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Effect of different levels and mode of application of micronutrient grades on growth, yield and economics of *Kharif* French bean (*Phaseolus vulgaris* L.)

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Abstract
At the Experimental Farm of the Agronomy Section, College of Agriculture, Latur (MS), a field Experiment was conducted during the kharif 2022–2023 to examine the impact of various levels and mode of application of micronutrient grades on growth, yield and economics of *kharif* French bean (*Phaseolus vulgaris* L.). There are three replications of each of the seven treatments that are arranged in a randomised block design in this experiment. The treatments were T_1- RDF (120:60:60 kg NPK ha^{-1}), T_2- RDF + FYM @ 5 t ha^{-1}, T_3- RDF + FYM @ 5 t ha^{-1} + Micronutrient Grade-1 complex @ 15 kg ha^{-1}, T_4- RDF + FYM @ 5 t ha^{-1} + Micronutrient Grade-1 complex @ 20 kg ha^{-1}, T_5- RDF + FYM @ 5 t ha^{-1} + Micronutrient Grade-1 complex @ 25 kg ha^{-1}, T_6- RDF + FYM @ 5 t ha^{-1} + Micronutrient Grade-2 complex @ 0.25% (foliar spray at 30 DAS), T_7- RDF + FYM @ 5 t ha^{-1} + Micronutrient Grade-2 complex @ 0.5% (foliar spray at 30 DAS). The results showed that application of RDF + FYM @ 5 t ha^{-1} + Micronutrient Grade-1 complex @ 25 kg ha^{-1} recorded significantly higher growth and yield attributes, yield, GMR and NMR followed by application of RDF + FYM @ 5 t ha^{-1} + Micronutrient Grade-1 complex @ 20 kg ha^{-1}. B:C ratio was also recorded higher with the application of RDF + FYM @ 5 t ha^{-1} + Micronutrient Grade^{-1} complex @ 25 kg ha^{-1}.

Keywords: French bean, micronutrient, FYM, RDF, application method

Introduction
One of the most significant edible legumes in the world for direct human consumption is the French bean (*Phaseolus vulgaris* L.). Over a period of 7,000–8,000 years, the French bean evolved from a wild-growing vine that was dispersed over the Andes and middle America's highlands. It is a member of the Leguminosae family and was first discovered in Central and South America (Swiader *et al.*, 1992) [12]. It is also known as bush bean, kidney bean, snap bean, green bean, raj bean, common bean, basic bean, haricot bean, navy bean, pole bean, wax bean, string bean and bonchi (Duke, 1983; Salunkhe *et al.*, 1987; Tindall, 1988) [4, 9, 13]. It is valued for its protein (23%) rich seeds. Iron, phosphate, and calcium are also abundant in seeds. As a vegetable, the fresh pods are consumed. The major French bean producing countries are India, Brazil, Myanmar, China, USA, Mexico, Uganda, Kenya and Ethiopia. Among these, India ranks first in area 13 million hectares and production 5.46 million tonnes followed by Myanmar and Brazil (Anonymous, 2020) [1]. In India, it is cultivated in an area of 297 thousand hectares with a production of 2744 thousand MT in year 2021-22 (second advance estimate) (Anonymous, 2022) [2]. It mainly grown in the states of Gujarat, Bihar, Karnataka, Maharashtra, Jharkhand, Andhra Pradesh, Odisha, Uttar Pradesh, Madhya Pradesh and Tamil Nadu. The total area of bean cultivation in Maharashtra is 5.50 thousand hectares, with a production of 55.48 thousand MT in year 2017-18. Among the various constraints of production, availability of essential nutrient in balanced form is major normal growth and development of the plant. Due to the impact of green revolution, Indian soils became deficient in micronutrients. Micronutrients were required in lesser amounts but they have a significant effect in enhancing the use efficiency of macronutrients and productivity of crop (Katyal *et al*., 2004; Singh, 2009; Shukla *et al*., 2009) [6, 11, 10]. Hence, a need arises to develop appropriate management systems of micronutrients among researchers to curtail the declining input use efficiency of NPK. Several micronutrient complexes in different grades were developed and out of them, micronutrient grade-I (Fe-2%, Mn-1%, Zn-5%, Cu-0.5% and B-1%) and grade-II (Fe-2.5%, Mn-1%, Zn-3%, Cu-1%, B-0.5% and Mo-0.1%) are utilized in this experiment. In accordance with this, the current investigation was planned.

