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Effect of fertigation, mulching and micronutrients on the soil and leaf nutrient contents of pole bean (*Phaseolus vulgaris* L.) under polyhouse

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Abstract
An experiment was conducted during *kharif* 2017-18 to study the effect of fertigation on the soil and leaf nutrient contents of pole bean (*Phaseolus vulgaris* L.) under naturally ventilated polyhouse at Zonal Agricultural and Horticultural Research Station (ZAHRS), Navile, Shivamogga. The experiment consisted of 12 treatments and three replications were laid out in randomized block design. As there is no standard recommended dose of fertilizers for pole bean under fertigation, the recommended fertilizer dosage for French bean (63:100:75 N, P_2O_5, K_2O kg/ha) was taken as the basis. The study revealed that, highest soil pH (7.24) and EC (0.13 dSm^{-1}) was found in the treatment (T_{12}) with fertigation at 70 per cent recommended dose of fertilizers (44.1:70:53 N, P_2O_5, K_2O kg/ha) along with the mulching and foliar application of micronutrients (0.5 %) and the highest available soil N (470.93 kg ha^{-1}), P (463.83 kg ha^{-1}) and K (292.63 kg ha^{-1}) was found in the treatment T_1 with fertigation at 100 per cent recommended dose of fertilizers (63:100:75 N, P_2O_5, K_2O kg/ha). It was also observed that the treatment T_{12} registered the highest leaf nutrient status like, nitrogen (0.86 %), potassium (0.2 %), iron (386 ppm), manganese (230 ppm), zinc (79.87 ppm), and copper content (13.88 ppm). Whereas, the leaf phosphorus (0.65 %) content was found highest in the treatment (T_{11}) with 80 per cent recommended dose of fertilizers (50.40:80:60 N, P_2O_5, K_2O kg/ha) as water soluble fertilizer combination with mulching and micronutrients spray (0.5 %).

Keywords: French bean, fertigation, protected cultivation

1. Introduction
Pole bean (*Phaseolus vulgaris* L.) is one of the most widely grown nutritious vegetable crop of India. Native to Central and South America, belongs to the family Leguminosae with the chromosome number 2n=22. It can be consumed as tender pods, shelled beans, dry beans, frozen, canned, whole or cut. It is a rich source of crude protein (21.25 %), fat (1.7 %) and carbohydrates (70 %). Besides, it also contains 0.16 mg iron, 1.76 mg calcium and 3.43 mg zinc per 100 g of edible part (Kaur and Mehta, 1994). Balanced nutrition is one of the most important factors to achieve higher productivity in pole bean. Further, the optimum levels at which the nutrients are to be applied and sources from which they have derived are equally important. The growth, yield and quality of the crop are largely influenced by the fertility status of the soil. It is estimated that losses of water and applied nutrients under conventional methods are more than 30 to 40 per cent. So, there is a need for proper fertigation management in order to ensure maximum crop productivity (Rajaraman and Pugalendhi, 2013) [12].
The adoption of fertigation has shown favorable results in terms of yield, fertilizer use efficiency, water use efficiency and quality of the produce. Plastic mulch which is often used in conjunction with drip fertigation, minimizes the evaporation loss from the soil surface, thus conserve and utilizes moisture for higher transpiration, improves yield and water use efficiency (Agele *et al*., 2002) [1]. Foliar nutrition usually penetrates the cuticle of the leaf or stomata, enter the cells rapidly and fulfil the nutrient demand of the growing plant and thus ameliorate nutrient deficiencies (Devi and Shanthi, 2013) [5]. Thus, with the foliar application of micronutrients along with judicious use of nutrients through fertigation will not only enhance productivity but also increase the total production and the efficiency of fertilizers without adversely disturbing the soil health.
With this context, this research will closely monitor the soil and leaf nutrient content of the pole bean under different doses of fertigation, mulching along with foliar application of

micronutrients. The availability of nutrients in the soil is essential for optimum growth and yield. Thus, this study will help to standardize the application of nutrients and reduce the possible wastage of applied nutrients, thereby improve the potentiality of the plant and nutrient use efficiency (Sureshkumar, 2000) [15]. Therefore, soil and leaf analysis serve as an elegant tool for understanding the growth and physiology of plants at various phases of their growth.

