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Effect of spacing and nutrient on growth of broccoli (*Brassica oleracea* var. *italica*) under open field condition

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Abstract
During the *Rabi* season 2021–2022, studies were conducted at sanjeevini vatika, Department of Horticulture, College of Agriculture, GKVK, Bengaluru (KARNATAKA), to determine the effects of various spacing levels and nutrient levels on the growth parameters of broccoli (*Brassica oleracea* var. *italica*). Plant height (38.12cm), leaf area (5439.35cm^2), chlorophyll content (77.29), number of leaves per plant (18.26), plant spread for north to south (86.22cm) and plant spread for east to west direction (85.21cm), were found to be significantly maximum in 60×45cm spacing level. Among different levels of Nutrients, N3 (125% RDF) was recorded highest in plant height (37.65cm), number of leaves per plant (18.51), leaf area (5394.94cm^2), chlorophyll content (79.06), plant spread for north to south (84.82 cm) and plant spread for east to west (84.75cm), was recorded in the spacing level of 60cmx45cm and also nutrient level of N3 (125% RDF).

Keywords: Broccoli, nutrients, spacing and growth parameters

Introduction
Broccoli is a member of the 'Brassicaceae' botanical family, also known as the 'Mustard family with chromosome number 2n = 18. A number of economically significant species in the family provide a significant portion of the world's winter vegetables. Broccoli is a high-quality fresh vegetable that is also one of the most popular frozen vegetables, nutrient-dense crop that contains a high concentration of vitamins (A and C) minerals (K, P, Ca and Fe) and it is also rich in thiamine, riboflavin and niacin (Roni *et al*, 2014) [7]. Broccoli has the highest protein content of than any Cole crop (. There are two kinds of broccoli: headed broccoli and sprouting broccoli (green and purple). Heading broccoli, like cauliflower, produces curd, whereas sprouting broccoli produces a head of green immature buds and a thick fleshy flower stalk.

It is grown primarily in Himachal Pradesh, Uttarakhand, Uttar Pradesh, Jammu and Kashmir, the Nilgiri Hills (Tamil Nadu) and India's northern plains. Plant spacing influences plant growth, development and yield significantly (Amare and Gebremedhin, 2020) [1]. Closer spacing causes intercultural operations to decline, resulting in increased competition for nutrients, air and light among the plants, whereas wider spacing produces larger plants with more vigorous growth and higher quality produce (Sing *et al*, 2012) [9]. Due to the nutrient requirements of broccoli, nutrient application should be determined by soil nutrient tests. The main nutrients for plants that are important for their growth and development are nitrogen, phosphorus and potassium. In order to improve nutrient utilization efficiency, nutrient application methods and dosage both matter. A nutrient management strategy should include split nutrient applications, which divide total nutrient applications into multiple doses based on crop demand. This technique increases nutrient utilization, encourages ideal yields and lowers losses.

Therefore, the objective of the experiment was. The effect of spacing and nutrition on growth of broccoli.

Material and Methods
During the *Rabi* season 2021-2022, a field experiment was conducted in the Sanjeevini Vatika block of the Department of Horticulture at the University of Agricultural Sciences, Bangalore. The Factorial Randomized Complete Block Design (FRCBD) was used to plan and lay out the

three different spacing's, S1 (45x30cm), S2 (45x45cm) and S3 (60x45cm), as well as the three levels of nutrients, N1 (120: 80: 60 Kg NPK/ha (100 percent RDF)), N2 (90: 60: 45 Kg NPK/ha (75 percent RDF)) and N3 (150:100:75Kg NPK/ha (125% RDF)). The land was repeatedly ploughed and harrowed to a fine tilth. After clearing the land, the layout was carried out in accordance with the treatments and seedlings that were thirty days old and had grown uniformly were used for transplanting. The different spacing and nutrient levels were combined when transplanting. After the transplants were made, a light irrigation was given. The transplanting was done in the evening. To grow a successful crop, we adhered to the rest of the recommended agronomic practices and packages.

