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Effect of Time of Foliar Application of Different Bio-stimulants on Growth, Yield and Economics of Chickpea (*Cicer arietinum* L.) in Mid Hills of Himachal Pradesh, India

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Authors' contributions

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

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ABSTRACT

The field experiment was conducted at Shoolini University, Solan during *rabi* season of 2023-24 to study the effect of time of foliar application of different bio-stimulants on growth, yield and economics of chickpea (*Cicer arietinum* L.) in mid hills of Himachal Pradesh. The soil of experimental field was sandy loam in texture, slightly alkaline in reaction with EC in safer range, higher in organic carbon and phosphorus, medium in available nitrogen and potassium. The field experiment was laid out in split plot design comprising three time of foliar application in main plot *viz.* (G_1) Pre-flowering, (G_2) Pod initiation and (G_3) Pre-flowering + Pod initiation and four Bio-stimulants in sub-plot *viz*. (B_1) Vermiwash at 10% solution, (B_2) Cow urine at 10% solution, (B_3) Jeevamrit at 10% solution and (B_4) Panchagavya at 3% solution. Recommended dose of nitrogen, phosphorus and potassium (30:60:30 kg ha^{-1}) were applied through urea, SSP and MOP, respectively at the time of sowing as basal dose. Himachal Channa-2 variety of chickpea was used for sowing. The results indicated that the foliar application of Panchagavya at 3% solution at Pre-flowering + Pod initiation recorded significantly higher yield attributes and yield and economics *viz.* number of pods per plant, number of seeds per pod, grain, straw, biological yield, gross returns, net returns and BCR over rest of the treatments.

Keywords: Foliar application; bio-stimulants; gross returns; net returns; BCR.

1. INTRODUCTION

Pulse crops play an important role in Indian agriculture and India is the largest producer and consumer of pulses in the world. Pulses account for 35.2 per cent of the world area and 30 per cent of world's production. Chickpeas (*Cicer arietinum* L.), which are mainly grown in semi-arid and temperate areas, are the most important pulse crop in the world during the *rabi* season. It is often referred to as Gram or Bengal gram and is also known as Chana in various areas of the country. Chickpea seeds contain on an average 23% protein, 63% total carbohydrates, 5% fat, 6% crude fiber, 3% ash and also rich in calcium, iron and niacin (Mula et al*.,* 2011). Chickpea is of prime importance because of vital source of protein as major food legume. Chickpea contributes a lot of organic matter to preserve and enhance soil health and fertility while leaving plenty of residual nitrogen for use in later crops (Gaur et al*.,* 2010).

With 75% of the global production, India is the world's top producer of chickpea. The global area of chickpea averages 13.0 million hectare with a total production of 12.4 million tons (FAOSTAT, 2022). In the Indian scenario, 35.15% of the area of total pulse production is cultivated with chickpea, producing 49.65% of total pulse production (MOA & FW, 2022). In India, Madhya Pradesh produces the most chickpeas, accounting for 39% of the nation's total production followed by Maharashtra (14%), Rajasthan (14%), Andhra Pradesh (10%), Uttar Pradesh (7%) and Karnataka (6%). Himachal Pradesh produces 0.45 metric tonnes of chickpeas over an area of about 0.35 million hectares, with an average productivity of 1285.71 kg ha^{-1} (HPDA, 2022).

Foliar application of pulses during the grain development stage had received considerable attention to increase their grain production. The efficiency of nutrient uptake through foliar spray is considered to be greater than soil application of nutrients particularly when the soil moisture is scarce (Kirnapure et al., 2020). Foliar feeding is an effective method for correcting soil deficiencies and overcoming the soil's inability to transfer nutrients to the plant under low moisture conditions. When fertilizers are foliar applied more than 90% of the fertilizer is utilized by plant. When similar amount is applied to the soil only 10% is utilized (Kachave et al*.,* 2018). Bio-stimulants are natural growth enhancers that stimulate crop yield via enhanced nutrient uptake and efficiency, improved tolerance to biotic and abiotic stresses and enhancement of the rhizospheric activities. It has been scientifically proven that they positively modify plant growth and production with alterations in metabolic processes under different cultivation practices (Jardin, 2015). The bio-stimulant products offer a sustainable, environmental-friendly means of enhancing crop productivity in broad acre and specialty crops worldwide. Many scientific studies have demonstrated the potential of various categories of bio-stimulants to improve crop production and to ameliorate abiotic stresses such as drought and soil salinity (Gawai & Gudadhe, 2023).