Material and Methods

The present investigation was carried out during *Kharif* 2017-18, at Zonal Agricultural and Horticultural Research Station (ZAHRS), Navile, Shivamogga, Karnataka. The experiment consisted of 12 treatments, three replications in randomized block design under naturally ventilated polyhouse. As there is no standard recommended dose of fertilizers for pole bean under fertigation, recommended fertilizer (RDF) of French bean (63:100:75 N, P_2O_5, K_2O kg/ ha) was considered as the basis for this research. Accordingly, treatments were fixed with different fertigation levels (100 %, 80 % and 70 % of RDF), along with mulching (40µ, LDPE) and micronutrient mixture *i.e*., vegetable special (Zn- 4.5 %, B- 1 %, Fe- 2.1 %, Cu- 0.10 % and Mn- 0.85 %) released from Indian Institute of Horticultural Research (IIHR), Bengaluru and it was sprayed as per the treatments at 0.5 per cent concentration. Pole bean variety NZ was sown at a spacing of 60 cm x 45 cm. Fertigation and micronutrient sprays were started three days after sowing and was given at fortnightly intervals up to grand growth period. Fertilizers were applied in the form of urea, 19:19:19, Mono Ammonium Phosphate (MAP) and Muriate of Potash (MOP).

The soil samples (collected from 0-30 cm depth, dried, ground to pass through 2 mm sieve) taken before sowing and after final harvest were chemically analyzed for pH, electrical conductivity and soil nutrient status (Available NPK) by using standard methods *viz*., pH (pH meter, Jackson, 1958) [8], EC (EC bridge, Jackson, 1958) [8], available N (Alkaline permanganate method suggested by Subbiah and Asija, 1956) [14], P_2O_5 (Bray and Kurtz method suggested by Bray and Kurtz, 1947) and K_2O (Neutral normal ammonium acetate extract using flame photometer suggested by Jackson, 1958) [8]. From the samples collected before the experiment, soil nutrient status analysed was pH (6.56), EC (0.037 dSm^{-1}), available N (376.32 kg/ha), available P (360.46 kg/ha) and available K (226.98 kg/ha).

To know the effect of fertigation on leaf nutrient status, the leaf samples from the top and middle portion of the plant at peak vegetative stage or grand growth stage were collected, dried (at 65^0 C ± 5^0 C until constant weight), ground and passed through a 40 mesh sieve and further leaf samples were analysed by employing standard methods of estimation *viz*., leaf nitrogen (Micro-kjeldahl method), phosphorous (Vandomolybdo phosphoric yellow color method) and potassium (Flame photometry method) as suggested by Jackson, 1958 [8]. Leaf manganese, iron, zinc and copper contents were analyzed by employing atomic absorption spectrophotometric method suggested by Lindsay and Norvell, 1978 [10]. The data was subjected to statistical analysis by adopting Fisher's method of analysis of variance as outlined by Gomez and Gomez (1984) [7].

Results and Discussion

Soil nutrient status

The soil pH and EC observed after final harvest (Table 1) was significantly influenced by the fertigation, mulching and foliar spray of micronutrients. Treatment T_{12} [70 % RDF + Micronutrient mixture (0.5 %) + Mulching] recorded highest value for pH (7.24) and EC of the soil (0.13 dSm^{-1}) as compared to the value of pH 6.56 and EC of 0.037 dSm^{-1} recorded before the experiment respectively. Least soil pH (6.64) and EC (0.07 dSm^{-1}) was noticed in the treatment T_1 and T_2 respectively. Even with the lower rate *i.e*., 70 per cent of RDF when applied through drip irrigation, a consistent increase in pH and EC was observed and significantly lower pH and EC was found in the treatments with only fertigation levels without mulching and micronutrient spray (T_1). Wien *et al*. (1993) [17] reported that increase in the nitrogen rate markedly decreased soil pH value while higher the rate of phosphorus and potassium did not affect the soil pH and EC value. Similar results were also reported by Bryla *et al*. (2010) [4].

The availability of nutrients in the soil is essential for optimum growth and yield of the crop. This will help to standardize the application of nutrients and reduce the possible wastage of applied nutrients, thereby improve the potentiality of the plant and nutrient use efficiency. To assess the availability of various nutrients in the soil, analysis of nutrients was made before and after the crop. The available soil nutrient content after final harvest was influenced by different levels of fertigation, mulching and foliar application of micronutrients (Table 1). Fertilizer levels significantly influenced the nutrient content in the soil. The highest available soil nitrogen (470.93 kg/ha) and available soil phosphorus (463 kg/ha) was observed in the treatment T_1 (100 % RDF) and least value for available soil nitrogen (360.53 kg ha^{-1}) and soil phosphorous (382 kg/ha) was found in the treatment T_{12}. The treatment T_1 and T_2 recorded higher available soil potassium content of 292.63 kg/ha and 292.00 kg/ha and least value for available soil potassium content of 202.57 kg/ha was recorded in the treatment T_{12}.

With the lower rate *i.e*., 70 per cent of RDF when applied through drip irrigation in conjunction with mulching and micronutrients spray, a consistent decrease in the soil nutrient content was observed. It was observed that when the combination of treatments like fertigation, mulching and micronutrients was considered together, there was a significant influence on soil nutrient content and found to have better uptake of nutrients from the soil and clearly demonstrates that fertigation can be helpful to minimize the fertilizer application in the soil by 30 per cent without any significant detrimental effect.