Data collection

Five tagged plants were chosen from each treatment and the results are being recorded for the following growth parameters: Plant height (cm), leaf area (cm^2), number of leaves per plant, chlorophyll content and plant spread (cm).

Growth parameters

Plant height (cm)

Plant height was recorded at 60 days after transplanting. Height of five tagged plants was recorded from the base level to tip of the leaf with the help of meter scale and average was calculated.

Number of leaves per plant

The numbers of leaves of five tagged plants were counted from each plot at 60 days after transplanting and the average number of leaves per plant was calculated.

Leaf area (cm^2)

The five tagged plants were used for leaf area measurement. Leaf area of individual tagged plant was recorded from each plot by leaf area meter at 60 days of transplanting and average leaf area in cm^2 was recorded as mean value.

Chlorophyll content (SPAD value)

SPAD value in leaves of five tagged plants were estimated from each plot with using chlorophyll meter (SPAD) by simple clamping the device over the leaf tissue at 60 days after transplanting.

Plant spread (cm)

The plant spread of five tagged plants from each plot were recorded at 60 days after planting from North to South and East to West by using meter scale and the average calculated and expressed in cm.

Data Analysis

Data was collected and subjected to analysis of variance and significant means using XLSTAT software, then they were separated using least significant difference (LSD) at 5% level of probability

Results and Discussion

The effect of spacing and nutrition on growth of broccoli

Growth parameters

Plant height (cm)

The effects of various levels of spacing, nutrients and their interaction of spacing and nutrient on plant height at 60 days after planting is presented in Table 1.

Effect of Spacing

At 60 days after planting significantly highest plant height of 38.12cm was found in the spacing level of S3 (60cmx45cm), whereas lowest plant height of 35.18cm was observed in the spacing level of S1 (45 cm x30 cm).

Effect of Nutrient

At 60 days after planting significantly higher plant height of 37.65cm was revealed in the nutrient level of N3 (125% RDF), while lowest plant height of 35.80cm was observed in the nutrient level of N2 (75% RDF).

Interaction effect of spacing and nutrient

The interaction effect of various spacing and nutrient levels on plant height at 60 days after planting in broccoli was showed non-significant. The highest plant height was reported in S3N3 (39.15cm) and lowest plant height was recorded in the S1N2 (34.42cm).

From the recorded data, the plant height of broccoli at 60 days after planting was significantly increased with increase in spacing levels. Similar kind of results was reported by Solunke *et al.* (2011) [10] in Broccoli and Kaur *et al.* (2021) [3] in Broccoli. Among various levels of fertilizer application, N3 (125% RDF) was produced maximum plant height at 60 days after planting, this might be due to greater amount of nutrient available to the plant in the nutrient level of N3 (125% RDF). A comparable study was done by Haque *et al.* (2015) [2] in Cabbage and Prasad *et al.* (2009) [6] in Chinese cabbage.

Number of leaves per plant

The effect of various levels of spacing, nutrients and their interaction on number of leaves per plant at 60 days after planting is presented in Table 1.

Effect of spacing

At 60 days after planting significantly maximum number of leaves per plant of 18.26 was recorded in the spacing level of S3 (60cmx45cm), while significantly minimum number of leaves per plant of 17.27 was reported in the spacing level of S1 (45cmx30cm).

Effect of Nutrient

At 60 days after planting significantly higher number of leaves per plant (18.51) was reported in the nutrient level of N3 (125% RDF), while significantly lowest number of leaves per plant of 17.26 was revealed in the nutrient level of N2 (75% RDF).

Interaction effect of spacing and nutrient

The combined effect of different levels of spacing and nutrient on number of leaves per plant at 60 days after planting exhibited non-significant. The highest number of leaves per plant of 19.26 was recorded in the S3N3, while lowest number of leaves per plant of 16.93 was recorded in the S1N2.

Among various levels of spacing, wider spacing of S3 (60cmx45cm) was produced highest number of leaves per plant in all stages of plant development. A comparable study was done by Thirupal *et al.* (2014) [11] in Broccoli. With respect to nutrient levels, the higher percentage of nutrient level *i.e.*, N3 (125% RDF) was produced maximum number of leaves per plant, this may be due the availability of nutrients in N3.

