Plant Archives Vol. 24, No. 2, 2024 pp. 931-935 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2024.v24.no.2.131

RESPONSE OF NANO NPK ON GROWTH, YIELD AND QUALITY OF FRENCH BEAN (*PHASEOLUS VULGARIS* L.)

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(Date of Receiving-30-03-2024; Date of Acceptance-14-06-2024)

ABSTRACT

French bean is a dual-purpose crop grown as a pulse and vegetable. The low-level productivity of French bean has been attributed mainly to inadequate fertilization. The modern-day intensive crop cultivation requires the use of chemical fertilizers. The new types of fertilizers based on nanotechnology are considered promising and non-traditional solution to upgrade the farming production worldwide. The common applications of nanotechnology in agriculture include nano-fertilizers, nano-pesticides and nano-carriers. The study was conducted in the Rabi season of 2021 at SHUATS, Prayagraj. The investigation was done to evaluate the influence of nano NPK application on growth, yield and Quality of French bean variety "Arka Komal".The experiment was set up using a FRBD one factor being application of nano N P K. The nano-fertilizers treatment given were $\mathbf{F_0}$– Control (without fertilizer); $\mathbf{F_1}$- 100% RDF as traditional fertilizer; $\mathbf{F_2}$-5ml/ L each of Nano NPK/ L of water as foliar application; $\mathbf{F_3}$- 4ml/L each of Nano NPK/ L of water as foliar application; $\mathbf{F_4}$- 3ml/L each of Nano NPK/ L of water as foliar application. 50% traditional fertilizers were applied in all treatments excluding control. From above experimental findings it was concluded that treatment $\mathbf{F_2}$ performed best for growth parameters like plant height; number of branches per plant, number of pods per plant, pod weight and pod yield per plot studied in French bean. It also performed best for quality parameters like TSS and ascorbic acid content.

Key words : *Phaseolus vulgaris*, TSS, Ascorbic acid content, Foliar application.

Introduction

Of all the leguminous vegetables, the French bean (*Phaseolus vulgaris* L.) is regarded as the most important legume in the world. This versatile crop can be used as a pulse or a vegetable. It is unique among beans in that its extremely nutritious dry seeds contain roughly 24.9% protein, 60.1% carbohydrate and fat. This is due to its short growth period and nutritional benefits (Anonymous, 2020). Since insufficient fertilisation is the primary cause of French beans' low productivity, chemical fertilisers have become essential to intensive crop production in the modern era. Originating in Central and South America, French beans are currently widely utilised in global agricultural practices (Swaider *et al*., 1992). The French bean, which belongs to the Fabaceae family and has chromosome number 2n=22, is a healthy vegetable that can be eaten in a variety of ways, such as tender pods, shelled beans, or dry beans. French beans are popular in both bush and pole varieties. This legume is widely grown in temperate, subtropical and tropical regions, making it one of the most important legumes in the world and satisfying a significant demand for human consumption (Dhakal *et al*., 2020). The low-level productivity of French bean has been attributed mainly to inadequate fertilization. The modern-day intensive crop cultivation requires the use of chemical fertilizers. Commercial cultivation of French bean, like all other vegetables, inherits the inclusion of higher doses of nitrogen for better growth and yield as the plants are capable of fixing atmospheric nitrogen from environment by microbes. However, feeding

of plants for nitrogen through application of fertilizers as well as organic manures has been proved to be beneficial for higher yield (Ghosh *et al.*, 2014). In the twenty-first century, agriculture has faced many challenges to produce food and fibre needs of the growing population. Since the population will be increased over nine billion by 2050, human beings will be faced more problems in satisfying their needs. In different fields, including agriculture, nanotechnology has extraordinary potential to make it easier for the next stage of precision farming methods. The agricultural sector will be using more of nanotechnology in the future to achieve higher yields in eco-friendly way even in challenging environment (Sohair *et al*., 2018). By 2050, an increase in cereal food supply is required to feed the predicted world population of 9.8 billion people (Ahmadi and Arain, 2021). The new types of fertilizers based on nanotechnology are considered promising and non-traditional solution to upgrade the farming production worldwide. The common applications of nanotechnology in agriculture include nano-fertilizers, nano-pesticides and nano-carriers (Belal and El-Ramady, 2016). The advancement and development of engineered nanoparticles is an imperative stage in agricultural field in particular using the biological methods. Although these nano-fertilizers are important for the future agriculture, there are many potential risks on the agro-ecosystems (Khan and Rizvi, 2017). Indeed, several investigations are needed to explore the efficacy of commercially available engineered nanomaterials on soil microbes, the proper application methods of nano fertilizers and the future of nano fertilizer market sector (Sanivada *et al*., 2017). Conventional application techniques are resulting in seriously overdosing of chemical fertilizers. Nanotechnology is a promising field of research which utilizes nano materials of less than 100 nm size, may offer an unprecedented opportunity to develop concentrated sources of plant nutrients having higher-absorption rate, utilization efficacy, and minimum losses. One of the most important uses of nano technology is nanofertilizer, which improves the ability of the plants to absorb nutrients (Mishra, 2020). Nano fertilizers are being prepared by encapsulating plant nutrients into nano materials, employing thin coating of nano materials on plant nutrients, and delivering in the form of nano-sized emulsions. Nano-pores and stomatal openings in plant leaves facilitate nanomaterial uptake and their penetration deep inside leaves leading to higher nutrient use efficiency (NUE). Nano fertilizers have higher transport and delivery of nutrients through plasmodesmata, which are nano sized (50–60 nm) channels between cells. The higher NUE and significantly lesser nutrient losses of nano fertilizers lead to higher productivity (6–17%) and nutritional quality of field crops (Mishra, 2020). Nanotechnology has proved its ability to solve problems in agriculture and related industries. Nanotechnology has many uses in all stages of production, processing, storing, packaging and transport of agricultural products.

