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Effect of head decapitation and planting density on quality seed production of sprouting broccoli (*Brassica oleracea* var. *italica* L.)

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Abstract: A study was carried out to evaluate the effect of head decapitation and planting density on plant growth, seed yield and quality of sprouting broccoli, *Brassica oleracea* var. italica L. using cultivar 'Green Head'. The twenty treatments comprised of combinations of four head decapitation methods viz., D_1 (decapitation of primary head at appearance and harvesting seeds from secondary heads), D_2 (decapitation of primary head at marketable stage and harvesting seeds from secondary heads), D_3 (removal of secondary heads at appearance and harvesting seeds primary head) and 'D_4' (No decapitation- control) and five planting densities *viz.*, S_1 (60x60 cm), S_2 (60x45 cm), S_3 (45x45 cm), S_4 (60x30 cm), and S_5 (45x30 cm). Decapitation of primary head at appearance and harvesting seeds from secondary heads (D_1) and planting density S_3 (45x45 cm) independently as well as in combination gave highest seed yield per plot and per hectare. This combination was also found comparable to other combinations for other characters like days to 50% flowering, days to seed harvesting, plant height at harvesting (cm), number of branches per plant, number of siliqua per plant, siliqua length (cm), number of seeds per siliqua and seed quality parameters. Therefore, it is suggested that decapitation of primary head at appearance and harvesting seeds from secondary heads (D_1) in combination with plant spacing of 45x45 cm i.e. D_1S_3 can be recommended for commercial seed production of sprouting broccoli.

Keywords: Head decapitation, Planting density, Quality, Seed yield

INTRODUCTION

Sprouting broccoli (*Brassica oleracea* var. *italica* L.) is one of the important and potential cole crops. It has not gained popularity with Indian farmers till early nineties despite having nutritional importance and high demand for export. However, now it is getting popularity since last few years. It is an excellent source of vitamin C, folic acid, sulforaphane glucosinolate (SGS) which is considered as anticancerous. Broccoli requires cool climate. It can tolerate frosty conditions. However the best quality sprouts are produced in the sunny weather and light frost during night. The optimum monthly temperature should be 10-25^{o}C. A period of comparatively low temperature is not essential for the seed production of sprouting broccoli as in case of cabbage. The process of flowering in sprouting broccoli starts at low temperature but pollination and seed setting will not occur until the average daily temperature goes above 15^{o}C (Ranjan *et al*., 2010). Hence quality seed production of broccoli can be done freely at an elevation of 1000-1200 m above mean sea level i.e. Srinagar valley of Jammu and Kashmir; upper Kullu valley, Kalpa valley, Kinnaur, Saproon valley Solan of Himachal Pradesh; Kumaon hills of Uttrakhand, Kalimpong and Darejeeling hills of West Bengal and Nilgiri hills of South India (Rai and Yadav, 2005).

Quality seed is the main carrier of genetic potential of an improved variety. It is estimated that good quality seeds of improved varieties can contribute about 25-40% increase in yield (Kanwar *et al*., 2010). Methods of seed production and planting density are two important factors which affect the quality and quantity of seed produced in cole crops. In broccoli *in situ* method of seed production is followed like in cauliflower as transplanting method is not successful in these crops unlike in cabbage where mostly transplanting method is performed. In cabbage three methods of seed production are followed viz. stump method, stump with central core intact method and head intact method. These methods affect the quantity and quality of seed produced significantly (Verma and Sharma, 2000). Similarly in cauliflower to facilitate bolting, different curd cutting methods like scooping, half curd cutting and curd pruning are recommended. These practices have impact on branching, seed yield and quality (Kumar *et al*., 2000). However, in sprouting broccoli no such methods to improve the quality of seed have been studied. Planting density also play an important role in quantity and quality of seed

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produced, thereby affecting the economics of seed production (Lal, 2013). Thus, keeping in view the above facts the present study was planned with the objective to study the individual and combined effect of head decapitation and planting density on seed yield and quality in sprouting broccoli.

MATERIALS AND METHODS

The present investigation was carried out at Pandah experimental farm and laboratory of the Department of Seed Science and Technology, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, HP. The twenty treatments comprised of combinations of four head decapitation methods viz., D_1 (decapitation of primary head at appearance and harvesting seeds from secondary heads), D_2 (decapitation of primary head at marketable stage and harvesting seeds from secondary heads), D_3 (removal of secondary heads at appearance and harvesting seeds primary head) and 'D_4' (No decapitation- control) and five planting densities *viz.*, S_1 (60x60 cm), S_2 (60x45 cm), S_3 (45x45 cm), S_4 (60x30 cm), and S_5 (45x30 cm) (Fig.1).

