



Research Article

Comparative Evaluation of Different Varieties of Cauliflower (*Brassica oleracea* L.) at Seedling Stage Under Normal Conditions

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Abstract | Cauliflower (*Brassica oleracea* L.) is one of the major cruciferous crops in Pakistan. It contributes significantly in the food security of country. This study aimed to evaluate different commercially grown cauliflower cultivars including three hybrid and two non-hybrid ones at seedling stage to assess their genetic variability and association of plant characters. The experiment was conducted in pots and 40 days-old healthy seedlings were selected for the study. Parameters studied included days to emergence, germination percentage, shoot length, root length, fresh seedling, shoot and root weights with dry seedling, shoot and root weights. Means, genotypic and phenotypic variation, heritability, genetic advance and correlation analysis were done for these characters. The phenotypic for germination percentage is 208.52 and genotypic variance is 254.44. For all the characters the phenotypic variance (PV) is greater than genotypic variance (GV) and phenotypic coefficient of variation (PCV) is greater than genotypic coefficient of variation (GCV). Days to emergence had negative correlation (-0.690) with germination percentage, and (-0.817) with root length. Hybrid seedlings showed early emergence, mostly in three days post-sowing. Overall, the results of this study demonstrated that hybrid cultivars of cauliflower perform at par with non-hybrid ones, providing baseline data for future vegetable breeding programs.

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Keywords | Seedling characteristics, Vegetable breeding, Cauliflower health benefits, Hybrid varieties, Correlation, Cauliflower importance



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Introduction

Cauliflower (*Brassica oleracea* var. *botrytis*), a member of the Brassicaceae family, is one of the important cruciferous vegetables with great nutritional and commercial value. It contains fiber, vitamins C and K, and a variety of compounds beneficial to human

health. Cauliflower plant constitutes substances such as glucosinolates which are thought to be anti-carcinogenic (Geng *et al.*, 2021). Having many culinary uses and health benefits, it has attracted considerable interest in agriculture and research. With an annual global production of over 18 million tons, cauliflower is an important crop in the horticultural

industry (FAO, 2010). In Pakistan, the total area harvested in 2022 was 11488 ha, which gave a yield of about 98.36 kilogram per acre and production was 279232 tons (FAO, 2022). Some recent studies have investigated various physiological, genetic as well as agronomic features of cauliflower with the goal of improving its nutritional value, resilience, and general environmental adaptation (Singh *et al.*, 2018). In order to ensure sustainable production and food security, it is imperative to comprehend the complexities of cauliflower biology, particularly as global food demands increase and climate change renders obstacles to sustainable agricultural production.

Modern vegetable research and breeding programs focus on evaluating genotypes of cauliflower at the seedling stage. A crucial stage in the entire life cycle of the cauliflower is represented by the seedling stage, during which the inherent features and genetic potential of various genotypes begin to be exhibited. It is possible to identify and select the traits linked to vigor, stress resistance, and overall robustness by studying cauliflower at this early developmental stage (Bhatia *et al.*, 2017). Such research offers important insights into genotypes' adaptability as well as performance under various environmental conditions (Li, 2020). Breeders can decide which genotypes have better germination percentages, root and shoot lengths, fresh and dry seedling weights, fresh and dry shoot and root biomass, etc. by early evaluations. Furthermore, determining the vigor of different genotypes of cauliflower seedlings aids in the development of plants with enhanced characteristics linked to seedling transplant success and field establishment, which eventually results in higher crop yields and higher-quality produce. The value of this early assessment goes beyond traditional breeding since it supports resource-efficient methods by choosing genotypes that are well-suited to certain growing circumstances, which is in line with the objectives of precision agriculture and sustainable crop management (Gómez-Candón *et al.*, 2023).

