



Effect of Bio-Stimulant (Plant Probiotics) on Growth, Yield and Microbial Activity of Chickpea (*Cicer arietinum* L.) Grown in Vertisol of Chhattisgarh

**Anupam Sahu ^a, Dayashankar Baghel ^{a*},
Anup Kumar Singh ^a, Tapas Chowdhury ^a
and Ravindra Soni ^a**

^a Department of Agricultural Microbiology, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G), India.

Authors' contributions

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

Article Information

DOI: 10.9734/CJAST/2023/v42i474323

Open Peer Review History:

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: <https://www.sdiarticle5.com/review-history/110650>

Original Research Article

Received: 14/10/2023

Accepted: 20/12/2023

Published: 22/12/2023

ABSTRACT

A field experiment was conducted to find out the effect of biostimulant (plant probiotics) on growth, yield, and the microbial activity of Chickpea (*Cicer arietinum* L.) grown in vertisol during the *rabi* season (December–April) of 2022–23 at the Instructional Cum Research Farm, College of Agriculture, IGKV, Raipur, Chhattisgarh, India. The RVG-202 variety of chickpea was used for the experiment, which was spaced in 45×10 cm. The experiment consists of seven treatments, viz., T₁

*Corresponding author: E-mail: baghelofficial5558@gmail.com;

(Control (without RDF)), T₂ (100% RDF), T₃ (1 L biostimulant + 200 L water acre⁻¹), T₄ (1 L biostimulant + 100 L water acre⁻¹), T₅ (1 L biostimulant + 300 L water acre⁻¹), T₆ (1 L biostimulant + 200 L water acre⁻¹ + 100% RDF) and T₇ (1 L Biostimulant + 200 L water acre⁻¹ + 50% RDF) and was laid out in a randomized block design (RBD) with three replications. Data regarding the Plant height, shoot dry weight, nodule number, nodule dry weight, pod number, grain yield and stover yield, microbial population, NPK content in grain and stover were observed. The experimental result revealed that the application of biostimulant with a combination of 50% RDF was found to have a significant impact on the Plant height, shoot dry weight, nodule number, nodule dry weight, pod number, grain yield, microbial population and phosphorous content in grain whereas the highest stover yield, potassium content in grain and phosphorous content in stover is accumulated where 100% RDF was applied, but that nitrogen content in grain and stover and potassium content in stover were not significantly affected. According to the performance of the crop and the analysis of rhizosphere soil, it can be concluded that the most effective response and good results over the control was found in application of bio-stimulant at 1 L acre⁻¹ along with 50% RDF (25:50:30 kg ha⁻¹ N:P:K).

Keywords: Bio-stimulant; plant probiotics; chickpea; microbial activity.

1. INTRODUCTION

An important part of Indian agriculture is the production of pulses. Chickpea (*Cicer arietinum* L.) is a member of the leguminaceae family. In Ethiopia, Turkey, Burma, Pakistan, Australia, and India, it is extensively grown. Also known as Bengal gram, it is a significant pulse crop for the *rabi* season. According to Pooniya et al. [1], India makes up roughly 25% of the world's total production of pulses. 21.1% protein, 61.5% carbs, and 4.5% fat are included in chickpeas. It also has high levels of niacin, iron, and calcium. It is fed to animals as well as utilized for human consumption. Modern agriculture faces serious issues such falling soil fertility and pollution contamination of soil and water [2]. There is a need for crop cultivation in unfavourable environments in the context of global climate change and food security, as well as for the sustainable use of precious and limited natural resources through the protection of biodiversity [3,4,5]. Over the years, numerous agricultural systems have proposed the use of biostimulants as a novel and sustainable approach to crop development, particularly in the face of biotic and abiotic stressors [6,5,7]. According to Bulgari et al. [7] and Halpern et al. [8], applying biostimulants is a practical and sustainable way to supplement crop nutrition and may help address environmental problems caused by overfertilization. Du Jardin [9] defines a biostimulant as "any substance or microorganism that applied to plants, regardless of its nutrients content, is able to enhance nutrition efficiency and also abiotic stress tolerance and quality traits" [10]. Biostimulants may advance plant development both explicitly and implicitly. Bio-

fertilization, sense of root development, resistance to established stressors, and rhizoremediation are a few examples of direct impacts on plant development advancement [11,12,13]. Enhancing plant enzymatic mobility and managing plant microorganisms may indirectly promote plant development [14]. Furthermore, bio-stimulatory compounds are known to be a successful way to repair semi-arid areas and damaged ecosystems by boosting microbial activity and improving soil biology [15,16,17,18].

