International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; 8(11): 991-995
www.biochemjournal.com
Received: 01-08-2024
Accepted: 04-09-2024

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Effect of dates of planting and plant spacing on growth and yield of broccoli (*B. oleracea* (L.) var. *italica*) cv. green magic under Marathwada condition

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DOI: https://doi.org/10.33545/26174693.2024.v8.i11m.2998

Abstract
The field experiment was conducted during autumn-winter (September to January) season of 2023-24 at Department of Horticulture, College of Horticulture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra (431402), India. Treatments comprised of three planting dates viz., D1- 30th September, D2- 15th October, D3- 30th October and three spacing viz., S1- 60 x 45 cm, S2- 60 x 60 cm, S3-60 x 75 cm, were assessed in factorial randomized block design with three replications. The broccoli transplanted on 30th September reported significantly maximum yield of main curd per hectare (11.83 t), yield of lateral curd per hectare (7.67 t), total yield (19.50 t ha^{-1}), while wider spacing S3- 60 x 75 cm showed higher yield components like yield of main curd per hectare (11.61 t), yield of lateral curd per hectare (6.74 t), total yield (18.35 t ha^{-1}), and maximum plant height (68.42) were recorded from a closer spacing of S1- 60 x 45 cm. Treatment combination D1S1 (30th September 2023 with a spacing of 60 cm x 45 cm) recorded maximum plant height (72.72) and yield of main curd per hectare (13.58 t), yield of lateral curd per hectare (8.58), total yield (22.16 t ha^{-1}). Whereas, treatment combination D1S1 (30th September 2023 with a spacing of 60 cm x 45 cm) recorded minimum days required for 50% curd initiation (44.13). D1S3 (30th September 2023 with a spacing of 60 cm x 75 cm recorded highest number of leaves per plant (24.95), stem diameter (47.17), leaf area (702.16) and diameter of main curd (19.09).

Keywords: Broccoli, growth, yield and quality

Introduction
Broccoli (*Brassica oleracea* var *italica* L.) is a member of the Cole group and an exotic vegetable crop in India. In the United States it is sometimes referred to as Heading Broccoli or Winter Broccoli. Cauliflower and broccoli are similar, but broccoli is green. Broccoli is the name for the blooming top of cabbages, derived from an Italian term. Broccoli is a member of the Brassica oleracea species' of Italica cultivar group. It is mostly farmed in India's northern plains, Himachal Pradesh, Jammu & Kashmir, Uttar Pradesh and the Nilgiri Hills. Broccoli curd grows from a tiny flower head, which produces a green curd that swiftly swells into a mass of fruitful flower buds. Broccoli has huge flower heads, usually green but occasionally purple that grow on branches that branch off of a sturdy, edible stalk. The arrangement of these flower heads resembles a tree. The clump of flower heads is surrounded by foliage. The heading variety, closely linked to cauliflower, is the most common form of broccoli that has a large center head. Italian or sprouting broccoli does not develop a large head instead, it produces many florets or small heads. Its edible part consists of young, fully developed flower buds and tender parts of the higher stem. Broccoli is a cool-weather crop that suffers greatly in the intense summer heat. The ideal growing temperature range for it is between 18 °C and 23 °C on average. In India, it is consumed as a fresh vegetable, while it is used both fresh and frozen in the USA and Europe. Any reduction in the anti-cancer properties of broccoli occurs when the vegetable is cooked. Other methods of preparation, like steaming, microwaving, and frying did not significantly alter the chemicals. Broccoli comes in two varieties: heading and sprouting. The majority of broccoli grown in gardens belongs to the heading variety, which shares a large centre head with cauliflower. Italian or sprouting broccoli does not create a solid head instead, it produces a large number of florets or little heads. The colours of the hybrids are white, green, and purple.

