International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(1): 869-873
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Received: 15-11-2018
Accepted: 20-12-2018

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Standardization of production technology of cabbage and cauliflower hybrids for off-season cultivation in Kullu Valley of Himachal Pradesh

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Abstract
A field experiment was carried out at ICAR-IARI Regional Station, Katrain, Kullu, and Himachal Pradesh to standardize the planting time and spacing for cabbage (Pusa Cabbage-1) and cauliflower (Pusa Snowball Hybrid-1) hybrids during summer season of 2018 for their off-season cultivation. The experimental results revealed that yield and its contributing traits affected significantly (at $P \leq 0.05$) due to different planting times and spacings. In case of cabbage, treatment combination, '$P_2 \times S_1$' (P_2: March 31, 2018 and S_1: 60 cm × 45 cm) resulted in highest plant height (26.43 cm) and gross head weight (1.77 kg), while maximum head length (15.80 cm) and breadth (15.43 cm) and net head weight (1.10 kg) was obtained with the treatment '$P_1 \times S_1$' (P_1: March 16, 2018 and S_1: 60 cm × 45 cm). However, highest yield per plot (21.65 kg) and per hectare (534.72 q) was recorded by planting the crop on 31st March, 2018 (P_2**)** at a spacing of 45 cm × 30 cm (S_3). While in case of cauliflower, maximum plant height (48.90 cm), number of leaves per plant (19.33), gross curd weight (1.17 kg), curd length (12.83 cm) and breadth (12.12 cm) and net curd weight (0.70 kg) was exhibited by the treatment combination, '$P_2 \times S_1$' (P_2: March 31, 2018 and S_1: 60 cm × 45 cm). However, planting the crop on 31st March, 2018 (P_2**)** at closest spacing of 45 cm × 30 cm (S_3) recorded significantly highest yield per plot (13.74 kg) and per hectare (339.22 q). Therefore, planting of cabbage and cauliflower on 31st March at a spacing of 45 cm × 30 cm can be recommended for commercial off-season cultivation in hilly regions of Himachal Pradesh and India as well.

Keywords: cabbage, cauliflower, off-season cultivation, planting time, spacing, yield and contributing traits

1. Introduction
Cabbage (*Brassica oleracea* var. *capitata* L.) and cauliflower (*Brassica oleracea* var. *botrytis* L.) are important members of Brassica family and they constitutes an integral part of traditional cuisine in several countries (Singh *et al.,* 2009 and Dey *et al.,* 2017) [15, 4]. Because of their consumer's preference, common availability in local markets, reasonable market price and year-around availability, they represent a significant source of phytonutrients in the human diet. At global level, cabbage and other brassica vegetables are grown in an area of 2.51 million hectares with a production of 71.45 million tonnes. While, in India area and production of cabbage and other brassica vegetables is 0.39 million hectares and 8.80 million tonnes, respectively (FAO, 2017) [6]. It is evident from the data that Indian productivity (22.56 tonne/hectare) of cabbage and other brassica vegetables is comparatively low as compared to world's productivity (28.46 tonne/hectare). Therefore, there is an immense need to increase productivity of these vegetable crops in India.

The productivity any crop can be improved by the use of high yielding varieties/hybrids and adoption of proper production technologies. Hence, in brassica vegetables, F_1 hybrids are very popular due to their uniformity, better quality and higher yield (Kucera *et al.,* 2006) [9]. But, a very few hybrids of cabbage and cauliflower are available from public sector for their commercial cultivation in India. Moreover, production technologies for their cultivation in different region of India have not been standardized yet. At ICAR-IARI Regional Station, Katrain, 'Pusa Cabbage-1' and 'Pusa Snowball Hybrid-1' hybrids of cabbage and cauliflower were released/identified for commercial cultivation during the year 2012 and 2015, respectively. Generally, these hybrids have been recommended for main/winter season cultivation.

But, in main season due to huge glut in market, farmers get very low price for their produce. The hilly regions of the country (J&K, Himachal Pradesh, Uttarakhand etc.) due to their favorable climatic conditions offers the scope for off-season cultivation of cabbage and cauliflower during summer season. Hence, farmers of hilly regions have started to cultivate these vegetables during summer season, hence fetch remunerative returns of their produce. But, production potential of cabbage and cauliflower hybrids available form public sector is still unknown in summer conditions. This necessitate to Standardized their production technology for summer/off-season cultivation.