The field experiment was laid out in Randomized Block Design (factorial) with twenty treatments replicated thrice. The observations were recorded on days to 50% flowering, days to seed harvesting, plant height at harvesting (cm), number of branches per plant, number of siliqua per plant, siliqua length (cm), number of seeds per siliqua, seed yield per plant (g), seed yield per plot (g/ 3.24 m^2), seed yield per hectare (q).

The laboratory studies were carried out in Completely Randomized Design (factorial) with similar twenty treatments replicated four times. The observations recorded were 1000 seed weight (g), seed germination (%), seedling length (cm), seedling dry weight (mg), seedling vigour index- 1 and seedling vigour index- II.

RESULTS AND DISCUSSION

Growth parameters: Days to 50% flowering and days to seed harvesting are important indicators of getting early seed yields where as taller plants are considered to be more desirable because they lead to more number of branches which ultimately bear more number of siliqua resulting in increased seed productivity in sprouting broccoli. In the present study most of these traits were significantly affected by different head decapitation methods, planting densities and their interaction (Table-1). The individual effect of head decapitation methods showed that removal of secondary heads at appearance resulted in early flowering and subsequently early seed harvesting where as pinching of main head at formation or at full marketable stage resulted in delay in flowering and seed harvesting. (Seharawat *et al.*, 2003) reported that pinching increased the number of days to 50% flowering and flowering duration. These results were in line with present investigation. Removal of secondary heads at appearance also resulted in more plant height where as control i.e. no decapitation gave maximum number of branches per plant as compared to other head decapitation methods. The main effect of planting density showed that the wider spacing (60x60 cm and 60x45 cm) resulted in early flowering, early seed harvesting and more number of branches per plant, whereas, its effect on plant height was found to be non-significant. This might be due to the fact that at wider spacing there is more penetration of light and less competition for nutrients and moisture amongst plants thereby increasing the chances of early flower-

Fig 1. Detail of treatments used for the study.

S. No.	Treatment combination	Treatment details
1.	D_1S_1	Decapitation of primary head at appearance and transplanting at a spacing of 60x60 cm
2.	D_1S_2	Decapitation of primary head at appearance and transplanting at a spacing of 60x45 cm
3.	D_1S_3	Decapitation of primary head at appearance and transplanting at a spacing of 45x45 cm
4.	D_1S_4	Decapitation of primary head at appearance and transplanting at a spacing of 60x30 cm
5.	D_1S_5	Decapitation of primary head at appearance and transplanting at a spacing of 45x30 cm
6.	D_2S_1	Decapitation of primary head at marketable stage and transplanting at a spacing of 60x60 cm
7.	D_2S_2	Decapitation of primary head at marketable stage and transplanting at a spacing of 60 x 45 cm
8.	D_2S_3	Decapitation of primary head at marketable stage and transplanting at a spacing of 45x45 cm
9.	D_2S_4	Decapitation of primary head at marketable stage and transplanting at a spacing of 60x30 cm
10.	D_2S_5	Decapitation of primary head at marketable stage and transplanting at a spacing of 45x30 cm
11.	D_3S_1	Decapitation of secondary heads at appearance and transplanting at a spacing of 60x60 cm
12.	D_3S_2	Decapitation of secondary heads at appearance and transplanting at a spacing of 60x45 cm
13.	D_3S_3	Decapitation of secondary heads at appearance and transplanting at a spacing of 45x45 cm
14.	D_3S_4	Decapitation of secondary heads at appearance and transplanting at a spacing of 60x30 cm
15.	D_3S_5	Decapitation of secondary heads at appearance and transplanting at a spacing of 45x30 cm
16.	D_4S_1	No decapitation and transplanting at a spacing of 60x60 cm
17.	D_4S_2	No decapitation and transplanting at a spacing of 60x45 cm
18.	D_4S_3	No decapitation and transplanting at a spacing of 45x45 cm
19.	D_4S_4	No decapitation and transplanting at a spacing of 60x30 cm
20.	D_4S_5	No decapitation and transplanting at a spacing of 45x30 cm

Table 1. Effect of head decapitation and planting density on growth characters in sprouting broccoli cv. green head.

