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Udayakumar
Department of Horticulture, College of Agriculture Raichur, UAS Raichur, Karnataka, India

Ramesh G
Department of Soil and Water Engineering, College of Agriculture Engineering, Raichur, Karnataka, India

Shekharagouda Patil
Department of Horticulture, College of Agriculture Raichur, UAS Raichur, Karnataka, India

Pampanna Y
Department of Horticulture, College of Agriculture Raichur, UAS Raichur, Karnataka, India

Anand N
Department of Agronomy, College of Agriculture Raichur, UAS Raichur, Karnataka, India

Correspondence
Udayakumar
Department of Horticulture, College of Agriculture Raichur, UAS Raichur, Karnataka, India

Effect of fertigation and foliar application of nutrients on growth and yield of French bean (*Phaseolus vulgaris* L.)

Udayakumar, Ramesh G, Shekharagouda Patil, Pampanna Y and Anand N

Abstract
A field experiment was conducted to evaluate the effect of fertigation and foliar application of nutrients on growth and yield of French bean (*Phaseolus vulgaris* L.). The experiment consisted of four main plots *i.e.*, different levels of fertigation and three sub plots *i.e.*, foliar spray of different nutrient solutions. The experiment was conducted in split plot design and it was replicated thrice. 100 per cent RDF through fertigation and foliar application of 0.5 per cent vegetable special recorded higher plant height (53.20 cm), maximum number of branches (5.70), higher leaf area (5.70 cm^2) and chlorophyll content (53.58 SPAD values). Maximum number of pods per clusters (7.87), more number of clusters per plant (6.73), yield per plant (171.73 g) and yield per hectare (8.22 t) were also higher in the same treatment. Higher nitrogen uptake (67.69 kg ha^{-1}), phosphorus uptake (11.24 kg ha^{-1}) and potassium uptake (90.90 kg ha^{-1}) was observed in 100 per cent RDF through fertigation and foliar application of 0.5 per cent vegetable special compared to other treatments. It was observed that 100 per cent RDF through fertigation and foliar application of 0.5 per cent vegetable special enhanced the growth, yield and nutrient uptake in French bean.

Keywords: Fertigation, foliar spray, clusters, vegetable special

Introduction
French bean (*Phaseolus vulgaris* L.) is one of the most important leguminous vegetable. It is also known as common bean, bush bean, kidney bean, snap bean, haricot bean and navy bean. It is grown for the tender green beans as well as dry beans seeds (Rajmah). It is originated in warm temperate region of Central America (Mexico and Guatemala) and Southern America, mainly the Andean regions. There are two distinct gene pools of French bean, one is Andean origin and other is the Central America and Mexican origin. The wild species *Phaseolus aborigineus* is considered as the progenitor of *Phaseolus vulgaris* L.

French bean is grown in different parts of the world for its mature dry seeds, immature tender green or yellow pods (Snap bean) and for its leaves (In Africa and Asia), which is being used as vegetable. In Northern India, dry pods of French bean fetch higher price compared to other pulse crops as its vegetable preparation is considered to be one of the most nutritious and delicious dish for the 'Sunday special'. The dry seeds can also be canned and exported for vegetable purpose. Tender pods of French bean can be harvested at about 50-60 days after sowing for vegetable purpose.

French bean is quite nutritious and potential source of protein, carbohydrates and minerals. The mineral matter and crude fibre are concentrated in seeds, while crude protein and energy are stored in the cotyledons. It contains about 1.7g protein, 0.8 g mineral matter, 1.8 g fibre, 0.1 g fat 4.5 g carbohydrates, 28 mg phosphorus, 50 mg calcium, 74 mg potassium and 0.6 mg iron per 100 g of edible part (Pandey and Singh, 2010) [9].

Micronutrients such as boron, copper and zinc also play a positive role for increasing pod as well as seed yield in French bean. Micronutrients are those elements that are essential for plant growth, but are required in smaller quantity. If these micronutrients are not available sufficiently, plants will suffer from physiological stress due to inefficiency of several enzymatic systems and other related metabolic functions. (Fageria, 2009) [5].

Fertigation has immense utility in increasing the production of French bean. Foliar spray of micronutrients play an important role in increasing yields. In the past, some efforts have been made to study the influence of fertigation on vegetative and reproductive parameters of French bean.

However the information on interactive effect of fertigation and foliar sprays of nutrients is lacking. Hence the study has been done with the following objectives. *i.e.*, to assess the influence of fertigation on growth, yield and quality of French bean and to know the effect of foliar sprays on growth, yield and quality of French bean.