Among the improved cultivation practices, selection of appropriate planting time and use of proper spacing are important factors for securing higher yields in brassica vegetables (Moniruzzaman, 2011) [12]. Moreover, head/curd size and quality attributes are mainly affected by planting time and spacing (Abed *et al.,* 2015 and Bacha *et al.,* 2017) [1, 3]. The suitable planting time helps to depict favourable environmental conditions for cultivation of brassica vegetables. It directly affects maturity and harvesting time and marketable yield of cabbage (Abed *et al.,* 2015 and Maria and Sawicki, 2012) [1, 11] and cauliflower (Din *et al.,* 2007) [5]. Similarly, appropriate plant spacing is directly related to head/curd size of cabbage (Singh *et al.,* 2004) [16] and cauliflower (Bacha *et al.,* 2017) [3] crops, thereby affecting total yields. Keeping in view the above facts in mind, the present investigation was carried to study the effect of planting time and spacing on yield and its attributing traits in cabbage and cauliflower for off-season cultivation.

2. Materials and Methods

2.1 Experimental location, materials and layout plan

The present investigation was carried out at Baragran Research Farm of ICAR-IARI Regional Station, Katrain, Kullu Valley, HP, India, during summer season of 2018. The experimental material for present investigation comprised of two promising hybrids of cabbage (Pusa Cabbage-1) and cauliflower (Pusa Snowal Hybrid-1) being released/identified for commercial cultivation during winter season from the IARI Regional Station, Katrain. The experiment was laid out separately each for cabbage and cauliflower in factorial randomized complete block design (RCBD) with three replications, having three planting times *viz.* P_1: March 16, 2018; P_2: March 31, 2018 and P_3: April 15, 2018 and three spacings *viz.* S_1: 60 cm × 45 cm; S_2: 45 cm × 45 cm and S_3: 45 cm × 30 cm. Standard cultural practices for raising a healthy crop stand of cabbage and cauliflower were followed according to package of practices for vegetable crops published by Directorate of Extension. Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, J&K (Anonymous, 2016) [2].

2.2 Data recording and Statistical analysis

The data were recorded on different yield and its contributing traits of cabbage *viz.* plant height (cm), number of non-wrapper leaves per plant, gross head weight (kg), head length (cm), head breadth (cm), net head weight (kg) and yield per plot (kg) and per hectare (q) and cauliflower *viz.* plant height (cm), number of leaves per plant, gross curd weight (kg), curd length (cm), curd breadth (cm), net curd weight (kg) and yield per plot (kg) and hectare (q). The data were subjected to analysis of variance using OPSTAT software (Sheoran *et al.,* 1998) [14] as per the formulae described by Panse and Sukhatme (1967) [13] for factorial randomized complete block design (RCBD).

3. Results and Discussion

3.1 Analysis of variance (ANOVA)

The analysis of variance revealed significant effect of planting time, spacing and their interactions (planting time × spacing) on different horticultural traits studied in cabbage (Table 1) and cauliflower (Table 2). It means that both the planting time and spacing had greater influence on growth and yield traits of cabbage and cauliflower hybrids.

3.1.1 Effect of planting time and spacing on growth and yield of cabbage

Effect of planting time: Significant variations were observed for all the horticultural traits of cabbage hybrid (Pusa Cabbage-1) planted at different times during summer season (Table 3). The plant height (23.71 cm) and gross head weight (1.60 kg) was recorded significantly highest with the planting time 'P_2' (March 31, 2018). However, planting the crop at earliest i.e. 'P_1' **(**March 16, 2018) resulted in highest head length (13.86 cm), head breadth (14.08 cm), net head weight (1.00 kg) and yield per plot (16.79 kg) and per hectare (414.58 q). In the meanwhile, lowest performance for all above mentioned traits was obtained with late planting time, 'P_3' **(**April 15, 2018). This might be due to the fact that cabbage crop planted either on 16th or 31st March, 2018 possibly got the favorable environmental conditions for better growth and development as compared to late planting time (P_3). Similar trend of results was also reported earlier by Ullah *et al.* (2013) [17] in cabbage crop grown during main season/winters.