Materials and Methods

Examining the effects of nano NPK on the growth, yield and quality of the french bean variety "Arka Komal" was the aim of the current study. In Prayagraj, during the *Rabi* season of 2021, the research was carried out at the Departmental Research Farm of the Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS). A Factorial Randomised Block Design (FRBD) was the experimental design used. One factor addressed the application of nano mixed micronutrients and the other factor addressed the application of nano fertilisers. This design aimed to systematically assess the combined effects of these factors on the specified parameters, providing valuable insights into the potential benefits of using nano mixed micronutrients in the cultivation of french beans, particularly the "Arka Komal" variety. The Fisher and Yates (1963) method was used to statistically analyse the data. The software used for analysis was OPSTAT. In the study, the height of randomly chosen plants from each plot was assessed in centimetres using a meter scale. This measurement was taken from ground level to the tip of the shoot at 50 days after sowing (DAS). Additionally, the number of branches per plant, emerging from the main shoot, was counted, and the values were averaged. Number of pods per plant was counted from each selected plants after harvest from each treatment and replication. Number of pods per plant serves the major parameter of yield attributes.Total harvested pod from individual plant were taken and weighed. This was done for randomly selected five plants for data recording. TSS was measured using refractometer. Ascorbic acid was measured by technique suggested by Rangana (1986). These parameters provide comprehensive insights into the growth, development and quality of the french bean variety "Arka Komal" under the influence of nano mixed micronutrients and nano fertilizers. The details of nano-fertilizers treatment given are $\mathbf{F_0}$– Control (without fertilizer); $\mathbf{F_1}$- 100% RDF as traditional fertilizer; $\mathbf{F_2}$-5ml/ L each of Nano NPK/ L of water as foliar application; $\mathbf{F_3}$- 4ml/L each of Nano NPK/ L of water as foliar application; $\mathbf{F_4}$- 3ml/L each of Nano NPK/ L of water as foliar application. 50% traditional fertilizers were applied in all treatments excluding control.

Results and Discussion

Effect of nano NPK on growth parameters of French bean

The data pertaining to plant height and number of branches (Table 1 and Fig. 1) in French bean showed significant differences among treatments applied for nano NPK studied for year 2021. In the range of treatments involving varying levels of nano NPK, $\mathbf{F_2}$ resulted in the tallest plant height (55.89 cm) followed by $\mathbf{F_3}$(53.89 cm) for the years 2021. Conversely, the shortest plant height (49.28 cm) was observed in $\mathbf{F_0}$ (Control). Within the spectrum of treatments that encompass diverse concentrations of nano NPK, $\mathbf{F_2}$ resulted in the highest number of branches per plant (11.46 branches) followed by $\mathbf{F_3}$ (11.25 branches) for the years 2021. In other way round, the lowest number of branches per plant (8.93 branches) was observed in $\mathbf{F_0}$ (Control). The superior performance in plant height and number of branches per plant observed in the treatment combination of nano fertilizer (5ml/L Nano NPK in water as foliar application) for French beans can be attributed to their synergistic action. This specific blend optimally balanced essential nutrients crucial for growth. The nano fertilizer provided a balanced NPK ratio, promoting robust growth fostering healthier development. The treatments ensured an ideal nutritional environment, surpassing other combinations and even outperforming the control group by delivering a well-rounded, enhanced nutrient profile that supported and maximized the French bean's growth potential. Similar findings were reported by Ali *et al*. (2021) for nano fertilizers.