Material and Methods

The experiment was conducted from November 2018 to February 2019 in the fields of All India coordinated research project on plasticulture engineering technology, at College of Agriculture Engineering, Raichur University of Agricultural Sciences, Raichur. This is located in the North Eastern dry zone *i.e.,* Zone –II of the region –I in Karnataka. The location corresponds to 16^0 25`North latitude and $77^0$ 33`East longitude. The climate of the experimental location is semi-arid and average annual rainfall is 722 mm. The elevation of Raichur is 406 m above mean sea level (MSL).

French bean variety Arka Arjun was procured from Indian Institute of Horticulture Research, Bengaluru. Experiment was laid out in split plot design with twelve treatments and three replications. The treatments consisted of main plot treatments i.e., M_1-50% of RDF through fertigation, M_2-75% of RDF through fertigation, M_3-100% of RDF through fertigation and M_4-100% RDF as soil application and drip irrigation and sub plot treatments: S_1- Foliar spray of humic acid (2%), S_2- Foliar spray of vegetable special (0.5%) and S_3- Foliar spray of vermiwash (5%). Fertigation was provided at weekly interval and foliar spray of micronutrients was taken up at 20, 40 and 60 DAS.

The land was thoroughly ploughed and brought to a fine tilt. Raised beds of 10m length and 1m width were prepared. French bean seeds were sown on the raised beds at a spacing of 45x15 cm. Drip laterals of 4 LPH were placed on the beds. Irrigation and fertigation was provided as per the plan of the experiment. The Required nitrogen, phosphorous and potassium was applied to the experimental plot through water soluble fertilizers (WSF) *i.e.* 19:19:19 and 00:52:34. Fertilizers were applied by pressure differential method by using venturi system. The required pressure was monitored by using pressure gauge fitted on the supply line just after the filter. Different growth promoting nutrients were used through foliar application *i.e.* Commercial formulation of humic acid used in the study, was brought from market, vegetable special was brought from Indian Institute of Horticultural Research, Bengaluru and vermiwash was procured from Entomology laboratory, University of Agricultural Sciences, Raichur. Five plants were tagged from each plot. Observations on growth parameters were recorded from these tagged plants at 15, 30, 45 DAS and at harvest. Yield parameters were recorded at harvest.

Results and Discussion

Growth parameters: The recorded and analysed data for growth parameters of French bean is presented in table 1. Fertigation with 100 per cent RDF has recorded significantly higher plant height (50.45 cm), maximum number of branches (5.07), higher leaf area (574.42 cm^2) and chlorophyll content (37.82 SPAD values).This was followed by fertigation with 75 per cent RDF. With respect to foliar spray, 0.5 per cent vegetable special has recorded the higher plant height (49.05 cm), maximum number of branches (5.03), higher leaf area (582.67 cm^2) and chlorophyll content (37.21 SPAD values). This was followed by foliar spray of humic acid (2%). Among the different interactions, 100% RDF through fertigation and foliar application of vegetable special (0.5%) has recorded the higher plant height (53.20 cm), maximum number of branches (5.70), higher leaf area (621.07 cm^2) and chlorophyll content (42.75 SPAD values).

This might be due to the better availability of macronutrients at the root zone of the plant in soluble form. Nitrogen and phosphorous are one of the major nutrients that propel the growth and development of plants, as the nitrogen is a major constituent of protoplasm, cell nucleus, amino acids, and chlorophyll (Godara *et al.*, 2013) [7]. Higher and luxuriant availability of macro nutrients through fertigation might have contributed for higher growth parameters and these results are in accordance with Durge *et al.,* (1997) [4], Bansod (2007) [1], and Chetan and Singh (2009) [3]. The better availability of macro and micro nutrients resulted in higher values in growth parameters, the synergetic effect of macronutrient *i.e.* P and micronutrient Zn may serve as a source of energy for the synthesis of auxin. Auxins play an important role in cell division and cell elongation. Enhanced photosynthetic reaction in the presence of zinc and boron was also reported by Mallick and Muthukrishnan (1980) [8]. This could have contributed for increase in growth parameters. Thus 100 per cent RDF through fertigation and foliar spray of 0.5 per cent vegetable special resulted in better growth parameters.

Yield and Yield Attributes: Yield attributes like number of pods per clusters and number clusters per plant and Yield parameters like, yield plant $^{-1}$ (g), yield ha^{-1} (t) are presented in table 2. Fertigation with 100 per cent RDF has recorded maximum number of pods per clusters (7.60), number of clusters per plant (6.47), yield $plant^{-1}$ (162.31 g) and yield ha^{-1} (7.42 t). Foliar spray of 0.5 per cent vegetable special has exhibited maximum number of pods per clusters (7.00), more number clusters per plant (5.73), yield $plant^{-1}$ (153.15 g) and yield ha^{-1} (7.04 t). Among the interactions, maximum number of pods per clusters (7.87), number of clusters per plant (6.73), yield $plant^{-1}$ (171.73 g) and yield ha^{-1} (8.22 t) was observed with 100 per cent RDF through fertigation and foliar spray of 0.5 per cent vegetable special.

