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Agronomic Response of Pole beans (*Phaseolus vulgaris* L.) to Drip Fertigation

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ABSTRACT

Background: Fertigation with water soluble fertilizers, unlike traditional fertilizer application in bulk quantity in few splits, improves quality and quantity of produce in pole beans.

Methods: The experiment was laid out in randomized block design consisting of ten treatments and replicated thrice. The treatments consisted of different levels of nutrient doses applied at varying frequencies through fertigation using water soluble fertilizers compared with soil application of nutrients through traditional fertilizers.

Result: The higher values for yield attributes *viz*; fresh weight of 5 pods (73.05 g), pod length (23.17 cm), pod girth (3.26 cm) and pod yield (34.67 t ha^{-1}) were recorded with application of 100% nutrient dose through fertigation on bi-weekly basis. However, fertilizer use efficiency (179.60 kg kg^{-1}) and benefit cost ratio (1.74) were higher with 75% of the nutrient dose of fertilizer through water soluble fertilizers at bi-weekly intervals.

Key words: Economics, Fertigation, Nutrient use efficiency, Pole beans, Yield.

INTRODUCTION

French bean is an important nutritious vegetable crop widely cultivated in many agro-climatic zones of India. Pole bean is a type of high yielding French bean with indeterminate growth habit that requires staking. As the pole beans fetch high prices in the market, the framers are cultivating this crop extensively in open fields as well as in protected conditions. Being leguminous and medium duration crop it fits well in the cropping system under intensive vegetable production system. The green pods of French bean contain 22% protein, 78% carbohydrate, 221 I.U. vitamin A, 11 mg vitamin C and 381 mg calcium per 100 g of edible portion. India occupied an area of 137.54 (000'ha) with annual production of 1370.21 (000'Mt) and an average productivity of 9.96 t ha^{-1} of French bean. The major French bean growing states are West Bengal, Andhra Pradesh, Jharkhand, Jammu and Kashmir and Himachal Pradesh in India (Kumar, 2022).

Drip irrigation is one of the efficient methods of irrigation having about 90% water application efficiency. Efficient use of water and fertilizer is extremely critical to sustain the agricultural production. The nutrients are applied exactly and uniformly only to the wetted root volume in drip fertigation which increases the application efficiency of the fertilizer (Debbarma and Bhatt, 2022).

Application of fertilizers at appropriate stages of crop growth ensures a regular flow of both water and nutrients. According to Kakade *et al*. (2023) fertigation can enhance the availability of nutrients and their uptake by the plants, if it is done at pre-determined schedule according to the developmental and physiological stage of the crop. However, most of the work on nutrient management in pole beans has been carried out using conventional methods of NPK fertilizer application. Despite the widespread use of high frequency irrigation system and fertigation elsewhere in India, the information on the use of water-soluble fertilizers for fertigation is meager on this crop. Hence, the present study was conducted to study the influence of fertigation, its frequency and the source of nutrients on growth and yield of pole beans.

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MATERIALS AND METHODS

The experiment was conducted at ICAR-Indian Institute of Horticultural Research, Hessarghatta, Bengaluru, Karnataka, India during consecutive *Rabi* seasons of 2020-21 and 2021-22. The institute is situated at 13°7′N latitude, 72°29′E longitude and an elevation of 890 meters above the mean sea level. The experimental soil was well drained red sandy loam (pH 6.35 and electrical conductivity 0.32 dSm^{-1}) characterized by medium organic carbon (0.54%), low available nitrogen (168.5 kg ha^{-1}), high available phosphorus (72.2 kg ha^{-1}) and medium available potassium (240.2 kg ha^{-1}). The soil has available water holding capacity of 130 mm in one-meter soil depth. The experiment was laid out in randomized block design with ten nutrient