In modern farming, liquid manure plays a crucial role in significantly increasing yields while simultaneously reducing the need for fertilizers. Liquid organic preparations like Panchagavya and Jeevamrit made from cow products such as cow dung, urine, milk, curd, ghee and other external products like legume flour and jaggery have demonstrated positive results in promoting higher growth, increased yield and improved crop quality. These preparations contain essential macro and micro nutrients, vitamins, essential amino acids, growth-promoting factors like IAA (Indole-3-acetic acid) and GA (Gibberellic acid) and beneficial microorganisms (Kadam et al., 2023). Cow urine has the ability to kills a wide range of bacteria. It is mainly composed of water (95%) and other substances such as enzymes, mineral salts, and urea (2.5%) (Singh et al., 2018). Vermiwash is a collection of the excretory byproducts and mucus produced by earthworm recreations, as well as nutrients and organic molecules from the soil. Gibberellins and Cytokinins, which are hormones secreted by earthworms, are present in vermiwash (Zambare et al., 2008).

2. MATERIALS AND METHODS

The field experiment was carried out during *rabi* season of 2023-24 at Kalaghat Agriculture Farm, MS Swaminathan School of Agriculture, Shoolini University of Biotechnology and Management Sciences, Solan which is situated 12 km away from Solan city at an elevation of 1,270 meters above mean sea level lying between latitude 30º51'67.26.9 N and longitude 77º09'29.6 E.

The experiment was arranged in split plot design and replicated thrice. There were 12 treatment combinations consisting three time of foliar application (pre-flowering, pod initiation and pre-flowering + pod initiation) in main plot and four bio-stimulants (Vermiwash at 10% solution, cow urine at 10% solution, Jeevamrit at 10% solution, Panchagavya at 3% solution) in sub-plot. Himachal channa-2 variety of chickpea was used for sowing. Recommended dose of N, P and K (30:60:30 kg ha^{-1}) through urea, SSP and MoP was applied as a basal dose. The soil of experimental field was sandy loam in texture, slightly alkaline in reaction with EC in safer range, higher in organic carbon and phosphorus, medium in available nitrogen and potassium. The crop was sown on 7th November 2023 with spacing of 30 cm × 10 cm. The total rainfall received during the crop season (November to May, 2023-24) was 209 mm. In order to test the significance of result, standard statistical method based on the analysis of variance technique as suggested by Panse & Sukhatme (1967) was employed. The treatment differences were compared with the critical difference (CD) at 5% level of significance to ascertain their significance.

3. RESULTS AND DISCUSSION

3.1 Effect on Crop Growth Parameters

The data presented in Table 1 revealed that the foliar application of Panchagavya at 3% solution when applied at pre-flowering + pod initiation stage recorded significantly higher plant height, number of branches $plant^{-1}$, dry matter accumulation, number of nodules per plant and dry weight of nodules $plant^{-1}$ over the rest of the treatments.

This increase in plant height due to greater availability of nutrients from foliar and organic sources, as well as more efficient conversion of organic nutrients like Fe, Mg and Zn available at the photosynthetic site, may be the cause of the increase in plant height. According to Patel et al. (2021), "the increase in plant height might be due to the availability of small quantities of macronutrients and growth promoting substances in addition to huge beneficial microbial population in Panchagavya and Jeevamrit, thus when applied to the crop as foliar spray and through soil they trigger the necessary plant growth". According to Panchal et al. (2017), "increase in plant height might be due to the application of nutrients through foliar spray of Panchagavya which enhanced the growth rate of plant since it contains the favourable macro and micro nutrients, growth hormones and biofertilizers in liquid formulation. Moreover, the presence of growth enzymes in Panchagavya might favoured rapid cell division and elongation".