Materials and Methods

The field experiment was carried out during *kharif* 2022-23 at Experimental farm of Agronomy Section, College of Agriculture, Latur. The experimental area is located between 18° 05' to 18° 75' North latitude and between 76° 25' to 77° 36' East latitude. The soil at the experimental location had clayey in texture, slightly saline in reaction (pH 7.7), low in available nitrogen (231 kg ha^{-1}), medium levels of phosphorus (17.57 kg ha^{-1}) and high levels of potassium (458.8 kg ha^{-1}). The rainfall received during the experiment was 913 mm and distribution was erratic. The maximum and minimum temperature was 29.53 ºC and 18.77 ºC, respectively and relative humidity in morning and evening was 80.29% and 62.47%, respectively. The experiment consists of seven treatments laid out in Randomized Block Design, replicated thrice. The treatments were T_1- RDF (120:60:60 NPK kg ha^{-1}), T_2- RDF + FYM @ 5 t ha^{-1}, T_3- RDF + FYM @ 5 t ha^{-1} + Micronutrient Grade-1 complex @ 15 kg ha^{-1}, T_4- RDF + FYM @ 5 t ha^{-1} + Micronutrient Grade-1 complex @ 20 kg ha^{-1}, T_5- RDF + FYM @ 5 t ha^{-1} + Micronutrient Grade-1 complex @ 25 kg ha^{-1}, T_6- RDF + FYM @ 5 t ha^{-1} + Micronutrient Grade-2 complex @ 0.25% (foliar spray at 30 DAS), T_7- RDF + FYM @ 5 t ha^{-1} + Micronutrient Grade-2 complex @ 0.5% (foliar spray at 30 DAS). The experimental unit measured 5.4 m × 4.5 m for the gross plot and 4.5 m x 3.9 m for the net plot. Sowing was done by dibbling method on 7th July 2022 at spacing 45 cm x 15 cm with seed rate of 50 kg ha^{-1}. The recommended dose of fertilizer 120:60:60 NPK kg ha^{-1} was applied. The half dose of N along with full dose of P and K was applied as basal and remaining half dose of N is applied as top dressing on 30 days after sowing. The crop was harvested on 25th September 2022. The recorded data were statistically examined using the analysis of variance technique (Panse and Sukhatme, 1967) [7].

Results and Discussion

Growth attributes

The data showed (Table 1) that, among various treatments, significantly higher plant height (42.59 cm), plant spread (92.37 cm), number of branches $plant^{-1}$ (9.50), number of functional leaves $plant^{-1}$ (47.47), leaf area $plant^{-1}$ (26.61 dm^2) and dry matter accumulation $plant^{-1}$ (24.80 g) were recorded with the application of RDF + FYM @ 5 t ha^{-1} + Micronutrient Grade-1 complex @ 25 kg ha^{-1} (T_5) which was at par with the application of RDF + FYM @ 5 t ha^{-1} + Micronutrient Grade-1 complex @ 20 kg ha^{-1} (T_4) and found significantly higher over rest of the treatments. The increase in growth parameters might be due to balanced application of nutrients through RDF, micronutrient grades and FYM which enhanced the plant height, number of branches and leaf area *i.e.*, overall growth and development of crop and resulted into higher mean number of pods $plant^{-1}$ of crop. It might be due to beneficial effect of micronutrient complex, which improves the uptake of major nutrients from soil and helps to increase the plant height, plant spread and number of branches $plant^{-1}$. The findings are analogous to those obtained by Chate *et al.* (2012) [3] and Raziq *et al.* (2016) [8]. Micronutrient complexes are essential for both growth and development. They also enhance nutrient absorption, leading to a greater build-up of dry matter $plant^{-1}$. These results were in accordance with the findings of Raziq *et al.* (2016) [8].

Yield and yield attributes

The impact of different treatments was found significant on yield and yield contributing characters of French bean as showed in Table 2. The maximum number of pods $plant^{-1}$ (10.57), dry weight of pods $plant^{-1}$ (12.87 g) and seed yield (1291 kg ha^{-1}) were obtained with the application of RDF + FYM @ 5 t ha^{-1} + Micronutrient Grade-1 complex @ 25 kg ha^{-1} (T_5) which was at par with application RDF + FYM @ 5 t ha^{-1} + Micronutrient Grade-1 complex @ 20 kg ha^{-1} (T_4) and found to be significantly superior over rest of the treatments. Increase in number of pods $plant^{-1}$ might be attributable to an increase in plant height, number of branches and leaf area due to the involvement of micronutrients in various metabolic activities of plant. It has been discovered that boron significantly affects the growth of anther, pollen germination, calcium uptake, blooming and fruiting in reproductive processes. Similar results are reported with the findings of Uddin *et al.* (2020) [14] and Raziq *et al.* (2016) [8]. Micronutrients enhance the translocation of photosynthates from source (leaves) to sink (seed) which leads to increase in dry weight of pods $plant^{-1}$. These findings were collaborative with Islam *et al.* (2018) [5] and Raziq *et al.* (2016) [8]. Increase in seed yield might be due to increase in number of pods $plant^{-1}$, number of seeds pod^{-1} and dry weight of pods $plant^{-1}$ as micronutrients are involved in various processes such as enzyme activation, chlorophyll formation, electron transport, stomata regulation and uptake of major nutrients in balanced form to build strong source-sink relation. Similar results are reported with the findings of Umamaheshwari and Singh (2002) [15], Chate *et al.* (2012) [3], Raziq *et al.* (2016) [8], Islam *et al.* (2018) [5] and Uddin *et al.* (2020) [14]. Harvest index was observed highest with application RDF + FYM @ 5 t ha^{-1} + Micronutrient Grade-1 complex @ 20 kg ha^{-1} (T_4), closely followed by the application of RDF + FYM @ 5 t ha^{-1} + Micronutrient Grade-1 complex @ 25 kg ha^{-1} (T_5).

