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Studies on Effect of Different Plant Spacing with Respect to Growth, Yield and Quality of Broccoli (*Brassica oleracea* var. *italica*. L) under North Gujarat Conditions

T. Tejaswini*, L.R. Varma, P. Verma, D.M. Thakur and F.B. Vani

Department of Vegetable Science, College of Horticulture, SD Agricultural University, Sardarkrushinagar – 385506, Gujarat, India

**Corresponding author*

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A B S T R A C T

The present investigation was carried out at Horticulture Instructional Farm, CP College of Agriculture, SD Agricultural University, Sardarkrushinagar, Gujarat to find out the effect of different plant spacing on growth, yield and quality of broccoli (*Brassica oleracea* var. *italica*. L). Three plant spacings *viz*., S_1 – 30 cm × 30 cm, S_2 – 45 cm × 30 cm and S_3 – 45 cm × 45 cm was analyzed statistically on growth, growth attributes, yield and quality parameters of broccoli and are summarized below. The results revealed that the treatment S_1 (30 cm x 30 cm) attained significantly maximum plant height at transplanting (21.90 cm), at 45 DAT (39.35 cm) and at harvest (57.67 cm), minimum number of days taken for head initiation (61.48) and head harvest (81.37), maximum yield per plot (5.73 kg) and yield per hectare (219.36 q). Whereas significantly maximum plant spread E-W (50.36 cm) & N-S (49.91 cm) at 45 DAT & at harvest E-W (62.15 cm) & N-S (62.12 cm), highest head diameter (14.10 cm), fresh weight of head (275.53 g), total dry matter content of the head (19.81 %), crude protein content (2.91%), potassium content (464.2 mg) and calcium content (42.65 mg) were recorded with the wider plant spacing treatment S_3 (45 cm x 45 cm).

Introduction

Broccoli (*Brassica oleracea* var. *italica* L.) is an important fancy and highly nutritive exotic vegetable. It is a member of cruciferous family having many important vegetables such as Cauliflower, Cabbage, Knol-khol, Brussels sprout, Kale and Chinese cabbage. It is also known as winter broccoli or heading broccoli or Italian broccoli. It is considered to be originated from wild cabbage, *Brassica oleracea* var. *oleracea* (syn. *Brassica oleracea* var. *Sylvestris* L.), which is found growing wild along the Mediterranean Sea. Broccoli is a rich source of sulphoraphane which is associated with reducing the risk of cancer (Guo *et al.*, 2001). The primary inflorescence was characterized by higher levels of dry matter, total nitrogen, vitamin-C, chlorophylls, β-carotene, carotenoids and by lower levels of nitrates.

Nutritionally, it is rich in vitamin-A (2500 I.U.), vitamin-C (113 mg), protein (3.6 g),

carbohydrates (5.9 g) and minerals like calcium (103 mg), iron (1.1 mg), phosphorous (78 mg), potassium (382 mg) and sodium (15 mg) per 100 gm of edible portion (Rana, 2008). After harvesting the head, its green leaves are also a good source of nutritious green fodder and serves in acute shortage in winter season (Kumar *et al.,* 2007).

In India, it is being used as a fresh vegetable, where as in USA and European countries it is used as fresh as well as frozen form. It is usually boiled or steamed but may be eaten raw as salad and is liked in soups. The anti-cancer benefits of broccoli are greatly reduced if the vegetable is boiled. However, other preparation method such as steaming, microwaving and frying had no significant effect on the constituent compounds (Jeffery, 2005).

There are two types of broccoli, heading and sprouting. Most common broccoli is of the heading type which is closely related to cauliflower and forms a large central head. Sprouting or Italian broccoli form many florets or small heads but they do not produce a solid head. Its edible portion consists of immature, fully-differentiated flower buds and tender portions of the upper stem.

The growth, yield and quality of crop plants are mainly influenced by two principal factors viz., genetical and cultural or management factors. The first factor deals with the various breeding techniques for the improvement in crop varieties. The second factor deals with the horticultural practises *viz*., plant population, date of planting, fertilizer dose, irrigation, and weed control etc. Among them plant population per unit area is very important.

Plant population per unit area plays an important role in growth and development of the crop. Optimum plant spacing is one of the important factors in increasing the yield and quality of crops. Therefore, present studies were aimed at promotion of high valued broccoli by identifying and standardization of optimum plant spacing to obtain better growth, yield and quality of broccoli is important for North Gujarat.

