DOI : 10.58993/ijh/2024.81.2.11

Indian J. Hortic. 81(2), June 2024: 191-195

Effect of nano-multi micronutrients on growth, quality and economics of French bean

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ABSTRACT

Given the vital role that micronutrients play in plants, significantly influencing fruit growth and quality, the present investigation was carried out at SHUATS, Prayagraj, during the *Rabi* season of 2021 and 2022. The study aimed to examine the effect of nano-multi micronutrients on the growth, quality, and economics of the French bean var. "Arka Komal". Nano-multi micronutrients were applied at rates of 0.2, 0.4, and 0.6 ml/L, with water application serving as the control. The experimental findings concluded that the application of 0.6 ml/L nano-multi micronutrients performed best for growth parameters such as plant height, leaf area, and pod yield per hectare in French bean. This treatment also excelled in quality parameters like total soluble solids (TSS) and ascorbic acid content. Additionally, it achieved the highest benefit-cost (BC) ratio (3.07) among the various treatments.

Key words: *Phaseolus vulgaris* L., quality, foliar application, B:C ratio, micro-nutrient.

INTRODUCTION

The French bean (*Phaseolus vulgaris* L.) holds significant importance among leguminous vegetables and is considered the most crucial legume globally. Functioning as a dual-purpose crop, it serves both as a pulse and a vegetable. With highly nutritious dry seeds containing approximately 24.9% protein, 60.1% carbohydrates, and fat, it stands out among beans for its widespread cultivation due to its brief growth period and nutritional benefits Anonymous (1). Originating from Central and South America, French bean has become a staple in agricultural practices worldwide Swaider *et al.* (12). According to FAOSTAT, (3), production of French bean has been recorded to be highest in China followed by Indonesia and India. In India, the French bean holds a prominent status as a crucial leguminous vegetable crop, extensively cultivated for its green pods and dry seeds, commonly referred to as *'Rajmah*.' Serving as an economical source of vegetable protein, it also provides essential vitamins such as thiamine, riboflavin, niacin, and minerals like calcium and iron. India covers an area of 137.54 thousand hectares for French bean cultivation, producing 1370.21 thousand metric tons annually, with an average yield of 9.96 metric tonnes per hectare. The primary French bean-producing states include West Bengal, Andhra Pradesh, Jharkhand, Jammu and Kashmir, and Himachal Pradesh (Kumar, 6). The limited productivity of French bean is primarily attributed to insufficient fertilization, and the adoption of chemical fertilizers has become essential in modern intensive crop cultivation. Micronutrients, including zinc, iron, and manganese, play a vital role in French bean production by supporting key physiological and biochemical processes. These nutrients are essential for enzyme activation, chlorophyll synthesis, and nitrogen fixation, which are crucial for plant growth and development. Adequate micronutrient supply improves plant vigour, disease resistance, and overall yield. Efficient management of micronutrients ensures a balanced nutrition profile for plants, contributing to sustainable and effective crop production. This becomes particularly crucial for global food security and agricultural sustainability (Lobanov, 9). The utilization of nano-multi micronutrient fertilizer in the cultivation of French beans holds the promise of ensuring optimal plant nutrition. Given that French beans are known to be a crop with high nutrient requirements, maintaining a balanced supply of trace elements is crucial for fostering healthy growth and achieving high yields. The low productivity of French beans in the absence of micronutrient supply is primarily due to impaired physiological and biochemical processes. Consequently, plants exhibit diminished vigour and lower yields, significantly impacting overall productivity and crop quality Chopra *et al.* (2). Therefore, application of micronutrients becomes crucial for better quality and yield output of French bean. Hence, the present investigation was carried out to elucidate importance of application of micronutrients in French bean.

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MATERIALS AND METHODS

The research was conducted at the Departmental Research Farm of the Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology, and Sciences (SHUATS) in Prayagraj during the *Rabi* season of 2021 and 2022. The experiment aimed to systematically assess the effects of using nano-multi micronutrients in the cultivation of French bean var. 'Arka Komal'. The Fisher and Yates (4) method was used to statistically analyze the data. The software used for analysis was OPSTAT. In the study, the height of randomly chosen plants from each plot was measured in centimeters using a meter scale. This measurement was taken from ground level to the tip of the shoot at 35 days after sowing (DAS). Additionally, the number of branches and leaves per plant, emerging from the main shoot, was counted and the values were averaged. Total soluble solids (TSS) were measured using a refractometer. Ascorbic acid content was measured using the technique suggested by Ranganna (10). These parameters provide comprehensive insights into the growth, development, and quality of the French bean variety 'Arka Komal' under the influence of nano-multi micronutrients and nano- fertilizers. The details of nano- multi micronutrients treatment given are M_0- control (Without micronutrient); M_1- 0.2 ml/L of nano-multi micronutrient/L of water as foliar application; M_2- 0.4 ml/L of nano-multi-micronutrient/ L of water as foliar application; M_3- 0.6 ml/L of nano-multi micronutrient/L of water as foliar application. The commercial micronutrient formulation 'Biosmart Nano Trace Elements' used was obtained from the M/s Homecrop, Telangana.

