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Effect of different planting time and spacing on growth, yield and quality of cabbage (*Brassica oleracea var. capitata*) cv. Golden Acre under Bundelkhand region in U.P.

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Abstract
A field experiment was carried out to know the optimum planting time and spacing for cabbage cultivation in Bundelkhand region at Organic Research Farm, Karguwan ji, Bundelkhand University, Jhansi (U.P.). The treatments comprises three planting times *viz.*, 5th November (P_1), 15th November (P_2) and 25th November (P_3) and three spacing *viz.*, 60 × 45 cm (S_1), 60 × 30 cm (S_2) and 45 × 30 cm (S_3). The experiment was laid out in Factorial Randomized Design with three replications. The observations were made on growth, yield and quality parameters of cabbage. The results revealed that highest plant height, number of leaves per plant, plant spread, stem diameter, head weight, head yield, head diameter and Total Soluble Solid content was obtained with early seedlings transplanting on 5th November while, minimum days taken to head maturity and highest head compactness was observed with seedlings transplanted on 25th November. There was no significant difference observed between planting times for dry matter content. Among the spacing's, highest growth and quality parameters were observed with seedlings transplanted on wider spacing (S_1) while, highest head yield was recorded with seedlings transplanted on medium spacing (S_2). The interaction effect of planting times and spacing were non-significant effect for all the parameters except yield however, highest plant height, number of leaves per plant, plant spread, stem diameter, head weight, head diameter, TSS and dry matter content was observed with treatment combination of P_1S_1 (5th November + 60 cm × 45 cm). The significantly highest yield (490.98 q ha^{-1}) was obtained with treatment combination of P_1S_2 (5th November + 60 cm × 30 cm). Minimum number of days taken to head maturity and crop harvest as well as highest head compactness was recorded with treatment combination of P_3S_1 (25th November + 60 cm × 45 cm).

Keywords: Cabbage, planting time, spacing, growth, yield, quality

Introduction
Cabbage (*Brassica oleracea var. capitata* Linn.) is an important leafy vegetable belonging to the family Cruciferae having chromosome number (2n) 18. It is herbaceous biennial grown during winter season in temperate, subtropical and tropical regions and now grown almost throughout the year. The word cabbage has been derived from the French word *Cobache*, meaning head, which is best described as a single large terminal bud comprised of tightly overlapped numerous thick leaves attached to and enclosing most of the un-branched short stem. It is rich in minerals and vitamins, 100 g of cabbage contain protein (1.4 g), Fat (0.2 g), Carbohydrate (5.7 g), Fiber (1.5 g), Vitamin A (70 I.U), Vitamin B_1 (0.05 mg), Vitamin B_2 (0.05 mg), Vitamin B_6 (0.11 mg), Vitamin C (46 mg), Vitamin E (0.7 mg), Fe (0.08 mg) etc. (Watt and Merrill, 1963) [14].

Planting date and plant spacing are of the important factors for production practices of cabbage. The use of suitable planting date and proper plant spacing effects on the yield contributing characters and consequently on the overall yield. Moreover, the head quality attributes are mainly affected. The effect of planting date on cabbage vegetative characters, yield and head attributes has been reported in earlier investigations (Singh *et al.*, 2010; Thirupal *et al.*, 2014 and Jayamanne *et al.*, 2015) [9, 12, 4]. Planting date plays a direct role in the maturity and harvesting time of cabbage plants. It is associated with temperature, day length and light intensity. The suitable planting date determines the favourable environmental climatic conditions for cabbage growing. Planting date affects total and marketable yield of

cabbage as well (Kleinhenz and Wszelaki, 2003). The late planting date resulted in denser cabbage heads and head volume, but the early planting date produced heavier heads with larger diameters and wider core width than late planting as well as the head diameter and head weight were also reduced at delayed planting date (Khan *et al.*, 2015) [7].

As we know that the farmers of the Bundelkhand region are grow cabbage at different time and using different plant spacing without knowing their effect on yield of cabbage. The cabbage growers of this region are in need of the information regarding the effect of planting time and plant spacing on cabbage production while very scanty information is available on this aspect for Bundelkhand region. Hence, considering the need of the farmers, the present investigation entitled "Effect of different planting time and spacing on growth, yield and quality of cabbage (*Brassica oleracea var. capitata*) cv. Golden Acre under Bundelkhand region in U.P."