Materials and Methods

The present investigation was executed at Horticulture Instructional Farm, CP College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat during the year 2015-16. The experiment was laid out in a split plot design with three replications. The experimental area was divided into plots of 2.70 m x 1.80 m size. The experiment was carried out with three different plant spacing (S_1- 30 cm × 30 cm, S_2- 45 cm × 30 cm and S_3- 45 cm × 45 cm). To raise the crop recommended package of practices was followed. The date of seed sowing in nursery bed was on 23rd November 2015 and date of transplanting on 17th December 2015 during Rabi season. The effect of different plant spacing treatments was studied and data recorded on germination, plant height (at transplanting, 45 days after transplanting, at harvest), number of leaves (45 days after transplanting, at harvest), plant spread (45 days after transplanting, at harvest), days taken for head initiation, days taken for harvesting, yield and quality parameters. The mean data were subjected to statistical analysis following analysis of variance technique (Panse and Sukhatme, 1985).

Results and Discussion

Growth parameters

Days taken for germination

Data on number of days taken for germination recorded from different plant spacing are

furnished in table 1 and was found to be not significant.

Plant height at the time of transplanting, at 45 days after transplanting and at harvest (cm)

Influence of different plant spacing with respect to height of the seedlings at the time of transplanting, 45 days after transplanting and at harvest are presented in table 1. The effect of different plant spacing on height of seedlings at the time of transplanting was found not significant.

The effect of different plant spacing with respect to plant height at 45 DAT (cm) was found significant. The significantly maximum plant height (39.35 cm) was found with the treatment S_1 (30 cm × 30 cm).

The minimum plant height (33.99 cm) was recorded with treatment S_3 (45 cm × 45 cm). This might be due to more terminal increase in closer spaced plants than wider spaced plants, where lateral growth is more. These findings are in close conformity with the findings of Rahman *et al.,* (2007) in cauliflower, Saikia *et al.,* (2010) and Gurjeet *et al.,* (2016) in broccoli.

The effect of different plant spacing with respect to plant height at the stage of head harvest was found significant. The significantly maximum plant height (57.67 cm) was found with the treatment S_1 (30 cm × 30 cm). The treatment S_1 was statistically at par with treatment S_2 (45 cm × 30 cm) (56.07 cm). The minimum plant height (51.19cm) was obtained with treatment S_3 (45 cm × 45 cm). This may be due to closer plant spacing leads to more terminal growth than the wider plant spacing. These findings are in close accordance with the findings of Saikia *et al.,* (2010), Solunke *et al.,* (2011), Gogoi *et al.,* (2016) and Vinod *et al.,* (2017) in broccoli.

Number of leaves at 45 DAT and at harvest

Effects of different plant spacings with respect to number of leaves at 45 DAT and at harvest was found to be not significant and are presented in table 2.

Plant spread (E-W and N-S) at 45 DAT and at harvest

Influence of different plant spacings with respect to plant spread (E-W) and (N-S) cm at 45 DAT and at harvest are presented in table 2. The effect of different plant spacings with respect to plant spread (E-W) and (N-S) at 45 DAT was found significant. The significantly maximum plant spread [E-W (50.36 cm) and N-S (49.91 cm)] was found with treatment S_3 (45 cm × 45 cm). The minimum plant spread [E-W (42.92 cm) and N-S (39.62 cm)] was recorded with treatment S_1 (30 cm× 30 cm).

Wider plant spacing leads to good growth and development, less competition for the uptake of nutrients, water and sunlight, which leads to more lateral growth and spread. These findings are in accordance with the findings of Munro *et al.,* (2007), Kumar *et al.,* (2007), Saikia *et al.,* (2010) and Bhangre *et al.,* (2001) in broccoli.

The effect of different plant spacings with respect to plant spread [E-W and N-S] at harvest was found to be significant. The significantly maximum plant spread [E-W (62.15 cm) and N-S (62.12 cm)] was found with treatment S_3 (45 cm × 45 cm). The minimum plant spread [E-W (57.37 cm and N-S (54.00 cm)] was recorded with treatment S_1 (30 cm × 30 cm). These might be due to wider plant spacing leads to the maximum plant spread which might be due to more availability of sunlight, nutrients and water. These findings are in accordance with the findings of Munro *et al.,* (2007), Kumar *et al.,* (2007), Saikia *et al.,* (2010) and Bhangre *et al.,* (2001) in broccoli.

