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Interaction effect of plant spacing and varieties on growth and yield traits of cauliflower *Brassica Oleracea var. botrysis*

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Abstract

This research was carried out at the Regional Research Station of PAU, Gurdaspur, Punjab and biochemistry laboratory, Department of Vegetable Science, Punjab Agricultural University, Ludhiana in the *rabi* season 2022-23. The experiment involved four spacings (45 × 45, 60 × 30, 67.5 × 30, and 75 × 50 cm) and three varieties (PGAC–25–17, Pusa Sharad and Private-Aghani) arranged in a factorial design. The results showed that leaf length (15.75 cm), leaf width (13.31 cm), leaf number (21.95), days to curd initiation curd polar diameter, gross curd weight (1.68 kg), marketable curd weight (0.46 kg) and marketable yield (22.65 q/ha) were found to be maximum in variety PGAC – 25 – 17 and at spacing 67.5 x 30 cm. The curd equatorial diameter, net curd weight was found to be highest in variety PGAC– 25– 17 and spacing 67.5 x 30 cm. Gross curd weight and marketable yield per plot were the only two parameters that were significantly affected by the sowing date. Narrow spacing (45 × 45 cm) restricted vegetative growth and curd development, whereas excessively wide spacing (75 × 50 cm) reduced per-unit area yield due to lower plant density. This study provides practical recommendations for cauliflower growers to optimize spacing and varietal selection, thereby improving productivity and resource-use efficiency under similar agro-climatic conditions.

Keywords: *Agro-climatic optimization, Cauliflower, growth traits, plant spacing, marketable yield*

Introduction

Cauliflower (*Brassica oleracea* L. var botrytis) is an herbaceous, versatile vegetable and one of the most esteemed cruciferous vegetables globally. Its significance in the agricultural sector is profound owing to its adaptability to diverse climates. This cross-pollinated crop is renowned for its rich composition of vital vitamins, minerals, and dietary fiber. Despite being low in calories, it boasts a notable content of carbohydrates, choline, phosphorus (76mg/100g fresh weight), calcium (30mg/100g fresh weight), protein (2.4g/100g fresh weight), vitamin C (75mg/100g fresh weight), and vitamin A (70 IU/100g fresh weight). With a chromosome number of 2n=2x=18, cauliflower has evolved through mutation and selective breeding from its common ancestor, *Brassica oleracea* var *sylvestris*, with *Brassica cretica* identified as a potential progenitor. Its origin is traced back to Cyperus. Indian cauliflowers, specifically, are adapted to high-temperature conditions, capable of initiating curd formation at temperatures exceeding 20°C (Dey *et al.*, 2019). Optimal plant spacing plays a pivotal role in maximizing cauliflower yield and growth. Adequate spacing can boost yield upto 25%, emphasizing the importance of precise plant arrangement. Wider spacing promotes larger heads and early maturity, while closer spacing enhances total curd production and yield. However, excessive spacing may lead to the development of undersized or poorly formed curds. In India, major cauliflower cultivation regions include Bihar, Uttar Pradesh, Odisha, West Bengal, Maharashtra, Assam, Punjab, and Haryana. Among these states, West Bengal stands out with the highest area, production, and productivity, encompassing 79.49 thousand hectares, producing 2037 tons, with a productivity of 25.63 mt/ha, respectively (Indiastat 2021).

Materials and Methods

The field experiment for the present investigation took place at the Regional Research Station of Punjab Agricultural University (PAU) in Gurdaspur during the *rabi* season of 2022-23. It is situated in the northernmost region of Punjab, Gurdaspur shares borders with Jammu and Kashmir and Himachal Pradesh, marked by the presence of the Ravi and Beas rivers. The Regional Research Station is located in Gurdaspur at latitude of 32°05' N and a longitude of 75°4' E. The main plots contain four plants spacing (S_1: 45 x 45 cm, S_2: 60 x 30 cm, S_3: 67.5 x 30 cm and S_4: 75 x 50 cm) and

sub-plots consist of three varieties (V_1: PGAC-25-17, V_2: Pusa Sharad and V_3: Aghani).