Chlorophyll content (SPAD - values)
The effect of various limits of spacing, nutrient and their interaction on chlorophyll content at 60 days after planting is presented in the Table 1.

Effect of spacing
The effect of various limits of spacing was showed significant at 60 days after planting. At 60 days after planting highest chlorophyll content (77.29) was observed in the spacing of S3 (60cmx45cm), whereas lowest chlorophyll content (74.13) was found in the spacing of S1 (45cmx30cm).

Effect of nutrient
The impact of different levels of nutrient on chlorophyll content in broccoli at 60days after planting was showed significant. At 60 days after planting maximum chlorophyll content of 79.06 was recorded in the nutrient level of N3 (125% RDF), while minimum chlorophyll content of 72.56 was revealed in the nutrient level of N2 (75% RDF).

Interaction effect of spacing and nutrient
The combined effect of spacing and nutrient was showed non-significant. The highest chlorophyll content of 80.62 was reported in the treatment S3N3 and the lowest chlorophyll content of 68.66 was found in the S1N2.
From the observations, the wider spacing at S3 (60cmx45cm) was recorded highest chlorophyll content. This observation indicated that the chlorophyll content per plant increased with increased in levels of spacing. A comparable result was noted by Thirupal *et al*. (2014) [11] in Broccoli. The recorded data indicate that the application of higher levels of nutrient exerted significant influence on chlorophyll content. The maximum chlorophyll content was found in the nutrient level of N3 (125% RDF). These results indicated that the chlorophyll content increased with increased levels of nutrient.

Plant spread (cm)
The effect of various levels of spacing, nutrients and their interaction on plant spread for East-West and North-South of broccoli at 60 days after planting was recorded and results are presented in Table 1.

Effect of spacing
The impact of various levels of spacing on plant spread for north to south of broccoli at 60 days after planting was shown significant. The maximum plant spread of broccoli for north to south (86.22cm) was recorded in the spacing level of S3 (60cmx45cm) and minimum plant spread of broccoli for north to south (83.54cm) was found in the spacing level of S1 (45cmx30cm) and the effect of various levels of spacing on plant spread for east to west direction of broccoli at 60 days after planting was found significant. The higher plant spread of broccoli for east to west direction (85.21cm) was found in the spacing level of S3 (60cmx45cm) and the lowest plant spread of broccoli from east to west direction (82.70cm) was observed in the spacing level of S1 (45cmx30cm).

Effect of nutrient
The effect of various levels of nutrient on plant spread for north to south of broccoli at 60 days after planting was found significant. The highest plant spread of broccoli for north to south (84.82cm) was found in the nutrient level of F3 (125% RDF) and lowest plant spread of broccoli for north to south direction (83.29cm) was reported in the nutrient level of F2 (75% RDF) and the impact of different limits of nutrient on plant spread for east to west of broccoli at 60 days after planting was recorded significant. The maximum plant spread of broccoli for east to west (84.75cm) was observed in the nutrient level of F3 (125% RDF) and minimum plant spread of broccoli for east to west direction (83.21cm) was recorded in the nutrient level of F2 (75% RDF).

Interaction effect of spacing and nutrient
The interaction effect of various levels of spacing and nutrient on plant spread for north to south and east to west of broccoli at 60 days after planting shown non-significant. The highest plant spread for north to south (87.03cm) was recorded in the treatment S3N3 and lowest plant spread for north to south (83cm) was found in the S1N2 treatment. The highest plant spread of broccoli for east to west (86.18cm) was reported in the S3N3, whereas minimum plant spread of broccoli for east to west (82.27cm) was observed in the S1N2.
Among various levels of spacing, the wider level spacing of S3 (60cmx45cm) was showed maximum plant spread for north to south and east to west. The similar results were reported by Kumar *et al*. (2021) [4] in Broccoli and Thirupal *et al*. (2014) [11] in Broccoli. From the above observations, the higher nutrient level of N3 (125% RDF) was revealed higher plant spread of broccoli for east to west and north to south. Similar findings have also been reported by Mohanta *et al*. (2018) [5] in Broccoli and Singh *et al*. (2015) [8] in Broccoli.