RESULTS AND DISCUSSION

The data on plant height, number of leaves, number of branches, and leaf area (Table 1) in French beans showed significant differences among treatments with nano-multi micronutrients studied over two years, 2021 and 2022. Among the treatment combinations, plant height was found to be the maximum in treatment M_3 (0.6 ml/L of nano-multi micronutrient in water as a foliar application). Similarly, the number of leaves per plant was also highest in treatment M_3. The application of a foliar treatment with 0.6 ml/L of nano-multi micronutrients per litre of water demonstrated superior outcomes in terms of plant height and the number of leaves per plant in French beans compared to the 0.2 and 0.4 ml/L treatments. The higher concentration of 0.6 ml/L proved advantageous, providing an optimal and comprehensive supply of micronutrients. This ensured that the plants had access to essential trace elements at levels conducive to robust growth. The nano-scale particles in the micronutrient formulation likely enhanced nutrient absorption and translocation within the plant, contributing to more efficient nutrient utilization, stimulated photosynthesis, and overall improved plant health. The balanced combination of micronutrients in the 0.6 ml/L treatment effectively prevented deficiencies, promoting vigorous growth and abundant leaf production. Consequently, the plants exhibited enhanced health, productivity, greater height, and a higher number of leaves. Similar findings were reported by Sathiyamurthy *et al*. (11), who observed increase in plant height and the number of branches per plant in tomatoes through the application of boric acid @ 100 ppm, $ZnSO_4$ @ 100 ppm, and a commercial formulation (Multiplex™) @ 4 ml/L.

Among the treatment combinations, the number of branches per plant was found to be maximum in treatment M_3. Additionally, leaf area was also highest in treatment M_3. The application of a foliar treatment with 0.6 ml/L of nano-multi micronutrients per litre of water resulted in a higher number of

Table 1. Effect of nano-multi micronutrients on growth parameters of French bean (pooled mean for two years).

Treatment		Plant height (cm) [35 DAS]	No. of leaves per plant [35 DAS]	No. of branches per plant [35 DAS]	Leaf area (cm^2) [35 DAS]
M_0	Control	23.71	9.11	5.78	72.69
M_1	0.2 ml/L of nano-multi micronutrient/L of water as foliar application	25.56	10.57	6.27	82.77
M_2	0.4 ml/L of nano-multi micronutrient/L of water as foliar application	26.93	11.20	6.57	89.48
M_3	0.6 ml/L of nano-multi micronutrient/L of water as foliar application	27.45	11.67	6.70	90.92
$CD_{0.05}$		0.077	0.019	0.075	1.627
SE.m (±)		0.027	0.007	0.026	0.566
Sig.		**	**	**	**

branches per plant in French beans compared to the 0.2 and 0.4 ml/L treatments. This can be attributed to several factors. The elevated concentration of micronutrients in the 0.6 ml/L treatment ensured that the plants received an optimal supply of essential trace elements, thereby promoting overall plant health. The presence of nano-scale particles in the multi micronutrient formulation likely played a crucial role in enhancing nutrient uptake and translocation within the plant. This improvement in nutrient utilization and photosynthesis contributed to increased lateral branching and the formation of secondary shoots, ultimately leading to more branches per plant. The balanced combination of micronutrients in the 0.6 ml/L treatment effectively prevented deficiencies, supporting robust vegetative growth and the development of branches. As a result, the plants exhibited a notable increase in branching under this treatment. Similar findings were also concluded by Ghidan *et al.* (5) on broad bean for enhanced plant height, a greater number of branches under influence of application of nano-zinc and copper.

In the present investigation, TSS, protein content, fiber content, and ascorbic acid (Table 2) showed significant differences among the different treatments of nano-multi micronutrients applied to French beans over the two successive years studied. Among the treatment combinations, the minimum TSS was found in treatment M_3 (0.6 ml/L of nano-multi micronutrient in water as a foliar application). Maximum ascorbic acid content, highest fiber content, and maximum protein content were all observed in treatment M_3. The treatment with 0.6 ml/L of nano-multi micronutrients as a foliar application exhibited superior performance in quality parameters like total soluble solids (TSS), ascorbic acid, protein content, and fiber content compared to the 0.2 and 0.4 ml/L treatments. The heightened micronutrient concentration in the 0.6 ml/L treatment played a pivotal role in enhancing the synthesis of essential compounds. Nano-scale particles in the multi micronutrient formulation likely facilitated increased nutrient uptake and translocation within the plant, leading to more efficient utilization of nutrients for enhanced biochemical processes. This, in turn, positively influenced the quality parameters, including enhanced TSS levels, increased ascorbic acid content, improved protein content, and enhanced fibre content. The balanced micronutrient combination in the 0.6 ml/L treatment effectively prevented deficiencies, contributing to superior overall quality in French bean produce compared to the 0.2 and 0.4 ml/L treatments. Similar findings were also concluded by Kumar *et al.* (7) in French bean incorporating integrated nutrient management using nano-fertilizers and nano-micronutrients that enabled better TSS content and fibre content, While Kumar *et al.* (8) reported enhancement in protein content and ascorbic acid content in French bean through application of nano-multi micronutrient applied along with standard fertilizer dose of French bean.