Material and Methods

The present investigation was carried out at organic research farm karguwan ji, Bundelkhand University, Jhansi (Uttar Pradesh) during *rabi* season 2019-2020. The soil of experimental field was sandy loam with good drainage and uniform texture with low to N (110.46 kg ha^{-1}), medium to P (15.36 kg ha^{-1}), K (162.31 kg ha^{-1}) status and soil pH (7.36). Seed of Golden Acre variety of cabbage were used in the experiment. The experiment was laid out in factorial randomized block design with three replications. The experiment was comprised of three planting time (P_1 = 5 November; P_2 = 15 November; P_3 = 25 November) and three levels of spacing (S_1 = 60 cm × 45 cm; S_2= 60 cm × 30 cm and S_3 =45 cm × 30 cm). There were altogether twenty nine plots each of 2.40 x 1.80 m^2 size. The crop was supplied with 20 t well rotten farm yard manure per hectare. The observation were recorded i.e. Plant height (cm), Number of leaves per plant, Plant spread (cm), Stem diameter (mm), Days taken to head maturity, Days taken to harvest, Head weight (kg), Head yield per plot (kg), Head yield per hectare (q ha^{-1}), Head diameter (cm), Head compactness, Total Soluble Solids (TSS%) and Dry matter content (%).

Result and Discussion

Growth and Morphological parameters

The data on growth stages and morphological parameters as influenced by date of planting and spacing has been presented in table1, table 2 and table 3. The plant height at different growth stages was significantly influenced with different dates of transplanting and spacings. The plant height was significantly decreased with delay in transplanting as well as with reducing plant spacing.

The highest plant height 30 DAT (13.10 cm), 60 DAT (19.61 cm) and at harvest stage (25.35 cm) was recorded with transplanting on 5th November (P_1) and the significantly highest plant height 30 DAT (13.05 cm), 60 DAT (20.21 cm) and at harvest stage (26.69 cm) was recorded with spacing 60 cm × 45 cm (S_1). Interaction effect of planting times and spacing were non-significant effect on plant height at different growth stages.

The highest number of leaves per plant 30 DAT (7.62), 60 DAT (15.99) and at harvest stage (18.20) was recorded with seedlings transplanted on 5th November (P_1) and wider plant spacing (60 cm × 45 cm) (S_1) was significantly superior and recorded highest number of leaves per plant 30 DAT (7.72), 60 DAT (16.76) and at harvest stage (18.79). Interaction effects of different levels of planting times and spacing were shown non-significant effect on number leaves per plant at all growth stages.

The plant spread was significantly affected by planting times and spacing. Highest plant spread 30 DAT (17.59 cm), 60DAT (36.77 cm) and at harvested stage (47.06 cm) was recorded with seedlings transplanted on 5th November (P_1) and Significantly highest plant spread 30 DAT (17.06 cm), 60 DAT (38.13 cm) and at harvested stage (48.80 cm) was noted with S_1 (60 cm × 45 cm). In case of interaction effects of different levels of planting times and spacing, all the treatments were statistically at par with each other for plant spread at all the growth stages.

The highest stem diameter 30 DAT (8.99 cm, 60 DAT (14.92 cm) and at harvested stage (19.26 cm) was recorded with early seedlings transplanted on 5th November (P_1) and wider plant spacing S_1 (60 cm × 45 cm) was significantly superior over other treatments and it was recorded highest stem diameter 30 DAT (9.53 cm, 60 DAT (15.72 cm) and at harvested stage (19.98 cm). Interaction effect with respect to stem diameter was found non-significant at all the growth stage.

The Seedlings transplanted on minimum number of days was taken to head maturity (19.25) by seedlings transplanted on 25th November (P_3). Early transplanted seedling was taken more days to head maturity as compare to late transplanted seedlings. Plant spacing was also significantly affected to days taken to head maturity. Wider plant spacing was shown early head maturity as compare to closer spacings. Minimum number of days taken to head maturity (20.54) was noted with wider spacing S_1 (60 cm × 45 cm). The treatment combination of P_3S_1 (25 November + 60 cm × 45 cm) was taken minimum number of days for head maturity (18.27). However, all the treatment combinations were statistically at par with each other.

