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Effect of head manipulation techniques and planting distance on seed quality parameters of cabbage (*Brassica oleracea* var. *capitata*) cv. golden acre

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Abstract
Present investigation was carried out during late Kharif to late Rabi seasons of 2014 & 2015 on cabbage variety 'Golden Acre'. Seed production was done at the experimental farm of Department of Vegetable Science and testing of harvested seeds in the laboratory of Seed Science and Technology department, College of Forestry, Ranichauri, Tehri Garhwal, Uttarakhand. Seeds were produced by using three head manipulation techniques viz., Stump method (T1), Stump with central core intact method (T2) and Head intact method (T3) and four planting distance viz., 60x60 cm (S1), 60x45 cm (S2), 45x40 cm (S3) and 40x30 cm (S4) as treatment variables. Seed testing results revealed that head intact method with 60x45 cm planting distance was found most superior for seedling root length (8.40 cm), seedling length (14.99 cm) and seedling fresh weight (0.525 g). Stump method and 45x40 cm showed highest values for first count (89.0%) and seedling vigour index-II (2.227). Stump with central core intact method at 60x60 cm and 60x45 cm exhibited highest value for 1000 seed weight (3.47 g) and seedling shoot length (6.88 cm), respectively. Maximum values for standard germination, seedling vigour index-I and seedling dry weight was noted in stump method at 60x60 cm (94.0%), stump method at 60x45 cm (1444.35) and head intact method at 45x40 cm (0.026 g), respectively.

Keywords: cabbage, head manipulation techniques, planting distance, seed, quality

1. Introduction
Seed is the basis of agricultural production and a key component among all inputs for sustainable crop production. It is estimated that quality of seed accounts for 20-25% of productivity (Anonymous, 2013) [3]. For sustainable crop production, good quality seed is very important. If the seed is not of standard quality, use of other inputs is less useful. In a word, no seed no plant, hence no good seed no good yield (Anonymous, 1999) [2]. According to Kelly (1985) [5] seeds are the focal points which strategies to boost crop yield. So, there is a strong demand for high quality seed. In developing countries like India, the unavailability of good seed is a major problem due to the absence of good varieties, inadequate technology for seed production, poor quality control, post-harvest seed handling, inadequate marketing, etc. (Anonymous, 1990) [1]. Therefore, good quality seed production is also an important aspect that cannot be ignored. The method of seed production also plays an important role to guarantee the desired crop performance and economic returns to the farmers.
Cabbage is an important vegetable crop of hilly areas and climatic conditions are quite conducive for growing the crop as well as for seed production. But poor yield of vegetables in hills was experienced by the farmers due to non-availability of desired seed and quality under the inclement weather conditions of hilly areas. Methods of seed production involving head manipulation techniques and planting distance are two important factors which affect the quality and quantity of seed produced in cabbage. 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) [15]. Planting density also play an important role in quantity and quality of seed produced, thereby affecting the economics of seed production (Lal, 2013) [7]. Keeping in view above points, the present study had been undertaken in cabbage with the objectives to

study the interaction effect of head manipulation techniques and planting distance on seed quality parameters.

2. Materials and Methods

The investigation was carried out during late *Kharif* to late *Rabi* seasons of 2014 & 2015 at the experimental farm of Department of Vegetable Science, College of Forestry, Ranichauri, Tehri Garhwal, Uttarakhand, on cabbage variety 'Golden Acre' by using three head manipulation techniques *viz.*, Stump method (T1), Stump with central core intact method (T2) & Head intact method (T3) and four planting distance *viz.*, 60x60 cm (S1), 60x45 cm (S2), 45x40 cm (S3) & 40x30 cm (S4) as treatment variables. After harvesting, seeds were evaluated for seed quality parameters viz., 1000 seed weight (g), standard germination (%), first count(%), seedling root length (cm), seedling shoot length (cm), seedling length (cm), seedling fresh weight (g), seedling dry weight (g), seedling vigour index I and II using standard methods according to ISTA Rules (ISTA 2010). Seed was germinated in Petri dishes/50 seed each, in four replications. Germination period was ten days at 25°C. Testing of seeds for seed quality parameters were performed in the laboratory of Seed Science and Technology department of College of Forestry, Ranichauri, Tehri Garhwal, Uttarakhand.

