nitrogen, phosphorous, potassium, pH, EC, organic carbon, bacteria, fungi and actinomycetes.

Among the different bio-enhancers T_6 (Chitosan @ 5%) recorded significantly higher gross monetory returns (₹ 218836 ha^{-1}), net monetory returns (₹ 144686 ha^{-1}) and B:C ratio (2.95). Where as treatment, T_5 Panchagavya @ 3% and treatment T_4 Vermiwash @ 20% found at par with superior treatment.

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