Numerous studies have looked at a variety of stimulants. *Ascophyllum nodosum* extracts are among the most widely studied biostimulants; they have different effects on different crops and nutritional quality [19,20,21]. They also lessen the effects of water stress on common beans [22,23]. Thus, the goal of the current studies is to examine how biostimulants affect the growth, yield, and microbial activity of chickpea (*Cicer arietinum* L.), which are grown in field experiments.

2. MATERIALS AND METHODS

The field trials were conducted during the *rabi* season (December–April) of 2022–23 at the Instructional Cum Research Farm, College of Agriculture, IGKV, Raipur, Chhattisgarh, India, which is situated at an altitude of 298.58 m above the mean sea level (MSL) at 21°16' N latitude and 81°36' E longitude. Vertisol soil with an alkaline (7.9) soil reaction, low organic carbon (0.54 dS m⁻¹), low available nitrogen (188.23 kg ha⁻¹), medium phosphorous (24.19 kg ha⁻¹), high potassium (505.90 kg ha⁻¹), and low EC

were the characteristics of the trial plots' soil. The seed of chickpea, variety RVG-202 was collected from college of Agriculture, IGKV Raipur, (C.G.). Healthy seeds were sown out manually on December 22, 2023, at a depth of 5 cm with an 80 kg ha⁻¹ seed rate at a spacing of 45 cm x 10 cm accommodating 22 plants / m² (5x5 m² plot size). The experiment was laid out in randomized block design with seven treatments and three replications. The treatments include T₁ (Control (without RDF)), T₂ (100% RDF), T₃ (1 L biostimulant + 200 L water acre⁻¹), T₄ (1 L biostimulant + 100 L water acre⁻¹), T₅ (1 L biostimulant + 300 L water acre⁻¹), T₆ (1 L biostimulant + 200 L water acre⁻¹ + 100% RDF) and T₇ (1 L Biostimulant + 200 L water acre⁻¹ + 50% RDF). Urea, single super phosphate, and murate of potash murate were used to apply the prescribed dosage of fertilizer, which is 25:50:30 kg NPK ha⁻¹, depending on the treatment. At the time of sowing, the full doses of potassium, phosphorus, and half dose of nitrogen were applied while the remaining half of the nitrogen was applied as a top dressing in split doses at 30, 45, and 60 days after sowing. Bio-stimulant was applied by drenching method in root zone. Bio-stimulant was applied three different times: the first application of bio-stimulant was at 20 days after sowing, the second was at 20 days after the first application, and the third at 20 days after the second application through a knapsack sprayer.

The plant received the proper irrigation for its maximum growth and development, and all essential plant protection techniques and intercultural protocols were followed. Observations on five randomly selected plants in each treatment were tagged properly for recording various observations viz. height of plant (cm), dry weight of shoot (g), number of nodule (plant⁻¹), nodule dry weight (g), number of pod (plant⁻¹), grain and stover yield (q ha⁻¹). N content (%) in grain and stover was determined by Micro-Kjeldahl method as described by Jackson [24] using auto digestion and distillation Unit. 0.5 gram sample (grain and stover) was taken in digestion tube and digested sample was taken for distillation. The solution collected in the conical flask was titrated by using 0.5 N of H₂SO₄. The titration value was noted and percentage of nitrogen was calculated and expressed in percentage. Bacterial population in rhizosphere soil was analyzed at 45 and 60 days after sowing by serial dilution plating method as describe by Subba Rao [25]. Nutrient agar medium was utilized to isolate all of the bacteria

[26]. Each plot soil sample was plated in triplicate, and the mean values for each sample were calculated. Each set of plating included a Control, which was used to monitor the colony-forming unit. Using detergent powder and distilled and tap water, all of the glassware used in this experiment was cleaned. The dried glassware was sterilized for two hours at 160°C in a hot air oven. Before use, the inoculation needle was heated over a spirit lamp flame after being dipped in alcohol. The media was sterilized by autoclaving at 15 lb pressure for 20 m, and laminar air flow was used for all soil sample isolation and inoculation procedures. For accurate interpretation, every observation made during this experimental study was methodically tabulated. ANOVA was used to statistically analyze the observations, and according to Panse and Sukhatme [27], a p value of less than 0.05 was deemed statistically significant. By taking the mean value of the observed data, statistical analysis was carried out.