treatments and three replications. Farmyard manure @ 25.0 t ha^{-1} was applied as basal dose uniformly to all the treatments as a common practice. The treatment details and quantity of different fertilizers applied are given in Table 1. Sowing was done in the month of November (16.11.2020 and 19.11.2022) at the spacing of 1.2 m × 0.5 m on raised beds. The height and width of the bed was 15.0 cm and 80.0 cm, respectively with a furrow width of 40 cm. The variety used for the experimentation was Arka Sukomal, characterized by yield potential of 24.0 to 26.0 t ha^{-1}. Fertigation treatments started two weeks after planting and the fertilizers were applied through drip system at weekly and bi-weekly intervals. The treatments were imposed by dissolving the desired amounts of fertilizers and applied via venturi system through drip irrigation to the field. A total of 12 and 24 numbers of fertigation were given for weekly and bi-weekly interval treatments, respectively which were continued up to 15 days before completion of crop growth period. Five plants per replication in each of the treatments were selected randomly for recording growth and yield parameters. Recommended package of practices, including agronomic and plant protection measures were adopted to raise the crop (Prabhakar *et al.,* 2010). Fertilizer use efficiency of pole bean was calculated by using the following formula:

$$\text{FUE (kg yield kg-NPK}^{-1}) = \frac{\text{Economic yield (kg ha}^{-1})}{\text{Total NPK applied (kg ha}^{-1})}$$

The experimental data were statistically analyzed (Gomez and Gomez, 1984) and compared using critical difference at five per cent probability level.

RESULTS AND DISCUSSION

Effect of fertigation on growth parameters

The data pertaining to plant growth and leaf parameters at 60 days after sowing (DAS) are presented in Table 2. Bi-weekly application of 100% nutrient dose of NPK (75:100:75 kg ha^{-1}) using water soluble fertilizers through drip fertigation (T_7) has resulted in significantly higher vine length (241.67 cm) than bi-weekly application of 75% nutrient dose, where 50% of N and K given through drip fertigation (T_{10}) in Arka Sukomal at 60 DAS. Soil application of traditional fertilizers (T_1), soil application and drip fertigation with traditional fertilizers (T_2) also recorded higher vine length (226.67 and 229.0 cm) than T_{10} (215.0 cm). Bi-weekly application of 100% nutrient dose of NPK through water soluble fertilizers (T_7) has resulted in significantly higher number of branches $vine^{-1}$ (15.84) than T_1, T_2, T_4, T_5,T_6,T_8 and T_{10} treatments and remained on par with bi-weekly application of 75% nutrient dose with water soluble fertilizers through drip fertigation (13.42) and weekly application of 100% nutrient dose using water soluble fertilizers through drip fertigation (13.84) at 60 days after sowing. The lowest number of branches $vine^{-1}$ were recorded with soil application of traditional fertilizers (10.92). Significantly higher number of leaves $vine^{-1}$ were recorded with T_7 (102.75) at 60 DAS, which remained on par with rest of the treatments except soil application of traditional fertilizers *i.e.* T_1 (76.75) and T_2 *i.e.* application of 100% nutrient dose, where 50% N and K given through drip fertigation using traditional fertilizers (84.25). Dalai *et al.* (2022) also documented similar findings on improved plant height and branches (primary and secondary) in dolichos bean with higher level of nutrient application. Likewise, Ramesh *et al.* (2021) also observed higher plant height and number of branches in French bean with the application of 100% RDF given through fertigation with water soluble fertilizers.

Bi-weekly application of 100% fertilizer dose (75:100:75 kg NPK ha^{-1}) with water soluble fertilizers through drip fertigation (T_7) has resulted in significantly higher leaf area (283.75 cm^2) than soil application of traditional fertilizers (240.55 cm^2), application of 100% nutrient dose where 50% N and K given weekly through drip fertigation using traditional fertilizers (253.38 cm^2) and application of 75%

Table 1: Fertigation treatment details.

