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Effect of Spacing and Nutrition on Soil Nutrient Status and Uptake of Broccoli (*Brassica oleracea* var. *italica*)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field study was conducted to investigate the influence of spacing and nutrition on soil nutrient status and Uptake of Broccoli and the investigation was titled "Effect of spacing and nutrition on soil nutrient status and uptake of Broccoli." The experiment consists of 3 limits of spacing i.e., S1 (45x30 cm), S2 (45x45 cm), S3 (60x45 cm) and 3 limits of nutrient i.e., N_1 (100 percent recommended dose of nutrients), N_2 (75 percent recommended dose of nutrients), N_3 (125 percent recommended dose of nutrients). It was designed in FRCBD includes nine treatment combinations

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with three replications. The analysed experimental data showed that the available nutrient in the soil and nutrient uptake by the plant after harvesting of Broccoli. Increasing the spacing and nutrient levels enhances the soil N, P and K availability and absorbed by the broccoli after harvesting. The maximum availability of N (296.57kg ha^{-1}), P (116.54kg ha^{-1}) and K (72.85kg ha^{-1}) in the soil was found in the S3. The higher availability of N (275.20kg ha^{-1}), P (104.88kg ha^{-1}) and K (71.37kg ha^{-1}) in the soil was shown in the fertilizer limit N3. The higher N (160.16kg ha^{-1}), P (127.13kg ha^{-1}) and K uptake (65.83kg ha^{-1}) by the Broccoli was reported in the wider level of spacing S3. The maximum N (158.09kg ha^{-1}), P (127.94kg ha^{-1}) and K uptake (65.84kg ha^{-1}) by Broccoli was observed in the nutrient level of N_3.

Keywords: Broccoli; nutrient availability; nutrient uptake; spacing; recommended dose of fertilizer; nitrogen; phosphorus; potassium and FRCBD.

1. INTRODUCTION

Broccoli (*Brassica oleracea* var. *italica*) is an herbaceous annual or biennial planted for its edible flower heads that are consumed as vegetable. The broccoli plant has a tall green stalk or stem that produces thick, leathery, rectangular leaves that range in colour from grey-blue to green. The plant produces huge spreading green flower heads that are covered with white or yellow blooms [1-3]. Plants have fibrous and shallow root systems. The fruit is a silique that dehisces when mature to reveal brown or black seeds that are tiny and spherical in shape. Broccoli contains the most carotenoids of any brassica vegetable [4-6]. It is particularly high in lutein and contains a small quantity of beta-carotene. large amounts of inorganic fertilizers are used on vegetables to increase production, maximize growth potential and excessive uptake by the plants [7]. However, using inorganic fertilizers excessively could have negative effects for both the environment and human health. As a result, inorganic fertilizer is regarded as a major source of plant nutrients and it should be used in sufficient quantities. Spacing also one of the important factor for quality of Broccoli production [8-12]. Wider spacing between plants occurs less population per hectare and lesser spacing between plants occurs more number of plants per hectare, more competition among plants for nutrients, air, sunlight and soil moisture [13-15]. The purpose of this study was to see how different levels of nutrients and spacing affected soil nutrient status and Broccoli nutrient uptake.

2. MATERIALS AND METHODS

A field experiment was completed in the years 2021–22 at the Department of Horticulture at the University of Agricultural Science, GKVK, Bengaluru. Table 1 displays the soil nutrient content after harvesting broccoli as well as the nutrients that the broccoli absorbed. The experimental field was ploughed and has three levels of spacing's, 45 cm x 30 cm, 45 cm x 45 cm, and 60 cm x 45 cm, as well as three levels of nutrients, 120: 80: 60 Kg NPK ha -1 (100 percent recommended dose of nutrients), 90: 60: 45 Kg NPK ha^{-1} (75 percent recommended dose of nutrients), and 150: 100: 75 Kg NPK ha^{-1} (125percent recommended dose of nutrients). The availability of Nitrogen, Phosphorus and Potassium in the soil after Broccoli harvesting and Nitrogen, Phosphorus and Potassium uptake by the Broccoli are the parameters being measured for each of the five tagged plants from each treatment. After the broccoli was harvested, soil samples were taken from the field up to a depth of 15cm from each treatment. After being collected, soil samples were dried in the open air, crushed, put through a 2 mm screen and then put in poly bags for chemical analysis. Table 1 presents the results of the analysis of the available nutrient content. Five tagged broccoli plants from each plot were picked for their above-ground components, which were subsequently 65°C oven dried. The dried samples were ground into a powder with a mortar and pestle, sieved through a 1 mm filtering device and the nutrient uptake was examined and displayed in Table 1.

