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Evaluation of cauliflower genotypes to different planting dates for early production in Kathmandu valley

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ABSTRACT

A field experiment was conducted to evaluate ten cauliflower genotypes at the National Horticulture Research Centre, Khumaltar, Lalitpur from June to December of 2019 and 2020. The experiment was laid out in Randomized Completely Block Design with ten genotypes (Chinese, Sarlahi Deepali, Pusa Katiki, Taichun, Pusa Sarad, Terai 1, Terai 2, Agheni, Cold Queen and Khumal Jyapu) planted on three dates i.e. June 25, July 15, and August 5 at a 20-day interval. The main objective of this study was to identify planting dates for cauliflower genotypes suitable recommended to planting in early-season under Kathmandu valley conditions. The results showed that planting dates significantly influenced the growth and yield of cauliflower genotypes. At 25th June planting, the genotype Sarlahi Deepali had the significantly lowest days to curd maturation (41 days after transplanting), which was at par with Pusa Katki and Terai -2 (46 DAT) with the lowest yield of 4.0 mt ha^{-1} and 3.2 mt ha^{-1}, respectively. However, curd weight (438.6 g) and yield (27.4 mt ha^{-1}) were recorded as the maximum in Chinese with 51 days maturity period. On the 15th July planting, Terai 2 had the lowest maturity days (44 DAT), but lower yield (14.6 mt ha^{-1}), while Cold Queen had the highest curd weight and yield (560.8 g and 35.1 mt ha^{-1}), which was at par with Chinese (546.7 g and 34.2 mt ha^{-1}). Similarly, on the 5th August planting, the genotype Terai 2 had the significantly ($p<0.001$) lowest days to maturity (46 DAT), followed by Sarlahi Deepali (57) and Pusa Katiki (57), whereas the genotype Cold Queen had the highest curd weight and yield (842.1 g and 52.6 mt ha^{-1}), followed by Taichun (718.8 g and 44.9 mt ha^{-1}) and Terai 1 (452 g and 28.3 mt ha^{-1}). The results revealed that genotype Sarlahi Deepali was found to be early maturing for June planting, while Terai 2 was found early for July and August planting, but were not found suitable due to lower yield. The genotypes Chinese and Cold Queen were found best for June and July planting, respectively. Similarly, Cold Queen and Taichun were promising genotypes for August planting.

Keywords: Early cauliflower, growth, planting dates, yield

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INTRODUCTION

Cauliflower (*Brassica oleracae*var. *botrytis* L.) is one of the most important commercial vegetable crops in Nepal and belongs to the Brassicaceae family. Cauliflower is usually grown for its immature curd, which is an excellent source of protein, carbohydrates, dietary fibre and different minerals and vitamins (Ara et al 2009). Cauliflower area, production and productivity in Nepal are 35,764 ha, 5,74,795 mt, and 16.07 mt ha^{-1}, respectively. It ranks first in terms of area and production among all cultivated vegetables (MoALD 2020). Cauliflower is very sensitive to temperature and it is usually a cool season crop that requires low temperatures for curd initiation. Cauliflower's minimum and maximum growing temperatures are 0 and 30 °C, respectively, while the optimal growing temperature for this crop is between 15 and 22 °C. Cauliflower varieties notified by the National Seed Board of Nepal can be classified as early, mid and late-season varieties, in general. Early varieties of cauliflower require a temperature of 25-27 °C for curd formation. Similarly, mid varieties require 13-19°C for curd formation, whereas late varieties require a lower temperature, i.e., 10–16 °C (Choudhury 1996). Cauliflower is a highly preferred winter vegetable among Nepalese people, grown during the months of November-February. However, the demand for early-season cauliflower is high from August to November because some of the main festivals of Nepalese people, like Teej, Sohrasarad, Dashain and Tihar fall during this season (Bhattrai et al 2014) and farmers also get a high price of cauliflower during these months (KFVMD 2013). During these months the majority of demand in domestic markets has been fulfilled by importing early cauliflower from India and to some extent, by growing in the high hills of Nepal, which is naturally off-season for the mid-hills and Terai of Nepal. Similarly, very little quantity of national demand was fulfilled by using registered hybrid varieties that were developed in India and other countries (HRD 2006). Due to poor quality, compactness, taste and lower yield, the imported hybrid varieties are not the choice of farmers and consumers. Some indigenous open-pollinated cauliflower varieties have good taste with disease and insect tolerance. However, they are late maturing and also not appropriate for August to November planting (HRD 2013). From the available indigenous open-pollinated cauliflower (genotypes) genetic resources within the country, it is likely difficult to produce early-season cauliflower in the mid-hills due to the start of the rainy season and high temperatures, while it is nearly impossible to grow early-season cauliflower in the Terai and plains of Nepal in open field due to flooding, high temperature and water stagnation (Bhattrai et al 2014).

