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Shubham Singh
Department of Horticulture, Babasaheb Bhimrao Ambedkar University, Vidya-Vihar, Rae Bareli Road, Lucknow, Uttar Pradesh, India

Sanjay Kumar
Department of Horticulture, Babasaheb Bhimrao Ambedkar University, Vidya-Vihar, Rae Bareli Road, Lucknow, Uttar Pradesh, India

Shatrunjay Yadav
Department of Horticulture, Babasaheb Bhimrao Ambedkar University, Vidya-Vihar, Rae Bareli Road, Lucknow, Uttar Pradesh, India

Sateesh Pratap Singh
Department of Horticulture, Babasaheb Bhimrao Ambedkar University, Vidya-Vihar, Rae Bareli Road, Lucknow, Uttar Pradesh, India

Sandeep Yadav
Department of Vegetable science, G.B Pant University of Agriculture and Technology, Pant Nagar, Uttarakhand, India

Abhilash Singh
Department of Vegetable science, G.B Pant University of Agriculture and Technology, Pant Nagar, Uttarakhand, India

Corresponding Author:
Shubham Singh
Department of Horticulture, Babasaheb Bhimrao Ambedkar University, Vidya-Vihar, Rae Bareli Road, Lucknow, Uttar Pradesh, India

Interaction effect of plant spacing and cultivar on sprouting broccoli

Shubham Singh, Sanjay Kumar, Shatrunjay Yadav, Sateesh Pratap Singh, Sandeep Yadav and Abhilash Singh

Abstract
Wider spacing produces larger and heavier heads, whereas closer spacing produces a higher yield per hectare, according to current field tests. As a result, in order to produce a higher yield with better quality, ideal plant spacing must be optimised. The study evaluated "Interaction effect of different plant spacing on performance of different varieties with respect to growth and yield attributes of sprouting broccoli (*Brassica oleracea var.italica* L.) was carried out at three different plant spacing such as S_1 (60 ×45 cm), S_2 (45×45 cm) and S_3 (45×30 cm) on Growth and yield attributes traits of sprouting broccoli (*Brassica oleracea* L var. *italica* Plenck). cvs. Palam Samridhi (V_1), Palam Vichitra (V_2) and Palam Kanchan (V_3).The interaction effect of variety and spacings affected all but Plant height (64.26 cm), Plant canopy spread (64.36 cm) (East-west), number of leaves (16.16), length of leaves (56.59 cm), stem diameter (6.49cm), curd weight (456.61g), curd diameter (15.33 cm), yield per plot (6.23 kg0 and yield (54.36 q/ha) was recorded maximum for the interaction (V_2 S_3) Palam Vichitra (V_2) and S_3 (45×30 cm); while maximum canopy spread (North-south) (55.14 cm) observed at treatment combination V_2 S_2 and leaves width was recorded at interaction V_1 S_1 (35.20 cm). Among different Treatment combination it is concluded that combination cultivar Palam vichitra (V_2) at spacing (45x45 cm) (S_3) was recorded higher plant height, curd weight, curd diameter, yield (Kg/plot), yield (q/ha) and other economic feasible character.

Keywords: Broccoli, interaction effect, growth and yield attributes, plant spacing, varietal performance

Introduction
Broccoli is the member of the Cruciferae family of vegetables is a rich source of sulforaphane, which has proved for its anti-carcinogenic properties. Broccoli (*Brassica oleracea* L. *var. italica* Plenck) is an "Italian word" derived from the Latin word "brachium" meaning an arm or branches (Boswell 1949). Broccoli and cauliflower both have edible inflorescences, and the two crops are extremely similar in this regard. The cauliflower head might be employed as a 'curd' or dome of tissue made up of a mass of proliferating floral meristems, making Broccoli and cauliflower both contain edible inflorescences, and the two crops are very similar. The cauliflower head might be used as a 'curd' or dome of tissue made up of proliferating floral meristems, allowing a practical distinction to be made between the two based on their relative ontogeny at marketable maturity (Gray 1977) [5].