3. RESULTS AND DISCUSSION

The data on average plant height were recorded at five different stages (30, 45, 60, 75 DAS and at harvest), which are presented in Table 1. Observation data indicate that the plant's growth was faster up to 30-60 DAS and then a slower growth rate was observed up to 75 DAS at harvest. The growth performance of the crop for the treatment T₂ (100% RDF) exhibited the maximum height at 30 and 45 DAS (19.23 and 30.15 cm). All other treatments have also shown equal effect on plant height similar to 100% RDF treatment except control where no significant changes in plant height was observed. The observations at 60 and 75 DAS revealed that maximum height (41.81 and 43.13 cm) was exhibited by the treatment T₇ (1:200 dilution with 50% RDF), all other treatments were found to be better than the control in increasing the plant height significantly. At harvest no significant differences were noticed among treatments may be due to senescence. Thus, it was concluded that the maximum plant height was obtained due to application of biostimulant with 50% RDF at the later phase of plant growth. This increases due to increase in nutrient availability by biostimulant. Similar result of these finding was also supported by Sharanya et al. [28], Gabilondo et al. [30], Fedeli et. al [31], Baradhan et al. [32]. The results on shoot dry matter accumulation grew linearly as a crop moved through its development phases. The shoot dry

weight of chickpea plant is a good indicator of plant growth which also determines the crop yield. Shoot dry matter of chickpea was quantified at two different stages of crop growth (45 and 60 DAS), which are presented in Table 2. At 45 DAS only the treatment T5 (bio-stimulant @ 1:300 dilutions) was found responsive to increase the shoot dry weight (3.87 g plant⁻¹) over control. However, at 60 DAS all the treatments taken under study found efficient to increase the shoot dry weight over control. Maximum dry weight (9.76 g plant⁻¹) was attributed to treatment T7 where bio-stimulant was applied @ 1:200 ratio with 50% RDF. Dry weight of shoot was increase due to availability of available soil enriched lignolytic, cellulolytic, and nitrate ammonification. Similar results were obtained by Mukherjee et al. [33]. Nodule count of chickpea is presented in Table 2. Nodule count was recorded at two different stages of crop growth (45 and 60 DAS). Nodule number was affected by different dilution ratio of bio-stimulant and their use with chemical fertilizers. Results revealed that bio-stimulant significantly affected the number of nodules over control. Maximum number (33.33 and 36.00 g plant⁻¹) of nodules was found in treatment T7 in both the growth stages (45 and 60 DAS) respectively, which received 1:200 diluted bio-stimulants with 50% RDF, followed by treatment T6 which received the same diluted bio-stimulant with 100% RDF. This finding was also supported by Sharanya et al. [28]. The observations of nodule dry weight were recorded in 45 and 60 DAS, which is presented in Table 2. The result of the nodule dry biomass study revealed that all the treatments had shown their effect on nodule dry weight at 45 DAS, except treatment T3 where bio-stimulant was applied @ 1:200 dilution. At 45 DAS Maximum dry weight (0.050 g plant⁻¹) of nodule was associated with the application of bio-stimulant @ 1:300 dilution. At 60 DAS all the treatments showed their superiority to increase the nodule dry biomass over control. Maximum dry weight (0.057 g plant⁻¹) of nodules was recorded due to application of bio-stimulation with 1:200 dilution with 50% RDF which was found at par with 100% RDF recorded under treatment T2. Similar finding number of nodule and dry weight of nodule was also reported by Garcia et al. [29], Gabilondo et al. [31], Lopez et al. (2021) [34]. The results revealed that all the bio-stimulant treatments, independent application of chemical fertilizers and their combinations significantly increased the number of pods (Table