As plant variation is the key to crop improvement, germplasm variation is necessary for the selection and other breeding objectives (Aleem *et al.*, 2021). In vegetables, seedling management is very crucial for proper plant growth and high yield. It has been demonstrated that different seedling parameters such as density of seedlings in the field, root length, fresh shoot and root biomass, plant height, number

of leaves, leaf area indices, and dry matter percentage play a significant role in the successful cauliflower production (Bhandari *et al.*, 2021; Rehman *et al.*, 2022). Therefore, keeping in view the economic importance of cauliflower, and the advantages of vegetable breeding at the seedling stage, this study was conducted to determine the genetic variability and correlation among seedling traits of different cauliflower genotypes in order to find out better cauliflower genotypes which can be recommended for further breeding programs.

Materials and Methods

Experimental site

This experiment was conducted in the Laboratory of the Department of Plant Breeding and Genetics, College of Agriculture, University of Sargodha (32.133°N; 72.686°E). Germination test of the seeds and pot experiment was performed in the lab during October, and pot experiment during November 2023.

Experimental material

Plant material used in this study consisted of five cauliflower genotypes named Snow Gold, Green Gold, CF-242428, Chiina Mouti, and Maharaja. CF-242428, Snow Gold, and Green Gold were hybrid cauliflower seeds and were procured from Syngenta® Pakistan. Maharaja and Chiina Mouti are local cauliflower cultivars and their seeds were purchased from the local grain market of district Sargodha, Punjab, Pakistan.

Seed germination

For seed germination, a total of 30 seeds of each cauliflower genotype were sown in plastic trays filled with loam soil mix. The completely randomized design was used with three replications for each treatment. Seeds were kept at room temperature (26 °C). Seed germination was monitored daily. The indication of germination was the emergence of a radicle tip. The seed germination percentage was recorded for each genotype using the following formula (Bhandari *et al.*, 2021).

$$\text{Germination percentage} = \left(\frac{\sum_{N=i}^n}{N} \right) \times 100$$

N_i = Number of seeds germinated in the sample in ⁱth day or time observation. N = Number of seeds taken from each sample.

Shifting of plants to pots

After germination of seeds, the seedlings were shifted to earthen pots (length 12 inches, width 11 inches, capacity 40kg, 10 kg) 10 days after sowing (DAS). The seedlings were maintained for 30 days in these pots. Three independent replications were maintained for each treatment. All cauliflower genotypes were equally treated.

Agronomic operations

Distilled water was used for watering containing 25% Hoagland solution (He *et al.*, 2020) at threeday intervals. Foliar spray of zinc and potash solutions was used as fertilizers for maintaining seedling's health.

Collection of data

Healthy seedlings (five cauliflower plants from each replication) were collected at 40 DAS. First of all, the potting soil was softened with water and then seedlings were uprooted carefully. Extra mud was removed from the roots under tap water. Shoot and root lengths were measured using the measuring scale, fresh and dry weights of seedlings, shoots, and roots were measured using a digital weighing balance. Dry weights were taken by drying the seedlings in an oven for 72 h at 60° C and were weighed on an electric balance (Table 1).

Statistical analysis of data

Analysis of variance (ANOVA) was performed on measured plant parameters followed by least significant difference (LSD) (Table 3) post-hoc test at a standard ($\alpha = 0.05$) level of probability (Channaoui *et al.*, 2016). Furthermore, genotypic and phenotypic variations, genotypic and phenotypic coefficient of variations, heritability, genetic advance, and correlation studies were calculated for all cauliflower genotypes.

Statistical analysis was performed on R-Studio and correlation calculations were determined on MS Excel.