Economics of French bean cultivation

Significantly higher gross monetary returns (₹1,03,318 ha^{-1}) and net monetary returns (₹50,280 ha^{-1}) were recorded with application of RDF + FYM @ 5 t ha^{-1} + Micronutrient Grade-1 complex @ 25 kg ha^{-1} (T_5) which was at par with application of RDF + FYM @ 5 t ha^{-1} + Micronutrient Grade-1 complex @ 20 kg ha^{-1} (T_4) and found significantly higher over rest of the treatments. The disparities in net returns observed across management practices due to fluctuations in both gross returns, which represent the total income generated and cultivation costs incurred within each respective treatment. These differences could be a result of factors such as the effectiveness of micronutrient complex employed and the crops overall yield, as well as the expenses associated with implementing and maintaining the crop. Highest B:C ratio (1.95) was also recorded with the application of RDF + FYM @ 5 t ha^{-1} + Micronutrient Grade-1 complex @ 25 kg ha^{-1} (T_5). These findings are confirmative with the findings of Raziq *et al.* (2016) [8].

Table 1: Effect of different treatments on growth attributes of French bean.

Treatments	Plant height (cm) at harvest	Plant spread (cm) at 60 DAS	Number of branches plant^{-1} at harvest	Number of leaves plant^{-1} at 60 DAS	Leaf area plant^{-1} (dm^2) at 60 DAS	Dry matter accumulation plant^{-1} (g) at harvest
T_1	30.96	71.21	7.47	33.27	20.18	17.13
T_2	33.92	75.40	7.70	37.93	20.86	18.87
T_3	35.20	78.29	7.90	39.47	21.94	19.47
T_4	39.03	87.41	9.13	45.00	25.53	22.37
T_5	42.59	92.37	9.50	47.47	26.61	24.80
T_6	37.84	82.22	8.47	41.27	23.18	20.93
T_7	37.53	80.34	7.93	43.07	22.42	19.93
SE±	1.74	3.30	0.34	1.23	1.13	1.30
CD @ 5%	5.13	9.73	1.00	3.59	3.34	3.83
General Mean	36.72	81.03	8.30	41.07	22.96	20.50

Table 2: Effect of different treatments on yield attributes, yield and economics of French bean.

Treatments	Number of pods plant^{-1}	Dry weight of pods plant^{-1} (g)	Seed yield (kg ha^{-1})	Harvest index (%)	GMR (₹ ha^{-1})	NMR (₹ ha^{-1})	B:C ratio
T_1	7.60	9.27	827	35.07	66163	20125	1.44
T_2	8.13	9.83	990	38.34	79189	28151	1.55
T_3	8.80	9.97	1050	38.12	84018	31780	1.61
T_4	10.00	12.20	1229	39.91	98336	45698	1.87
T_5	10.57	12.87	1291	38.56	103318	50280	1.95
T_6	9.27	10.80	1012	38.16	80960	28772	1.55
T_7	9.10	10.53	1069	37.91	85521	32183	1.60
SE±	0.43	0.66	60	-	4776	4776	-
CD @ 5%	1.25	1.93	176	-	14089	14089	-
General Mean	9.07	10.78	1067	38.01	85358	33856	1.65

Conclusion

Growth and yield qualities have been found to be significantly greater when RDF + FYM @ 5 t ha^{-1} + Micronutrient Grade-1 complex @ 25 kg ha^{-1} is applied. This was followed by RDF + FYM @ 5 t ha^{-1} + Micronutrient Grade-1 complex @ 20 kg ha^{-1}. Application of RDF + FYM @ 5 t ha^{-1} + Micronutrient Grade-1 complex @ 25 kg ha^{-1} was found to be more remunerative for getting higher yield, GMR and NMR of French bean and it was followed by RDF + FYM @ 5 t ha^{-1} + Micronutrient Grade-1 complex @ 20 kg ha^{-1}. The application of RDF + FYM @ 5 t ha^{-1} + Micronutrient Grade-1 complex @ 25 kg ha^{-1} also resulted in higher B:C ratio.

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