Particular	Characters			
	Days to 50% flowering	Days to seed harvesting	Plant height at harvesting (cm)	Number of branches per plant
Head Decapitation methods				
D_1	145.40	205.53	67.25	11.57
D_2	152.67	209.13	70.16	11.91
D_3	141.73	200.13	76.13	7.81
D_4	144.47	206.07	69.32	13.85
CD at 5%	1.21	0.81	2.34	0.99
Planting Density (spacing in cm)				
S_1	144.17	203.92	70.18	12.26
S_2	144.75	204.75	70.35	12.27
S_3	145.25	204.92	69.66	11.28
S_4	146.67	205.67	71.43	10.70
S_5	149.50	206.84	71.95	9.92
CD at 5%	1.36	0.90	NS	1.11
Interaction between head decapitation and planting density (D X S)				
$D_1 S_1$	144.00	204.00	60.07	12.03
$D_1 S_2$	144.33	205.00	64.00	12.00
$D_1 S_3$	145.00	205.00	70.13	11.87
$D_1 S_4$	146.00	206.00	72.00	11.06
$D_1 S_5$	147.67	207.67	70.07	10.90
$D_2 S_1$	150.00	208.00	76.40	13.20
$D_2 S_2$	150.67	208.67	70.47	13.03
$D_2 S_3$	152.67	209.00	66.33	11.80
$D_2 S_4$	153.67	209.33	67.47	11.53
$D_2 S_5$	156.33	210.67	70.13	9.97
$D_3 S_1$	140.00	198.00	74.60	8.93
$D_3 S_2$	140.33	199.33	78.73	8.47
$D_3 S_3$	139.67	200.33	74.87	7.87
$D_3 S_4$	143.33	201.00	76.73	6.93
$D_3 S_5$	145.33	202.00	75.73	6.87
$D_4 S_1$	142.67	205.67	69.67	14.87
$D_4 S_2$	143.67	206.00	68.20	15.60
$D_4 S_3$	143.67	205.33	67.33	13.60
$D_4 S_4$	143.67	206.33	69.53	13.27
$D_4 S_5$	148.67	207.00	71.87	11.93
CD at 5%	NS	NS	5.24	2.21

ing and seed maturity as well as more number of branches per plant. (Chatterjee, 2006) studies the effect of spacing (45x45, 60x45, 60x60 and 90x60 cm) on growth characteristics, seed yield and quality of cauliflower cv. Pusa Early in cauliflower. He reported significantly early flowering and highest seed yield (5.28q/ha) with 60x45 cm spacing. The interaction effects of head decapitation and planting density was found to be non- significant for days to 50% flowering and days to seed harvesting where as tallest plants were obtained in D_3S_2 (removal of secondary heads at appearance with spacing 60x45 cm) which was at par with D_3S_4, D_2S_1, D_3S_5, D_3S_3 and D_3S_1. Maximum number of branches per plant was obtained in D_4S_2 (control with spacing 60x45 cm) which was at par with D_4S_1 and D_4S_3.

Seed yield and contributing parameters: Seed yield and yield contributing characters play an important role in deciding the profitability and in establishing seed production an economic venture for the concerned farmer. In the present study most of these characters were significantly (at 5% level; of significance) affected by head decapitation methods and different planting densities (Table 2). Number of siliqua per plant, which contributes directly towards the higher seed yield in sprouting broccoli, was maximum in D_1 i.e. decapitation of primary head at appearance. The pinching is known to accumulate more photo-synthates which are utilized for production of more number of flower bearing branches and more number of flowers per plant (Mihov and Antonova, 2009). The maximum siliqua length and number of seeds per siliqua was obtained in D_3 i.e. removal of secondary heads at appearance which was at par with

Table 2. Effect of head decapitation and planting density on seed yield and contributing characters in sprouting broccoli cv. green head.