Effect of nano NPK on yield parameters of French bean

From Table 1 and Fig. 1, it is depicted that within the spectrum of treatments that encompass diverse concentrations of nano NPK, $\mathbf{F_2}$ exhibitedhighest number of pods per plant (25.66 pods) at par with $\mathbf{F_3}$ (24.31 pods) for the years 2021. In other way round, the lowest number of pods per plant (17.98 pods) was observed in $\mathbf{F_0}$ (Control). Individual pod weight was recorded maximum in $\mathbf{F_2}$ (9.81grams) among various treatments applied, which included the level of nano fertilisers. $\mathbf{F_3}$ came in second (9.07gram) for the years 2021 better over $\mathbf{F_0}$ (Control) with minimum pod weight (7.76gram). $\mathbf{F_2}$ recorded the highest pod yield per plot (3.00kg/plot) for the various treatments applied, which included the level of nano fertilisers followed by $\mathbf{F_3}$ (2.71kg/plot) for the years 2021 better over $\mathbf{F_0}$ (Control) with lowest pod yield per plot (2.62kg/plot). The increased number of pods per plant, pod weight and yield per plot in the treatment

Table 1 : Effect of Nano NPK on growth, Yield and quality parameters of French bean.

Treatment Details		Plant height (cm) [50 DAS]	No of branches per plant [50 DAS]	Number of pods per plant	Individual pod weight (grams)	Pod yield per plot (kg/plot)	TSS [°Brix]	Ascorbic acid content (mg/100 g)
$\mathbf{F_0}$	Control (without fertilizer)	49.28	8.93	17.98	7.76	2.62	5.34	13.20
$\mathbf{F_1}$	100% RDF as traditional fertilizer	54.41	10.87	22.34	8.78	2.78	5.19	14.57
$\mathbf{F_2}$	5 ml/L each of Nano NPK/L of water as foliar application	55.89	11.46	25.66	9.81	3.00	5.03	15.40
$\mathbf{F_3}$	4 ml/L each of Nano NPK/L of water as foliar application	53.89	11.25	24.31	9.07	2.71	5.16	15.04
$\mathbf{F_4}$	3 ml/L each of Nano NPK/L of water as foliar application	52.58	9.32	17.94	7.69	2.64	5.38	13.13
	'F' test	**S**	**S**	**S**	**S**	**S**	**S**	**S**
	$CD_{0.05}$	**0.080**	**0.127**	**0.604**	**0.188**	**0.062**	**0.059**	**0.083**
	S.Em (±)	**0.028**	**0.044**	**0.210**	**0.065**	**0.012**	**0.021**	**0.029**