2) in chickpea recorded at 60 and 75 DAS. At 60 DAS the treatment T7 (Bio-stimulant at 1:200 dilution + 50% RDF) and T5 (Bio-stimulant at 1:300 dilution) both produced the highest (28.83) number of pods. At 75 DAS the treatment T7 produced the maximum number of pods (30.00) followed by treatment T5 which produced 29.33 and at par with treatment T7. The result was supported by Praveen et al. [35] and Gabilondo et al. [30]. The grain yield of chickpea was significantly increased by use of bio-stimulants and chemical fertilizers applied alone and in different combinations (Table 2). Highest grain yield (779.33 kg ha⁻¹) was attributed to treatment T7 where bio-stimulant was applied at 1:200 dilution with 50% RDF. This highest yield was followed by the yield (732.92 kg ha⁻¹) obtained in treatment T5 where bio-stimulant was applied at 1:300 dilution. In case of stover yield two treatments T₂ and T₇ was found significantly superior over control. Highest stover yield (1342.27 kg ha⁻¹) was recorded in treatment T₂ where 100% RDF was applied, followed by treatment T7 (1087.33 kg ha⁻¹) where 50% RDF was applied along with bio-stimulants at 1:200 dilution level. Similar findings was also observed by Dhegavath et al. [36]. Population of bacteria in rhizosphere soil was analysed at 45 and 60 days after sowing. Data obtained (Table No. 1) thus revealed that the highest population of total bacteria (25.23 and 26.07 x 10⁷ g⁻¹ soil respectively,) was found significantly in treatment T₇ due to the application bio-stimulant at 1:200 dilution along with 50% RDF whereas the lowest population of total bacteria at 45 and 60 DAS (17.03 and 17.37 x 10⁷ g⁻¹ soil respectively,) was found from treatment T₁ (Control, without RDF). The present findings are supported with the result of Tejada et al. [37], who mentioned that the soil amended with bio-stimulant had the highest soil enzymatic activities and bacterial biomass. Additionally, the use of bio stimulants improved the biological characteristics of the soil and encouraged the growth of vegetation that will shield the soil from erosion and aid in its restoration. Similar to this, Sani et al. [38] reported that the application of bio stimulants based on *Trichoderma* and bio stimulants extracted from seaweed increased soil fertility and nutrient availability as a result of an abundance of bacterial populations in the rhizosphere. Collectively, findings indicated that biostimulant can be used to activate the beneficial soil and plant-associated microbiota

Table 1. Effect of Bio-stimulant on plant height of chickpea and the microbial population of chickpea grown soil

Treatment details	Plant height (cm)					Total bacteria (10^7 g ⁻¹ soil)	
	30 DAS	45 DAS	60 DAS	75 DAS	At harvest	45 DAS	60 DAS
T ₁	15.55	26.34	37.20	38.15	42.72	45.33	101.67
T ₂	19.23	30.15	40.64	42.05	44.02	45.33	108.33
T ₃	18.25	28.70	40.47	40.95	43.65	43.33	111.67
T ₄	18.36	28.56	39.59	40.98	43.66	54.67	104.67
T ₅	18.20	28.13	39.93	41.05	43.68	52.67	112.67
T ₆	18.67	28.92	39.99	40.69	43.56	54.33	118.67
T ₇	18.38	28.30	41.81	43.13	44.38	47.33	88.00
SEm±	0.60	1.16	1.53	1.36	1.35	2.13	3.25
CD ($p=0.05$)	1.62	3.13	4.00	3.73	N.S.	NS	10.01

Table 2. Effect of Bio-stimulant on growth parameters and yield of chickpea

Treatment details	Shoot dry weight (g plant ⁻¹)		Nodule number (g plant ⁻¹)		Nodule dry weight (g plant ⁻¹)		Pod number (g plant ⁻¹)		Grain yield (kg/ha)	Stover yield (kg/ha)
	45 DAS	60 DAS	45 DAS	60 DAS	45 DAS	60 DAS	60 DAS	75 DAS	At harvest	At harvest
T ₁	3.27	5.43	12.33	15.67	0.030	0.028	21.50	21.05	528.13	835.53
T ₂	3.66	9.16	30.00	32.33	0.042	0.053	25.17	26.67	604.00	1342.27
T ₃	3.21	8.00	30.33	33.33	0.027	0.045	25.83	26.00	619.20	859.07
T ₄	3.35	8.33	28.33	30.67	0.042	0.042	27.83	29.00	700.00	800.00
T ₅	3.87	8.50	30.67	33.67	0.050	0.047	28.83	29.33	732.92	867.07
T ₆	3.18	8.32	31.67	34.00	0.045	0.047	25.33	28.67	666.27	800.40
T ₇	3.52	9.76	33.33	36.00	0.049	0.057	28.83	30.00	779.33	1087.33
SEm±	0.15	0.38	1.31	1.47	0.002	0.003	1.11	1.03	25.87	29.73
CD ($p=0.05$)	0.43	1.04	3.48	3.88	0.005	0.007	2.96	2.75	67.63	103.63