Results and Discussion

Analysis of variance (ANOVA) showed significant ($P \leq 0.01$) results for different seedling characters under normal conditions. There was considerable variation present in seedling characters for all the evaluated genotypes of cauliflower. Mean squares and significance levels for each studied character and means of different characters of the cauliflower genotypes have been given in Tables 1 and 2, respectively. These results showed that the hybrids of cauliflower exhibited early emergence (within three days after sowing), while non-hybrids showed late emergence (4 days after sowing for Maharaja and 6 days after sowing for Chiina Mouti). Similarly, hybrids showed better germination percentage than non-hybrids. Snow Gold and CF-242428 showed higher germination percentage with highest means of 53.33 and 52.22%, respectively, followed by Green Gold (33.33%), Maharaja (25.56%) and Chinna Mouti (21.11%). The longest root length was recorded for CF-242428 (9.33 cm), followed by Snow Gold (8.60 cm), Green Gold (8.10 cm), Maharaja (6.67 cm), and Chiina Mouti (4.20 cm). The longest shoot length was determined for Green Gold (13.33 cm) followed by Snow Gold (13.10 cm), CF-242428 (13.00 cm), Maharaja (12.33 cm), and Chiina Mouti (9.36 cm).

Furthermore, seedling weights were also calculated. According to Table 2, fresh and dry seedling weights for hybrid cauliflower were higher than non-hybrids. Green Gold had high fresh and dry seedling weights

Table 1: Characters of cauliflower seedlings and their measuring method with abbreviations.

Characteristic	Abbreviation	Description of measurement
Days of emergence	DE	data taken daily; value were taken after 5 seedlings emerge
Germination percentage	GP	$GP = (\sum ni \div N) \times 100\%$
Root length	RL	was measured using scale (in cm)
Shoot length	SL	was measured using scale (in cm)
Fresh seedling weight	FSW	was measured using digital balance (in grams)
Dry seedling weight	DSW	after 72 hours drying in oven was measured using digital balance (in grams)
Fresh shoot weight	FStW	was measured using digital balance (in grams)
Dry shoot weight	DStW	after 72 hours drying in oven was measured using digital balance (in grams)
Fresh root weight	FRW	was measured using digital balance (in grams)
Dry root weight	DRW	after 72 hours drying in oven was measured using digital balance (in grams)

Table 2: Analysis of variance (mean squares) for seedling traits of cauliflower genotypes.

Parameter	Source of variation		
	Genotype	Replication	Error
Degree of freedom	4	2	8
Days of emergence	6.2667***	0.0667	0.0667
Germination percentage	671.48***	38.52	45.93
Root length	12.3327**	3.032	1.4687
Shoot length	8.1253*	0.0501	1.9798
Fresh seedling weight	0.312393**	0.066887	0.041003
Dry seedling weight	0.0078368**	0.0009546	0.0011185
Fresh seedling shoots weight	0.30021**	0.070427	0.040985
Dry seedling shoots weight	0.0050566*	0.0003025	0.000862
Fresh seedling root weight	0.0141733*	0.0000467	0.0020383
Dry seedling root weight	0.0005709*	0.00018687	0.00008245

Significant codes: 0 *** 0.001 ** 0.01 * 0.05 . ' 0.1 ' ' 1

(1.84 and 0.25 g, respectively). It was followed by Snow Gold (1.78 and 0.23 g), CF-242428 (1.61 and 0.17 g), Maharaja (1.30 and 0.17 g) and Chiina Mouti (1.08 and 0.12 g). Similarly, the fresh and dry seedling shoot weight was recorded for Green Gold (1.69 and 0.19 g), Snow Gold (1.58 and 0.19 g), CF-242428 (1.55 and 0.12 g), Maharaja (1.08 and 0.13 g), and Chiina Mouti (0.99 and 0.10 g). Genotype Maharaja exhibited high fresh seedling root weight (0.21 g), followed by Snow Gold (0.20 g), Green Gold (0.15 g), Chiina Mouti (0.09 g), and CF-242428 (0.06 g). Dry seedling root weight was determined as Green Gold (0.06 g), CF-242428 (0.05 g), Snow Gold and Maharaja (0.04 g) in Chiina Mouti (0.02 g).