Appropriate planting time is one of the important factors for boosting up the production of broccoli. One of the key elements in increasing broccoli yield is choosing the right time to plant. The planting dates of broccoli plants have a major impact on yield and yield- contributing characteristics. With delay in each planting time, the yield fell. Crop yields have a diminishing tendency with delay planting date and are higher when planted earlier (Bianco *et al*., 1996) [3]. Compared to late planted crops, early planted crops had a longer growing season, which produced taller plants with more leaves, a greater leaf size index and a lower percentage of aberrant curds all of which were attributed to a higher curd output. (Gautam *et al*., 1998) [6]. Plant spacing has a major impact on plant development, growth and production. (Amare and Gebremedhin, 2020) [2]. Wider spacing results in larger plants with more vigorous development and greater quality output, whereas closer spacing reduces intercultural activities and increases competition among the plants for nutrients, air and light. (Singh *et al.*, 2012) [19]. Knowing the best planting time and density will assist ensure a decent yield and quality of broccoli. Hence, keeping in view the above facts in mind present investigation was framed to study the "Effect of dates of planting and plant spacing on growth and yield of broccoli (*Brassica oleracea* L. Var. *italica*) cv. Green Magic under Marathwada condition."

Materials and Methods

The field experiment was conducted during autumn-winter (September to January) season of 2023-24 at Department of Horticulture, College of Horticulture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra (431402), India, situated at 409 m above mean sea level. Geographically it is situated between 19° 16' N latitude and 76° 47' E longitude. Treatment combinations of total 09 were comprises of three planting dates *viz*., D1-30th September, D2-15th October, D3-30th October and three spacing *viz*., S1-60 x 45 cm, S2-60 x 60 cm, S3-60 x 75 cm, were assessed in factorial randomized block design with three replications. A basal dose of half of the nitrogen @ 50 kg ha^{-1}, full dose of phosphorous @ 50 kg ha^{-1} and potash @ 50 kg ha^{-1} was applied at the time of land preparation. The remaining dose of nitrogen @ 50 kg ha^{-1} was applied after 30 DAT. Appropriate management practices were adopted to raise the crop. Seeds were sown in nursery and seedlings were hardened before uprooting and transplanted after about 30 days when they were ready. Each plot had an area of 3x3 m2 accommodating 90, 75 and 60 plants. Five plants were selected from each plot and observations were recorded various growth and yield parameters such as plant height, number of leaves per plant, stem diameter, leaf area, days required for 50% curd initiation, diameter of main curd, yield of main per hectare, yield of lateral curd per hectare and total yield. The collected data two subsequent years were pulled and statistically analysed by using OP-STAT.

Results and Discussion

Data on as plant height, number of leaves per plant, stem diameter, leaf area, days required for 50% curd initiation, diameter of main curd, yield of main curd per hectare, yield of lateral curd per hectare and total yield were statistically analysed and the means were presented in Table 01 and Table 02 along with interaction of date of planting and spacing.

Growth Parameters

The plant height significantly reduced from D2 (October 15th) to D3 (October 30th) transplanting, this could have been caused due to conducive climatic conditions existed during the crop period. Similar results were obtained by Sighal *et al.* (2009) [20] and Saikia *et al*. (2010) [17] in broccoli. Among the plant spacing, S1 (60 cm x 45 cm) showed maximum plant height, this might be due to congenial temperature during growth period and more terminal increase in lower spaced plants. Closer spacing can create a micro environment that helps to regulate temperature around the plants. This could be beneficial for heat retention or preventing extreme temperature fluctuations, both of which could promote better growth. When plants are spaced closer together, there may be competition for light and nutrients. As a result, plants often grow taller to compete for light, leading to increased plant height. Additionally, more terminal growth could occur in such conditions as plants try to optimize their vertical growth. Similar findings were reported by Saikia *et al.* (2010) [17] in broccoli. At the stage 90 days after transplanting treatment D1 (September 30th) exhibited the highest number of leaves per plant (22.72). In contrast, treatment D3 (October 30th) recorded the lowest number of leaves per plant, averaging (19.53) leaves. Higher leaf production per broccoli plant at ambient temperature was reported by Saikia *et al*. (2010) [17] in broccoli. Early planting seems to favor the increase in stem diameter whereas, late Planting results in reduced stem diameter, possibly due to adverse conditions such as high temperatures and low humidity. High temperatures and low humidity in late planting might stress the plants, impacting their growth negatively. This is in conformity with the results already obtained. In wider spacing, plants generally have more access to light and nutrients, which can lead to better growth and larger stem diameters. This is because each plant has more space to spread its roots and capture sunlight, reducing competition with neighbouring plants. Consequently, they can allocate more resources to stem development, resulting in a larger stem diameter. Similar results were obtained by Gonzalez (1980) [7] and Bobade (2001) [4] in cabbage and Nieuwhof (1961) [13] and Kelley (2007) [9] in broccoli. Treatment D1 (September 30th) recorded the maximum leaf area (620.27 cm²), while treatment D3 (October 30th) recorded minimum leaf area (486.76 cm²). Decreasing plant growth with decrease in temperature during vegetative growth was reported by Kumar *et al*. (2007) [11] in broccoli and Srivastava *et al*. (2002) [20] in cauliflower. Wider spacing, S3 (60 cm x 75 cm), allows plants to spread out more, which can lead to better growth conditions. With more space, plants have better access to sunlight, air circulation and nutrients, all of which can contribute to a larger leaf area. In contrast, closer spacing might lead to competition for these resources, which can restrict plant growth. The results are similar with the findings of Kumar (1984) [10] and Bobade (2001) [4] in cabbage and Patil *et al.* (2003) [15] in knol-khol. Minimum days (47.51) required for 50% curd initiation were observed in treatment D1 (September 30th). Treatment D3 (October 30th) took maximum days for 50% curd initiation. Treatment D2 (October 15th) took intermediate days for 50% curd initiation, between D1 (September 30th) and D3 (October 30th).Delay in flowering due to late planting was also reported by Thapa *et al*. (2002) [23] in cauliflower, Saikia *et*