Table.1 Effect of different plant spacing with respect to days taken for germination, plant height at the time of transplanting, 45DAT and harvesting

Treatments	Days taken for germination	Plant height at(cm)		
		Transplanting	45DAT	Harvesting
S_1 (30 cm × 30 cm)	3.84	21.90	39.35	57.67
S_2 (45 cm × 30 cm)	3.75	20.95	34.96	56.07
S_3 (45 cm × 45 cm)	3.75	20.62	33.99	51.19
S.Em±	0.06	0.433	0.615	1.152
C.D. at 5 %	NS	NS	2.42	4.52
C.V. %	5.47	7.10	5.90	7.26

Table.2 Effect of different plant spacing with respect to number of leaves per plant at 45 DAT and harvesting, plant spread at 45 DAT and harvesting

Treatments	Number of leaves per plant		Plant spread(cm)			
	45 DAT	Harvesting	45 DAT		Harvesting	
			(E-W)	(N-S)	(E-W)	(N-S)
S_1 (30 cm × 30 cm)	10.63	19.68	42.92	39.62	57.37	54.00
S_2 (45cm × 30 cm)	10.37	20.14	44.13	44.65	57.61	58.41
S_3 (45cm × 45 cm)	11.42	21.30	50.36	49.91	62.15	62.12
S.Em±	0.307	0.560	0.666	1.212	0.956	1.112
C.D. at 5 %	NS	NS	2.614	4.757	3.753	4.364
C.V. %	10.03	9.52	5.04	9.38	5.61	6.62

Table.3 Effect of different plant spacing with respect to days taken for head initiation, days taken for head harvesting, head diameter, yield per plant (g), yield per plot (kg) and yield per hectare (q)

Treatments	Days taken for head initiation	Days taken for head harvesting	Head diameter (cm)	Yield per plant (Fresh weight of head) (g)	Yield per plot (kg)	Yield per hectare (q)
S_1(30 cm × 30 cm)	61.48	81.37	11.8	220.8	5.73	219.3
S_2(45 cm × 30 cm)	65.53	86.27	12.8	236.3	2.99	127.0
S_3(45 cm × 45 cm)	68.93	87.85	14.1	275.5	1.66	111.5
S.Em±	0.47	0.60	0.40	10.59	0.097	7.407
C.D. at 5 %	1.86	2.38	1.58	41.61	0.38	29.07
C.V. %	2.50	2.46	10.8	15.04	9.74	16.81

Table.4 Effect of different plant spacing with respect to quality parameters

Treatments	Total dry matter content of the head (%)	Crude protein (%)	Potassium (mg/100gm)	Magnesium (mg/100gm)
S_1 (30 cm × 30 cm)	19.68	2.89	459.2	42.32
S_2 (45 cm × 30 cm)	19.80	2.85	460.8	42.62
S_3 (45 cm × 45 cm)	19.81	2.91	464.2	42.65
S.Em±	0.19	0.04	3.26	0.43
C.D. at 5 %	NS	NS	NS	NS
C.V. %	3.39	5.38	2.65	3.54

Days taken for head initiation

Influences of different plant spacings with respect to days taken for head initiation are presented in table 3.

Effect of different plant spacings with respect to days taken for head initiation was found significant. The significantly minimum days taken for head initiation (61.48 days) were recorded with treatment S_1 (30 cm × 30 cm). The maximum number day taken for head initiation (68.93 days) was observed with treatment S_3 (45 cm × 45 cm). The significant difference in days taken for head initiation by different plant spacing might be due to closer pant spacing. These findings are in accordance with the findings of Sorensen and Grevsen (1994), Singh *et al.,* (2006), Rahman *et al.,* (2007) in cauliflower, Saikia *et al.,* (2010) and Bhangre *et al.,* (2011), Thirupal *et al.,* (2014) and Vinod *et al.,* (2017) in broccoli.

Days taken for first head harvesting

Influences of different plant spacing with respect to number of days taken for first head harvest are presented in table 3.

Effect of different plant spacing with respect to number of days taken for first head harvest was found significant. The significantly minimum day taken for first head harvest (81.37 days) was recorded with treatment S_1 (30 cm × 30 cm). The maximum number of days taken for first head harvest (87.85 days) was observed with treatment S_3 (45 cm × 45 cm). The significant difference in days taken for first head harvest by different plant spacing might be due to early head initiation and development of small head. Wider spacing leads to large head size, which requires more number of days for food accumulation and to prepare photosynthetases. These findings are in accordance with the findings of Sorensen and Grevsen. (1994), Singh *et al.,* (2006), Singhal *et al.,* (2009), Saikia *et al.,* (2010) in broccoli, Moniruzzaman (2011) in cabbage and Bhangre *et al.,* (2011) in broccoli.

Yield parameters

Influences of different plant spacings with respect to head diameter (cm), yield per plant, yield per plot and yield per hectare are presented in table 3.