High phenotypic variation (PV) was observed than genotypic variation (GV) in all seedlings characters (Table 4). The highest phenotypic and genotypic variance was observed in germination percentage (208.52, and 254.44, respectively), followed by root length (5.09 and 3.62), shoot length (4.028 and 2.048) days of emergence (2.06 and 2.13), fresh seedling weight (0.131 and 0.091), fresh shoot weight (0.127 and 0.086), fresh Root weight (0.006 and 0.004), dry seedling weight (0.003 and 0.002), dry shoot weight (0.002 and 0.001) and dry root weight (0.0003 and 0.0002), respectively.

The lower value of GCV than PCV value was observed in fresh seedling root weight (44.33, 54.294, respectively), followed by germination percentage (38.91, 42.982). With 37.17 GCV for days of emergence and 42.176 PCV for dry seedling root weight came after germination percentage, followed by dry seedling root weight with 34.43 GCV and

PCV of 37.774 for days of emergence, dry seedling shoots weight (25.49, 32.684), seedling root length (25.78, 30.570), dry seedling weight (24.97, 30.588), fresh seedling shoots weight (21.32, 25.889), fresh seedling weight (19.77, 23.836) and shoot length (11.70, 16.418).

Mtilimbanya *et al.* (2020) reported significant results for the same seedlings characters as were chosen in this study in *Brassica juncea* under control and salinity stress environment. The results indicate significant variances among genotypes for seedling characters at 5 percent and a 1 percent significance level.

Similarly, Mtilimbanya *et al.* (2020) and Zahid *et al.* (2024) reported the same trend regarding higher PV than GV and high PCV than GCV. These authors demonstrated that under control conditions *B. juncea* and *B. oleracea* var. *Capitata* showed high PV than GV and high PCV than GCV. The low GCV value than PCV value also exhibited a positive outcome of the environment on the character articulation (Mtilimbanya *et al.*, 2020).

Heritability and genetic advance are very important for the selection of traits for further breeding programs. High genetic advance and heritability (broad sense) indicate improvement of traits through direct selection (Pal *et al.*, 2019).

Correlation provides an insight for what kind of relationship the plant characters have with each other, their degree, and nature of the relationship. The dependence of one character over another did not affect the correlation (Pandey *et al.*, 2021).

Table 3: Coefficient of variation and least significant differences (LSD) value table for different cauliflower genotypes.

	Varieties					CV	t. value	LSD
	Chiina mouti	Maharaja	CF-282824	Green gold	Snow gold			
Days to emergence	6.33	4.00	3.00	3.00	3.00	7.039	2.262	0.503
	a	b	c	c	c			
Germination percentage	21.11	25.56	52.22	33.33	53.33	18.841	2.262	12.915
	b	b	a	b	a			
Root length (cm)	4.20	6.67	9.33	8.10	8.60	17.169	2.262	2.340
	c	b	a	ab	ab			
Shoot length (cm)	9.36	12.33	13.00	13.33	13.10	10.858	2.262	2.452
	b	a	a	a	a			
Fresh seedling weight (g)	1.08	1.30	1.61	1.84	1.78	13.584	2.262	0.382
	c	bc	ab	a	a			
Dry seedling weight (g)	0.12	0.17	0.17	0.25	0.23	18.009	2.262	0.062
	b	B	b	a	a			
Fresh seedling shoot weight (g)	0.99	1.08	1.55	1.69	1.58	15.055	2.262	0.383
	b	b	a	a	a			
Dry seedling shoot weight (g)	0.10	0.13	0.12	0.19	0.19	19.370	2.262	0.052
	b	a	b	a	a			
Fresh seedling root weight (g)	0.09	0.21	0.06	0.15	0.20	29.885	2.262	0.079
	bc	a	c	ab	a			
Dry seedling root weight (g)	0.02	0.04	0.05	0.06	0.04	25.155	2.262	0.019
	c	bc	ab	a	bc			

Table 4: Variability parameters of germination and seedling traits of *Brassica oleracea*.