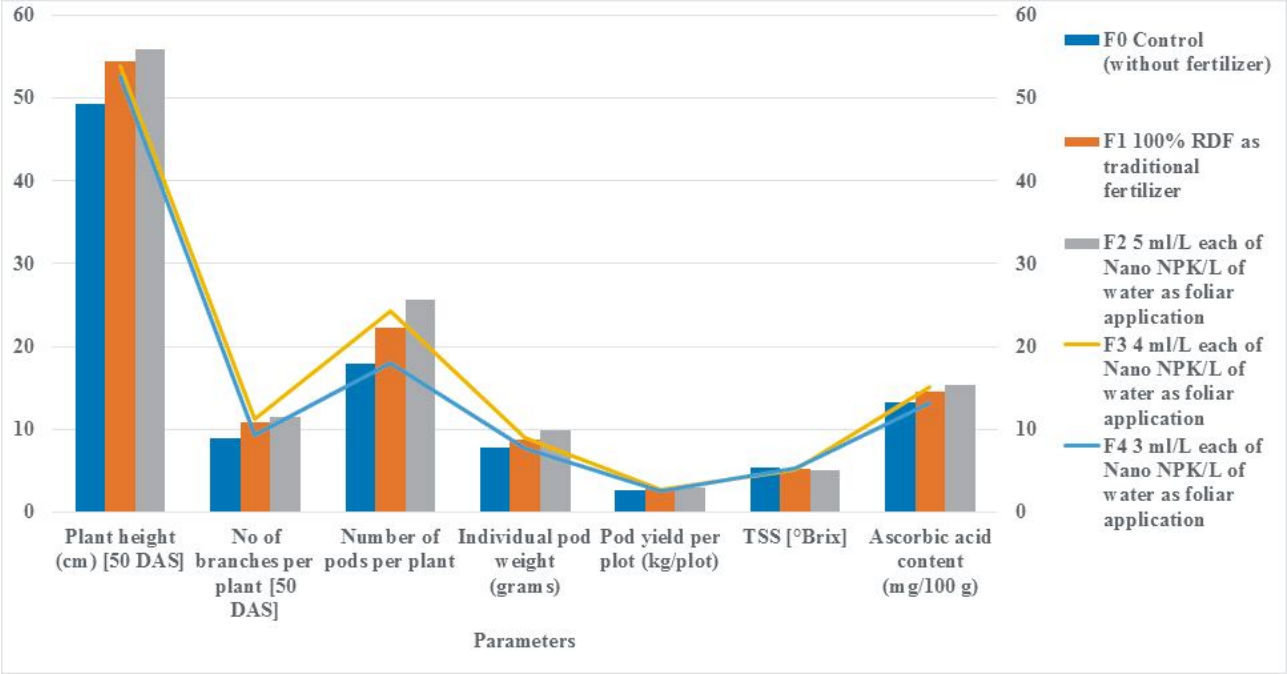

Fig. 1 : Effect of Nano NPK on growth and quality parameters of french bean.

comprising nano fertilizer (5ml/L Nano NPK in water as foliar application) for French beans is attributed to their efficient nutrient synergy also reported by Nofal *et al.* (2021) for nano fertilizer. This specific combination offered an optimal nutrient balance crucial for prolific flower initiation and fertilization. The nano fertilizer, with its balanced NPK ratio, stimulated robust floral initiation, promoting increased pods production earlier reported by Elizabeth *et al.* (2017) for nano fertilizer. It created a nutrient-enriched environment, surpassing other combinations and the control group. This comprehensive nutrient synergy stimulated a higher number of pods per plant, enhancing the plant's reproductive capacity and outperformed others by delivering an enriched, balanced nutritional mix that facilitated abundant pods in French beans. Moreover, the pod weight enhanced due to better accumulation of photosynthates due to proper supply of nutrients for photosynthesis resulting in better yield of pods. Similar findings were previously made by Lekshmi *et al.* (2022) for nano fertilizers.

Effect of nano NPK on quality parameters of French bean

In the present investigation, TSS and ascorbic acid (Table 1 and Fig. 1) showed significant difference within different treatments of nano NPK applied in French bean studied. Among the various treatments involving different levels of nano fertilizers, $\mathbf{F}_2$ displayed the best required Total Soluble Solids (TSS) levels (5.03 °Brix), followed by $\mathbf{F}_3$ (5.16 °Brix) across the years 2021. Conversely, the control group ($\mathbf{F}_0$) exhibited the poor for required TSS levels (5.34 °Brix).The ascorbic acid content for $\mathbf{F}_2$ was the highest (15.40 mg/100g) across all treatments, including the amount of nano fertilisers. For the year 2021 $\mathbf{F}_3$ performed better than $\mathbf{F}_0$-Control (13.20 mg/100g), with a better ascorbic acid content coming in second (15.04 mg/100g). The enhanced TSS and ascorbic acid content in the treatment merging nano fertilizer (5ml/L Nano NPK in water as foliar application) for French beans stems from their synergistic nutrient impact. This specific blend provided an optimal nutrient balance crucial for heightened ascorbic acid and TSS levels. The nano fertilizer, with its balanced NPK ratio, facilitated robust nutrient absorption and fortified the plants with essential trace elements, promoting increased ascorbic acid synthesis. This comprehensive nutrient synergy elevated ascorbic acid content, enhancing the nutritional quality of the beans and outperformed others by delivering an enriched, balanced nutritional mix that optimized ascorbic acid and TSS levels in French beans. Similar inferences were drawn by Abdel-Aziz *et al.* (2021), Al-Burki *et al.* (2021) in French bean.

Conclusion

From above experimental findings, it was concluded that treatment $\mathbf{F}_2$ performed best for growth parameters like plant height; number of branches per plant, number of pods per plant, pod weight and pod yield per plot studied in French bean. It also performed best for quality parameters like TSS, ascorbic acid content.

Authors' contribution

P. K. Maurya formulated the theory and conducted the calculations. Vijay Bahadur and S. E. Topno validated the analytical techniques. Under the guidance of Vijay Bahadur, P. K. Maurya explored and oversaw the outcomes of this research. The results were collectively deliberated by all authors, and each played a role in shaping the final manuscript.

Declaration

The corresponding author is responsible for ensuring that the descriptions are accurate and agreed by all authors and do not have any conflict of interest.

Acknowledgement

The author is thankful to the Advisor and Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj (U.P.), India for providing necessary facilities to undertake this research. This manuscript has not received any grant from any sources.

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