Table 3. Effect of bio-stimulants on nutrient content in grain and stover of chickpea

Treatment details	Nutrient content in grain (%)			Nutrient content in stover (%)		
	N	P	K	N	P	K
T ₁	3.12	0.43	0.52	0.69	0.24	1.24
T ₂	3.24	0.56	0.60	0.71	0.28	1.32
T ₃	3.15	0.54	0.55	0.72	0.27	1.27
T ₄	3.19	0.52	0.56	0.68	0.26	1.30
T ₅	3.2	0.54	0.55	0.63	0.27	1.27
T ₆	3.21	0.45	0.56	0.66	0.25	1.26
T ₇	3.21	0.58	0.56	0.68	0.27	1.23
SEm±	0.09	0.02	0.02	0.02	0.01	0.04
CD ($p=0.05$)	NS	0.05	0.05	NS	0.02	NS

without significant changes in the relative abundance of populations of pathogenic microbial species. Nitrogen content in grain not affected significantly by bio-stimulants application (Table 3). In case of phosphorus content, highest phosphorus content was associated with treatment T₇ (Bio-stimulants at 1:200 dilution with 50% RDF) with a mean value of 0.58 %, followed by treatment T₂ (RDF) with a mean value of 0.56%. Similar findings was

reported by Dhegavath et al. [36], Varma et al. [39]. Potassium content in grain varied among treatments. However, treatment T₂ (100% RDF) accumulated highest K in grain with a mean value of 0.60%, which was only treatment found significantly superior over control. Similar findings was reported by Dhegavath et al. [36]. Nitrogen and potassium content in stover did not differ significantly by the application of bio-stimulants, as well as by chemical fertilization. However,

phosphorus content was varied significantly in stover by imposing treatments which was reflected in the improvement of P-content in stover. Highest phosphorous content (0.28%) was found in stover which was attributed with 100% RDF application in treatment T₂. A similar finding was also reported by Rafique et al. [40].

4. CONCLUSION

The study found that applying biostimulant with 50% RDF significantly improved plant height, shoot dry weight, nodule number, pod number, grain yield, microbial population, and phosphorous content in grain. However, 100% RDF resulted in higher stover yield, potassium content in grain and phosphorous content in stover, while nitrogen content in grain and stover and potassium content in stover remained unaffected. Further, it can be concluded that the most effective response and good results over the control was found in application of biostimulant @ 1 L acre⁻¹ along with 50% RDF (25:50:30 kg ha⁻¹ N:P:K).

ACKNOWLEDGEMENTS

The author would like to thank the Department of Agricultural Microbiology, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur, India, for providing facilities to conduct my research work. We also thank Dr. Tapas Chowdhury and Dr. A. K. Singh for their valuable suggestions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