The National Horticulture Research Centre (NHRC) has already started the collection and characterization of early cauliflower genotypes from different locations and also from neighboring countries, i.e., China and India. As a result, nine different genotypes of cauliflower were selected in the year 2018. The response of these cauliflower genotypes differs from location to location and planting date as they are collected from different growing environments. Some genotypes may perform well in the early season, while others may perform better in late-season planting. Therefore, the present study was undertaken to identify suitable genotypes for early-season planting in the mid-hills of Nepal.

MATERIALS AND METHODS

The experiment was conducted at the research field of the National Horticulture Research Centre, Khumaltar, and Lalitpur for two consecutive years in 2019 and 2020, from June to December. Geographically, Khumaltar is located in the hilly region of Nepal with a subtropical climate at 27º 67' N Latitude and 85º 31' E Longitude at an altitude of 1365 masl. The area has a warm to hot summer and a cool to mild winter with infrequent frost and a

distinct rainy season. The average maximum and minimum temperatures were 25 ºC and 14 ºC, respectively, and the average temperature was 19.5 ºC during the entire research period. Similarly, a total rainfall of 972 mm and an average relative humidity of 77% were recorded during the entire research period. The soil composition of the study area was found to be sandy loam to clay loam with a pH of around 5.95–6.04. Chemical analysis of soil was carried out at the National Soil Science Research Centre (NSSRC) of the NARC for organic matter (%), total nitrogen (%), available phosphorus (mg kg^{-1}) and potassium (mg kg^{-1}) analysis. The report of the soil test was presented in Table 1.

Table 1. Physical and chemical characteristics of soil at the research site, Khumaltar, Lalitpur during 2019-2020

Properties	**2019**	**2020**
Organic matter (%)	2.80	4.84
Total Nitrogen (%)	0.12	0.16
Available P_2O_5 (mg kg^1)	181.79	143.05
Exchangeable K_2O (mg kg^1)	92.84	121.8
pH	5.95	6.04

The design of the experiment was Randomized Complete Block Design (RCBD) with ten treatments (Chinese, Sarlahi Deepali, Pusa Katiki, Taichun, Pusa Sarad, Terai 1, Terai 2, Agheni, Cold Queen and Khumal Jyapu) with three replications of each. Among ten genotypes, seeds of two released varieties (Sarlahi Deepali and Khumal Jyapu) were collected from National Horticulture Research Centre and used as standard checks. Seeds of the remaining eight genotypes were introduced from China and India with the help of the Nepal Seed and Fertilizer (NSAF) project. Seed of ten different genotypes of cauliflower was sown on the nursery bed on three different dates, i.e., Ashad 10 (June 25), Ashad 30 (July 15) and Shrawan 20 (August 5) at a 20-day interval. Twenty two days old, healthy and uniform seedlings from each sown date were transplanted in the main field. The plot size was $4m^2$, and a spacing of 40 cm × 40 cm was maintained between row to row and plant to plant, accommodating twenty-five seedlings per plot. Fertilizer was applied at the rate of 20 tons FYM and 200:120:80 kg NPK ha^{-1}. The full dose of FYM, phosphorous, potash and half dose of nitrogen as a basal applied in a pit one week before transplanting while only the half dose, whereas the remaining half dose of nitrogen was applied in two split doses at 15 and 30 days after transplanting. Data were recorded from nine plants in a selected inner row from each treatment. Curd initiation days were recorded as fifty percent of the plants in the plot showed curd, while maturity days were recorded, when fifty percent of the plants in the plot were ready for harvesting. Other parameters were recorded during harvesting. Plant height was measured from the ground level to the growing tip of the longest leaf with the help of a measuring scale; number of leaves in a single plant was counted and noted. Similarly, for the ground covered by the plant, the criss-cross spread of the plant was measured by measuring scale and the average was computed. The total shoot weight, root weight and curd weight were measured by electronic balance while, curd diameter and curd height were measured by measuring scale.