Leaf nutrient status

The data presented in Table 2 revealed that the treatment which received fertigation with mulching and micronutrients spray had significantly influenced the leaf nutrient content at grand growth. From the present study, it was found that leaf NPK and micronutrient content was increased by fertigation through water-soluble fertilizers along with mulching and micronutrients spray. This was due to the fertigation technique which provides consistent moisture regimes in the soil due to which roots remain active throughout the season resulting in the optimum availability of nutrients (Fontes *et al*., 2000) [6]. The higher nutrient content of N, P, K, Zn, Fe and B in leaves indicates the critical stage of the crop as nutrients are required for metabolic activity and onward translocation of food materials to the developing fruits.

Nitrogen is an important constituent of amino acids, proteins, enzymes, nucleic acids and chlorophyll content. In the present investigation, treatment (T_{12}) with fertigation of 70 per cent recommended dose of water-soluble fertilizers along with mulching and micronutrients spray led to higher nitrogen content in leaves (0.86 %) and the lowest (0.59 %) was recorded in the treatment T_3. However, even with the lower rate *i.e*., 70 per cent level of RDF when applied through drip irrigation in conjunction with mulching and micronutrients spray, a consistent increase in the soil nitrogen content and better uptake by plants was observed (Table 2). The time trend of N content indicated an increase up to flowering, this situation was attributed to efficient utilization of N by the developing sink. Similar findings were also reported by Umamaheswarappa *et al*. (2005) [16].

Phosphorus plays a key role in the plant's energy transfer system. In the present study, highest value (0.65 %) for leaf phosphorus content was found in the treatment T_{11} and the least value for leaf phosphorous content of 0.32 per cent was recorded in the treatment T_2. This could be attributed to the optimum availability of P might have helped in better root proliferation, leading to the formation of more feeder roots and better uptake of available nutrients. This finding was in accordance with Balasubramanian (2008) [2].

Potassium, being a protoplasmic factor is an essential plant nutrient. Many enzymes are activated by potassium and also involved in photooxidative phosphorylation, thus augmenting the energy required for the growth. The potassium content in leaf exhibited similar pattern as that of nitrogen and phosphorus. Treatment T_{12} (0.20 %) and T_{11} (0.20 %) exhibited highest leaf potassium content and lowest leaf potassium content (0.06 %) was recorded by T_2 (Table 2). The transformation reactions that took place would have led to greater availability of potassium in the soil and consequently resulted in better utilization by the plants. Water soluble fertilizers might have activated the physiological processes for the rapid absorption and utilization of the nutrients for the primary metabolic process. Similar findings were reported by Singh *et al*. (1995) [13] and the. Fontes *et al*. (2000) [6] also opined that, application of N and K in combination with irrigation increased the yield by way of maximizing the mobility of the nutrients around the root zone.

Micronutrients are involved in all metabolic and cellular functions of the crop. Therefore, most of the micronutrients are highly essential for normal plant growth and development. Pole bean as observed in the present study, very well responded to the application of micronutrients through foliar application and fertigation with 70 per cent recommended dose fertilizers along with mulching and micronutrients (T_{12}) led to higher zinc (79.87 ppm), iron (386.33 ppm), manganese (230 ppm) and copper (13.88 ppm) content in leaves. The supply of micronutrients in adequate amounts and in proper proportions is one of the factors which control the growth of the plants (Table 2).

Conclusion

Treatments with different levels of fertigation, mulching and foliar application with micronutrients when considered together, had marked considerable effect on soil and leaf nutrient content of the pole bean. Fertigation with water-soluble fertilizers at 70 per cent RDF with mulching (40µ, LDPE) and micronutrient spray [IIHR vegetable special (0.5 %)] recorded the highest values for soil pH, EC and leaf nutrient content. Whereas, treatment T_1 (63:100:75 N, P_2O_5, K_2O kg/h (100 % RDF) recorded highest for available soil NPK status when compared to treatments with 80 per cent and 100 per cent fertigation levels with and without mulching and micronutrients spray.

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Table 1: Effect of fertigation, mulching and micronutrients on soil parameters after the experiment

Treatments	pH	EC (dSm^{-1})	N (kg/ ha)	P (kg/ ha)	K (kg/ ha)
T_1	6.64	0.08	470.93	463.83	292.63
T_2	6.67	0.07	470.13	462.33	292.00
T_3	6.59	0.09	465.20	452.67	284.47
T_4	7.18	0.12	431.70	452.40	280.77
T_5	7.15	0.12	442.27	451.10	280.13
T_6	7.19	0.12	422.73	444.40	278.87
T_7	7.16	0.10	361.30	453.67	278.20
T_8	7.11	0.09	364.30	452.87	270.60
T_9	7.13	0.11	364.07	451.10	266.57
T_{10}	7.23	0.12	367.73	447.77	246.43
T_{11}	7.19	0.10	365.73	442.77	209.30
T_{12}	7.24	0.13	360.53	382.00	202.30
S. Em ±	0.09	0.01	8.54	9.79	9.20
C. D @5%	0.27	0.03	25.05	28.72	26.98

