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Interaction Effect of Plant Spacing and Varieties on Growth, Yield and Quality of Cabbage (*Brassica oleracea* var. *capitata* L.)

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ABSTRACT

The objective of the present study was to assess the influence of different varieties and spacing on horticultural attributes of cabbage. Cultivar Golden Acre, Pusa Drum Head and Pusa Mukta were selected for the study and transplanted planted at three spacing viz., 45 cm x 30 cm, 45 cm x 45 cm and 45 cm x 60 cm laid out in Factorial Randomized Block Design with three replications. The results revealed that the maximum plant height (36.90 cm), number of non wrapped leaves (16.38), leaf length (20.85cm), leaf width (11.74 cm), stem diameter (10.46 cm), plant spread E-W (35.18 cm), N-S (39.36 cm) and weight of untrimmed head (943.28 g) were noted in variety Pusa Drum Head. While, the highest values for the weight of trimmed head (395.89 g), head diameter (13.83 mm), yield (307.55 q ha^{-1}), Vit-C (43.13 mg/100g) and TSS (7.45 ^{o}B) were noticed in Golden Acre (V_1). In general, the lowest values of growth and yield attributes were noted under Pusa Mukta. In respect of plant spacing, the maximum plant height (37.37 cm), number of non wrapped leaves (16.44), leaf length (21.34 cm), leaf width (11.88 cm), stem diameter (10.46 cm), plant spread E-W (34.79 cm), N-S (39.06 cm) and Vit-C (42.58 mg/100g) were recorded in spacing of 45 cm x 45 cm (S_2) but, the maximum weight of untrimmed head (950.72 g) and trimmed head (356.66 g) and yield (296.08 qha^{-1}) were found in spacing 45 cm x 30 cm (S_1) whereas, the maximum head diameter (13.81 mm) was recorded in 45 cm x 60 cm spacing. Thus, S_2 (45 cm x 45 cm) caused better vegetative growth, but, the highest yield parameter was reported in S_1 (45 cm x 30 cm). Therefore, considering the combined effect, cultivar V_1 (Golden Acre) when planted at spacing S_1 (45 cm x 30 cm) may be suggested for production of more cabbage head yield.

Keywords Cabbage, Variety, Spacing, Yield, Quality.

INTRODUCTION

Cabbage (*Brassica oleracea* var. *capitata* L.) a popular cole crop belongs to Brassicaceae family (2n=2x=18), is native to Western Europe and the Mediterranean Region's Northern Shore (Schlegel 2010, Singh and Kumar 2015). Cabbage is one of the oldest vegetables, having been produced for over 4,000 years (Schlegel 2010) and was the first

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cole crop ever grown by humans. Cabbage is one of the top twenty vegetables and a major food source around the world (FAO 1988) having Vitamin C, A, K (Fowke *et al*. 2003) along with 1.8 g protein, 0.1 g fat, 4.6 g carbohydrate, 0.6 g mineral, 29 mg calcium, 0.8 mg iron and 14.1 mg sodium per 100 g. Cabbage is recognized by its inflated head, which develops when edible buds stiffen, resulting in a large head with thick, closely packed overlapping leaves. Depending on the variety, the head might be spherical, conical, oblong, flat or savoyed. It also contains high amount of sulfhur, amino acids, minerals, carotenes, ascorbic acid, antioxidants and has anti-carcinogenic property (Singh *et al*. 2009). Cabbage is often used in traditional medicine to treat symptoms related with gastrointestinal diseases (gastritis, peptic and duodenal ulcers, irritable bowel syndrome), as well as small cuts and wounds and mastitis, due to its antioxidant, anti-inflammatory, and antibacterial characteristics (Samec *et al*. 2011). It has therapeutic benefit as well, since it provides a cooling impact on the body, promotes appetite, avoids constipation, increases digestive speed, and is especially beneficial to diabetic patients (Jensen 2004, BBS 2010). Thus, it became one of the important edible vegetables in our daily life. Among the various agro-techniques, spacing of crops may be varied on climatic conditions, soil fertility and the suitability of the cultivar for a particular region and a proper spacing can provide the best quality products along with the maximum yield potential. This may be due to less competition for light, nutrients and water than for close spacing (Bairwa *et al*. 2017). Cultivation of vegetable crops requires a high population density, which is widely used in a variety of crops. Closer spacing has some benefits like to reduce weeds, improve soil protection, increase fertilizer efficiency and increase yield (Neto *et al*. 2016). Proper spacing is an important factor in ensuring higher yields of the desired Knobs of knolkhol. Dense planting can result in higher yields due to the higher number of plants per unit area, but many reported to have smaller heads and bulbs regardless of variety (Rahman *et al*. 2007, Prasad *et al*. 2010, Moniruzzaman 2011).