al. (2010) [17], EI-Magad and Nooprom *et al*. (2013) [14] in broccoli. The closer spacing of S1 (60 cm x 45 cm) resulted in a significantly shorter time to reach 50% curd initiation compared to the wider spacing of S3 (60 cm x 75 cm). This suggests that closer spacing might be more conducive to quicker curd initiation in broccoli. Wider spacing S3 (60 cm x 75 cm) allows for more light penetration and increased photosynthesis, which can indeed prolong the vegetative phase. Similar results were shown by Saikia *et al*. (2010) [17]. Treatment D1 (September 30th) recorded the largest curd diameter (17.17 mm), while treatment D3 (October 30th) had the smallest diameter (15.64 mm). Lower temperatures during curd initiation and development can promote better curd quality, leading to a larger diameter. In contrast, high temperatures during these stages can stress the plants and adversely affect curd formation. Early and mid planting dates may align better with the cool temperatures needed for optimal curd development. Such influence of temperature on curd quality was also reported by Sighal *et al*. (2009) [20] in broccoli, Ara *et al*. (2009) [1] in cauliflower, Saikia *et al*. (2010) [17], Sermenli *et al*. (2011) [18], Hossain *et al*. (2011) [8], and EI- Magad (2013) [14]. Treatment S3 (60 cm x 75 cm) resulted in the largest diameter (18.01 mm), while treatment S1 (60 cm x 45 cm) recorded the smallest diameter (14.25 mm). In narrower spacing S1 (60 cm x 45 cm), plants compete more intensely for resources, leading to reduced curd quality. Conversely, wider spacing S3 (60 cm x 75 cm) allow for better access to water, nutrients, and sunlight, which promotes superior curd development. This underscores the importance of optimal plant spacing for maximizing crop quality and yield. Similar results were obtained by, Kumar and Rawat (2002) [12] in cabbage, Sighal *et al*. (2009) [20] in broccoli, Ara *et al*. (2009) [1] in cauliflower Saikia *et al*. (2010) [17] and Hossain *et al*. (2011) [8].