Characters	Mean±SEM	Genotypic variation	Phenotypic variation	Percentage heritability	GCV	PCV	Genetic advance	Genetic advance as %age of mean
Days of emergence	3.87±0.15	2.07	2.13	96.87	37.17	37.77	2.91	75.38
Germination %age	37.11±3.91	208.52	254.44	81.95	38.91	42.98	26.93	72.56
Root length	7.38±0.70	3.62	5.09	71.15	25.78	30.57	3.31	44.80
Shoot length	12.22±0.81	2.05	4.023	50.85	11.70	16.42	2.10	17.19
Fresh seedling weight	1.52±0.12	0.09	0.13	68.82	19.77	23.84	0.51	33.79
Dry seedling weight	0.19±0.02	0.02	0.00	66.67	24.97	30.59	0.08	42.01
Fresh shoot weight	1.38±0.12	0.09	0.13	67.82	21.32	25.89	0.49	36.17
Dry shoot weight	0.15±0.02	0.01	0.01	60.87	25.49	32.68	0.06	40.96
Fresh root weight	0.14±0.03	0.04	0.01	66.67	44.33	54.29	0.11	74.58
Dry root weight	0.04±0.01	0.00	0.00	66.67	34.43	42.18	0.02	57.95

There was a negative correlation for days to emergence with all the characters under study (Table 5). Correlation studies reveal that fresh seedling root weight had a negative correlation with germination percentage, root length, and fresh seedling shoot weight. All other characters are positively related to others.

Kayaçetin (2022) reported the similar results, having same positive correlation with seedling characters of *B. juncea*. The author also reported that there is negative correlation with mean germination time

with shoot length, root length, seedling fresh weight and seedling dry weight.

The similar results were found in the present research. The same result was found for fresh root weight and fresh shoot weight in an experiment conducted at Cotton Research Institute, Faisalabad for different seedling characters of cotton genotypes. The authors reported a negative correlation between fresh shoot weight and fresh root weight under water stress (Riaz et al., 2013).

Table 5: Correlation analysis table for germination and seedling characters of *Brassica oleracea*.

	DE	GP	RL	SL	FSW	DSW	FSStW	DSStW	FRW	DRW
DE	1									
GP	-0.690	1								
RL	-0.817	0.596	1							
SL	-0.803	0.407	0.787	1						
FSW	-0.771	0.450	0.856	0.785	1					
DSW	-0.665	0.276	0.555	0.621	0.835	1				
FSStW	-0.733	0.482	0.869	0.758	0.978	0.764	1			
DSStW	-0.591	0.307	0.458	0.534	0.749	0.974	0.671	1		
FRW	-0.229	-0.127	-0.010	0.178	0.162	0.389	-0.045	0.419	1	
DRW	-0.664	0.099	0.656	0.672	0.813	0.752	0.786	0.582	0.177	1

Conclusions and Recommendations

The present study demonstrated that the hybrid genotypes of cauliflower exhibited better results than non-hybrid ones. Farmers rely primarily on non-hybrid cauliflower seeds because of their illiteracy and often don't get authorized hybrid seeds. Therefore, their yields remain quite low. Moreover, hybrids are also a major source of variation in germplasm and this variation is necessary for better breeding results.

Novelty Statement

The market available varieties and hybrids were evaluated at seedling stage for their comparative performance using biometrical technique. Hybrids provided comparative edge in most traits over the varieties and may be used further in breeding programs aimed to develop high yielding varieties of cauliflower.

Author's Contribution

Ikram ul Haq: Conceptualization, investigation, methodology, supervision, writing-review and editing, validation, data curation

Muhammad Huzaifa: Funding acquisition, formal analysis, resources software, writing -original draft visualization, project administration

Zeeshan Majeed: Writing-review and editing, validation, data curation

Abdul Hannan Afzal: Software, formal analysis, methodology, resources, project administration

Iqra Bibi: Writing-original draft, data collection

Tashfeen Fatima: Software, validation, data collection

Tayyaba Batool: Resources, formal analysis,

investigation, visualization

Mudassar Nawaz: Funding acquisition, resources

Conflict of interest

The authors have declared no conflict of interest.

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