The seedlings transplanted on 25th November (P_3) was taken significantly minimum number of days to harvest (97.32) and minimum number of days taken to head maturity (96.89) was noted with wider spacing S_1 (60 cm × 45 cm). The treatment combination P_3S_1 was taken minimum number of days (93.22) for head maturity. These findings are in conformity with Ullah *et al.*, (2013) [13], Abed *et al.*, (2015) [1], Choudhary *et al.*, (2015) [2] and Patel *et al.*, (2019) [8]. The minimum change in diameter of main stem might be due to lower day and night average temperatures prevailed during the vegetative growth period when compared to earlier dates of planting reported by Kanse *et al.*, (2018) [6]. This might be due to early planted crop got more duration for growth period as well as lower day and night average temperature prevailed during the vegetative growth period as compared to delayed transplanting. Similar results were also found by Kanse *et al.*, (2018) [6] and Thakre and Dalal (2019) [11]. Decreasing plant growth with decrease in temperatures during vegetative growth period leads to delay in head maturity and crop harvest reported by Kanse *et al.*, (2018) [6].

Table 1: Effect of different planting time and spacing on Plant height and Number of leaves per plant of cabbage

Treatment	Plant height (cm)			Number of leaves per plant		
	30 DAT	60 DAT	At harvest	30 DAT	60 DAT	At harvest
Planting times (P)						
P_1	13.10	19.61	25.35	7.62	15.99	18.20
P_2	12.05	18.20	23.89	7.36	15.21	16.95
P_3	10.71	16.92	22.50	6.96	13.54	15.13
SEm±	0.16	0.19	0.25	0.19	0.21	0.21
CD at 5% level	0.47	0.58	0.76	NS	0.63	0.62

Treatment	Plant height (cm)			Number of leaves per plant		
	30 DAT	60 DAT	At harvest	30 DAT	60 DAT	At harvest
Plant spacing (S)						
S_1	13.05	20.21	26.69	7.72	16.76	18.79
S_2	11.91	18.10	23.50	7.23	14.91	17.05
S_3	10.89	16.53	21.54	6.99	13.06	14.44
SEm±	0.16	0.19	0.25	0.19	0.21	0.21
CD at 5% level	0.47	0.58	0.76	0.57	0.63	0.62

Treatment	Plant height (cm)			Number of leaves per plant		
	30 DAT	60 DAT	At harvest	30 DAT	60 DAT	At harvest
Interaction (P×S)						
P1S1	14.40	21.65	28.18	8.11	18.21	20.71
P1S2	13.03	19.35	25.32	7.42	15.84	18.09
P1S3	11.85	17.84	22.54	7.33	14.21	15.81
P2S1	13.20	20.11	26.85	7.64	16.87	18.88
P2S2	12.22	17.96	23.17	7.35	15.32	17.22
P2S3	10.72	16.52	21.64	7.10	13.45	14.75
P3S1	11.54	18.87	25.05	7.42	15.21	16.77
P3S2	10.49	16.68	22.02	6.92	13.88	15.85
P3S3	10.11	15.22	20.43	6.54	11.52	12.77
SEm±	0.27	0.25	0.44	0.33	0.36	0.36
CD at 5% level	NS	NS	NS	NS	NS	NS

Table 2: Effect of different planting time and spacing on Plant spread (cm) and Stem diameter (mm) of cabbage

Treatment	Plant spread (cm)			Stem diameter (mm)		
	30 DAT	60 DAT	At harvest	30 DAT	60 DAT	At harvest
Planting times (P)						
P_1	17.59	36.77	47.06	8.99	14.92	19.26
P_2	16.44	34.33	43.94	8.52	14.13	17.74
P_3	14.49	29.33	37.54	7.95	13.14	16.39
SEm±	0.37	0.39	0.41	0.28	0.46	0.60
CD at 5% level	1.09	1.19	1.21	0.83	1.38	1.74

Treatment	Plant spread (cm)			Stem diameter (mm)		
	30 DAT	60 DAT	At harvest	30 DAT	60 DAT	At harvest
Plant spacing (S)						
S_1	17.06	38.13	48.80	9.53	15.72	19.98
S_2	16.22	33.57	42.97	8.58	14.21	17.97
S_3	15.24	28.73	36.77	7.36	12.27	15.45
SEm±	0.37	0.39	0.41	0.28	0.46	0.60
CD at 5% level	1.09	1.19	1.21	0.83	1.38	1.74