Leaf area (cm^2)
The effect of different levels of spacing, nutrient and their interaction on leaf area at 60 days after planting is presented in Table 1.

Effect of spacing
At 60 days after planting significantly highest leaf area (5439.35cm^2) was observed in the spacing level of S3 (60cmx45cm), while significantly lowest leaf area of 5172.59cm^2 was found in the spacing level of S1 (45cmx30cm).

Effect of nutrient
At 60 days after planting significantly maximum leaf area (5394.94cm^2) was found in the nutrient level of N3 (125% RDF), while significantly lowest number of leaves per plant of 5228.16cm^2 was recorded in the nutrient level of N2 (75% RDF).

Interaction effect of spacing and nutrient
The interaction effect of various levels of spacing and nutrient showed non-significant. The highest leaf area (5550.7cm^2) was recorded in the S3N3 and lowest leaf area (5117.067cm^2) was observed in the treatment S1N2.
Among of various levels of spacing, the wider spacing of S3 (60cmx45cm) was recorded highest leaf area (5439.35cm^2**)**, this may be due to better availability of spacing, air, soil moisture, nutrient, sunlight, less number of plants per plot and less competition among plants. Similar results recorded were by Solunke *et al*. (2011) [10] in Broccoli. Among various levels of nutrient, N3 (125% RDF) recorded maximum leaf area per plant, this might be due the application of greater doses of nutrient level increases the leaf width, leaf length and

leaf area, so nutrient level of N3 (125% RDF) observed highest leaf area per plant. These findings are very similar to those of Prasad *et al*. (2009) [6] in Chinese cabbage.

Table 1: Effect of various levels of spacing, nutrition and their interaction on plant height, number of leaves per plant, chlorophyll content, plant spread (N to S), plant spared (E to W) and Leaf area

Treatment	Plant Height (cm)	Number of leaves per plant	Chlorophyll content	Plant spread (cm) (N to S)	Plant spread (cm) (E to W)	Leaf area (cm^2)
	60^{th} day	60^{th} day	60^{th} day	60^{th} day	60^{th} day	60^{th} day
Spacing (S)						
S1	35.18	17.27	74.13	83.54	82.70	5172.59
S2	36.90	17.86	76.40	85.26	84.18	5328.13
S3	38.12	18.26	77.29	86.22	85.21	5439.35
F-test	*	*	*	*	*	*
S.E m±	0.19	0.24	0.81	0.21	0.25	20.27
CD (5%)	0.58	0.71	2.42	0.63	0.76	60.78
Nutrient (N)						
N1	36.72	17.61	76.21	85.11	84.13	5316.97
N2	35.83	17.61	72.56	84.17	83.21	5228.16
N3	37.65	18.51	79.06	85.75	84.75	5394.94
F-test	*	*	*	*	*	*
S.E m±	0.19	0.24	0.81	0.21	0.25	20.27
CD (5%)	0.58	0.71	2.42	0.63	0.76	60.78
Interaction (SXN)						
S1N1	35.33	17.06	75.86	83.67	82.93	5183.60
S1N2	34.42	16.93	68.66	83.00	82.27	5117.07
S1N3	35.78	17.80	77.86	83.97	82.90	5217.10
S2N1	36.83	17.70	77.64	85.50	84.40	5350.30
S2N2	35.86	17.40	72.84	84.03	82.97	5217.10
S2N3	38.01	18.46	78.71	86.24	85.17	5417.03
S3N1	37.22	18.06	75.10	86.16	85.06	5417.02
S3N2	37.99	17.43	76.15	85.47	84.39	5350.33
S3N3	39.15	19.26	80.62	87.03	86.18	5550.70
F-test	NS	NS	NS	NS	NS	NS
S.E m±	0.33	0.41	1.40	0.36	0.44	35.12
CD (5%)	1.00	1.23	4.19	1.09	1.32	105.28

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)

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