3. Results and Discussion

3.1 Effect of head manipulation techniques and planting distance on seed yield parameters

3.1.1 1000-seed weight

The trait 1000-seed weight is a measure of seed boldness, which is expected to be affected with genetic constitution of the crop and variety as well as agronomical practices. The data on 1000-seed weight indicated that there were non-significant difference on this trait with head manipulation techniques as well as planting distance, individually. However, interaction effect of these two factors was found significant (Table 1&2). Maximum value of 1000-seed weight was recorded in treatment combination of stump with central core intact method and 60x60m cm spacing (3.47 g) followed by stump method and 60x60 cm spacing (3.32 g), head intact method and 60x45 cm (3.32 g), stump with central core intact method and 60x45 cm (3.30 g), head intact method and 45x40 cm (3.22 g), stump method and 60x45 cm (3.20 g), stump method and 45x40 cm (3.17 g), stump method and 40x30 cm (3.15 g) and head intact method and 60x60 cm (3.12 g), which were statistically *at par* (Table 3). From the results of this study, it was evident that 1000-seed weight was expression of genetic constitution which was less affected by the environmental manipulations.

The results were confirmed with the findings of Sharma (2001) [14] in Chinese cabbage, Kumar *et al*. (2000) [6] and Singh *et al*. (2005) [13] in cauliflower, Pant *et al*. (2007) [11] in cabbage, Mamun *et al*. (2014) [8] in rapeseed and mustard and Mehta *et al*. (2015) [9] in broccoli.

Table 1: Effect of head manipulation techniques on seed quality parameters

S. No	1000-seed weight (g)	First count (%)	Standard germination (%)	Seedling root length (cm)	Seedling shoot length (cm)	Seedling Length (cm)	Seedling fresh weight (g)	Seedling dry weight (g)	Vigour index I	Vigour index II
T1	3.21	84.25	91.06	8.12	5.88	14.00	0.467	0.020	1315.18	1.817
T2	3.16	80.12	86.12	6.58	6.48	13.06	0.419	0.016	1143.55	1.391
T3	3.17	72.74	78.12	7.54	6.31	13.85	0.504	0.024	1082.64	1.906
CV (%)	8.08	6.91	5.05	11.49	7.93	6.55	9.776	23.607	12.31	22.344
CD (5%)	0.28	1.98	3.09	0.61	0.35	0.64	0.032	0.003	104.59	0.274

Table 2: Effect of planting distances on seed quality parameters

S. No.	1000-seed weight (g)	First count (%)	Standard germination (%)	Seedling root length (cm)	Seedling shoot length (cm)	Seedling length (cm)	Seedling fresh weight (g)	Seedling dry weight (g)	Vigour index I	Vigour index II
S1	3.30	81.00	87.33	7.27	6.52	13.79	0.462	0.020	1195.84	1.760
S2	3.27	78.50	84.66	7.82	6.46	14.28	0.482	0.021	1285.59	1.798
S3	3.14	79.00	84.33	7.31	6.01	13.32	0.467	0.021	1133.87	1.775
S4	3.01	80.66	84.08	7.24	5.92	13.16	0.442	0.017	1106.52	1.485
CV (%)	8.08	6.91	5.05	11.49	7.93	6.55	9.776	23.607	12.31	22.344
CD (5%)	0.37	2.29	3.57	0.70	0.41	0.74	0.037	0.003	120.77	0.316

3.1.2 First count (%)

The individual effect of head manipulation revealed that there was significant effect of it on first count and highest value was found in stump method (85 %) followed by stump with central core intact method (80.12 %) and head intact method (72.74 %) (Table 1). Planting distance had non-significant effect on first count. The interaction effect of head manipulation and planting distance was found significant on first count and the highest value was obtained in stump method accompanied with 45x40 cm spacing (89.0 %) followed by stump method along with 60x60 cm (86.5 %), stump method along with 40x30 cm (85.5 %) and stump with central core intact method along with 60x60 cm (85.0%), which were statistically *at par*. The lowest value was exhibited in head intact method accompanied with three spacing *i.e.* 40x30 cm, 45x40 cm and 60x60 cm (71.5 % in each) (Table 3).

Table 3: Combined effect of head manipulation techniques and planting distances on seed quality parameters

S. No.	1000-seed weight (g)	First count (%)	Standard germination (%)	Seedling root length (cm)	Seedling shoot length (cm)	Seedling length (cm)	Seedling fresh weight (g)	Seedling dry weight (g)	Vigour index I	Vigour index II
T1S1	3.32	86.50	94.00	8.32	6.41	14.74	0.454	0.019	1345.05	1.819
T1S2	3.20	79.00	87.00	8.36	5.91	14.28	0.440	0.017	1444.35	1.494
T1S3	3.17	89.00	92.50	7.98	5.63	13.61	0.509	0.024	1256.76	2.227
T1S4	3.15	85.50	90.75	7.81	5.58	13.39	0.465	0.018	1214.55	1.683
T2S1	3.47	85.00	91.00	6.84	6.57	13.42	0.452	0.018	1221.37	1.627
T2S2	3.30	80.00	87.50	6.70	6.88	13.58	0.480	0.021	1225.25	1.874
T2S3	3.02	76.50	82.50	6.30	6.31	12.61	0.374	0.012	1070.67	1.030
T2S4	2.87	79.00	83.50	6.49	6.15	12.64	0.370	0.012	1056.92	1.033
T3S1	3.12	71.50	77.00	6.67	6.56	13.22	0.481	0.023	1021.10	1.835
T3S2	3.32	76.50	79.50	8.40	6.58	14.99	0.525	0.025	1187.19	2.027
T3S3	3.22	71.50	78.00	7.68	6.08	13.75	0.520	0.026	1074.18	2.024
T3S4	3.02	71.50	78.00	7.41	6.03	13.45	0.490	0.022	1048.09	1.738
CV (%)	8.08	6.91	5.05	11.49	7.93	6.55	9.776	23.607	12.31	22.344
CD (5%)	0.41	3.96	6.18	1.22	0.71	1.28	0.065	0.006	209.18	0.548