Treatment	Plant spread (cm)			Stem diameter (mm)		
	30 DAT	60 DAT	At harvest	30 DAT	60 DAT	At harvest
Interaction (P×S)						
P1S1	18.69	42.05	53.82	9.94	16.40	21.32
P1S2	17.37	36.48	46.69	9.06	15.04	19.55
P1S3	16.72	31.77	40.66	7.99	13.34	17.34
P2S1	17.10	38.48	49.25	9.57	15.79	19.89
P2S2	16.56	34.78	44.51	8.58	14.25	17.96
P2S3	15.65	29.73	38.05	7.40	12.37	15.58
P3S1	15.39	33.85	43.33	9.08	14.99	18.73
P3S2	14.73	29.46	37.71	8.10	13.33	16.67
P3S3	13.34	24.68	31.59	6.68	11.09	13.86
SEm±	0.63	0.69	0.70	0.48	0.79	1.00
CD at 5% level	NS	NS	NS	NS	NS	NS

Table 3: Effect of different planting time and spacing on Days taken to head maturity, Days taken to harvest, Head weight of cabbage (kg), Head yield per plot (kg) and Head yield (q ha^{-1}) of cabbage

Treatment	Days taken to head maturity	Days taken to harvest	Head weight of cabbage (kg)	Head yield per plot (kg)	Head yield (q ha^{-1})
Planting times (P)					
P_1	24.32	104.41	1.13	24.22	455.26
P_2	22.28	100.81	1.01	21.25	399.50
P_3	19.25	97.32	0.88	17.41	327.19
SEm±	0.31	0.43	0.03	0.37	3.67
CD at 5% level	0.93	1.28	0.08	1.10	11.00

Treatment	Days taken to head maturity	Days taken to harvest	Head weight of cabbage (kg)	Head yield per plot (kg)	Head yield (q ha^{-1})
Plant spacing (S)					
S_1	20.54	96.89	1.35	20.15	378.82
S_2	21.59	99.79	0.98	22.43	421.68
S_3	23.72	105.86	0.68	20.29	381.45
SEm±	0.31	0.43	0.03	0.37	3.67
CD at 5% level	0.93	1.28	0.08	1.10	11.00

Interaction (P×S)	Days taken to head maturity	Days taken to harvest	Head weight of cabbage (kg)	Head yield per plot (kg)	Head yield (q ha^{-1})
P1S1	22.52	100.34	1.46	22.36	420.30
P1S2	23.53	103.67	1.13	26.12	490.98
P1S3	27.12	109.23	0.79	24.18	454.51
P2S1	20.82	97.11	1.38	20.88	392.48
P2S2	22.23	99.44	0.98	22.32	419.55
P2S3	23.78	105.87	0.68	20.56	386.47
P3S1	18.27	93.22	1.22	17.22	323.68
P3S2	19.21	96.26	0.84	18.86	354.51
P3S3	20.26	102.49	0.57	16.14	303.38
SEm±	0.54	0.74	0.05	0.63	6.36
CD at 5% level	NS	NS	NS	NS	19.06

Yield parameter

The results presented in Table 3. It is apparent from data that planting times had significant influence on head weight of cabbage.

The early transplanting of seedlings on 5th November (P_1) was recorded highest head weight (1.13 kg) and further it was revealed that different plant spacing also had highly significant effects on head weight of cabbage. Highest head weight (1.35 kg) was recorded with seedlings transplanted on wider spacing at 60 cm × 30 cm (S_1). The interaction effect of planting times and plant spacing in respect to head weight was found non-significant.

It is apparent from data that head yield per plot was significantly reduced with delay in planting time. The highest head yield per plot (24.22 kg) was recorded with early planting on 5th November (P_1) and effect of spacing was also found significant on head per plot. The highest head yield per plot (22.43 kg) was observed with S_2 (60 cm × 30 cm). The interaction effect of planting times and plant spacing in respect to head yield per plot was found non-significant.

The data revealed that head yield per hectare was significantly reduced with delay in planting time. The highest head yield per hectare (455.26 q) was recorded with early planting on 5th November (P_1) and it was further revealed that spacing also had significant effect on head yield per hectare. The highest head yield per plot (421.68 q) was observed with S_2 (60 cm × 30 cm). The interaction effect of planting times and plant spacing in respect to head yield per hectare was found significant. Seedling transplanted on 5th November with 60 cm × 30 cm spacing (P_1S_2) was recorded highest yield per hectare (490.98q ha^{-1}).