RESULTS

Planting date 25 June

Curd initiation and maturity days

The days to 50% curd initiation of different cauliflower genotypes for both years were presented in Table 2. The mean results from both years showed that the cauliflower genotypes differ significantly ($P<0.05$) from each other in terms of curd initiation days. From

pooled results, the maximum days to curd initiation was reported in genotype Cold Queen (63 days after transplanting), which was at par with Khumal Jyapu (61 DAT). However, the lowest days to curd initiation was recorded in genotype Terai-2 (33 DAT), which indicates earliness in harvesting. Significant (P<0.05) differences among genotypes were observed on maturity days during both years. The highest maturity days was recorded in Cold Queen (88 DAT) followed by Khumal Jyapu (74 DAT) and the lowest days to maturity was recorded in Sarlahi Deepali (41 DAT) (Table 2).

Table 2. Effect of different cauliflower genotypes on curd initiation and maturity days during 25th June planting of 2019 and 2020 at Khumaltar, Lalitpur

Genotypes	Curd initiation days			Curd maturity days		
	2019	2020	Mean	2019	2020	Mean
Chinese	43bc	32a	38ab	56c	46abc	51bcd
PusaKatiki	41abc	34a	38ab	48b	44ab	46abc
SarlahiDeepali	39ab	34a	36ab	43a	39a	41a
Taichun	46cd	37a	41ab	58c	54c	56d
PusaSarad	45c	35a	40ab	57c	46abc	52cd
Agheni	50b	36a	43b	60c	53bc	57d
Terai 1	37a	37a	37ab	51b	48abc	50bc
Terai 2	35a	31a	33a	48b	44ab	46abc
KhumalJyapu	65e	56b	61c	74d	75d	74e
Cold Queen	76f	51b	63c	92e	85e	88f
Mean	48	38	43	59	53	56
F test	***	***	***	***	***	***
LSD (0.05)	5.190	6.081	8.15	4.00	8.690	5.882

***P<0.001 Figures with same letter (s) within the same column do not differ significantly by Duncan Multiple Range Test at 0.05 level.

Plant height and leaf number

The plant height and leaf number of different cauliflower genotypes for both years were presented in Table 3. From pooled analysis among ten genotypes highest plant height (58.4 cm) was recorded in Khumal Jyapu followed by Agheni (44.6 cm) and the least was recorded in Terai-2 (21.7 cm) followed by remaining all genotypes. The mean results from both years showed that the cauliflower genotypes differ significantly (P<0.05) from each other in terms of leaf number.

Table 3. Effect of different cauliflower genotypes on plant height and leaf number during 25thJune planting of 2019 and 2020 at Khumaltar, Lalitpur

Genotypes	Plant height (cm)			Leaf number		
	2019	2020	Mean	2019	2020	Mean
Chinese	37.18c	33.5abc	35.3b	19ab	16a	17ab
PusaKatiki	29.83b	31.1abc	30.4b	18a	18a	18abc
SarlahiDeepali	31.53bc	37.4bc	34.3b	19ab	16a	18abc
Taichun	30.12ab	31.6abc	30.9b	22bc	18a	20bc
PusaSarad	30.62bc	42.1bc	36.4b	19ab	16a	17abc
Agheni	44.98d	44.3c	44.6c	19ab	16a	17ab
Terai 1	32.87bc	28.3ab	30.6b	23c	18a	20c
Terai 2	23.58a	19.9a	21.7a	16a	14a	15a
KhumalJyapu	54.34e	62.5d	58.4d	27d	28b	27d
Cold Queen	32.05bc	32.2abc	32.1b	17a	16a	17a
Mean	34.71	36.3	35.5	20	17	19
F test	***	***	***	***	***	***
LSD (0.05)	6.23	12.92	6.918	3.22	3.057	2.691
CV%	10.5	20.8	16.8	9.4	10.2	12.4

***P<0.001, Figures with same letter (s) within the same column do not differ significantly by Duncan Multiple Range Test at 0.05 level.

From pooled results, the maximum leaf number at maturity stage was reported in genotype Khumal Jyapu (27 leaves at maturity) which was followed by Terai 1 (20 leaves at maturity) and Taichun (20 leaves at maturity). However, the lowest number of leaves was recorded in genotype Terai 2 (15 leaves at maturity) which indicates low harvesting (Table 3).

Root weight and shoot weight

Root weight and shoot weight of different cauliflower genotypes were presented in Table 4. Significant (P<0.05) differences among genotypes were observed in terms of root weight during both years. The highest root weight was recorded in Khumal Jyapu (88.5 g) followed by Agheni (40.6 g) and the least weight was recorded in Terai 2 (15.4 g) which was at par with Pusa Katiki (15.7 g). The shoot weight of cauliflower was influenced by different genotypes during both research years. From pooled analysis among ten genotypes highest shoot weight (1142.4 g) was recorded in genotype Khumal Jyapu followed by Chinese (831.4 g) and the least weight was recorded in Pusa Katiki (346.4 g) which was at par with Cold Queen (376.4 g) (Table 4).