Broccoli in India is commonly grown green sprouting broccoli but now a day with the intensive research has been made by IARI to developed purple color like (Palam vichitra) and yellow color like (Palam Kanchan) has been increasingly grown among Indian grower due to the demand color rich vegetable and increasing awareness about neutral-rich vegetable due to anti- cancer properties. It is used as a salad, half-boiled vegetables, mixed in soup with the juice of other vegetables, and cooked as a single or mixed vegetable with potato from a nutritional standpoint. Broccoli is the most nutrient-dense of all the vegetables, and it can help prevent diseases including prostate, colon, and breast cancer, as well as heart disease, osteoporosis, and high blood pressure. Broccoli has a high level of anti-oxidant activity due to the presence of flavonoids such as kempherol, B-carotene, and ascorbic acid. Over half of the world's population, however, does not benefit from this because they lack specific receptor gene (*GSTMI*) that help retain the compound in the bodies Kirsh *et al*, (2007) [7]. Broccoli contains about, 103 mg calcium, 78 mg phosphorus, 382 mg potassium and per 100 g edible portion. Broccoli is a rich source of vitamins and minerals such as vitamin A (3500 IU/100 gm fresh) and C (137mg/100g fresh), protein (3.3g/100g fresh), carotenoids, fibres, calcium, and folic acid. Glucosinolates generally are the amino acid occur in the plant mostly as the

potassium salt which impart the sensory properties like odour and flavour.

Materials and Methods

The field experimental was conducted at Horticulture Research farm of the Department of Horticulture) at Babasaheb Bhimrao Ambedkar University, (A Central University), Vidya-Vihar, Rae Bareli Road, Lucknow-226025 (U.P.), India during Rabi season of 2017-18 from the mid-October to mid-March. The geographically Lucknow is situated at 26^0 50, N latitude, 80^0 52, E longitude and the altitude of 111 meter above mean sea level (MSL). The topography of the experimental field is plain. The climatic condition, Lucknow has fall under the humid subtropical climate with the average rainfall of about 110cm and relative humidity ranged during these conditions approximately ranging 60-90% depending upon the weather and the climatic factor. The varieties *viz*. Palam Samridhi, Palam Kanchan, Palam Vichitra and also three plant spacing such as 45x30, 45x45, and 60x45 were used for study. The experiment was laid out in factorial Randomized Block design with three replications. The observations were made on plant height (cm), Leaves length (cm), Leaves width (cm), Stem diameter (mm), Curd Diameter, Weight of curd (kg), etc. All the parameters were collected from three randomly selected plants of each treatments. The maximum growth of broccoli plant was obtained with medium spacing and moderate curd size might be due to the fact that the greater spacing of plant stem to have helped the individual plant to help it to put up better growth. Similarly, initial storage of enough food material might be helpful in vigorous growth of plant. The mean data were subjected to statistical analysis using OPSTAT software developed Hisar Agricultural University, Hisar, following the analysis of variance techniques (Panse and Sukhatme, 1985). The whole detailed of experimental layout has been illustrated Table no 1.

Result and Discussion

Interaction effect of spacing and cultivar on Agronomic performance of broccoli.

The interaction effect between different plant spacing and varieties with respect to days taken for germination was found non-significant. The significantly maximum plant height of seedling at the time of transplanting was found with the treatment combination V_1S_2 (25.02 cm) and found to be statistically lowest V_3S_1 (24.48 cm) at 30DAT while 45 DAT maximum plant height recorded V_3S_3 (49.40 cm) while 60 DAT maximum height observed V_2S_3 (64.25 cm) and lowest V_1S_2 (55.23 cm) (Table no-2). These findings are in accordance with the findings of Bhangre *et al*. (2011) [1] and Gurjeet (2016) [6] in broccoli and Moniruzzaman *et al*. (2011) [8] in cabbage.

The maximum plant canopy spread (North- south) direction has been recorded in treatment combination at V_2S_3 (44.07 cm) and lowest V_1S_1 (31.17 cm) at 30 DAT, while at 45 DAT maximum plant canopy recorded V_2S_2 (50.13 cm) and lowest V_3S_1(36.41 cm) and 60 DAT maximum plant canopy observed V_2S_2 (55.14 cm) and lowest V_3S_3 (38.68 cm). These findings are in accordance with the findings of Bhangre *et al*. (2011) [1], Solunke *et al*. (2011) [11] and Vinod *et al*. (2017) [12] in broccoli.

The combined effect of varieties and plant spacing (interaction) was recorded significantly for canopy spread (east-west) direction, the maximum spreading was observed in treatment combination V_2S_1 (37.33 cm), followed by the V_3S_3 (35.68 cm) at 30 DAT, while at 45 DAT data indicate that maximum in V_1S_2 (50.51 cm) and lowest at V_2S_1 (42.45 cm). The data at 60 date indicate maximum canopy was found at V_2S_3 (64.36 cm) and lowest was recorded at V_2S_1 (44.38 cm). The interaction of different varieties of sprouting broccoli and planting spacing on canopy spread (east-west) was found significant among all growth stages.