Growth and yield parameters were recorded using standardized methods. Leaf length and width (cm) were measured from five leaves per plant at the time of harvesting from the base to the tip for length and at central portion for width. Leaf number was determined by counting all emerged leaves per plant. Days to curd initiation were recorded from sowing to 50% curd formation. Curd polar and equatorial diameter was measured from randomly selected plants using a chord and a meter scale, respectively. Gross curd weight included stalk and leaves, whereas marketable curd weight included partial stalk and leaves and net curd weight excluded both. Marketable yield per hectare was calculated by generalizing the per plant curd weight, including some stalk and leaves to a hectare basis. All observations were averaged as per treatment to evaluate the effects of spacing and variety on cauliflower growth and productivity.

Results and Discussion

Leaf length

Among different planting geometries it was found that cauliflower sown at 67.5 x 30 cm had the highest leaf length (15.75 cm) followed by 60 x 30 cm (15.07 cm). The plants sown at other two spacings *viz*. 45x 45 cm and 75 x 50 cm varied significantly (13.46 cm and 14.03 cm) indicating that wider spacing favors longer leaves (Table 1). However, in case of S_4 (75 x 50 cm) the reason for decreased leaf length was that there were two plants sown on one ridge which also increased the competition among the population. The decreased leaf length when plants were sown at 45 x 45 cm, was attributed to the increased competition at closer spacing had a significant impact on plant growth, which resulted in smaller leaves as compared to plants sown at wider spacing. Sharma and Chaudhary (1996) stated that with the increase in plant spacing the plant spread or leaf area increased and Kaur *et al*., (2020) also confirmed an increase in spacing with the increase in leaf length. Singh *et al*., (2019) found that the plants spaced at 30 cm and 60 cm apart had substantial differences in plant height, fresh weight and number of leaves along with their dry weight.

Leaf width

Across different planting structures, 67.5x 30 cm outperformed all other planting configurations followed by 60 x 30 cm having highest leaf width of cauliflower at 13.31 cm and 12.75 cm respectively. The plants sown at other two spacings *viz*. 45 x 45 cm and 75 x 50 cm had

Table 1: Effect of sowing date, spacing and variety on growth and yield parameters of cauliflower

Treatments	Leaf length (cm)	Leaf width (cm)	Leaf number	Days to curd initiation	Curd polar diameter (cm)	Curd equatorial diameter (cm)	Gross curd weight (kg)	Marketable curd weight (kg)	Net curd weight (kg)	Marketable yield (q ha^{-1})
Spacing (A)										
S_1 (45 x 45 cm)	13.46	12.21	20.71	67.72	5.49	13.08	1.14	0.44	0.30	175.8
S_2 (60 x 30 cm)	15.07	12.75	21.54	69.00	7.50	19.68	1.66	0.71	0.49	281.6
S_3 (67.5 x 30 cm)	15.75	13.31	21.95	71.33	8.98	18.06	1.68	0.76	0.46	302
S_4 (75 x 50 cm)	14.03	12.01	20.50	69.26	5.93	14.23	1.11	0.42	0.30	167.3
LSD (p=0.05)	0.327	0.367	0.730	1.362	0.289	0.614	0.032	0.013	0.012	0.427
Variety (B)										
V_1 (PGAC-25 -17)	14.91	13.12	21.70	69.40	7.65	16.81	1.43	0.66	0.41	263.7
V_2 (Pusa Sharad)	14.54	12.67	21.26	68.84	7.03	16.14	1.42	0.56	0.38	222.3
V_3 (Private – Aghani)	14.28	11.92	20.56	69.75	6.24	15.83	1.35	0.53	0.37	209.2
LSD (p=0.05)	NS	0.509	0.639	NS	0.279	0.669	0.065	0.028	0.016	0.761
LSD (p=0.05) (A x B)	NS	NS	NS	2.78	0.56	1.34	0.130	0.033	0.033	1.52