Symbol	Application dose	Basal dose and top dressing (kg ha^{-1})			Fertigation (kg ha^{-1})			
		Urea	Single super phosphate	Muriate of potash	Urea	Muriate of potash	Mono ammonium phosphate	Potassium nitrate
T_1	100% soil application	162.7	625.0	125.2	0.0	0.0	0.0	0.0
T_2	50% NK fertigation	81.5	625.0	62.5	81.5	62.5	0.0	0.0
T_3	100% NPK fertigation	0.0	0.0	0.0	74.0	0.0	164.0	167.0
T_4	50% NK fertigation	81.5	625.0	62.5	58.0	0.0	0.0	84.0
T_5	100% NPK fertigation	0.0	0.0	0.0	56.0	0.0	123.0	125.0
T_6	50% NK fertigation	61.0	469.0	61.0	44.0	0.0	0.0	62.0
T_7	100% NPK fertigation	0.0	0.0	0.0	74.0	0.0	164.0	167.0
T_8	50% NK fertigation	81.5	625.0	62.5	58.0	0.0	0.0	84.0
T_9	100% NPK fertigation	0.0	0.0	0.0	56.0	0.0	123.0	125.0
T_{10}	50% NK fertigation	61.0	469.0	61.0	44.0	0.0	0.0	62.0

T_1,T_2,T_3,T_4,T_7,T_8 - 100% fertilizer dose (75:100:75 kg N:P_2O_5:K_2O ha^{-1}), T_5,T_6,T_9 T_{10} -75% fertilizer dose (56.25:75:56.25 kg N:P_2O_5:K_2O ha^{-1}), Treatment 2 to 6 - Weekly and Treatment 7 to 10 - Bi-weekly application.

nutrient dose where 50% N and K given weekly using water soluble fertilizers through drip fertigation (253.20 cm^2) at 60 days after sowing. Improved leaf area could be attributed to better availability of nutrients in soluble form at the root zone of the plant. The growth of plants is propelled by nitrogen and phosphorus as nitrogen is an important constituent of protoplasm, cell nucleus, amino acids and chlorophyll. The large size leaves also receive more sunlight for photosynthesis as compared to smaller leaves. Leaf area responded significantly to different levels of NPK at various growth stages (Dalai *et al.,* 2022). Higher leaf area with higher fertilizer application was also reported by Ramesh *et al.* (2021) in French bean. Significant improvement in growth parameters noticed under higher fertilization dose might be attributed to better utilization of plant nutrients that reflected in luxuriant crop growth owing to enhanced cell division, elongation and differentiation as compared to lower level of fertilizer application. Similar results in dolichos beans have also been confirmed by Dalai *et al.* (2022). Improved plant height, number of branches per plant, dry matter weight per plant at 60 days after sowing might be due to enhanced photosynthesis, leaf area and translocation of nutrients to the reproductive parts as compared to conventional method of fertilizer application in few splits through traditional fertilizers. Manikandan *et al.* (2015) also reported the beneficial effect of higher levels of N, P and K fertigation on growth and yield attributes of pigeon pea.

Effect of fertigation on yield attributing characters, yield and fertilizer use efficiency

In case of yield attributing characters like fresh weight of 5 pods, bi-weekly application of 100% nutrient dose of NPK (75:100:75 kg ha^{-1}) (T_7) through water soluble fertilizers has resulted in significantly higher pod weight (73.05 g) than other treatments except weekly application of 75% nutrient dose of NPK through water soluble fertilizers (63.42 g), bi-weekly application of 75% nutrient dose of NPK through water soluble fertilizers (64.58 g) and weekly application of 100% nutrient dose using water soluble fertilizers through drip fertigation (66.23 g). Soil application of traditional fertilizers (T_1) recorded the minimum fresh pod weight (55.33 g). Bi-weekly application of 100% nutrient dose of NPK using water soluble fertilizer through drip fertigation (T_7) has resulted in significantly higher pod length (23.17 cm) than T_1 (21.05 cm), T_2 (21.79 cm), T_4 (21.85 cm), T_6 (21.81 cm) and T_{10} (21.82 cm). Treatment T_7 maintained its superiority in terms of pod girth (3.26 cm) than rest of the treatments except bi-weekly application of 75% nutrient dose of NPK through water soluble fertilizers (3.19 cm) and weekly application of 100% nutrient dose using water soluble fertilizers through drip fertigation (3.20 cm). Soil application of nutrients through traditional fertilizers (T_1) recorded the minimum pod girth (2.28 cm) followed by application of 100% nutrient dose where 50% N and K given weekly through drip fertigation using traditional fertilizers (2.41 cm). Improved yield attributes like pod length, pod girth and fresh pods weight with 100% RDF through fertigation could be attributed to adequate and available supply of nutrients through fertigation in the root vicinity of plant coupled with optimum nutrient concentration in the root zone throughout the crop growth period (Udaykumar *et al.,* 2019).