The effects of plant density on broccoli (*Brassica oleracea L. var. italica Plenck*) commercial characteristics are well determined. However, it is not completely clear how the broccoli plant responds to changes in plant shading as a result of different plant densities. The maximum interaction effect for number of leaves was noticeable at treatment combination V_3S_1 (9.26/plants) and lowest in V_1S_2 (4.36/plants) was recorded 30 DAT, while data at 45 days revealed that maximum V_3S_3 (14.23/plants) and lowest V_2S_1 (9.10/plants) and at 60 days data indicate that the maximum no of leaves found in V_2S_3 (19.20/plants), while lowest V_3S_2 (11.16/plants) was recorded respectively. These findings are in accordance with the findings of Bhangre *et al*. (2011) [1], Solunke *et al*. (2011) [11] and Vinod *et al*. (2017) [12] in broccoli.

The interaction data among varieties and plant spacing should be indicated that maximum leaves was noted at V_2S_2 (33.53 cm) and lowest at V_3S_2 (19.50 cm) was obtained at 30 DAT, while at 45 days data should be indicated that maximum leaves length at V_2S_1 (46.63 cm) and lowest at V_3S_1 (26.50 cm) and at 60 days was found maximum leaves length in V_2S_3 (56.59 cm) and lowest at V_3S_1 (36.60 cm) was recorded respectively during the experimentation.

The combined effect of plant varieties and spacing (interaction Vx S) has been revealed that maximum leaves width reported at V_2S_1 (13.26 cm) and lowest at V_1S_2 (8.70 cm) at 30 DAT, while at 45 days indicated maximum width at V_1S_3 (19.83 cm) and lowest at V_1S_1 (14.30 cm) and at data at 60 days tell us maximum widths was obtained at V_1S_1 (35.36 cm) and lowest at V_2S_3 (22.26 cm) was recorded respectively during our experimentation.

Interaction effect of spacing and cultivar on yield and yield attributes of broccoli.

The interaction effect between different plant spacing and varieties with respect to fresh weight of head and head diameter was found non-significant. In broccoli, spear size is the most essential commercial attribute (Wescott and Callan, 1990) [13], and when yield is represented on an area basis, plant density is the most important factor impacting production (Wien and Wurr, 1997) [14]. The amount of competition between broccoli plants has a significant impact on spear weight, which can be modified to meet the needs of different markets by adjusting plant density. The combined effect of varieties and plant spacing (interaction V x S) for maximum curd weight was observed at treatment combination V_2S_3 (454.61 g) and minimum curd weight reported at treatment combination V_3S_3 (207.90 g). The maximum fresh weight of curd might be due wider plant spacing and also due to genetic makeup of the variety. Peduncle or stem diameter is most significantly important trait; responsible for maximum translocation of photosynthate to sink/ head and give rise bigger size of curd. Hence, keeping of this point stem diameter was also measured by using vernier calliper which revealed the, curd having maximum stem diameter are relatively larger in size than other. The maximum stem diameter was recorded in treatment combination V_2S_3 (6.49

cm) and minimum at treatment V_1S_2 (3.53 cm). Hence, interaction effect between different plant spacing and varieties with respect to head diameter and curd weight was found significant with stem diameter.

The interaction effect of varieties and plant spacing was recorded significant with respect to curd diameter. The maximum curd diameter was observed at treatment combination in V_2S_3 (15.33 cm) and minimum curd size was reported at V_1S_3 as (11.40 cm). The maximum size of curd diameter might be due wider plant spacing and also due to genetic inheriting character of the variety.

The yield kg/plot should be calculated after the harvesting. After perusal of the data it is clear that the yield kg/plot was significantly co-related with the varieties under the different plant spacing. Salter *et al.* (1984) [10] found that yield eventually reaches a plateau as plant density increases, while Chung (1982) [2] and Dufault and Waters (1985) [4] determined that high plant densities reduced spear size and weight rendering the spears unmarketable. High plant density in broccoli has been related to low number of secondary spears, low peduncle diameter, and less incidence of ‘‘hollow stem’’ (Zink and Ankana, 1951; Cutcliffe, 1972) [15]. Light is an important environmental factor affecting crop development and growth in broccoli. The maximum yield per plot (kg/plot) was recorded at treatment combination V_2S_3 (6.23kg/plot) followed by the V_1S_3 (6.04 kg/plot). Minimum yield was recorded in V_2S_1 (4.91 kg/plot) in our study.