According to Kumawat et al. (2009), "application of Panchagavya will boost up the plant growth attributes will lead to accumulation of growth regulators which leads enhancement in the photosynthesis". According to Kumar et al. (2011), "The inoculation of Panchagavya supplied the plant with enough macronutrients (N, P and K) and micronutrient (Zn, Fe, Cu and Mn) that are required for overall plant growth and development thus the application of Panchagavya increased the dry matter production in plants".

Table 1. Growth parameters of chickpea as influenced by time of foliar application of different bio-stimulants at harvest

Treatments	Growth parameters				
	Plant height (cm)	Number of branches plant^{-1}	Dry matter accumulation (g plant^{-1})	Number of nodules plant^{-1}	Dry weight of nodules (mg plant^{-1})
Time of Foliar Application (G)					
G1: Pre-flowering	42.69	17.21	7.59	7.78	13.90
G2: Pod initiation	39.67	15.99	7.15	6.98	12.24
G3: Pre-flowering + Pod initiation	48.03	19.24	8.28	8.59	15.52
SEm±	1.31	0.45	0.17	0.20	0.40
LSD (*p*=0.05)	5.14	1.76	0.65	0.77	1.57
Bio-Stimulants (B)					
B1: Vermiwash at 10% solution	41.47	16.21	7.17	5.34	12.39
B2: Cow urine at 10% solution	42.24	16.54	7.49	6.87	13.20
B3: Jeevamrit at 10% solution	43.17	17.67	7.80	8.90	14.32
B4: Panchagavya at 3% solution	46.98	19.51	8.23	10.02	15.62
SEm±	1.26	0.44	0.13	0.19	0.39
LSD (*p*=0.05)	3.74	1.32	0.39	0.58	1.15
Interaction (G × B)	**NS**	**NS**	**NS**	**NS**	**NS**

Table 2. Yield attributes and yield of chickpea as influenced by time of foliar application of different bio-stimulants at harvest

Treatments	Yield attributes and yield						
	No. of pods plant^{-1}	No. of seeds pod^{-1}	Seed index (g)	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Time of Foliar Application (G)							
G1: Pre-flowering	18.44	1.83	17.29	1007	2220	3227	31.20
G2: Pod initiation	15.73	1.66	16.01	914	2021	2935	31.14
G3: Pre-flowering + Pod initiation	22.01	2.05	18.23	1038	2254	3292	31.53
SEm±	0.53	0.06	0.48	21	47	57	0.65
LSD (*p*=0.05)	2.07	0.22	NS	81	184	223	NS
Bio-Stimulants (B)							
B1: Vermiwash at 10% solution	16.37	1.76	16.44	940	2094	3034	30.98
B2: Cow urine at 10% solution	17.23	1.80	16.83	947	2100	3047	31.07
B3: Jeevamrit at 10% solution	19.92	1.82	17.26	985	2169	3154	31.23
B4: Panchagavya at 3% solution	21.38	2.00	18.19	1073	2296	3369	31.84
SEm±	0.48	0.06	0.47	20	44	56	0.60
LSD (*p*=0.05)	1.42	0.17	NS	58	132	167	NS
Interaction (G × B)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 3. Economics of chickpea as influenced by time of foliar application of different bio-stimulants at harvest

Treatments	Economics (₹ ha^{-1})			BCR
	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	
Time of Foliar Application (G)				
G1: Pre-flowering	31961	77713	45753	1.43
G2: Pod initiation	31961	70552	38591	1.21
G3: Pre-flowering + Pod initiation	32336	80104	47768	1.48
SEm±	-	1531	1531	0.05
LSD (*p*=0.05)	-	6013	6013	0.20
Bio-Stimulants (B)				
B1: Vermiwash at 10% solution	33015	72560	39545	1.20
B2: Cow urine at 10% solution	32015	73108	41093	1.28
B3: Jeevamrit at 10% solution	31678	76052	44374	1.40
B4: Panchagavya at 3% solution	31635.3	82771	51136	1.62
SEm±	-	1483	1483	0.04
LSD (*p*=0.05)	-	4405	4405	0.13
Interaction (G × B)	-	**NS**	**NS**	**NS**

According to Kadam et al. (2023), "increase in number of nodules per plant might be due to the better availability of nutrients that were supplied by application of Panchagavya. The foliar application of panchagavya supplies micronutrients, which creates a stimulus in the plant system and enhancing the cell division increased number of nodule production in plants, ultimately promoting the required growth and development".