Treatment details are furnished below,
T_1 - 63:100:75 N, P_2O_5, K_2O kg/ha (100 % RDF)
T_2 - 50.40:80:60 N, P_2O_5, K_2O kg/ha (80 % RDF)
T_3 - 44.1:70:53 N, P_2O_5, K_2O kg/ha (70 % RDF)
T_4 - 63:100:75 N, P_2O_5, K_2O kg/ha (100 % RDF) + Micronutrient mixture (0.5 %)
T_5 - 50.40:80:60 N, P_2O_5, K_2O kg/ha (80 % RDF) + Micronutrient mixture (0.5 %)
T_6 - 44.1:70:53 N, P_2O_5, K_2O kg/ha (70 % RDF) + Micronutrient mixture (0.5 %)
T_7 - 63:100:75 N, P_2O_5, K_2O kg/ha (100 % RDF) + Mulching
T_8 - 50.40:80:60 N, P_2O_5, K_2O kg/ha (80 % RDF) + Mulching
T_9 - 44.1:70:53 N, P_2O_5, K_2O kg/ha (70 % RDF) + Mulching
T_{10} - 63:100:75 N, P_2O_5, K_2O kg/ha (100 % RDF) + Micronutrient mixture (0.5 %) + Mulching
T_{11} - 50.40:80:60 N, P_2O_5, K_2O kg/ha (80 % RDF) + Micronutrient mixture (0.5 %) + Mulching
T_{12} - 44.1:70:53 N, P_2O_5, K_2O kg/ha (70 % RDF) + Micronutrient mixture (0.5 %) + Mulching

Table 2: Effect of fertigation, mulching and micronutrients on leaf nutrient content of pole bean at grand growth stage

Treatments	N (%)	P (%)	K (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
T_1	0.65	0.45	0.13	284.50	142.97	66.93	10.66
T_2	0.61	0.32	0.06	283.00	145.40	63.47	10.85
T_3	0.59	0.40	0.10	285.40	162.43	66.67	10.11
T_4	0.81	0.48	0.12	351.43	219.87	74.90	11.04
T_5	0.78	0.45	0.11	352.40	212.00	73.87	10.72
T_6	0.82	0.49	0.12	356.37	218.70	74.70	11.94
T_7	0.82	0.42	0.16	295.17	166.40	66.02	11.84
T_8	0.77	0.40	0.15	289.60	163.77	67.87	11.33
T_9	0.66	0.50	0.16	285.03	167.97	67.27	11.20
T_{10}	0.83	0.64	0.19	384.53	227.07	78.40	13.79
T_{11}	0.85	0.65	0.20	380.99	225.23	78.10	11.14
T_{12}	0.86	0.62	0.20	386.33	230.00	79.87	13.88
S. Em ±	0.03	0.05	0.01	8.50	6.11	1.72	0.47
C. D @5%	0.10	0.14	0.03	24.94	17.91	5.04	1.37

Treatment details are furnished below,

T_1 - 63:100:75 N, P_2O_5, K_2O kg/ha (100 % RDF)
T_2 - 50.40:80:60 N, P_2O_5, K_2O kg/ha (80 % RDF)
T_3 - 44.1:70:53 N, P_2O_5, K_2O kg/ha (70 % RDF)
T_4 - 63:100:75 N, P_2O_5, K_2O kg/ha (100 % RDF) + Micronutrient mixture (0.5 %)
T_5 - 50.40:80:60 N, P_2O_5, K_2O kg/ha (80 % RDF) + Micronutrient mixture (0.5 %)
T_6 - 44.1:70:53 N, P_2O_5, K_2O kg/ha (70 % RDF) + Micronutrient mixture (0.5 %)
T_7 - 63:100:75 N, P_2O_5, K_2O kg/ha (100 % RDF) + Mulching
T_8 - 50.40:80:60 N, P_2O_5, K_2O kg/ha (80 % RDF) + Mulching
T_9 - 44.1:70:53 N, P_2O_5, K_2O kg/ha (70 % RDF) + Mulching
T_{10} - 63:100:75 N, P_2O_5, K_2O kg/ha (100 % RDF) + Micronutrient mixture (0.5 %) + Mulching
T_{11} - 50.40:80:60 N, P_2O_5, K_2O kg/ha (80 % RDF) + Micronutrient mixture (0.5 %) + Mulching
T_{12} - 44.1:70:53 N, P_2O_5, K_2O kg/ha (70 % RDF) + Micronutrient mixture (0.5 %) + Mulching

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