The combined effect of varieties and plant spacing revealed statistically significant influence on curd yield q/ha. Among the treatment combination V_2S_3 (254.30 q/ha) followed by the V_3S_2 (235.53 q/ha) and minimum yield was recognised at treatment combination V_1S_3 (121.16 q/ha). Among different combination Palam vichitra at spacing (45x45 cm) was recorded highest yield q/ha.

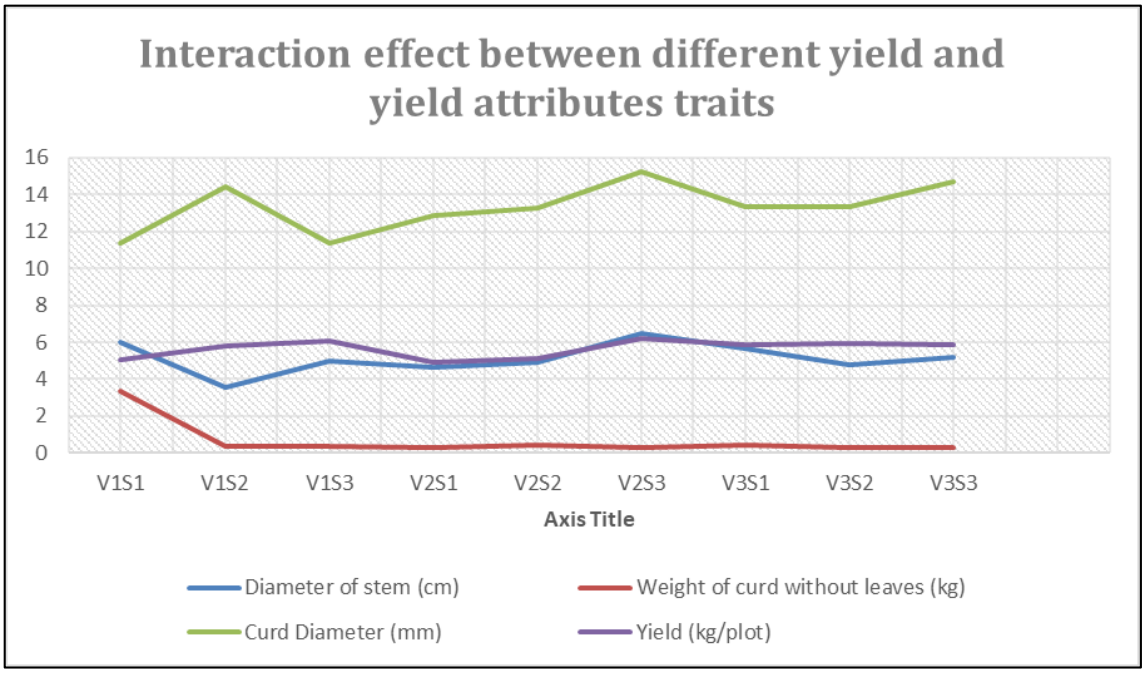

Fig 1: Interaction effect on yield attributes traits in broccoli

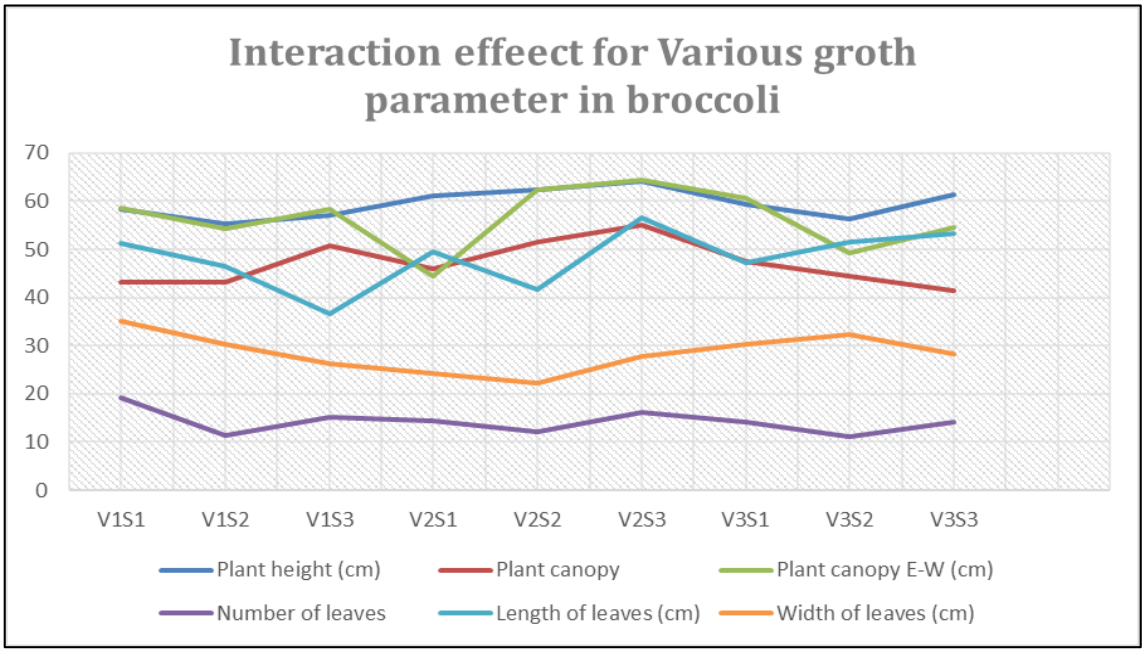

Fig 2: Interaction effect for various Growth parameter in broccoli

Table 1: Details of experiment layout

Treatment	Replication 1st	Replication 2nd	Replication 3rd
T_1	60X45, Palam Samridhi	45x45, Palam vichitra	45x30, Palam kanchan
T_2	60x45, Palam samridhi	45x45, Palam vichitra	45x30, Palam kanchan
T_3	60x45, Palam samridhi	45x45, Palam vichitra	45x30, Palam kanchan
T_4	45x30, Palam kanchan	60x45, Palam samridhi	45x45, Palam vichitra
T_5	45x30, Palam kanchan	60x45, Palam samridhi	45x45, Palam vichitra
T_6	45x30, Palam kanchan	60x45, Palam samridhi	45x45, Palam vichitra
T_7	45x45, Palam vichitra	45x30, Palam kanchan	60x45, Palam samridhi
T_8	45x45, Palam vichitra	45x45, Palam kanchan	60x45, Palam samridhi
T_9	45x45, Palam vichitra	45x45, Palam kanchan	60x45, Palam samridhi

Table 2: Interaction effect of spacing and different varieties on growth and yield of broccoli