Particular	Characters					
	Number of siliqua per plant	Siliqua length (cm)	Number of seeds per siliqua	Seed yield/ plant (g)	Seed yield/ plot (g)	Seed yield per hectare (qtls)
Head Decapitation methods						
D_1	994.73	4.82	12.05	35.23	496.38	11.42
D_2	771.8	4.04	9.76	21.54	299.80	6.90
D_3	573.27	4.94	12.4	23.97	364.40	8.38
D_4	876.87	4.43	10.68	30.52	419.60	9.65
CD at 5%	119.56	0.19	0.68	3.37	41.11	0.95
Planting Density (spacing in cm)						
S_1	964.00	4.61	12.36	37.06	333.53	7.67
S_2	856.50	4.78	12.53	33.56	402.70	9.26
S_3	911.58	4.65	11.35	31.12	497.87	11.45
S_4	869.58	4.58	10.51	25.88	465.75	10.71
S_5	419.17	4.15	9.35	11.48	275.40	6.34
CD at 5%	133.67	0.21	0.75	3.76	45.96	1.06
Interaction between head decapitation and planting density (D X S)						
$D_1 S_1$	1366.33	4.44	11.10	45.63	410.67	9.45
$D_1 S_2$	950.00	4.45	14.90	43.27	519.24	11.94
$D_1 S_3$	1138.67	4.75	12.18	41.20	659.20	15.16
$D_1 S_4$	1155.00	5.80	11.23	35.47	638.40	14.68
$D_1 S_5$	363.67	4.66	10.82	10.60	254.40	5.85
$D_2 S_1$	866.00	4.71	12.08	30.27	272.40	6.27
$D_2 S_2$	857.33	4.53	11.45	27.90	334.80	7.70
$D_2 S_3$	977.33	3.49	9.12	24.30	388.80	8.94
$D_2 S_4$	728.00	3.87	8.78	17.10	307.80	7.08
$D_2 S_5$	430.33	3.61	7.37	8.13	195.20	4.49
$D_3 S_1$	701.67	4.58	11.50	28.23	254.10	5.84
$D_3 S_2$	586.33	5.38	11.52	22.57	270.80	6.23
$D_3 S_3$	615.00	5.23	12.27	25.43	406.93	9.36
$D_3 S_4$	528.00	4.89	14.62	26.03	468.60	10.78
$D_3 S_5$	435.33	4.63	12.10	17.57	421.60	9.70
$D_4 S_1$	922.00	4.73	14.78	44.10	396.90	9.13
$D_4 S_2$	1032.33	4.78	12.27	40.50	486.00	11.18
$D_4 S_3$	915.33	5.13	11.83	33.53	536.53	12.34
$D_4 S_4$	1067.33	3.78	7.40	24.90	448.20	10.31
$D_4 S_5$	447.33	3.72	7.13	9.60	230.40	5.30
CD at 5%	267.34	0.42	1.51	7.53	91.92	2.13

D_1 for both the characters. However, D_3 had significantly lowest number siliqua per plant. The results showed that number of siliqua per plant and siliqua length is inversely related to each other, whereas siliqua length and number of seeds per siliqua are positively related to each other. The main effect of head decapitation also revealed that seed yield per plant or per plot or per hectare was significantly highest in D_1 as compared to all other decapitation methods. D_1 observed 18.34 % increase in yield/ hectare over control i.e. no decapitation D_4. (Mihov and Antonova, 2009) concluded that decapitation of central flower head has the strongest effect on the individual plant seed productivity and in this way the seed yield is increased by several times in broccoli. Contrary to this, (Elyazied *et al.*, 2007) studied the effects of four pinching treatments (pinching the main apical head just after appearance, pinching the main head at marketable stage, pinching the axillary head just after appearance and without pinching) on seed production of broccoli. Pinching the main head at the marketable stage recorded the highest values of number of siliqua per plant, number of seeds per plant, and seed yield. (Sukthong, 2008) also concluded that the best seed production techniques in broccoli were either no thinning or selecting fifteen best

Table 3. Effect of head decapitation and planting density on seed quality parameters in sprouting broccoli cv. Green Head.

Particular	Characters					
	1000 seed weight (gm)	**Seed germi-nation (%)**	**Seedling length (cm)**	**Seedling dry weight (mg)**	**Seed vigour index-I**	**Seed vigour index-II**
Head Decapitation methods						
D_1	3.93	91.40 (9.56)	9.62	2.77	880.61	253.58
D_2	3.30	82.27 (9.07)	8.66	2.48	713.14	203.75
D_3	4.11	92.67 (9.63)	9.75	2.79	904.81	258.52
D_4	3.48	89.87 (9.48)	9.46	2.71	851.07	243.17
CD at 5%	**0.19**	**0.08**	**0.15**	**0.13**	**27.27**	**13.63**
Planting Density (spacing in cm)						
S_1	3.87	92.00 (9.59)	9.68	2.75	893.07	252.91
S_2	3.75	90.50 (9.51)	9.53	2.78	864.44	252.44
S_3	3.69	89.08 (9.44)	9.38	2.70	837.4	240.45
S_4	3.60	89.17 (9.44)	9.39	2.66	838.96	237.77
S_5	3.50	84.50 (9.19)	8.90	2.55	753.18	215.19
CD at 5%	0.21	0.09	0.17	NS	30.49	15.24
Interaction between head decapitation and planting density (D x S) Non- significant for all the seed quality parameters						

Figures in the parenthesis represent square root transformation

inflorescence after a thinning treatment.