Table 4. Effect of different cauliflower genotypes on root weight and shoot weight during 25thJune planting of 2019 and 2020 at Khumaltar, Lalitpur

Genotypes	Root weight (g)			Shoot weight (g)		
	2019	2020	Mean	2019	2020	Mean
Chinese	36.6cd	23.1ab	29.9bcd	1053.5cd	609.3a	831.4d
PusaKatiki	17.98ab	14.1a	15.7a	370.2a	322.6a	346.4a
SarlahiDeepali	16.93ab	19.6ab	18.7ab	402.2a	402.5a	402.3abc
Taichun	37.35cd	30.6ab	34.0cd	768.4bc	539.1a	654.0cd
PusaSarad	27.20abc	25.3ab	26.2abc	606.3ab	565.7a	586.0bcd
Agheni	52.76d	28.5ab	40.6d	788.4bc	549.9a	669.1cd
Terai 1	28.73abc	18.8a	23.8abc	784.4bc	415.0a	599.7bcd
Terai 2	15.59a	15.2a	15.4a	406.0a	397.9a	402.0ab
KhumalJyapu	89.17e	87.9c	88.5e	1157.5d	1127.3b	1142.4e
Cold Queen	34.33bc	36.7b	35.5cd	375.4a	377.3a	376.4ab
Mean	34.7	30.0	32.8	671	531.0	601.0
F test	***	***	***	***	***	***
LSD (0.05)	16.57	15.48	11.33	294.2	317.3	226.9
CV%	27.1	30.1	29.7	25.5	34.9	32.5

**P<0.01, Figures with same letter (s) within the same column do not differ significantly by Duncan Multiple Range Test at 0.05 level.

Curd diameter and curd height

The curd diameter and curd height of different cauliflower genotypes for both years were presented below in Table 5. The mean results from both years showed that the cauliflower genotypes differ significantly (P<0.05) each other in terms of curd diameter.

From pooled results, the maximum curd diameter was reported in genotype Chinese (12.7cm), which was closely followed by genotype Terai 1 (11.4 cm). However, the minimum curd diameter was reported in genotype Pusa Katiki (6.8 cm), which was at par with Sarlahi Deepali (7.1 cm). Significant (P<0.05) differences among genotypes were observed in terms of curd height during both years. The maximum curd height was reported in genotype Khumal Jyapu (11.8 cm) followed by Chinese (8.3cm) and the minimum height was observed in genotype Taichun (6.4 cm) which was at par with Terai 2 (6.4 cm) (Table 5).

Table 5. Effect of different cauliflower genotypes on curd diameter and curd height during 25th June planting of 2019 and 2020 at Khumaltar, Lalitpur

Genotypes	Curd diameter (cm)			Curd height (cm)		
	2019	2020	Mean	2019	2020	Mean
Chinese	14.14c	11.2d	12.7d	9.13bc	7.4ab	8.3a
PusaKatiki	8.43ab	6.8ab	6.8a	8.07abc	6.2ab	6.9a
SarlahiDeepali	7.39a	6.3a	7.1a	6.58a	8.9bc	7.9a
Taichun	12.06c	8.4abcd	10.2bcd	7.51abc	5.3a	6.4a
PusaSarad	10.84bc	9.6bcd	10.2bcd	7.39abc	6.4ab	6.9a
Agheni	12.01c	8.4abcd	10.2bcd	8.89abc	6.1ab	7.5a
Terai 1	13.86c	9.0abcd	11.4cd	9.58c	6.3ab	8.0a
Terai 2	11.65bc	10.4cd	11.0cd	6.94ab	5.9ab	6.4a
KhumalJyapu	11.09bc	7.5abc	9.3abc	13.15d	10.5c	11.8b
Cold Queen	8.35ab	6.8ab	7.6ab	7.48abc	6.0ab	6.7a
Mean	10.98	8.4	9.71	8.48	6.9	7.69
F test	**	**	***	***	**	***
LSD (0.05)	3.13	2.70	2.525	2.2	2.809	2.041
CV%	16.6	18.7	22.4	15.3	23.7	22.9

**P<0.01, ***P<0.001, Figures with same letter (s) within the same column do not differ significantly by Duncan Multiple Range Test at 0.05 level.