- Pooniya V, Choudhary AK, Dass A, Bana RS, Rana KS, Rana DS, Prabhu M, Ramesh Kumar A, Rajam et al. Improved crop management practices for sustainable pulse production: an indian perspective. *Indian J Agril Sci.* 2015;85(9):747-58.
- Schwarz D, Rouphael Y, Colla G, Venema JH. Grafting as a tool to improve tolerance of vegetables to abiotic stresses: thermal stress, water stress and organic pollutants. *Scientia Horticulturæ.* 2010;127(2):162–171.
- Szparaga A, Kuboń M, Kocira S, Czerwińska E, Pawłowska A, Hara P, Kobus Z, Kwaśniewski D. Towards sustainable agriculture - agronomic and economic effects of biostimulant use in common bean cultivation. *Sustainability.* 2019;11(17):4575.
- Postel SL. Entering an era of water scarcity: The challenges ahead. *Ecological Applications* 2000;10(4):941–948.
- Del Buono D. Can bio stimulants be used to mitigate the effect of anthropogenic climate change on agriculture? It is time to respond. *Science of the Total Environment.* 2021;751: 141763.
- Bertrand C, Gonzalez-Coloma A, Prigent-Combaret C. Plant metabolomics to the benefit of crop protection and growth stimulation. *Advances in Botanical Research.* 2021;98:107–132.
- Bulgari R, Cocetta G, Trivellini A, Vernieri P, Ferrante A. Bio stimulants and crop responses: a review. *biological agriculture & horticulture.* 2015;31(1):1–17.
- Halpern M, Bar-Tal A, Ofek M, Minz D, Muller T, Yermiyahu U. The use of bio stimulants for enhancing nutrient uptake. *Advances in Agronomy.* 2015;130:141–174.
- Du Jardin P. Definition, concept, main categories and regulation. *scientia horticulturæ. plant Bio Stimulants* 2015;196:3–14.
- Ronga D, Biazzi E, Parati K, Carminati D, Carminati E, Tava A. Microalgal bio stimulants and biofertilisers in crop productions. *Agronomy.* 2019;9(4):192.
- Massa D, Lenzi A, Montoneri E, Ginopro M, Prisa D, Burchi G. Plant response to biowaste soluble hydrolysates in hibiscus grown under limiting nutrient availability. *Journal of Plant Nutrition.* 2018;41(3):396–409.
- Lugtenberg B, Kamilova F. Plant-growth-promoting rhizobacteria. *Annual Review of Microbiology.* 2009;63:541–556.
- De Vries FT, Griffiths RI, Knight CG, Nicolitch O, Williams A. Harnessing rhizosphere microbiomes for drought-resilient crop production. *Science.* 2020;368(6488):270–274.
- Pérez-Montaño F, Alías-Villegas C, Bellogín RA, Del Cerro P, Espuny MR, Jiménez-Guerrero I, López-Baena FJ, Ollero FJ, Cubo T. Plant growth promotion in cereal and leguminous agricultural important plants: from microorganism capacities to crop

- production. Microbiological Research. 2014;69(5–6):325–336.
15. Askari-Khorasgani O, Hatterman-Valenti H, Flores Pardo FB, Pessaraki M. Plant Symbiont metabolic regulation and biostimulants application improve symbiotic performance and cold acclimation. Journal of Plant Nutrition. 2019;42(17):2151–2163.
 16. Karapouloutidou S, Gasparatos D. Effects of biostimulant and organic amendment on soil properties and nutrient status of *lactuca sativa* in a calcareous saline-sodic soil. Agriculture. 2019;9(8):164.
 17. Kumar D, Baghel D, Banwasi R, Singh AK, Soni R. Effect of cell free microbial biostimulant on growth, yield and the microbial activity of tomato (*solanum lycopersicum* L.) grown in vertisol. Journal of Experimental Agriculture International. 2023;45(8):90-96.
 18. Calvo P, Nelson L, Kloepper JW. Agricultural uses of plant biostimulants. plant and soil. 2014;383:3–41.
 19. Pereira C, Dias MI, Petropoulos SA, Plexida S, Chrysargyris A, Tzortzakis N, Calhelha RC, Ivanov M, Stojković D, Soković M, Barros L. The effects of bio stimulants, biofertilizers and water-stress on nutritional value and chemical composition of two spinach genotypes (*spinacia oleracea* L.).Molecules. 2019;24(24):4494.
 20. Fan D, Hodges DM, Critchley AT, Prithviraj BA. Commercial extract of brown macroalga (*ascophyllum nodosum*) affects yield and the nutritional quality of spinach in vitro. Communications in Soil Science and Plant Analysis. 2013;44(12):1873–1884.
 21. Roupheal Y, Giordano M, Cardarelli M, Cozzolino E, Mori M, Kyriacou MC, Bonini P, Colla G. Plant-and seaweed-based extracts increase yield but differentially modulate nutritional quality of greenhouse spinach through biostimulant action. Agronomy. 2018;8(7):126.
 22. Petropoulos SA, Fernandes A, Plexida S, Chrysargyris A, Tzortzakis N, Barreira JC, Barros L, Ferreira IC. Bio stimulants application alleviates water stress effects on yield and chemical composition of greenhouse green bean (*phaseolus vulgaris* L.). agronomy. 2020;10(2):181.
 23. Galvão ÍM, dos Santos OF, de Souza MLC, de Jesus Guimarães J, Kühn IE, Broetto F. Bio stimulants action in common bean crop submitted to water deficit. Agricultural Water Management. 2019;225:105762.
 24. Jackson ML. soil chemical analysis, prentice hall of India Pvt. Ltd., New Delhi. 1973:38-56.
 25. Subba Rao NS. Phosphate solubilization by soil microorganisms. in: subba rao, n.s. (ed.), advances in agricultural microbiology. Butterworth Scientific. 1982:295–304.
 26. CLARK F. Agar-plate method for total microbial count. Method of Soil Analysis. 1965;2:1460-1466.
 27. Panse VG, Sukhatme PV. Statistical methods of agricultural workers (2nd endorsement). icar publication, New Delhi, India. 1967:381.
 28. Sharanya BR, AP MG, Srinivasappa KN. Impact of bio-stimulants on growth and yield of cowhage (*Mucunapruriens* L.); 2022.
 29. García-Fraile P, Menéndez E, Celador-Lera L, Díez-Méndez, Jiménez-Gómez A, Marcos-García A, Cruz-González M, XA Martínez-Hidalgo, P Mateos PF, Rivas, R. Bacterial probiotics: A truly green revolution. Probiotics and plant health. 2017:131-162.
 30. Gabilondo R, Sánchez J, Gandía ML, Montero-Muñoz I, Mauri PV, Marín J, Muñoz P, Mostaza-Colado D. Rhizobacteria-based biostimulant mixture effect on chickpea (*cicer arietinum* L.) in greenhouse and cultivation assays. International Journal of Plant & Soil Science. 2023;35(1):47-61.
 31. Fedeli R, Vannini A, Celletti S, Maresca V, Munzi S, Cruz C, Alexandrov D, Guarnieri M, Loppi S. Foliar application of wood distillate boosts plant yield and nutritional parameters of chickpea. Annals of Applied Biology. 2023;182(1):57-64.
 32. Baradhan G, Kumar SS, Elankavi S, Ramesh S, Rao GS. Effect of biostimulant foliar nutrition on the growth attributes of black gram (*Vigna mungo* L.). Journal of Pharmacognosy and Phytochemistry. 2019;8(2):500-502.
 33. Mukherjee A, Singh S, Gaurav AK, Chouhan GK, Jaiswal DK, de Araujo Pereira AP, Passari, AK, Abdel-Azeem AM, Verma JP. Harnessing of phytomicrobiome for developing potential biostimulant consortium for enhancing the productivity of chickpea and soil health under sustainable agriculture. Science of