The effect of planting density showed that in general number of siliqua per plant, siliqua length and number seeds per siliqua increased with decrease in planting density (Table-2). At wider spacing more pods setting and more number seeds per pod may be there due to better pollination by honey bees and less competition amongst plants for nutrient and light. (Sharma, 2001) reported maximum number of siliqua per plant at wider spacing in Chinese cabbage. The highest seed yield per plant was obtained at widest spacing of 60x60 cm (S_1) where as spacing of 45x45 cm (S_3) gave highest seed yield per plot and per hectare. The increase in yield/hectare over recommended spacing of 60x45 cm (S_2) was 23.65 %. (Das *et al.*, 2000) also recorded highest seed yield per hectare with 45x45 cm plant spacing in cauliflower.

The interaction effect of head decapitation and planting density showed that decapitation of primary head at appearance under wider spacing resulted in more number of siliqua per plant, siliqua length, number seeds per siliqua and seed yield per plant. However, the highest seed yield per plot and per hectare was recorded in D_1S_3 (decapitation of primary head at appearance with spacing 45x45 cm), which was at par with D_1S_4 (decapitation of primary head at appearance with spacing 60x30 cm). The increase in seed yield over control (no decapitation and 60x45 cm spacing) was 35.60 % and 31.31%, respectively. The higher seed yield per plot and per hectare obtained with of D_1S_3 might be due decapitation of primary head at appearance resulting in more number of productive flowering branches and pod number per plant while planting at optimum spacing contributed to higher seed yield per unit area.

Seed quality parameters: Test weight, germination and vigour are important parameters which determine the physiological quality as well as contribute to planting value of seeds. When environmental conditions in the field are close to ideal for a crop, field emergence will correlate well with germination. However, in practice, optimum field conditions are not often encounter and environmental stress can lead to varying field performance depending upon vigour status of the seeds. In the present studies, the head decapitation and planting density individually affected seed quality parameters significantly however their interactions for all these characters were non- significant (Table 3). The individual effect of head decapitation revealed that maximum 1000 seed weight, seed germination, seedling length, seedling dry weight, seed vigour index-I and II were maximum in D_3 (removal of secondary heads at appearance) and it was at par with D_1 for all these parameters. As discussed earlier that in D_3 there were less number of branches and siliqua per plant but siliqua length was more as compare to other decapitation methods because there is a less competition for nutrient uptake and light absorption. Hence, it appeared that weight of individual seed may be stimulated by better availability of nutrients and light. Similar results were also reported by (Singh *et al.*, 2005) in Indian cauliflower. They obtained highest 100 seed weight, germination and vigour with scooping and side cutting of curd at half loose stage. The main effect of planting density indicated that seed quality parameters decreased with increase in planting density. The best seed quality was obtained at widest spacing of 60x60 cm, however at this spacing lowest seed yield per plot or per hectare was recorded. These findings are

in-conformity to those of Mihov and Antonova (2009). They reported that wider spacing resulted in increased seed quality but gave less seed yield per unit area in broccoli. In the present study, the plant spacing of 45x45 cm which gave highest seed yield per unit area was also found to be satisfactory in seed quality parameters as compared to the wider spacing.

Conclusion

Finally it can be concluded that head decapitation and planting density individually or in combination significantly affected the growth, seed yield and quality characters in sprouting broccoli. The head decapitation D_1 i.e. decapitation of primary head at appearance has strongly influenced all the growth, seed yield and quality characters in positive direction. Wider plant spacing gave better seed quality but seed yield per unit area was low. The interaction effect also revealed that highest seed yield per plot and per hectare was obtained with D_1S_3. Hence it is suggested that decapitation of primary head at appearance and harvesting seeds from secondary heads in combination with plant spacing of 45x45 cm can be recommended for commercial seed production of sprouting broccoli.

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