Effect of spacing: The planting of cabbage hybrid at different spacings significantly affected all growth and yield traits under study (Table 3). The experimental results clearly demonstrated that significantly highest plant height (24.50 cm), gross head weight (1.44 kg), head length (14.15 cm), head breadth (14.07 cm) and net head weight (1.03 kg) was obtained at wider spacing i.e., 'S_1' (60 cm × 45 cm). This might be attributed to the fact that cabbage crop planted at wider spacing received efficient nutrients, light and moisture as compared to the plants grown at closer spacings, which resulted in better performance for growth and other yield contributing traits. While, minimum performance for all these traits was recorded with the narrow spacing 'S_3' (45 cm × 30 cm). However, highest yield per plot (18.50 kg) and per hectare (456.89 q) was obtained by planting the crop at closer spacing, 'S_3'. This is due to the accommodation of higher number of plants per plot and per hectare at closer spacing of 45 cm × 30 cm, which resulted in higher crop yields. The earlier workers like Moniruzzaman (2011) [12] and Khatiwada (2000/2001) [8] had also obtained the highest yield of cabbage per hectare from closer spacing, while other traits were recorded maximum by planting the cabbage crop at wider spacing.

Interaction effect between planting time and spacing: The interaction of planting time and spacing exhibited significant effect on all the traits under study (Table 3). The treatment combination, 'P_2×S_1' (P_2: March 31, 2018 and S_1: 60 cm × 45 cm) resulted in highest plant height (26.43 cm) and gross head weight (1.77 kg), while maximum head length (15.80 cm), head breadth (15.43 cm) and net head weight (1.10 kg) was

obtained by planting the crop at earliest with wider spacing i.e., '$P_1 \times S_1$' (P_1: March 16, 2018 and S_1: 60 cm × 45 cm). While, poorest performance for all these traits was recorded with the treatment combination, '$P_3 \times S_3$' (P_3: April 15, 2018 and S_3: 45 cm × 30 cm). It is apparent from the results that performance of all yield attributing traits cabbage was enhanced when planted earlier at wider spacing. This might be attributed to the availability of sufficient amount of light and nutrients for crop growth and development (Ullah *et al.* 2013) [17]. However, highest yield per plot (21.65 kg) and per hectare (534.72 q) was recorded by planting the crop on 31st March, 2018 (P_2**)** at a spacing of 45 cm × 30 cm (S_3) and it was found statistically at par with the treatment combination, '$P_1 \times S_3$' (P_1: March 16, 2018 and S_1: 45 cm × 30 cm) and lowest yield was observed in '$P_3 \times S_1$' (P_3: April 15, 2018 and S_1: 60 cm × 45 cm). Similarly, Abed *et al.* (2015) [1] had also obtained highest total yield of cabbage at first and second planting dates with closer plant spacing.

3.1.2 Effect of planting time and spacing on growth and yield of cauliflower

Effect of planting time: The growth and yield traits of cauliflower hybrid (Pusa Snowball hybrid-1) were affected significantly by different planting times when grown during summer season (Table 4). Significantly highest plant height (47.64 cm), number of leaves per plant (16.53), gross curd weight (1.07 kg), curd length (11.74 cm), curd breadth (11.67 cm), net curd weight (0.65 kg) and yield per plot (11.01 kg) and per hectare (271.75 q) was recorded by planting the crop on 31st March, 2018 (P_2), while poorest performance for all above mentioned traits was observed with late planting i.e., 'P_3' (April 15, 2018). This might be attributed to the possible favorable environmental conditions prevailed during foliar and curd developmental stages, when planted on 31st March, 2018. After, this planting time a severe reduction in the performance for yield traits was recorded due to high temperature conditions during curd development stage. In cauliflower, Din *et al.* (2007) [5] had also reported better results in early sown crop as compared to late planting.

Effect of spacing: The cauliflower hybrid planted at different spacings revealed significant variations for all growth and yield traits under study (Table 4). It is evident from the results that maximum plant height (46.58 cm), number of leaves per plant (17.58), gross curd weight (1.02 kg), curd length (11.12 cm), curd breadth (10.73 cm) and net curd weight (0.59 kg) was obtained with the wider spacing i.e., 'S_1' (60 cm × 45 cm) and the performance for these traits was reduced by planting the crop at closer spacings (S_2: 45 cm × 30 cm and S_3: 45 cm × 30 cm). However, highest yield per plot (9.71 kg) and per hectare (239.63 q) was obtained at closest spacing, 'S_3' (45 cm × 30 cm). This is due to the accommodation of higher number of plants per plot and per hectare at closer spacing, resulting in higher yields. The highest marketable yield in cauliflower at closer spacing was also reported earlier by Hill (2007) [7].