Yield Parameters

The plants of D1 (September 30th) planting produced maximum yield (11.83 t ha^{-1}). While the minimum yield (9.34 t ha^{-1}) was observed in D3 (October 30th) planting.The plants of S1 (60 cm x 45 cm) planting produced maximum yield (11.61 t ha^{-1}). While the minimum yield (9.13 t ha^{-1}) was observed in S3 (60 cm x 75 cm). When plants are spaced further apart, they may produce larger individual heads but fewer heads per unit area. In contrast, closer spacing can lead to a higher number of heads per unit area, which can result in a higher total yield even if individual heads are smaller. The beneficial effect of closer spacing towards higher main curd yield ton/ha have also been observed by Kumar and Rawat (2002) [12] in cabbage, Rahman *et al*. (2022) [16] in cauliflower, Dragan *et al*. (2007) [5], in broccoli and Hossain *et al*. (2011) [8]. The highest yield (7.67 t ha^{-1}) was observed for crops planted on (September 30th**)** D1 planting. The lowest yield (5.31 t ha^{-1}) was observed for crops planted on D3 (October 30th**)** D3 planting. This suggests that planting earlier, around the end of September, is optimal for maximizing yield, while delaying planting decreases productivity. The closer spacing of S1 (60 cm x 45 cm) produced a higher yield (6.74 t ha^{-1}) compared to the wider spacing of S3 (60 cm x 75 cm), which resulted in a lower yield (5.79 t ha^{-1}). The beneficial effect of closer spacing towards higher main curd yield ton per ha have also been observed by Kumar and Rawat (2002) [12] in cabbage, Rahman *et al*. (2022) [16] in cauliflower, Dragan *et al*. (2007) [5], in broccoli and Hossain *et al*. (2011) [8]. The maximum yield (19.50 t ha^{-1}) was recorded with the D1 planting date (September 30th), while the minimum yield (14.66 t ha^{-1}) was observed in the D3 planting date (October 30th). The planting arrangement of S1 (60 cm x 45 cm) produced the highest yield (18.35 t ha^{-1}), whereas the arrangement with wider spacing S3 (60 cm x 75 cm) resulted in a lower yield (14.92 t ha^{-1}).

Interaction effects

The maximum main curd yield (13.58 t ha^{-1}) in a treatment combination of September 30th (D1) planting at a closer spacing of S1 (60 cm x 45 cm) (D1S1) might be due to the reason that curd development stage perfectly coincided with the optimum temperature range required for it and also increase in number of plants per unit area. Similar trend was also reported by Hossian *et al*. (2011) [8] in broccoli. Higher yields can be attributed to optimal environmental conditions and efficient use of space. Favorable conditions can enhance vegetative growth and development, while closer spacing allows for more plants to grow in the same area, potentially increasing overall yield. Interaction effects of transplanting dates and spacing on yield were also reported by Saikia *et al*. (2010) [17] and Solunke *et al*. (2011) [21] in broccoli. Maximum yield of lateral curd (8.58 t ha^{-1}) was noticed in treatment combination of closer spacing S1 (60 cm x 45 cm) when transplanted on September 30th (D1S1), but it was statistically at par (7.64 t ha^{-1}) with planting on October 15th (D2) with a spacing of S2 (60 cm x 60 cm) (D1S2). However, minimum yield of lateral curd (4.44 t ha^{-1}) was noticed in treatment combination (D3S3) with transplanting on October 30th (D3) and spacing of S3 (60 cm x 75 cm). Favorable environmental conditions like temperature, moisture and light support the better development of the curd, resulting in healthier plants. By planting more plants per unit area, closer spacing allows for a higher population, which can lead to a greater overall yield despite individual plants possibly being smaller. Interaction effects of transplanting dates and spacing on yield were also reported by Saikia *et al*. (2010) [17] and Solunke *et al*. (2011) [21] in broccoli. Maximum main curd yield (22.16 t ha^{-1}) was noticed in treatment combination D1S1 (30th September 2023 and 60 cm x 45 cm), but it was statistically at par (19.44 t ha^{-1}) with D1S2 (30th September 2023 and 60 cm x 60 cm). However, minimum yield per plot (12.97 t ha^{-1}) was noticed in treatment combination D3S3 (30th October 2023 and 60 cm x 75 cm). Favorable environmental conditions can enhance vegetative growth, which often leads to increased yield. Additionally, closer spacing of plants allows for more efficient use of space, potentially leading to a higher number of plants per unit area, which can also contribute to a greater overall yield. Interaction effects of transplanting dates and spacing on yield were also reported by Saikia *et al*. (2010) [17] and Solunke *et al*. (2011) [21] in broccoli.