With respect to yield, bi-weekly application of 100% nutrient dose of NPK using water soluble fertilizers through drip fertigation (T_7) recorded significantly higher pod yield (34.67 t ha^{-1}) than soil application of traditional fertilizers - T_1 (28.82 t ha^{-1}), soil application and fertigation with traditional fertilizers - T_2 (30.60 t ha^{-1}) and 75% of nutrient dose where 50% N and K given using water soluble fertilizers - T_6 (30.54 t ha^{-1}). The next best treatment with respect to yield was recorded with weekly application of 100% nutrient dose of NPK (T_3) through water soluble fertilizers (34.03 t ha^{-1}). All the fertigation treatments recorded higher yields to the tune of 6.17 to 20.3 per cent over soil application of

Table 2: Effect of fertigation treatments on growth characters at 60 days after sowing, yield attributing characters and yield at harvest (pooled of 2 years).

Treatment	Vine length (cm)	No. of branches $vine^{-1}$	No. of leaves $vine^{-1}$	Leaf area (cm^2)	Fresh wt. of 5 pods (g)	Pod length (cm)	Pod girth (cm)	Yield (t ha^{-1})	FUE (kg kg^{-1})
T_1	226.67	10.92	76.75	240.55	55.33	21.05	2.28	28.82	115.28
T_2	229.00	11.84	84.25	253.38	59.50	21.79	2.41	30.60	122.40
T_3	240.00	13.84	99.00	278.83	66.23	23.13	3.20	34.03	136.12
T_4	232.50	12.58	91.91	263.00	61.78	21.85	2.99	32.15	128.60
T_5	234.83	13.33	95.34	270.01	63.42	22.40	3.01	33.33	177.76
T_6	230.84	12.00	88.92	253.20	59.83	21.81	2.54	30.54	162.88
T_7	241.67	15.84	102.75	283.75	73.05	23.17	3.26	34.67	138.68
T_8	234.58	12.92	94.50	269.20	62.60	22.21	3.05	31.96	127.84
T_9	240.00	13.42	96.67	272.29	64.58	22.52	3.19	33.68	179.62
T_{10}	215.00	12.50	89.67	255.70	60.51	21.82	2.85	31.67	168.90
SE (m)	5.21	0.85	5.44	9.73	3.35	0.44	0.07	0.99	
CD (p=0.05)	15.06	2.45	15.73	28.12	9.69	1.27	0.20	2.98	

Table 3: Economics of pole beans as influenced by fertigation.

Treatments	Pod yield (t ha^{-1})	Gross income (₹ ha^{-1})	Cost of cultivation (₹ ha^{-1})	Net income (₹ ha^{-1})	B:C
T_1	28.82	432300	173660	258640	1.49
T_2	30.60	459000	173660	285340	1.64
T_3	34.03	510450	190360	320090	1.68
T_4	32.15	482250	178780	303470	1.70
T_5	33.33	499950	183900	316050	1.72
T_6	30.54	458100	175580	282520	1.61
T_7	34.67	520050	190360	329690	1.73
T_8	31.96	479400	178780	300620	1.68
T_9	33.68	505200	183900	321300	1.74
T_{10}	31.67	475050	175580	299470	1.71