Interaction effect between planting time and spacing: Significant effect of interaction between planting time and spacing was observed on growth and yield traits of cauliflower (Table 4). The maximum plant height (48.90 cm), number of leaves per plant (19.33), gross curd weight (1.17 kg), curd length (12.83 cm), curd breadth (12.12 cm) and net curd weight (0.70 kg) was exhibited by the treatment combination, '$P_2 \times S_1$' (P_2: March 31, 2018 and S_1: 60 cm × 45 cm) and it was found statistically at par with '$P_1 \times S_1$' (P_1: March 16, 2018 and S_1: 60 cm × 45 cm) for all above mentioned yield contributing traits except gross curd weight. It means that yield contributing traits performed well with early planting of cauliflower at wider spacing. This might be caused due to the availability of favorable environmental conditions, sufficient light and nutrients at early sowing at wider spacing. The significantly highest plant height and curd polar and equatorial diameter was also obtained by Kumari (2017) [10] with early planting and wider spacing in cauliflower. However, planting the crop on 31st March, 2018 (P_2**)** at closest spacing of 45 cm × 30 cm (S_3) recorded significantly highest yield per plot (13.74 kg) and per hectare (339.22 q). It may be attributable to the accommodation of higher number of plants per plot and per hectare at closer spacing and favorable environmental conditions with early planting. In the meanwhile, later planting with closer spacing due to unfavorable climatic conditions resulted in severe reduction in performance for growth, yield and its contributing traits in cauliflower.

Table 1: Analysis of variance (ANOVA) for growth and yield traits of cabbage var. Pusa Cabbage-1

Traits Source of variation	Mean sum of squares								
	df	Plant height (cm)	Number of non-wrapper leaves per plant	Gross head weight (kg)	Head length (cm)	Head breadth (cm)	Net head weight (kg)	Yield per plot (kg)	Yield per hectare (q)
Replication	2	0.96	0.02	0.00	0.26	0.00	0.00	0.19	113.19
Planting time(P)	2	32.54*	77.85*	1.36*	9.67*	22.95*	0.18*	64.37*	39289.36*
Spacing(S)	2	72.74*	8.46*	0.31*	16.35*	12.95*	0.15*	87.08*	53102.59*
P×S	4	3.59*	0.52*	0.08*	0.73*	0.64*	0.01*	11.59*	7075.73*
Error	16	0.80	0.10	0.00	0.11	0.11	0.00	0.49	297.13
Total	26	110.62	86.96	1.75	27.11	36.66	0.35	163.72	99878.01

*significant at $P \leq 0.05$

Table 2: Analysis of variance (ANOVA) for growth and yield traits of cauliflower var. Pusa Snowball Hybrid-1

Traits Source of variation	Mean sum of squares								
	df	Plant height (cm)	Number of leaves per plant	Gross curd weight (kg)	Curd length (cm)	Curd breadth (cm)	Net curd weight (kg)	Yield per Plot (kg)	Yield per hectare (q)
Replication	2	0.14	0.91	0.00	1.71	0.50	0.00	0.05	28.27
Planting time(P)	2	217.85*	75.82*	0.41*	50.73*	50.68*	0.38*	123.23*	75121.08*
Spacing(S)	2	151.47*	76.87*	0.13*	12.62*	5.50*	0.08*	16.36*	9972.38*
P×S	4	23.90*	2.61*	0.01*	1.89*	0.65*	0.00*	9.03*	5498.30*
Error	16	2.62	0.76	0.00	0.33	0.19	0.00	0.45	276.07

Total	26	395.98	156.97	0.55	67.29	57.53	0.47	149.12	90896.09

*****significant at $P \leq 0.05$

Table 3: Effect of planting time and spacing on growth and yield of cabbage var. Pusa Cabbage-1

Traits	Plant height (cm)	Number of non-wrapper leaves per plant	Gross head weight (kg)	Head length (cm)	Head breadth (cm)	Net head weight (kg)	Yield per plot (kg)	Yield per hectare (q)
Effect of planting time(P)* on growth and yield of cabbage								
P_1	22.38	15.98	1.34	13.86	14.08	1.00	16.79	414.58
P_2	23.71	15.43	1.60	12.68	13.63	0.98	16.60	410.01
P_3	19.96	10.63	0.83	11.79	11.12	0.74	12.07	297.92
$C.D._{(0.05)}$	0.90	0.33	0.04	0.33	0.34	0.04	0.70	17.37
Effect of spacing(S)# on growth and yield of cabbage								
S_1	24.50	15.13	1.44	14.15	14.07	1.03	12.36	305.09
S_2	22.64	13.50	1.26	12.73	13.07	0.91	14.60	360.53
S_3	18.92	13.41	1.07	11.46	11.68	0.77	18.50	456.89
$C.D._{(0.05)}$	0.90	0.33	0.04	0.33	0.34	0.04	0.70	17.37
Interaction effect of planting time and spacing on growth and yield of cabbage								
$P_1 \times S_1$	24.27	17.53	1.66	15.80	15.43	1.10	13.16	324.83
$P_1 \times S_2$	22.30	15.40	1.41	13.72	14.57	1.03	16.38	404.62
$P_1 \times S_3$	20.58	15.00	0.94	12.07	12.23	0.87	20.83	514.29
$P_2 \times S_1$	26.43	16.43	1.77	13.72	14.78	1.06	12.67	312.85
$P_2 \times S_2$	25.20	14.70	1.54	12.53	13.58	0.97	15.49	382.45
$P_2 \times S_3$	19.50	15.17	1.48	11.80	12.53	0.90	21.65	534.72
$P_3 \times S_1$	22.80	11.43	0.89	12.93	12.00	0.94	11.24	277.59
$P_3 \times S_2$	20.42	10.40	0.83	11.95	11.07	0.75	11.93	294.51
$P_3 \times S_3$	16.67	10.07	0.78	10.50	10.28	0.54	13.03	321.66
$C.D._{(0.05)}$	1.56	0.56	0.07	0.57	0.58	0.07	1.22	30.09