- The Total Environment. 2022;836:155550.
34. Lopez-Padron I, Martinez-Gonzalez L, Perez-Dominguez G, Cedeno-Rodriguez L, Reyes-Guerrero Y, Cardenas-Travieso RM, Nunez-Vazquez M, Cabrera-Rodriguez JA, Postal G, San José de lasLajas m. Effects of bioactive products on *cicerarietinum l.* plants. CultivosTropicales. 2021;42(1):NA-NA.
 35. Praveen G, Bara BM, Lal GM, Pal AK. Response of different pre-sowing seed treatments with biofertilizers, biostimulant and botanicals on growth, yield and yield attributing traits in chickpea (*cicerarietinum l.*) var. Desi Himmat. International Journal of Plant & Soil Science. 2022;34(19):273-279.
 36. Dhegavath S, Anjaiah T, Sharma SHK, Chauhan S. Effect of soybean crop residue incorporation, biofertilizers on nutrient uptake, yield of chickpea (*cicer arietinum l.*). International Journal of Environment and Climate Change. 2022;12(1):117-133.
 37. Tejada M, Benítez C, Gómez I, Parrado J. Use of bio stimulants on soil restoration: effects on soil biochemical properties and microbial community. Applied Soil Ecology. 2011;49: 11–17.
 38. Sani MNH, Islam MN, Uddain J, Chowdhury MSN Subramaniam S. Synergistic effect of microbial and nonmicrobial bio stimulants on growth, yield, and nutritional quality of organic tomato. Crop Science. 2020;60(4): 2102–2114.
 39. Verma S, Pandey AK. Enhancement of plant nutrient uptake by bacterial biostimulant. In New and Future Developments in Microbial Biotechnology and Bioengineering. Elsevier. 2022:435-456.
 40. Rafique M, Naveed M, Mustafa A, Akhtar S, Munawar M, Kaukab S, Ali HM, Siddiqui MH, Salem MZ. The combined effects of gibberellic acid and rhizobium on growth, yield and nutritional status in chickpea (*cicerarietinum l.*). Agronomy. 2021;11(1): 105.

© 2023 Sahu et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:

The peer review history for this paper can be accessed here:
<https://www.sdiarticle5.com/review-history/110650>