traditional fertilizers. Significantly higher pod yield with higher fertilizer dose was due to improved growth parameters and yield attributes. Due to better utilization of NPK, which enhanced photosynthetic activity, accumulation and translocation of assimilates from source to sink.These results are corroborated with the findings of Palankar and Malabasari (2014) in cluster bean and Udaykumar *et al.* (2019) in French bean. Unlike conventional fertilizer application, fertigation ensures precise application of nutrient solution in the root zone which improves the nutrient uptake and facilitates better translocation of photosynthates from source to sink (Saileela *et al.,* 2017). The fertilizer use efficiency ranged between 122.40 to 179.62 kg kg^{-1} across the different fertigation treatments (Table 2). Though bi-weekly application of 100% nutrient dose using water soluble fertilizers through drip fertigation (T_7) recorded the highest yield (34.67 t/ha), but the fertilizer use efficiency was higher (179.62 and 177.76 kg kg^{-1}) in the treatments consisting of 75 % of nutrient dose applied through fertigation at bi-weekly and weekly intervals. The minimum fertilizer use efficiency was recorded in soil application of traditional fertilizers (115.28 kg kg^{-1}). Khedkar *et al.* (2018) also documented higher fertilizer use efficiency at 75% of the recommended dose of NPK through fertigation than 100% recommended NPK fertigation in green chilli and green pea. Liquid as well as water soluble fertilizers used in drip fertigation ensures 80-90% use efficiency, which leads to higher crop yields in vegetables (Sandal and Kapoor, 2015).

Effect of fertigation on net income and B:C ratio

Economic feasibility of the fertilizer practices should be an essential element of studies aimed at improved crop productivity (Shahid *et al.,* 2015). The average data pertaining to economic returns and B:C ratio of pole bean cv. Arka Sukomal is given in Table 3. The data revealed that fertigation treatments with water soluble fertilizers recorded higher gross income than soil application (T_1) and fertigation with traditional fertilizers (T_2) except T_6, where 50% NK was applied through drip fertigation and only 75% of the nutrient dose was given. Among the fertigation treatments, application of 100% nutrient dose using water soluble fertilizer through drip fertigation on bi-weekly basis (T_7) resulted in highest gross income (₹ 520050 ha^{-1}) followed by T_3 (₹ 510450 ha^{-1}). Treatment T_7 maintained its superiority and recorded highest net returns (₹ 329690 ha^{-1}). Soil application of traditional fertilizer (T_1) resulted in minimum net income of ₹ 258640 ha^{-1}. Irrespective of dosage and frequency, fertigation with water soluble fertilizers resulted in higher B:C ratio (1.61 to 1.75) compared to soil application of traditional fertilizers (1.49). The highest B:C ratio of 1.74 was accrued with bi-weekly application of 75% nutrient dose given through water soluble fertilizers (T_9), which was closely followed by the treatment consisting of 100% nutrient dose given bi-weekly using water soluble fertilizers through drip fertigation. Very marginal difference in yield, coupled with less cost of cultivation resulted in higher B:C ratio in application of 75% fertilizer dose given bi-weekly through water soluble fertilizers (T_9) than application of 100% fertilizer dose given bi-weekly with water soluble fertilizers through drip fertigation (T_7). Kapoor *et al.* (2014) observed that fertigation through water soluble fertilizers resulted in significant improvement in yield of cauliflower and gross returns, but higher price of water-soluble fertilizers in comparison to conventional fertilizers reduced the net return and B:C ratio. Similarly, Kumar *et al.* (2017) also reported higher marketable yields in capsicum with drip fertigation over non-fertigated treatment, whereas reverse trend was observed in B:C ratio owing to higher cost of water-soluble fertilizers in comparison to conventional fertilizers.

CONCLUSION

The emanating results of the present investigation, reveals that the application of water soluble fertilizers @ 75:100:75 kg N: P_2O_5: K_2O ha^{-1} during the crop period through fertigation at bi-weekly interval resulted in higher yield (34.67 t ha^{-1}), gross income (₹ 520050 ha^{-1}), net income (₹ 329690 ha^{-1}) and B:C ratio (1.73) in *rabi* grown pole beans in red sandy loam soil of Eastern dry zone of Karnataka.

Conflict of interest

The authors declare that they have no conflict of interest.

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