*Planting time (P): P_1 = March 16, 2018; P_2 = March 31, 2018; P_3 = April 15, 2018
#Spacing(S): S_1 = 60 cm × 45 cm; S_2 = 45 cm × 45 cm; S_3 = 45 cm × 30 cm

Table 4: Effect of planting time and spacing on growth and yield of cauliflower var. Pusa Snowball Hybrid-1

Traits	Plant height (cm)	Number of leaves per plant	Gross curd weight (kg)	Curd length (cm)	Curd breadth (cm)	Net curd weight (kg)	Yield per plot (kg)	Yield per hectare (q)
Effect of planting time on growth and yield of cauliflower								
P_1	43.51	16.07	0.96	10.77	10.84	0.58	9.68	238.99
P_2	47.64	16.53	1.07	11.74	11.67	0.65	11.01	271.75
P_3	37.84	11.29	0.66	7.23	7.21	0.26	4.04	99.69
$C.D._{(0.05)}$	1.63	0.88	0.04	0.58	0.44	0.03	0.68	16.75
Effect of spacing on growth and yield of cauliflower								
S_1	46.58	17.58	1.02	11.12	10.73	0.59	7.05	174.10
S_2	43.90	14.58	0.89	9.86	9.81	0.50	7.97	196.70
S_3	38.52	11.73	0.78	8.76	9.17	0.40	9.71	239.63
$C.D._{(0.05)}$	1.63	0.88	0.04	0.58	0.44	0.03	0.68	16.75
Interaction effect of planting time and spacing on growth and yield of cauliflower								
$P_1 \times S_1$	48.43	18.87	1.05	12.33	11.80	0.66	7.94	196.12
$P_1 \times S_2$	43.37	15.53	0.94	10.17	11.10	0.58	9.25	228.43
$P_1 \times S_3$	38.73	13.80	0.89	9.80	9.62	0.49	11.84	292.42
$P_2 \times S_1$	48.90	19.33	1.17	12.83	12.12	0.70	8.42	207.92
$P_2 \times S_2$	47.70	17.60	1.11	12.60	11.60	0.68	10.86	268.10
$P_2 \times S_3$	46.33	12.67	0.93	9.78	11.28	0.57	13.74	339.22
$P_3 \times S_1$	42.40	14.53	0.84	8.20	8.27	0.40	4.79	118.24
$P_3 \times S_2$	40.63	10.60	0.62	6.80	6.73	0.24	3.79	93.58
$P_3 \times S_3$	30.50	8.73	0.52	6.68	6.62	0.15	3.53	87.25
$C.D._{(0.05)}$	2.83	1.52	0.07	1.00	0.77	0.05	1.18	29.01

*Planting time (P): P_1 = March 16, 2018; P_2 = March 31, 2018; P_3 = April 15, 2018
#Spacing(S): S_1 = 60 cm × 45 cm; S_2 = 45 cm × 45 cm; S_3 = 45 cm × 30 cm

4. Conclusion

The present investigation concludes that planting of cabbage (Pusa Cabbage-1) and cauliflower (Pusa Snowball hybrid-1) hybrids on 31st March, 2018 with a spacing of 45 cm × 30 cm resulted in highest crop yields per plot and per hectare. Therefore, standardized technology after multilocation testing may be recommended for commercial off-season cultivation of cabbage and cauliflower during summer season in hilly regions of Himachal Pradesh and India as well.

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