Keeping these views, the present experiment was conducted under Lucknow subtropical condition having alkaline soil (pH 8.2) to find the suitable variety of cabbage with appropriate spacing to produce superior quality head with higher yield.

MATERIALS AND METHODS

Experimental site: The experiment was done at Department of Horticulture, Babasaheb Bhimrao Ambedkar University, Lucknow (UP) ($26^{0}50'$ N latitude, $80^{0}52'$ E longitude, 111 meters above mean sea level) during the rabi season of 2020-21. The soil was a light alluvial with a sandy loam texture and a slightly alkaline (pH 8.2). The area receives average annual rainfall 800-1000 mm with average day temperature ranging from 15 to 30°C during rabi season and fall under subtropical climate.

Planting materials: Three varieties viz., Golden Acre (V_1), Pusa Drum Head (V_2) and Pusa Mukta (V_3) were experimented with three spacing 45 cm x 30 cm (S_1), 45 cm x 45 cm (S_2), 60 cm x 45 cm (S_3) and treatment lay out was done with two factor RBD. Seed treatment was done with Vitavax 200 WP at 2.5 g/kg of seeds before seed sowing on well prepared nursery. Seedlings (32 days old) transplanting was done on plot of 1.8 m x 1.8 m size, with a 50 cm spacing between neighbouring plots and 1 m between blocks after treating seedlings with Bavistin @ 2 g/l of water.

Observation, data collection and statistical analysis: The observation was made on the growth, yield and quality parameters like plant height, number of non wrapping leaves, leaf length, leaf width, plant spread, weight of head (untrimmed and trimmed), head diameter, head yield (per ha), Vitamin C (Ascorbic acid) and TSS. All the parameters were observed from five randomly sampled plants of each treatment and each replication. To avoid the border effect outer two lines and the outer plants of the middle lines were excluded. The height of the plants was measured from the ground level to the tip of the highest leaves. The length and breadth of the largest leaf were measured from the base of the petiole to the tip. To record the diameter, the cabbage heads were sectioned vertically at the middle position and the horizontal distance from one side to another side of the widest part of the sectioned head. The thickness of the head was measured as the vertical distance from the lower to the uppermost leaves of the head. Physico-chemical

Table 1. Effect of plant spacing and varieties on growth of cabbage. V_1-Golden Acre, V_2-Pusa Drum Head, V_3-Pusa Mukta, S_1-45×30 sq cm, S_2-45×45 sq cm, S_3-45×60 sq cm.

Treatments	Plant height (cm)	No. of non wrapped leaves	Leaf length (cm)	Leaf width (cm)	Stem diameter (cm)	Plant spread (E-W) (cm)	Plant spread (N-S) (cm)
S_1	35.41	15.00	18.91	10.40	8.63	30.98	36.13
S_2	37.37	16.44	21.34	11.88	10.39	34.79	39.06
S_3	36.43	16.33	20.32	11.41	10.21	33.64	38.42
SE(m)	0.29	0.270	0.27	0.20	0.25	0.51	0.36
CD	0.82	0.821	0.81	0.62	0.73	1.50	1.06
V_1	35.64	14.77	19.22	10.97	8.56	30.62	36.34
V_2	36.90	16.38	20.85	11.74	10.46	35.18	39.36
V_3	36.67	16.22	20.50	10.98	10.22	33.61	38.01
SE(m)	0.27	0.271	0.26	0.21	0.24	0.50	0.35
CD	0.83	0.820	0.80	0.61	0.71	1.52	1.05
V_1S_1	35.17	13.67	17.50	10.40	7.70	28.07	34.47
V_1S_2	36.03	15.33	20.97	11.47	8.63	32.00	37.30
V_1S_3	35.73	15.33	19.20	11.03	9.33	31.80	37.37
V_2S_1	35.33	15.67	19.57	11.07	9.07	34.17	37.60
V_2S_2	39.13	18.33	22.47	13.30	12.27	38.87	42.57
V_3S_3	36.23	16.33	20.53	10.87	10.03	32.50	37.60
V_3S_1	35.73	15.67	19.67	9.73	9.13	30.70	36.43
V_3S_2	36.93	15.67	20.60	10.87	10.27	33.50	37.30
V_3S_3	37.33	17.33	21.23	12.33	11.27	36.63	40.30
SE(m)	0.47	0.470	0.46	0.35	0.41	0.86	0.61
CD	1.41	1.420	1.38	1.07	1.22	2.60	1.83

quality parameters of head were estimated following standard procedures (Ranganna 2001). The recorded data of various observations were analyzed statistically (Sheoran *et al*. 1998) and treatment mean was compared at 5% level of significance.