3.1.3 Standard germination (%)

In the present investigation, head manipulation techniques significantly affected standard germination and highest value was found in stump method (91.06 %) followed by stump with central core intact method (86.12%) and head intact method (78.12%) (Table 1). Whereas, the effect of distance was found to be non-significant on standard germination (Table 2). The interaction effect of head manipulation techniques and planting distance was also found significant on this trait and maximum value was recorded in stump method at 60x60 cm (94.0 %) followed by stump method at 45x40 cm (92.50 %), stump with central core intact method at 60x60 cm (91.0 %) and stump method at 40x30 cm (90.75 %), which were statistically *at par* (Table 3). The results indicated that stump method at all spacing resulted in higher standard germination of seed probably due to higher seed quality in early maturity (dry season) crops as compared to those harvested late (cloudy weather) in other head manipulation techniques.

The results were confirmed with the findings of Singh *et al*. (2005) [13] (86.67 %) and Moniruzzaman *et al*. (2007) [10] (93.46 %) in cauliflower, Dev (2012) [4] (92.25 %) in cabbage and Mehta *et al*. (2015) [9] (92.67 %) in broccoli.

3.1.4 Seedling root length (cm)

The data on root length of seedlings indicated that there was significant difference among the head manipulation techniques and combinations of head manipulation techniques and planting distance on this trait. Maximum root length was recorded in stump method (8.12 cm) which was significantly higher than that in head intact method (7.54 cm) and stump with central core intact method (6.58 cm) (Table 1). The highest value of seedling root length was noted in treatment combinations consisting head intact method and 60x45 cm (8.40 cm) followed by stump method and 60x45 cm (8.36 cm), stump method and 60x60 cm (8.32 cm), stump method and 45x40 cm (7.68 cm) and head intact method and 40x30 cm (7.41 cm), which were statistically *at par* (Table 3).

The root length of the seedling is a measure of seedling vigour in respect of ability of seedlings to penetrate the subsoil and tolerance to moisture stress conditions.

3.1.5 Seedling shoot length (cm)

Head manipulation techniques significantly affected shoot length and maximum value was found in stump with central code intact method (6.48 cm) followed by head intact method (6.31 cm) and lowest value in stump method (5.88 cm) (Table 1). Significantly higher value for shoot length was registered in 60x60 cm (6.52 cm) followed by 60x45 cm (6.46 cm), which were statistically *at par*. The lowest value was noted in 40x30 cm (5.92 cm) spacing (Table 2). The interaction effect of head manipulation techniques and planting distance was also found significant on seedling shoot length. Maximum value of this trait was observed in stump with central core intact method at 60x45 cm (6.88 cm) followed by head intact method at 60x45 cm (6.58 cm), stump with central core intact method at 60x60 cm (6.57 cm), head intact method at 60x60 cm (6.56 cm), stump method at 60x60 cm (6.41 cm) and stump with central core intact method at 45x40 cm (6.31 cm), which were statistically *at par* (Table 3).

The shoot length of seedling is a consequence of bio contra version efficiency of seedlings to nutrients drawn by roots. Higher seedling root and shoot length is an indicator of seedling vigour.

3.1.6 Seedling length (cm)

Head manipulation techniques significantly affected seedling length and maximum value was found in stump method (14.00 cm) followed by head intact method (13.85 cm) which were *at par* and lowest value in stump with central core intact method (13.06 cm) (Table 1). Significantly higher value for seedling length was found in 60x45 cm (14.28 cm) followed by 60x60 cm (13.79 cm) which were *at par* and lowest value was noted in 40x30 cm (13.16 cm) spacing (Table 2). The interaction effect of head manipulation techniques and planting distance was also found significant on seedling length (Table 3). Maximum seedling length was noted in head intact method at 60x45 cm (14.99 cm) followed by stump method at 60x60 cm (14.74 cm), stump method at 60x45 cm (14.28 cm) and head intact method at 45x40 cm (13.75 cm), which were statistically *at par* (Table 3).