Higher number of pods per clusters, number of clusters per plant, yield plant $^{-1}$ (g), and yield ha^{-1} (t) were noticed with 100 per cent RDF through fertigation and foliar spray of vegetable special. Higher doses of fertigation promotes the increase in number of leaves and leaf area which resulted in proper utilization of solar energy leading to increase in photosynthesis and higher dry matter accumulation in plants. Chlorophyll is an essential component in photosynthesis, which is increased by higher nitrogen content in the plants. Further phosphorous plays an important role in transformation of sugar to starch, transformation of ADP to ATP, vice versa and strengthening of roots of the plant (Patel and Patel 1990) [10]. Potassium improves overall crop growth by playing an important role in photosynthesis and transpiration. Higher level of nitrogen, phosphorous and potassium at early stages of crop growth and critical stages *i.e.* at flowering and pod set might have resulted in production of more number of pods per plant. Foliar spray of micronutrients might have ameliorated the physical and chemical properties of soil, leading to adequate supply of nutrients. This further, might have increased the production and accumulation of carbohydrates (Basavarajeswari *et al.* 2008) [2]. Due to these reasons, the interaction of 100 per cent RDF through fertigation and foliar spray of vegetable special have resulted in higher yield parameters.

Nutrient Uptake: Nutrient uptake by different levels of fertigation and foliar sprays in French bean is presented in table 3. Among the different fertigation levels 100 per cent RDF through fertigation has resulted in higher nitrogen uptake (62.07 kg ha^{-1}), phosphorus uptake (10.44 kg ha^{-1}) and potassium uptake (86.31 kg ha^{-1}). This was followed by 75 per cent RDF through fertigation. With respect to foliar spray, higher nitrogen uptake (56.92 kg ha^{-1}), phosphorus uptake (8.77 kg ha^{-1}) and potassium uptake (76.37 kg ha^{-1}) was observed with the foliar application of vegetable special (0.5%). This was followed by foliar spray of humic acid (2%). Combined effect of 100% RDF through fertigation and foliar application of vegetable special (0.5%) showed higher nitrogen uptake (67.69 kg ha^{-1}), phosphorus uptake (11.24 kg ha^{-1}) and potassium uptake (90.90 kg ha^{-1}).

Fertigation with 100 per cent RDF has resulted in higher NPK uptake by plants. The application of soluble fertilizers near the root zone by fertigation, facilitates easy absorption of plant nutrients. Unlike surface irrigation and conventional fertilizer application, fertigation makes uniform distribution of nutrient solution in the root zone and thereby increases the fertilizer use efficiency, Fertigation at higher dose would increase the availability of macronutrients in the soil solution, which further would lead to higher uptake and better translocation of photosynthates from source to sink (Saileela 2017) [11]. The combined influence of 100 per cent RDF through fertigation and foliar spray of vegetable special also resulted in higher uptake of NPK by plants. A properly designed fertigation system delivers, nutrients and water in such a way that it maximises the nutrient uptake (Gardenas *et al.*, 2005) [6]. Thus, these reasons could be attributed to higher nutrient uptake with the conjunctive fertigation of 100 per cent RDF and foliar spray of 0.5 per cent micronutrients.

Table 1: Effect of different levels of fertigation and foliar spray of nutrients on growth parameters at harvest in French bean

Treatment	Plant height (cm)	Number of primary branches	Leaf area (cm^2)	Chlorophyll content (SPAD values)
Main plot				
M_1-50% RDF through fertigation	46.40	4.60	498.80	35.64
M_2-75% RDF through fertigation	46.88	4.67	506.96	34.45
M_3-100% RDF through fertigation	50.45	5.07	574.42	37.82
M_4-100 RDF as soil application	44.49	4.71	458.69	32.78
SEm±	1.10	0.03	15.15	0.73
CD at 5%	3.81	0.09	53.46	2.57
Sub plot				
S_1-Foliar spray of humic acid (2%)	47.01	4.73	502.27	34.21
S_2-Foliar spray of vegetable special (0.5%)	49.05	5.03	582.67	37.21
S_3-Foliar spray of vermiwash (5%)	45.10	4.53	444.22	34.11
SEm±	0.53	0.08	9.27	0.43
CD at 5%	1.58	0.23	28.02	1.30
Interaction				
M_1S_1	47.20	4.73	479.01	35.04
M_1S_2	47.67	4.80	553.23	36.29
M_1S_3	44.33	4.27	464.17	35.61
M_2S_1	45.65	4.87	507.99	33.41
M_2S_2	48.60	4.67	570.10	35.89
M_2S_3	46.40	4.47	442.79	34.06
M_3S_1	48.73	4.67	591.82	36.23
M_3S_2	53.20	5.70	621.07	42.75
M_3S_3	49.41	4.83	510.36	34.49
M_4S_1	46.47	4.67	430.26	32.15
M_4S_2	46.73	4.93	586.26	33.91
M_4S_3	40.27	4.53	359.56	32.29
SEm±	1.05	0.15	18.53	0.86
CD at 5%	3.17	0.45	55.55	2.58