2.1 Soil Collection and Analysis

The soil samples up to depth of 15 cm were taken from field after harvesting of the crop, soil samples were collected from each treatment. After collection of soil samples were air dried, crushed, passed through 2mm sieve and stored in poly bags for chemical analysis. Available nutrient content was analyzed.

2.2 Plant Sample Collection and Analysis

Above ground parts of five tagged broccoli plants from each plot was harvested and then oven dried at 65°C. The dried samples were powdered

and sieved in 1mm mesh and nutrient uptake was analyzed.

3. RESULTS AND DISCUSSION

3.1 Soil Nutrient Status after Harvesting of Broccoli

Available N (kg ha^{-1}): The impact of different spacing levels, nutrients and their interactions on the level of available nitrogen in the soil after crop harvest is shown in Table 1.

Impact of spacing: Table 1 includes the results. Different levels of spacing had a substantial impact on the amount of nitrogen that was available in the soil after crop harvest. After broccoli harvesting, the soil maximum available nitrogen content was found at S_3, while the soil minimum available nitrogen content was noticed at S_1. The maximum available nitrogen content was reported to be 296.57 kg ha^{-1} and the minimum available nitrogen content was found to be 258 kg ha^{-1}.

Impact of nutrient: Table 1 includes the results. The influence of different fertilizer levels on the accessible nitrogen in the soil after broccoli harvest was shown significant. After broccoli was harvested, the soil available nitrogen content ranged from 275.20kg ha^{-1} to 267.42kg ha^{-1} with N_3 (125percent recommended dose of nutrients) having the highest and N_2 (75percent recommended dose of nutrients) having the lowest values. Similar studies were carried out by Rauniyar and Bhattarai [16] and Naresh et al [17].

Combined impact of spacing and nutrient: After broccoli was harvested, the combination impact of spacing and nutrient on the available nitrogen in the soil was found to be non-significant. The results are shown in Table 1. The S_3N_3 treatment had the highest available nitrogen content in the soil (302.45 kg ha^{-1}) and the S_2N_2 treatment had the lowest available nitrogen content (253.07 kg ha^{-1}).

Available P (kg ha^{-1}): After crop harvest, Table 1 shows the influence of various spacing levels, nutrients and combination impact on available phosphorus in the soil.

Impact of spacing: The findings are displayed in Table 1 and they indicate the significant impact of various spacing levels on available phosphorus in the soil after crop harvest. The maximum available phosphorus content in the soil after harvest of broccoli (116.54kg ha^{-1}) was discovered in the S_3, while the minimum available phosphorus content in the soil after harvest of broccoli (89.18kg ha^{-1}) was discovered in the S_1.

Impact of nutrient: Table 1 presents the results. The influence of different nutrient levels on available phosphorus in the soil after broccoli harvest was shown significant. The nutrient level of N_3 (125percent recommended dose of nutrients) had the highest available phosphorus content in the soil after broccoli harvest (104.88kg ha^{-1}), whereas the nutrient level of N_2 had the lowest available phosphorus content in the soil after broccoli harvest (93.70kg ha^{-1}). A similar investigation was conducted by Rauniyar and Bhattarai [16].

Combined impact of spacing and nutrient: After broccoli was harvested, the combined impact of spacing and nutrient on available phosphorus in the soil was found to be non-significant. The outcomes are displayed in Table 1. S_3N_3 had the highest reported available P level in the soil after broccoli harvest (126.14 kg ha^{-1}) and S_1N_2 had the lowest (85 kg ha^{-1}).

Available K (kg ha^{-1}): The impact of varying limits of spacing, nutrients and their combined impact on obtainable potassium content in the soil after crop harvest is provided in Table 1.

Impact of spacing: The effect of various spacing limits on accessible potassium content in the soil after broccoli harvesting was found to be significant and Table 1 presents the outcomes. The spacing level of S_3 had the highest available potassium content in the soil after harvest of broccoli (72.85kg ha^{-1}), whereas the spacing level of S_1 had the minimum available potassium content in the soil after harvest of broccoli (63.16kg ha^{-1}).

Impact of nutrient: The impact of various nutrients limits on potassium availability in the soil after broccoli harvest was found to be significant, as stated in Table 1. The nutrient level of N_3 displayed the maximum available potassium content in the soil after harvest of broccoli (72.85kg ha^{-1}), while the nutrient level of N_2 revealed the lowest available potassium content in the soil after harvest of broccoli (62.32kg ha^{-1}). A comparable study was done by Naresh et al. [17].