Head diameter

Effect of different plant spacing with respect to head diameter was found significant and was shown in the table 3. The significantly maximum head diameter (14.1 cm) was obtained with treatment S_3 (45 cm × 45 cm).The treatment S_3 was significantly at par with treatment S_2 (45 cm × 30 cm) (12.8 cm).

The minimum head diameter (11.8 cm) was obtained with treatment S_1 (30 cm× 30 cm). This might be due to more food accumulation in the plant which was grown at wider plant spacing, therefore head weight will be more which further shows more head diameter. These findings are in accordance with the findings of Sharif (2008), Hossain *et al.,* (2011), Thirupal *et al.,* (2014), Gurjeet (2016) and Vinod *et al.,* (2017) in broccoli.

Yield per plant (fresh weight of head)

The significantly maximum fresh weight of the head (275.53 g) was obtained with treatment S_3 (45 cm × 45 cm). The treatment S_2 (45 cm× 30 cm) was found statistically at par with treatment S_3. The minimum fresh weight of head (220.8 g) was observed with treatment S_1 (30 cm × 30 cm).

The significant differences among different plant spacing with respect to fresh weight of head was due to good growth occurrence in wider plant spacing, more interception of light, less competition for moisture and nutrients which increases photosynthesis and accumulation of photosynthates in the main head. These finding are in accordance with the findings of Dev. H (2012), Bhangre *et al.,* (2011), Gurjeet *et al.,* (2015), Thirupal *et al.,* (2014) and Vinod *et al.,* (2011) in broccoli.

Yield per plot

The significantly maximum head yield per plot (5.73 kg) was recorded with treatment S_1 (30 cm × 30 cm). The minimum head yield per plot (1.66 kg) was obtained with treatment S_3 (45 cm × 45 cm). The variation in yield of head per plot at different plant spacings may be due to maximum plant density i.e. more number of plants per plot. This type of results was also reported by Sharma *et al.,* (2005) in Brussels sprout, Singh *et al.,* (2006) in cauliflower, Sharif *et al.,* (2008), Saikia *et al.,* (2010) in Fabek *et al.,* (2011), Hossain *et al.,* (2011), Khatun *et al.,* (2011), Solunke *et al.,* (2011), Gogoi *et al.,* (2016) and Vinod *et al.,* (2017) in broccoli.

Yield per hectare

The significantly maximum head yield per hectare (219.36 q) was obtained with treatment S_1 (30 cm × 30 cm). The minimum head yield per hectare (111.59 q) was obtained with treatment S_3 (45 cm × 45 cm). The main reason for maximum yield per hectare in closer plant spacing was due to higher plant population per unit area. These findings are in close accordance with the finding of Bhangre *et al.,* (2011), Saikia *et al.,* (2010), Fabek *et al.,* (2011), Hossain *et al.,* (2011), Khatun *et al.,* (2011), Solunke *et al.,* (2011), Gogoi *et al.,* (2016) and Vinod *et al.,* (2017) in broccoli.

Quality parameters

Influences of different plant spacings with respect to total dry matter content of the head, crude protein, potassium and magnesium content are presented in table 4.

The plant density S_3 (45 cm × 45 cm) recorded the highest values for different quality parameters *viz.,* Total dry matter content of the head (19.81%), Crude protein (2.91%), Potassium (464.2 mg/100gm), Magnesium (42.65 mg/100gm) were shown in the table 4. These results were in conformity with the findings of Bhangre *et al.,* (2011), El-Magd *et al.,* (2006) and Islam *et al.,* (2015) in broccoli. Kalloo *et al.,* (2005) in vegetable pea, Lal (1996) in cabbage Uddain *et al.,* (2012) in Knol-khol and Chandan *et al.,* (2013) in broccoli.

In conclusion, from the above investigations it can be concluded that the treatment S_1 (30 cm x 30 cm) attained significantly maximum

plant height at transplanting (21.90 cm), at 45 DAT (39.35 cm) and at harvest (57.67 cm), minimum number of days taken for head initiation (61.48) and head harvest (81.37), maximum yield per plot (5.73 kg) and yield per hectare (219.36 q). Whereas significantly maximum plant spread E-W (50.36 cm) and N-S (49.91 cm) at 45 DAT and at harvest E-W (62.15 cm) and N-S (62.12 cm), highest head diameter (14.10 cm), fresh weight of head (275.53 g), dry matter percent of head (19.81 %), protein content (2.91 %), potassium content (464.2 mg) and calcium content (42.65 mg) were recorded with the wider plant spacing treatment S_3 (45 cm x 45 cm).

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