RESULTS AND DISCUSSION

The data presented in Table 1 revealed a significant effect of plant spacing and varieties on plant height. Among the varieties, V_2 (Pusa Drum Head) have found highest plant height as compare to V_3 (Pusa Mukta) and V_1 (Golden Acre) recorded minimum height. There was the significant effect of plant spacing pacing on plant height and spacing S_2 (45 cm X 45 cm) recorded maximum plant height statistically at par with S_3 (45 cm X 60 cm). Interaction effect of variety and plant spacing also had a significant effect on plant height improvement, where, V_2S_2 (Pusa Drum Head at 45 cm x 45 cm spacing) showed maximum plant height (39.13 cm) followed by V_3S_3 (Pusa Mukta at 45 cm x 60 cm). Increased plant density coupled with shallow root system limits the availability of space for lateral growth. This leads to the competition between the plants for light and nutrients, resulting in increased plant height. These findings were in agreement with Rastogi *et al*. (1987) in radish, Khurana *et al*. (1990) in cauliflower and Hill (2000) in Chinese cabbage.

Similar results were recorded in case of number of non wrapper leaves when S_2 and S_3 as well as V_2 and V_3 had statistically very close number of non wrapper leaves as the maximum number and in combination treatment V_2S_2 showed the highest number of non wrapper leaves. This might be due to lesser competition for nutrients and light amongst the plants with lower plant density. Hence in wider spacing due to the availability of more space and light, the crop might have produced more number of leaves per plant. These results were in conformity with the results of Hill (2000) in Chinese cabbage, Singh (2005) in cauliflower and Agarkar *et al*. (2010) in broccoli.

The maximum length of leaves (20.85 cm) was recorded in V_2 (Pusa Drum Head) at par with V_3 (Pusa Mukta) and minimum leaf length (19.22 cm)

Table 2. Influence of spacing and varieties on head yield and quality.

Treatments	Weight of untrimmed head (g)	Weight of trimmed head (g)	Head diameter (mm)	Yield (q/ha)	Vitamin C (mg/100g)	TSS (° Brix)
S_1	950.72	356.66	12.53	296.08	36.77	5.97
S_2	941.36	325.06	13.68	286.75	42.58	6.88
S_3	927.70	328.92	13.81	283.11	41.81	6.86
SE(m)	0.81	0.38	0.29	3.43	0.56	0.24
CD	2.47	1.18	0.89	10.38	1.70	0.72
V_1	939.25	395.89	13.83	307.55	43.13	7.45
V_2	943.28	338.25	13.80	295.89	35.34	6.90
V_3	937.24	276.51	12.40	263.11	42.70	5.37
SE(m)	0.81	0.39	0.29	3.43	0.56	0.24
CD	2.47	1.18	0.89	10.38	1.70	0.72
V_1S_1	945.00	430.35	12.86	317.86	40.46	8.4
V_1S_2	935.53	302.70	13.30	304.40	42.10	6.1
V_1S_3	937.23	454.61	15.33	300.40	46.83	7.8
V_2S_1	953.66	336.23	13.33	295.20	28.86	4.6
V_2S_2	952.70	354.27	13.36	312.13	37.46	9.8
V_3S_3	923.49	324.26	14.70	278.53	39.70	6.2
V_3S_1	953.50	303.40	11.40	253.73	41.00	4.8
V_3S_2	935.85	318.23	14.40	271.73	48.20	4.7
V_3S_3	922.37	207.90	11.40	263.86	38.90	6.5
SE(m)	1.416	0.677	0.511	5.947	0.974	0.417
CD	4.283	2.047	1.542	17.984	2.945	1.260

was found in V_1 (Golden Acre). It was maximum (21.34 cm) in S_2 (45 cm x 45 cm) followed by S_3 (45 cm x 60 cm) while minimum leaf length was recorded in S_1 (45 cm x 30 cm). While, V_2S_2 (V_2- Pusa Drum Head, S_2- 45×45cm) had maximum leaf length (22.47 cm) which was at par with V_3S_3 (V_3- Pusa Mukta, S_3- 45×60cm). Similar pattern was also observed in case of leaf width found superior with S_2 and S_3, V_2 as main effect and V_2S_2 followed by V_3S_3 as interaction effect that observed to be continued for stem diameter also having maximum stem diameter (12.27 cm) by V_2S_2 (V_2- Pusa Drum Head, S_2- 45×45cm). More vegetative growth of cabbage plant under wider spacing in the investigation may be because of wider spacing provided more space which ultimately resulted in more growth of plants by receiving maximum sun light and more photosynthesis.