Among the treatment combinations studied, the maximum yield per hectare and the highest cost of cultivation were found in treatment M_3 (0.6 ml/L of nano-multi micronutrient in water as a foliar application). The cost of cultivation for M_3 was Rs. 92,110 per hectare. The maximum gross return (Rs. 282,400 per hectare) and net return (Rs. 190,290 per hectare) were also observed in treatment M_3. Additionally, the highest B:C ratio was reported in M_3 (Tables 3 & 4). Similar findings were reported by Sathiyamurthy *et al*. (11) in tomatoes, where the use of nano-micronutrient sprays, including boron chelates, led to higher yields and increased returns with increasing doses of nano-micronutrients.

Table 2. Effect of nano-multi micronutrients on quality parameters of French bean (pooled mean for two years).

Treatment	TSS (°Brix)	Ascorbic acid content (mg/ 100g)	Fibre content (%)	Protein content (%)
M_0 Control	5.72	12.92	4.04	3.65
M_1 0.2 ml/L of nano-multi micronutrient/L of water as foliar application	5.64	13.37	4.24	3.96
M_2 0.4 ml/L of nano-multi micronutrient/L of water as foliar application	5.55	14.29	4.41	4.13
M_3 0.6 ml/L of nano-multi micronutrient/L of water as foliar application	5.52	14.38	4.43	4.19
$CD_{0.05}$	0.059	0.044	0.030	0.037
SE.m (±)	0.020	0.015	0.010	0.013
Sig.	**	**	**	**

Table 3. Effect of nano-multi micronutrients on fixed cost of french bean (pooled mean for two years).

Sl. No.	Particulars	Unit	Unit rate (Rs.)	Cost of cultivation (Rs.)
A.	Land preparation			
	Ploughing and harrowing	5.5 hours	850\hour	4,675
	Layout preparation	8 labour	350\labour	2,800
	Planting	10 labours	350\labour	3,000
	Gap filling	4 labours	350\labour	1,400
	Fertilizer and micronutrient application	15 labours	350\labour	5,250
B.	Seed			
	Cost of seed	50 kg	225 Rs/kg	11,250
C.	Intercultural operations			
	Weeding	10 labours	350\labour	3,500
	Spraying	5 labours	350\labour	1,750
	Insecticide and Pesticide	6 liter	650	3,900
D.	Irrigation	8 irrigations	350\irrigation	2,800
	Tube well charges	6 man days	500	3,000
E.	Harvesting	25 labours	350\labour	8,750
	Transportation			10,000
	Supervision charges			12,600
	Rental value	4 months	1800\month	7,200
	Miscellaneous			2,500
	Total			Rs. 84,375

Table 4. Effect of nano-multi micronutrients on economics of french bean (pooled mean for two years).

Combination Notation	Treatment Details	Urea @ Rs 5.50 kg^{-1}	DAP @ Rs 29 kg^{-1}	MOP @ Rs 16/kg	Nano-micronutrients multi @ Rs 275/ 250ml	Total variable cost (Rs)	Total Fixed cost (Rs)	Total cost of cultivation (Rs)	Mean Yield per hectare (t ha^{-1})	Gross Return (Rs) [Selling price @ Rs 20 kg^{-1}]	Net Return (Rs)	B:C Ratio
M_0	Control	-	-	-	-	0	84375	84375	11.92	238400	154025	2.83
M_1	0.2 ml/L of nano- multi micronutrient/L of water as foliar application	393	1262	800	1760	4215	84375	88590	12.11	242200	153610	2.73
M_2	0.4 ml/L of nano- multi micronutrient/L of water as foliar application	393	1262	800	3520	5975	84375	90350	13.14	262800	172450	2.91
M_3	0.6 ml/L of nano- multi micronutrient/L of water as foliar application	393	1262	800	5280	7735	84375	92110	14.12	282400	190290	3.07

AUTHORS' CONTRIBUTION

Research conceptualization (VB, SET, PKM); designing of the experiments (VB, PKM); providing the materials for the experiments (VB, SET); carrying out the experiments and gathering data (VB, PKM); data interpretation and analysis (PKM, GT, VB); manuscript preparation (PKM, RKG and GT).

DECLARATION

The corresponding author is responsible for ensuring that the descriptions are accurate, agreed upon by all authors, and free of any conflict of interest.

ACKNOWLEDGEMENT

The author is thankful to the Department of Horticulture, Naini Agricultural Institute, Sam

Higginbottom University of Agriculture Technology and Sciences, Prayagraj (U.P.) India for providing the necessary facilities to undertake this research.

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Received : November, 2023; Revised : June, 2024; Accepted : June, 2024