Table 1. Effect of various levels of spacing, nutrient and their interaction on available NPK after harvesting and Nutrient uptake by Broccoli

Treatment	Available nutrients in the soil after harvest			Nutrients uptake by the plant (kg/ha)		
	Available Nitrogen (kg ha^{1})	Available Phosphorus (kg ha^{1})	Available Potassium (kg ha^{1})	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)
Spacing (S)						
S1	258.00	89.18	63.16	139.63	122.25	62.65
S2	259.06	91.26	64.96	154.85	125.63	64.57
S3	296.57	116.54	72.85	160.16	127.13	65.83
F-test	*	*	*	*	*	*
S.E m±	1.08	1.20	1.14	3.59	1.01	0.35
CD (5%)	3.23	3.58	3.41	10.77	3.03	1.03
Nutrient (N)						
N1	271.01	98.39	67.27	154.38	124.18	64.35
N2	267.42	93.70	62.32	142.17	122.89	62.86
N3	275.20	104.88	71.37	158.09	127.94	65.84
F-test	*	*	*	*	*	*
S.E m±	1.08	1.20	1.14	3.59	1.01	0.35
CD (5%)	3.23	3.58	3.41	10.77	3.03	1.03
Interaction (SXN)						
S1N1	258.16	89.67	63.63	140.59	120.77	62.57
S1N2	256.38	85.00	59.17	127.00	120.62	61.18
S1N3	259.48	92.87	66.67	151.31	125.36	64.19
S2N1	260.44	92.25	65.86	161.13	126.78	64.81
S2N2	253.07	85.89	59.49	149.31	123.25	63.60
S2N3	263.66	95.64	69.53	154.11	126.85	65.31
S3N1	294.45	113.26	72.33	161.42	125.01	65.68
S3N2	292.80	110.21	68.30	150.22	124.78	63.79
S3N3	302.45	126.14	77.92	168.85	131.59	68.01
F-test	NS	NS	NS	NS	NS	NS
S.E m±	1.86	2.07	1.97	6.22	1.75	0.60
CD (5%)	5.59	6.21	5.91	18.65	5.25	1.79

NOTE: The application of FYM 20 tonnes per hectare was common for all the treatments.
NS = non-significant * = significant
S1- 45cmx30cm N1- 120:80:60Kg NPK/ha (100% RDF)
S2- 45cmx45cm N2- 90:60:45Kg NPK/ha (75% RDF)
S3-60cmx45cm N3- 150:100:75Kg NPK/ha (125% RDF)

Combined impact of spacing and nutrient: In Table 1, the outcomes are shown. The combined impact of various limits of spacing and nutrition on the available of potassium that is accessible in the soil after broccoli has been harvested is shown to be non-significant. The S_3N_3 soil showed the highest available potassium level in the soil after broccoli harvest (77.92 kg ha^{-1}), whereas the S_1N_2 exhibited the lowest available phosphorus content (59.17 kg ha^{-1}).

3.2 Nutrients Uptake by the Plant

Nitrogen uptake by the plant: Table 1 demonstrated the influence of different spacing limits, nutrients and combinations on Nitrogen uptake by the Broccoli.

Impact of spacing: The results of the investigation, which showed the significant impact of different spacing limits on Nitrogen uptake by the Broccoli, is displayed in Table 1. The spacing level S_3 (60 cm x 45 cm) noticed the broccoli's highest nitrogen uptake of 160.16 kg ha^{-1} while the spacing level S_1 (45 cm x 30 cm) showed the broccoli lowest nitrogen uptake of 139.63 kg ha^{-1}. A comparable study was done by Choudhari and More [18].

Impact of nutrient: The effect of varied nutritional levels on nitrogen uptake by broccoli was significant, as shown in Table 1. The highest nitrogen uptake by broccoli (158.09kg ha^{-1}) was shown in the nutrient limit of N_3, whereas the lowest nitrogen uptake by broccoli (142.17kg ha^{-1}) was noticed in the nutrient limit of N_2.

Combined impact of spacing and nutrient: The Combined impact of different limits of spacing and nutrients on nitrogen uptake by the broccoli was found non-significant and data is displayed in the Table 1. The maximum nitrogen uptake by the broccoli (168.85kg ha^{-1}) was found in the S_3N_3 treatment and the minimum nitrogen uptake by the broccoli (127.00kg ha^{-1}) was observed in the S_1N_2.