Highest plant spread in both the direction (East-West and Nort- South) was recorded in V_2 (Pusa Drum Head) as compare to V_3 (Pusa Mukta) while minimum spread was recorded in V_1 (Golden Acre). Spacing was observed maximum significantly in S_2 (45 cm x 45 cm) compare to spacing S_3 (45 cm x 60 cm) (Table 1). Planting of Pusa Drum Head at a spacing of 45 cm x 45 cm (V_2S_2) recorded the maximum plant spread at both direction of East – West and North – South. These results can be attributed to fact that, in wider spacing the individual plant gets plenty of light and more nutrients in comparison to closer spacing. The results of present findings were in agreement with the findings of Sharma and Chaudhary (1996) in cauliflower and Purushottam (2001) in cabbage.

Head yield and head quality parameters were presented in Table 2 that showed that S_1 had maximum head weight (trimmed and untrimmed). But, V_2 had maximum weight of untrimmed head whereas, V_1 showed maximum trimmed head weight. Similarly, weight of trimmed and untrimmed head were differed as interaction effect of variety and spacing viz., V_2S_1 (V_2- Pusa Drum Head, S_2- 45 cm × 30 cm) and V_3S_1 (V_3- Pusa Mukta, S_1- 45 cm × 30 cm) showed maximum untrimmed head weight but, maximum trimmed head weight was calculated in V_1S_3 followed by V_1S_1 (V_1-Golden Acre, S_1-45 cm × 30cm)

It is clear from the results (Table 2) that head

diameter was significantly superior in S_3 planting. It was statistically at par for V_1 and V_2 having maximum head diameter. Considering the interaction effect, V_1S_3 (V_1-Golden Acre, S_3-45 cm × 60 cm) followed by V_3S_3 (V_3- Pusa Mukta, S_3- 45cm × 60cm) had maximum head diameter.

Varieties and spacing showed significant effect on the cabbage head yield (q/ha). The recorded data revealed that the maximum yield was found in variety V_1 (Golden Acre) (307.55 q/ha) followed by V_2 (Pusa Drum Head). The minimum head yield was recorded in V_3 (Pusa Mukta). According to estimated data it was found that the spacing S_2 (45 cm × 45 cm) recorded the highest head yield (296.08 q/ha). The interaction effect showed the maximum head yield which recorded under V_1S_1 (V_1-Golden Acre, S_1-45 cm × 30cm) followed by V_2S_2 (V_2- Pusa Drum Head, S_2- 45 cm × 45 cm) but, were at par. This was due to the reality that as plant spacing decreases, total plant population increases and this in turn contributes to increase in total head yield. The current result was in agreement with works of Hossain *et al*. (2011).

The recorded data revealed that the maximum Vitamin C in terms of ascorbic acid (42.58 mg/100g) was found in S_2 (45 cm x 45 cm) and with variety V_1 (Golden Acre) (43.13 mg/100g)) followed by V_3 (Pusa Mukta) (42.70 mg/100g). V_2 (Pusa Drum Head) had minimum ascorbic acid (35.34 mg/100g). There was significant effect of combination treatment of variety and spacing recorded maximum Vitamin C content in V_3S_2 (V_3- Pusa Mukta, S_2- 45 cm × 45 cm) closely followed by V_1S_3 (V_1-Golden Acre, S_3-45 cm × 60 cm). Among the varieties, it was recorded that the maximum TSS content was recorded in V_1 (Golden Acre) (7.45 °Brix) followed by V_2 (Pusa Drum Head). Among spacing, it was found maximum at spacing S_2 (45 cm × 45 cm) as (6.88 °Brix) statistically at par with S_3 (45 cm x 60 cm) (6.86 °Brix) and the lowest TSS (4.6 °Brix) was recorded in V_2S_1(Pusa Drum Head planted at 45 cm x 30 cm). Significant effect on vegetative growth allowed plants to receive more light energy and consequently produced more photosynthesis and to conserve more photosynthetic metabolites which was translocated and stored in the forms of head yield and might have positive effect of head quality.

CONCLUSION

On the basis of the present experimentation, it was conclude that the variety V_2 was found superior in growth parameter. In yield attributes characters, V_2 (Pusa Drum Head) has highest untrimmed head weight but V_1 (Golden Acre) was found superior for trimmed head, head diameter, head yield. V_1 (Golden Acre) was also found superior in quality attributes character like ascorbic acid, TSS. Among the plant spacing studied, S_2 (45 cm x 45 cm) promoted better vegetative growth, but, the highest yield parameter was reported in S_1 (45 cm x 30 cm). Considering the combined effect, V_1 (Golden Acre) when planted at spacing S_1 (45 cm x 30 cm) may be suggested for more cabbage yield.

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