Variety x Spacing	Plant height (cm)	Plant canopy N-S (cm)	Plant canopy E-W (cm)	Number of leaves /plant	Diameter of stem	Length of leaves (cm	Width of leaves (cm)	Weight of curd without leaf(g)	Curd Diameter (mm)	Yield (kg/plot)	Yield (Q/ha)
V_1S_1	58.40	43.28	58.53	16.16	6.20	51.26	35.20	336.23	11.40	5.08	205.13
V_1S_2	55.23	50.66	54. 21	11.30	3.53	46.56	30.26	354.27	14.40	5.78	212.69
V_1S_3	57.16	45.92	58.38	15.06	4.99	36.66	26.26	324.26	11.40	6.04	121.16
V_2S_1	61.00	51.62	44.38	14.30	4.62	49.46	24.20	430.35	12.86	4.91	158.40
V_2S_2	62.30	55.14	62.30	12.00	4.94	41.66	22.26	302.70	13.30	5.10	167.13
V_2S_3	64.26	47.65	64.36	19.20	6.49	56.59	27.66	454.61	15.33	6.23	254.30
V_3S_1	59.26	44.37	60.56	14.10	5.90	47.30	30.30	303.40	13.33	5.88	224.20
V_3S_2	56.36	41.36	49.34	11.16	5.64	51.46	32.36	318.23	13.36	5.95	235.33
V_3S_3	61.46	38.68	54.54	14.10	4.79	53.33	28.33	207.90	14.70	5.85	205.16
SE (m)	0.509	0.499	0.239	0.213	0.176	0.151	0.576	0.67	0.511	0.178	0.780
CD @ 5%	1.53	1.509	0.723	0.645	0.537	0.457	1.742	2.04	1.542	0.538	2.359

Conclusion

From the above study, it is concluded that among the different plant spacing and varieties interaction with respect to growth parameters V_2S_3 recorded maximum number of leaves at harvest, plant height, plant spread (E-W & N-S) at 60 DAT, curd diameter, weight of curd, yield (kg/plot) and Yield (q/ha). Hence cultivars Palam vichitra (V_2) is best suited at plant spacing (45x45 cm) (S_3) for higher yield and give more economic return to farmer.

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