Results indicate that the wider level of spacing S_3 was recorded maximum nitrogen uptake by the broccoli as compared to the lower spacing level i.e. S_2 and S_1 and also increased the level of spacing favoured nitrogen uptake in broccoli.

The application of higher levels of nutrients N_3 was recorded higher nitrogen content in the broccoli as compared to the lower level of nutrient i.e., N_1 and N_2 and this was due to the application of higher level of nutrient favoured in the higher nitrogen uptake in the broccoli.

Phosphorus uptake by the plant: The influence of different limits of spacing, nutrients and their combinations on Phosphorus uptake by broccoli is provided in Table 1.

Impact of spacing: The impact of varied spacing limits on phosphorus uptake by broccoli was found to be substantial, as indicated in Table 1. The broccoli received the highest phosphorus (127.13 kg ha^{-1}) at the S_3, while lower phosphorus (122.25 kg ha^{-1}) was absorbed at the S_1. A comparable study was done by Choudhari and More [18].

Impact of nutrient: The influence of different nutrient limits on phosphorus uptake by broccoli was found to be substantial, as shown in Table 1. When nutrients were at a level of N_3, broccoli absorbed highest amounts of phosphorus (127.94 kg ha^{-1}), while nutrients at a level of N_2 absorbed the least (122.89 kg ha^{-1}). A similar investigation was conducted by Chaitanya et al. [19].

Combined impact of spacing and nutrient: The interaction impact of various limits of spacing and nutrients on phosphorus uptake by the broccoli was non-significant and the results are displayed in Table 1. The maximum phosphorus uptake by the broccoli (131.59kg ha^{-1}) was observed in the S_3N_3 and the minimum phosphorus uptake by the broccoli (120.62kg ha^{-1}) was noticed in the S_1N_2.

The broccoli absorbed the maximum phosphorus at the wider spacing of S_3 than at the smaller levels of S_1. This might be because phosphorus uptake increases with increased levels of spacing and nutrient availability in the root zone is better.

The application of higher levels of nutrient N_3 was found to favour higher phosphorus uptake in the broccoli and the uptake of phosphorus increased with increasing the percentage level of nutrient. This was compared to the lower level of nutrients N_1 and N_2 which were used in the experiment.

Potassium uptake by the plant: Table 1 exhibit the influence of different spacing limits, nutrients and combined effect on the uptake of potassium by Broccoli.

Impact of spacing: The influence of different limits of spacing on potassium uptake by broccoli was found to be substantial and the results are provided in Table 1. The broccoli showed the maximum potassium uptake (65.83kg ha^{-1}) in the spacing of S_3, while the broccoli showed the lowest potassium uptake (62.65kg ha^{-1}) in the spacing of S_1.

Impact of nutrient: The data is shown in Table 1, which shows the significant impact that different nutrient levels found on the potassium uptake by broccoli. The highest potassium uptake by broccoli was recorded at a nutrient level of N_3 and lowest potassium uptake by broccoli was discovered at a level of N_2 (65.84kg ha^{-1}). A similar investigation was carried out by Chaitanya et al. [19].

Combined impact of spacing and nutrient: The combined impact of varying limits of spacing and nutrients on potassium uptake by the broccoli was non-significant and the data is shown in Table 1. The highest potassium uptake by the broccoli (68.01kg ha^{-1}) was found in the S_3N_3 and the lowest potassium uptake by the broccoli (61.18kg ha^{-1}) was revealed in the S_1N_2.

The broccoli was shown to absorbed potassium at a higher rate at the wider spacing of S_3 than at the lesser limits of spacing S_1 and S_2. This may be because increased spacing results in higher potassium uptake, which improves nutrient availability in the root zone.

The application of maximum levels of nutrition N_3 resulted in higher potassium uptake by broccoli when compared to lower levels of nutrient, i.e., N_1 and N_2, and this was attributed to increased level of nutrient with enhanced potassium uptake in broccoli from vegetative to harvesting stage.

4. CONCLUSION

The current study revealed that the influence of spacing and nutrition on soil nutrient status and uptake of Broccoli was significant. The application of 125 percent recommended dose of nutrients with a spacing of S_3 resulted in best nutrient availability in the soil after broccoli harvesting and maximum nutrient uptake by broccoli.

5. FUTURE SCOPE

- The investigation should be repeated to confirm the findings.
- In the future, different nutrient levels and spacing levels may be tested.
- In the future, repeat the experiment in other districts of Karnataka.

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