High seedling length is associated with overall vigour of seeds for earliness in growth and development. Higher seedling length is also an indicator of response of seedling stored food material in seed and available plant nutrients in the soil.

3.1.7 Seedling fresh weight (g)

Seedling fresh weight is a function of mobilization of stored food materials in seeds and plant nutrients as water absorbed from the soil and therefore, this is also an important parameter of seed and seedling vigour. This trait was affected significantly by head manipulation techniques. Significantly higher seedling fresh weight was recorded in head intact

method (0.504 g) followed by stump method (0.467 g) and stump with central core intact method (0.419 g) (Table 1). The effect of planting distance was found to be non-significant on seedling fresh weight. The combined effect of head manipulation techniques and planting distance was also found significant and higher value was recorded in head intact method along with 60x45 cm spacing (0.525 g) followed by *at par* values in head intact method and 45x40 cm (0.520 g), stump method and 45x40 cm (0.509 g), head intact method and 40x30 cm (0.490 g), head intact method and 60x60 cm (0.481 g), stump with central core intact method and 60x45 cm (0.480 g) and stump method and 40x30 cm (0.465 g) (Table 3).

3.1.8 Seedling dry weight (g)

The data depicted in Table 1,2 &3 revealed that seedling dry weight was affected significantly by head manipulation techniques, planting distance and their interaction. Significantly higher seedling dry weight was recorded in head intact method (0.024 g) followed by stump method (0.020 g) and stump with central core intact method (0.016 g).While maximum seedling dry weight was recorded in 60x45 cm (0.021 g) and 45x40 cm (0.021 g) followed by 60x60 cm (0.020 g), which were statistically *at par*. Whereas, lowest value was noted in 40x30 cm (0.017 g). The interaction effect indicated that head intact method at 45x40 cm was superior for this trait (0.026 g) followed by *at par* values in head intact method at 60x45 cm (0.025 g), stump method at 45x40 cm (0.024 g), head intact method at 60x60 cm (0.023 g) and stump with central core intact method at 60x45 cm (0.021 g).
The seedling dry weight is a function of organic matter and mineral contents in seedling and therefore, treatments with high seedling dry matter showed high initial vigour of seedlings due to accumulation of organic matter and minerals.

3.1.9 Seedling vigour index-I

The data showed significant effect of head manipulation techniques on seedling vigour index-I and maximum and significantly higher value was recorded in stump method (1315.18) followed by stump with central core intact method (1143.55) and head intact method (1082.64) (Table 1). Different planting distances were also found significantly different in respect of vigour index I and maximum value was recorded in 60x45 cm (1285.59) followed by 60x60 cm (1195.84), which were *at par*. The planting distance of 45x40 cm (1133.87) and 40x30 cm (1106.52) had comparatively lower values for this parameter (Table 2). As far as, interaction effect was concerned, stump method accompanied with 60x45 cm was the most promising treatment combination for seedling vigour index-I (1444.35) followed by *at par* values in stump method and 60x60 cm (1345.05) and stump method and 45x40 cm (1256.76) (Table 3).

3.1.10 Seedling vigour index-II

Seedling vigour index-II was affected significantly by head manipulation techniques. Highest value for seedling vigour index-II was recorded in head intact method (1.906) followed by stump method (1.817), which were *at par* and lowest value was noted in stump with central core intact method (1.391) (Table 1).While the effect of planting distance was found to be non-significant for seedling vigour index-II. The combined effect of head manipulation techniques and planting distance was also found to be significant and highest value was recorded in stump method along with 45x40 cm spacing (2.227) followed by head intact method along with 60x45 cm (2.027), head intact method along with 45x40 cm (2.024), stump with central core intact method along with 60x45 cm (1.874), head intact method along with 60x60 cm (1.835) and stump method along with 60x60 cm (1.819), which were statistically *at par*. The lowest value for this trait was noted in stump with central core intact method along with 45x40 cm (1.030) (Table 3).
Seedling vigour index-I and II are the products of standard germination per cent of seed and seedling length and seedling dry weight, respectively. Owing to higher values for standard germination of seeds and seedling length and for seedling dry weight, stump and head intact methods at wider planting distance appeared to be the promising treatments individually or in combination for these parameters. The results were in conformity with the studies done by Rehman *et al*. (1988) [12], Singh *et al*. (2005) [13], Moniruzzaman *et al*. (2007) [10] and Mehta *et al*. (2015) [9].

4. Conclusion

From the results of above investigation, it could be concluded that head manipulation techniques and planting distance individually or in combination significantly affected the quality parameters in cabbage cv. Golden Acre. Among the head manipulation techniques, stump method with wider spacing strongly influenced all the seed quality characters in positive direction.

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