A perusal of data presented in previous chapter revealed that yield attributes and yield was also significantly influenced by planting times. Early transplanting of seedlings on 15th November (P_1) was obtained significantly higher head weight, per plot yield as well as per hectare yield as compare to delayed transplanting on 5th November (P_2) and 25th November (P_3). Reduction in weight of head with delayed plantings might be due to gradual increase in temperatures during head development stage which leads to reduction in yield of crop. Such influence of climate factors on head weight were reported by Hossain *et al.*, (2011) [3], Abed *et al.*, (2015) [1], Singh *et al.* (2017) [10] and Kanse *et al.*, (2018) [6]. Moderate temperatures during crop growth allow better photosynthesis and translocation of metabolites reflecting increases in vegetative growth and consequently head yield reported by Kanse *et al.*, (2018) [6].

Quality parameter

The results presented in Table 4. As regards to planting times, early planting on 5th November (P_1) was found significantly superior and recorded highest head diameter (14.78 cm) and it was further observed that head diameter significantly influenced with plant spacing. The highest head diameter (14.72 cm) was observed under seedlings planted on wider spacing (60 cm × 45 cm). The interaction effect of planting times and plant spacing in respect to head diameter was found non-significant.

The highest head compactness (38.96) was noted with planting on 25th November (P_3) and the significantly higher head compactness (42.49) was recorded with wider spacing S_1 (60 cm × 45 cm). The interaction effect of planting times and plant spacing in respect to head compactness was found non-significant.

The revealed that total soluble solids were significantly influenced with planting times and spacing. The highest TSS

(8.65%) was obtained with early planting on 5th and further data showed that TSS level in cabbage was significantly influenced with plant spacing in which wider plant spacing S_1 (60 cm × 45 cm) observed highest TSS (8.77%). The interaction effect of planting times and plant spacing in respect to TSS was found non-significant.

The dry matter content was non-significantly affected by planting times and spacing. The highest dry matter content (11.62 g) was recorded with early planting on 5th November (P_1) and Further it was revealed that dry matter content was also non-significantly influenced with plant spacing. The highest dry matter content (11.57 g) was recorded with wider spacing (S_1). The interaction effect of planting times and plant spacing in respect to dry matter content was also found non-significant.

Table 4: Effect of different planting time and spacing on Head diameter (cm), Head compactness, TSS (%) and Dry matter content (%) of cabbage

Treatment	Head diameter (cm)	Head compactness	TSS (%)	Dry matter content (%)
Planting times (P)				
P_1	14.78	34.25	8.65	11.62
P_2	13.96	36.20	8.59	11.51
P_3	12.95	38.96	8.33	11.33
SEm±	0.27	0.54	0.03	0.10
CD at 5% level	0.80	1.61	0.09	NS

Treatment	Head diameter (cm)	Head compactness	TSS (%)	Dry matter content (%)
Plant spacing (S)				
S_1	14.72	42.49	8.70	11.57
S_2	13.91	36.44	8.51	11.50
S_3	13.07	30.48	8.37	11.39
SEm±	0.27	0.54	0.03	0.10
CD at 5% level	0.80	1.61	0.09	NS
Interaction (P×S)	**Head diameter (cm)**	**Head compactness**	**TSS (%)**	**Dry matter content (%)**
P1S1	15.41	39.90	8.77	11.68
P1S2	14.82	34.72	8.65	11.62
P1S3	14.11	28.12	8.54	11.56
P2S1	14.84	42.23	8.72	11.57
P2S2	13.94	36.18	8.59	11.52
P2S3	13.11	30.18	8.47	11.44
P3S1	13.91	45.33	8.61	11.45
P3S2	12.98	38.41	8.28	11.37
P3S3	11.98	33.15	8.11	11.18
SEm±	0.47	0.93	0.05	0.18
CD at 5% level	NS	NS	NS	NS

It might be due to optimum favorable low temperatures prevailing during head initiation and head development period. Such influence of temperature on head quality was also reported by Hossain *et al.,* (2011) [3], Abed *et al.,* (2015) [1], Kanse *et al.,* (2018) [6] and Kavalgi *et al.,* (2019) [5]. Head compactness was increased with delaying in planting and significantly highest head compactness was observed with planting on 25th November followed by 15th and 5th November. The increase in metabolic activities and photosynthesis due to high temperature attributed to early maturity, it might also be influenced the decrease in head weight and diameter which leads to increase in head compactness. Similar results have been reviled in cabbage by Abed *et al.,* (2015) [1] and in broccoli by Kanase *et al.,* (2018) [6].

Conclusion

Thus, it may be concluded that the cabbage planted on 5th November at 60 cm × 30 cm plant spacing found significantly superior in terms of productivity, profitability and quality over other treatments under Bundelkhand region of Uttar Pradesh.

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