Panchal et al. (2017) reported that fresh and dry weight of nodules plant^{-1} increased due to better availability of nutrients. The IAA and GA present in Panchagavya when applied as foliar spray created stimuli in the plant system and increased the production of growth regulators in cell system and the action of growth regulators in plant system ultimately stimulated the necessary growth and development.

3.2 Effect on Yield Attributes and Yield

Effect on yield attributes: The data presented in Table 2 revealed that the foliar application of Panchagavya @ 3% solution when applied at pre-flowering + pod initiation stage recorded significantly higher number of pods plant^{-1}, number of seeds pod^{-1} over rest of the treatments. Whereas, treatment had no significant effect on seed index.

The higher yield attributes might be due to the fact that the crop was provided with nutrients to fulfil its requirement at proper stages. Chickpea require adequate nourishment throughout pre-flowering and pod initiation in order to achieve healthy growth and development. Chickpea yield was increased when nutrients were applied foliarly at both the pre-flowering and pod initiation stages. This was because the nutrients were delivered to the photosynthesis site promptly, just when the supply of photosynthates to developing organs waslimited due to leaf depletion reducing nutrient uptake deficit by roots. The possibility to boost chickpea yields in areas where terminal droughts limit yield by applying foliar nitrogen close to flowering. In the chickpea crop, flower retention was enhanced and the number of pods per plant increased when cow urine and Vermiwash, a mixture of hormones, enzymes, minerals and other growth-promoting chemicals, were given as a foliar spray. Similar outcome was also reported by Satyanarayanamma et al. (1996), Palta et al. (2005) and Vora et al. (2019).

Effect on yield (kg ha^{-1}): The data presented in Table 2 revealed that the foliar application of Panchagavya at 3% solution at pre-flowering + pod initiation stage recorded significantly higher grain, straw and biological yield over rest of the treatments. While, treatment had no significant effect on harvest index.

The presence of growth hormones (IAA and GA_3), micronutrients and all major nutrients in Panchagavya may have contributed to shoot elongation by promoting cell enlargement and division with excess vegetative growth, increasing the number of reproductive flowers and pod-bearing branches. The yield parameters like grain, stover and biological yields recorded significantly higher through foliar application of Panchagavya @ 3% solution. This might be due to the fact that cow urine supplies nitrogen which is necessary for crop growth and cow dung in Panchagavya serves as a medium for the growth of advantageous bacteria. The similar findings were also reported by Shariff et al. (2017), Yadav et al. (2017) and Shinde et al. (2020).

Effect on economics (₹ ha^{-1}): The data presented in Table 3 revealed that the foliar application of Panchagavya @ 3% solution at pre-flowering + pod initiation stage recorded significantly higher gross returns, net returns and BCRratio over rest of the treatments.

This might be due to higher grain and stover yield and less cost of cultivation. These results are in close conformity with the results of Swaminathan et al. (2007), Panchal et al. (2017) and Prabhu et al. (2010).

4. CONCLUSION

The result concluded that the foliar application of Panchagavya @ 3% solution at pre-flowering + pod initiation stage recorded significantly higher growth parameters, yield attributes and yield and economics *viz.* plant height, number of branches plant^{-1}, dry matter accumulation, number of nodules plant^{-1}, dry weight of nodules, number of pods plant^{-1}, number of seeds pod^{-1}, grain, straw, biological yields, gross returns, net returns and BCR of chickpea under mid hills of Himachal Pradesh.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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