Table 2: Effect of different levels of fertigation and foliar spray of nutrients on yield and yield attributes in French bean

Treatment	Number of pods per clusters	Number of pod clusters per plant	Yield plant^{-1} (g)	Yield ha^{-1} (t)
Main plot				
M_1-50% RDF through fertigation	6.36	4.93	139.65	5.97
M_2-75% RDF through fertigation	7.02	5.64	148.60	6.45
M_3-100% RDF through fertigation	7.60	6.47	162.31	7.42
M_4-100 RDF as soil application	6.07	5.24	139.05	6.23
SEm±	0.08	0.06	1.66	0.04
CD at 5%	0.26	0.21	5.87	0.15
Sub plot				
S_1-Foliar spray of humic acid (2%)	6.73	5.45	147.54	6.53
S_2-Foliar spray of vegetable special (0.5%)	7.00	5.73	153.15	7.04
S_3-Foliar spray of vermiwash (5%)	6.55	5.53	141.52	5.98
SEm±	0.05	0.07	1.23	0.09
CD at 5%	0.17	0.22	3.71	0.26
Interaction				
M_1S_1	6.07	4.87	137.00	6.34

M_1S_2	6.67	5.20	145.87	6.40
M_1S_3	6.33	4.73	136.08	5.19
M_2S_1	7.07	5.33	151.13	6.21
M_2S_2	7.13	5.60	148.73	6.92
M_2S_3	6.87	6.00	145.93	6.22
M_3S_1	7.60	6.27	163.73	7.33
M_3S_2	7.87	6.73	171.73	8.22
M_3S_3	7.33	6.40	151.47	6.71
M_4S_1	6.20	5.33	138.29	6.25
M_4S_2	6.33	5.40	146.27	6.62
M_4S_3	5.67	5.00	132.60	5.82
SEm±	0.11	0.14	2.45	0.17
CD at 5%	0.33	0.44	7.34	0.52

Table 3: Effect of different levels of fertigation and foliar spray of nutrients on NPK uptake in French bean

Treatment	Nitrogen uptake (kg ha^{-1})	Phosphorous uptake (kg ha^{-1})	Potassium uptake (kg ha^{-1})
Main plot			
M_1-50% RDF through fertigation	45.21	7.84	66.50
M_2-75% RDF through fertigation	49.00	7.90	73.19
M_3-100% RDF through fertigation	62.08	10.44	86.31
M_4-100 RDF as soil application	47.95	6.74	62.59
SEm±	0.78	0.05	0.82
CD at 5%	2.74	0.17	2.90
Sub plot			
S_1-Foliar spray of humic acid (2%)	49.85	8.08	72.74
S_2-Foliar spray of vegetable special (0.5%)	56.92	8.72	76.37
S_3-Foliar spray of vermiwash (5%)	46.41	7.88	67.33
SEm±	0.47	0.04	0.69
CD at 5%	1.42	0.13	2.09
Interaction			
M_1S_1	44.62	7.55	64.50
M_1S_2	48.74	8.17	72.61
M_1S_3	42.29	7.78	62.37
M_2S_1	49.00	7.67	77.78
M_2S_2	53.40	8.37	77.35
M_2S_3	44.61	7.65	64.43
M_3S_1	61.51	10.17	86.38
M_3S_2	67.69	11.24	90.90
M_3S_3	57.05	9.90	81.66
M_4S_1	44.28	6.91	62.31
M_4S_2	57.87	7.11	64.63
M_4S_3	41.69	6.18	60.84
SEm±	0.94	0.08	1.38
CD at 5%	2.81	0.25	4.14

Conclusion

From the investigation, it can be concluded that the application of 100% RDF through fertigation exhibited higher growth and yield parameters. Thus, drip fertigation helps to improve the plant growth and pod yield of French bean, compared to conventional method of fertilizer application. Foliar spray of 0.5 per cent vegetable special resulted in higher growth and yield parameters. Combined effect of 100 per cent RDF through fertigation and foliar spray of 0.5 per cent vegetable special improved the plant growth and pod yield of French bean, compared to other interactions. From the present research we can concluded that 100 per cent RDF through fertigation and 0.5 per cent foliar spray of vegetable special is suitable for the cultivation of French bean as it provides higher yields.

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