width of the leaves at par with each other at 12.21 cm and 12.01 cm suggested that these two spacings did not affect the leaf width. The main reason for decreased leaf width of crop planted at 75 x 50 cm was that two plants were sown on one ridge which boosted competition among the population. With respect to varieties, the variety PGAC– 25–17 excelled all other varieties having broader leaves (Table 1). The width of the leaf in variety PGAC–25–17 was observed as 13.12 cm followed by Pusa Sharad (12.67 cm) and Aghani by 11.92 cm. Pusa Sharad and Aghani varied significantly from each other and the variety PGAC–25–17 varied significantly from variety Aghani but not from Pusa Sharad in case of this character. Kaur *et al*., (2020) confirmed that with increase in spacing there was increase in leaf length. In case of plant geometries, cauliflower sown at 67.5 x 30 cm gave highest number of leaves *i.e.* 21.95 which was statistically at par when cauliflower sown at 60 x 30 cm. The other two plant spacings *i.e.* 45 x 45 cm and 75 x 50 cm were at par with each other but gave slightly fewer leaves than other two planting arrangements. The reason for the consistent increase in number of leaves up to 67.5 x 30 cm was due to the decrease in the competition among the plants. Similar findings were also reported by Hill (2000) and Sarker *et al*., (2002) indicating thar wider spacing increased the number of leaves in Chinese cabbage and cabbage.

Curd initiation

The longest time for curd initiation was taken when the cauliflower planted at spacing of 67.5 x 30 cm *i.e* 71.33 days followed by 75 x 50 cm (69.26 days) and 60 x 30 cm with 69 days and lastly by 45 x 45 cm. All of these planting geometries gave significant number of days for curd initiation. Similarly, the interaction effect of spacing and varieties was found to be significant on days to curd initiation (Table 2). Cauliflower variety PGAC–25–17 when sown at the spacing of 60 x 30 cm took maximum number of days for curd initiation which was statistically at par with spacing of 67.5 x 30 cm but significantly greater than at 45 x 45 cm. However, variety Pusa Sharad when planted at the spacing of 67.5 x 30 cm took the maximum number of days for the curd initiation as opposed to minimum number of days taken when planted at 75 x 50 cm which was statistically at par when the same was planted at 45 x 45 cm. Moreover, the variety planted at the spacing of 67.5 x 30 cm took the maximum number of days when which was statistically at par with when the same variety when planted at 75 x 50 cm. Similarly, when it is planted at the spacings of 45 x 45 cm and 60 x 30 cm it gave insignificant difference in the number of days for curd initiation. Within the range of treatment combination, the maximum number of days for taken for the curd initiation is observed with the Aghani when planted at the distance of 67.5 x 30 cm (72.50) suggesting its probable non suitability for late season planting. On the other extreme, the minimum number of days were taken when the variety Pusa Sharad was planted at the distance of 75 x 50 cm (66.53) which was at par with variety PGAC – 25 – 17 when planted at 45 x 45 cm (66.84) and when variety Aghani planted at the 45 x 45 cm (67.50) and 60 x 30 cm (67.00) emphasizing their suitability for late plantings (Table 1).

Curd polar diameter and equatorial diameter

In the array of planting patterns, cauliflower at 67.5 x 30 cm spacing had the highest curd polar diameter (8.98 cm) which was at par with the spacing 60 x 30 cm (7.50). Although the widest spacing (75 x 50 cm) has had the negative correlation with the curd polar diameter but spacing up to a certain limit (67.5 x 30 cm) has increased the curd polar diameter highlighting the significance of finding the optimal spacing for the curd polar diameter. Likewise significant variations in curd polar diameter were noticed based on distinct varieties. Highest curd yield was observed with PGAC-25-17 (7.65 cm) which was followed by Pusa Sharad (7.03 cm) and Aghani (6.24 cm). PGAC-25-17 significantly outperformed both Pusa Sharad and Aghani on mean criteria (Table 1).

Among the different planting structures cauliflower when planted at the spacing of 60 x 30 cm achieved the highest curd equatorial diameter which was significantly different from and followed by the planting distance of 67.5 x 30 cm. Similarly, the varieties also gave the significant results for the curd equatorial diameter. However, the closer spacing and spacing exceeding a certain limit shows counterproductive effects on the curd equatorial diameter. The main reason for this condition is the fact that there is maximum competition for the resources like water, sunlight and nutrients. The variety PGAC – 25 – 17 performed significantly better than other two varieties and achieved the highest curd equatorial diameter which was followed by Pusa Sharad and Aghani. However, when the variety Aghani was planted at the distance of 60 x 30 cm it had the significantly highest curd equatorial diameter followed by the spacing of 67.5 x 30 cm. Correspondingly, in case of treatment combinations the highest curd polar diameter was observed when the variety Aghani was planted at the distance of 60 x 30 cm, which was at par with when variety Pusa Sharad was planted at the same spacing or when variety PGAC-25-17 when planted at 67.5 x 30 cm. Conclusively, variety PGAC-25-17 performs best and spacing 60 x 30 cm performs best. However, Mihov and Antonova (2001) reported that a hybrid (The Batsman