Table 1: Growth Parameters of broccoli

Treatments	Plant height (cm)			No. of leaves/plant			Stem diameter	Leaf area
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT		
Date of Planting (D)								
D1	34.94	54.42	67.30	8.73	18.29	22.72	43.64	620.27
D2	33.42	52.01	63.11	8.37	16.43	20.78	39.57	541.96
D3	32.60	47.93	57.27	7.99	15.72	19.53	38.89	486.76
S.E ±	0.797	1.250	1.549	0.204	0.490	0.697	0.972	14.699
C. D. at 5%	NS	3.747	4.642	NS	1.470	2.089	2.914	44.062
Spacing of Planting (S)								
S1	34.18	55.09	68.42	8.32	14.81	19.06	37.54	486.77
S2	33.54	49.69	60.94	8.36	17.09	20.98	41.39	541.52
S3	33.23	48.68	58.33	8.41	18.53	22.98	43.17	620.70
S.E ±	0.797	1.250	1.549	0.204	0.490	0.697	0.972	14.699
C. D. at 5%	NS	3.747	4.642	NS	1.470	2.089	2.914	44.062
Interaction (D × S)								
D1S1	36.09	60.67	72.72	8.61	15.31	19.78	37.85	521.43
D1S2	34.43	51.33	65.09	8.64	19.27	23.42	45.90	637.23
D1S3	34.29	51.27	64.09	8.93	20.30	24.95	47.17	702.16
D2S1	33.31	58.17	70.35	8.36	14.88	19.76	37.84	520.01
D2S2	34.01	49.20	62.12	8.54	16.65	19.80	39.29	495.33
D2S3	32.93	48.67	56.86	8.22	17.76	22.77	41.57	610.53
D3S1	33.12	49.13	62.19	7.99	14.25	17.65	36.94	418.86
D3S2	32.18	48.54	55.59	7.91	15.34	19.71	38.98	492.01
D3S3	32.49	46.10	54.04	8.08	17.56	21.23	40.76	549.41
S.E ±	1.38	2.16	2.68	0.35	0.85	1.21	1.68	25.46
C. D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS

Table 2: Yield Parameters of broccoli

Treatments	Days required to 50% curd initiation	Diameter of main curd	Yield of main curd (t/ha)	Yield of lateral curd (t/ha)	Total yield (t/ha)
Date of Planting (D)					
D1	47.51	17.17	11.83	7.67	19.50
D2	52.54	15.77	9.66	5.49	15.15
D3	54.51	15.64	9.34	5.31	14.66
S.E ±	2.190	0.444	0.174	0.190	0.356
C. D. at 5%	6.566	1.332	0.522	0.571	1.069
Spacing of Planting (S)					
S1	49.17	14.25	11.61	6.74	18.35
S2	51.13	16.34	10.10	5.93	16.03
S3	54.26	18.01	9.13	5.79	14.92
S.E ±	2.190	0.444	0.174	0.190	0.356
C. D. at 5%	6.566	1.332	0.522	0.571	1.069
Interaction (D × S)					
D1S1	44.13	14.80	13.58	8.58	22.16
D1S2	46.75	17.63	11.80	7.64	19.44
D1S3	51.65	19.09	10.11	6.78	16.89
D2S1	49.00	14.03	10.84	5.84	16.68
D2S2	52.94	15.78	9.39	5.23	14.62
D2S3	55.45	17.51	8.74	5.41	14.15
D3S1	53.69	13.91	10.40	5.81	16.21
D3S2	54.37	15.60	9.10	4.93	14.03
D3S3	55.67	17.42	8.53	4.44	12.97
S.E ±	3.79	0.77	0.30	0.33	0.62
C. D. at 5%	NS	NS	0.90	7.67	1.851

Conclusion

The study highlights that early transplanting (September 30th, D1) significantly enhances the growth and yield of broccoli, while late transplanting (October 30th, D3) reduces both. Closer spacing (60 cm x 45 cm, S1) promotes plant height, curd initiation, and yield, although wider spacing (60 cm x 75 cm, S3) supports larger curd diameter due to better access to light and nutrients. The combination of D1S1 (September 30th, 60 cm x 45 cm) resulted in the highest yield, suggesting that early planting and closer spacing optimize conditions for vegetative growth, curd development, and overall yield.

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