Table 2: Combined influence of spacing and variety on curd development and yield attributes of cauliflower

Spacing	Variety	Days to curd initiation	Polar diameter (cm)	Equatorial diameter (cm)	Gross curd weight (kg)	Marketable curd weight (kg)	Net curd weight (kg)	Marketable yield (q ha{ ^{1})
S• (45 × 45 cm)	V• (PGAC-25-17)	66.84	5.74	13.84	1.27	0.53	0.36	211.50
	V, (Pusa Sharad)	68.83	5.61	12.90	1.22	0.43	0.31	172.00
	Vƒ (Aghani)	67.50	5.13	12.50	0.95	0.36	0.24	144.40
S, (60 × 30 cm)	V• (PGAC-25-17)	71.50	8.83	19.03	1.61	0.78	0.50	311.60
	V, (Pusa Sharad)	68.50	6.98	19.57	1.72	0.68	0.48	271.30
	Vƒ (Aghani)	67.00	6.70	20.43	1.66	0.66	0.49	255.40
Sƒ (67.5 × 30 cm)	V• (PGAC-25-17)	70.00	9.89	19.52	1.62	0.87	0.47	346.10
	V, (Pusa Sharad)	71.50	9.60	18.27	1.66	0.72	0.46	287.80
	Vƒ (Aghani)	72.50	7.45	16.39	1.78	0.68	0.44	272.10
S„ (75 × 50 cm)	V• (PGAC-25-17)	69.25	6.17	14.87	1.22	0.47	0.32	185.60
	V, (Pusa Sharad)	66.53	5.94	13.82	1.09	0.40	0.28	157.80
	Vƒ (Aghani)	72.00	5.70	14.00	1.02	0.40	0.30	158.50
LSD (p=0.05)	2.78	0.56	1.34	0.13	0.03	0.03	1.52	

F1) performed best in terms of parameters like maximum number of rosette leaves and longest curd (14.72 cm) (Table 1).

Gross, net and marketable curd weight

Variety Pusa Sharad gave the heaviest curd weight when planted at the distance of 60 x 30 cm which was significantly better than the spacing of 67.5 x 30 cm. But the variety Aghani demonstrated the same trend of variety PGAC-25-17 when planted at 67.5 x 30 cm and 60 x 30 cm by giving the highest and second highest gross curd weight respectively (Table 1). However, Joshi *et al* (2018) The best response was shown for all parameters at 52.5 x 30cm however the highest plant height maximum curd diameter and the heaviest curd (682 g) was noted on plants sown at spacing 52.5 x 45 in a single row. Among different planting geometries, cauliflower at 60 x 30 cm spacing achieved the highest net curd weight (0.49 kg), followed by 67.5 x 30 cm spacing (0.46 kg). However, the net curd weight when the planting was done on 45 x 45 cm and 75 x 50 cm was the same i.e. 0.30 kg significantly lower than other varieties. Similarly, among different varieties, PGAC-25-17 outperformed other two varieties and it (0.41 kg) followed by Pusa Sharad (0.38 kg) and Aghani (0.37 kg) on mean basis, however, Pusa Sharad and Aghani were not significantly different from each other in net curd weight. These observations align with study conducted by Das *et al* (2000) stated that 60 x 60 cm planting geometry had the highest curd yield. However, Rahman *et al* (2007) argues that maximum curd weight is obtained at plant-to-plant distance of 45 cm.

Conclusion

Based on the findings and discussion we fund that leaf length, leaf width, leaf number, days to curd initiation curd polar diameter, gross curd weight, marketable curd weight and marketable yield per plot were found to be maximum in variety PGAC – 25 – 17and at spacing 67.5 x 30 cm. The curd equatorial diameter, net curd weight was found to be highest in variety PGAC – 25 – 17and spacing 67.5 x 30 cm. Gross curd weight and marketable yield per plot were the only two parameters that were significantly affected by the sowing date. The current study provides the conclusion that, the spacing 67.5 x 30 cm proved to be the best among other spacings for the growth and yield of variety PGAC – 25 – 17.

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