Curd weight and yield

Curd weight and yield (mt ha^{-1}) of different cauliflower genotypes for both years is presented in Table 6. The mean results showed that the cauliflower genotypes differ significantly (P<0.01) with each other in terms of curd weight. From pooled analysis among ten genotypes, the highest curd weight was recorded in genotype Chinese (438.6 g) followed by Terai 2 (223.8 g) and the least curd weight was recorded in Pusa Katiki (51.1 g) which was at par with Sarlahi Deepali (64.0 g). Significant differences among genotypes were observed in terms of yield during both years. The highest yield was recorded in genotype Chinese (27.3 mt ha^{-1}) followed by Terai 2 (14.0 mt ha^{-1}) and least yield was recorded in genotype Pusa Katiki (3.2 mt ha^{-1}) which was at par with Sarlahi Deepali (4.0 mt ha^{-1}) (Table 6).

Table 6. Effect of different cauliflower genotypes on curd weight and yield (mt ha^{-1}) during 25th June planting of 2019 and 2020 at Khumaltar, Lalitpur

Genotypes	Curd weight (g)			Yield mt ha^{-1}		
	2019	2020	Mean	2019	2020	Mean
Chinese	459.5f	417.8e	438.6e	28.7f	26.1e	27.4e
PusaKatiki	55.2a	47a	51.1a	3.5a	2.9a	3.2a
SarlahiDeepali	56.8a	71.2a	64a	3.6a	4.4a	4.0a
Taichun	261.2e	144.5c	202.9cd	16.3e	9.0c	12.7cd
PusaSarad	171.8c	133.3bc	152.5bc	10.7c	8.3bc	9.5bc
Agheni	210d	137.5bc	173.7cd	13.1d	8.6bc	10.9cd
Terai 1	279.1e	129.8bc	204.5cd	17.4e	8.1bc	12.8cd
Terai 2	226.7d	220.8d	223.8d	14.2d	13.8d	14.0d
KhumalJyapu	203.1cd	113b	158.1bc	12.7cd	7.1b	9.9bc
Cold Queen	109.7b	124.3bc	117b	6.9b	7.8bc	7.3b
Mean	202.3	153.9	178.6	12.7	9.6	11.2
F test	***	***	***	***	***	***
LSD (0.05)	32.88	24.19	50.4	2.055	1.512	3.128
CV%	9.4	9.2	24.3	9.4	9.2	24.2

**P<0.01, ***P<0.001, Figures with same letter (s) within the same column do not differ significantly by Duncan Multiple Range Test at 0.05 level.

Planting date July 15

Curd initiation days and maturity days

The days to 50% curd initiation of different cauliflower genotypes for both years were presented in Table 7. The mean from both years showed that the cauliflower genotypes differ significantly (P<0.001) with each other in terms of curd initiation days. From pooled results, the maximum days to curd initiation was reported in genotype Cold Queen (66 Days after transplanting) followed by Khumal Jyapu (59 DAT). However, the lowest days to curd initiation were recorded in Terai 1 (36 DAT) which was at par with Terai 2 (36 DAT). It indicates earliness in harvesting. Significant differences among genotypes were observed on maturity days during both years. The highest maturity days was recorded in genotype Cold Queen (94 DAT) followed by Khumal Jyapu (74 DAT) and the lowest days to maturity was reported in genotype Terai 2 (44 DAT) which was at par with Sarlahi Deepali (45 DAT) (Table 7).

Table 7. Effect of different cauliflower genotypes on curd initiation and maturity days during 15th July planting of 2019 and 2020 at Khumaltar, Lalitpur

Genotypes	Curd initiation days			Maturity days		
	2019	2020	Mean	2019	2020	Mean
Chinese	39b	34a	36a	51b	47^{ab}	49a
Pusa Katiki	38b	37ab	37a	44a	47^{ab}	46a
Sarlahi Deepali	38b	39ab	38a	45a	45^{ab}	45a
Taichun	50d	43bc	47bc	69d	62^{c}	65c
Pusa Sarad	45c	44bc	44b	60c	56^{bc}	57b
Agheni	53e	49cd	51c	61c	63^{c}	62bc
Terai 1	38b	33a	36a	50b	46^{ab}	48a
Terai 2	33a	38ab	36a	45a	43^{a}	44a
Khumal Jyapu	62f	55de	59d	71d	78^{d}	74d
Cold Queen	72g	61e	66e	84e	103^{e}	94e
Mean	47	43	45	58	59	58
F test	***	***	***	***	***	***
LSD (0.05)	1.43	6.509	5	5.01	9.69	7
CV%	1.8	8.8	9	5	9.6	10

***P<0.001, Figures with same letter (s) within the same column do not differ significantly by Duncan Multiple Range Test at 0.05 level.

3.2.3 Plant height and leaf number

The plant height and leaf number of different cauliflower genotypes for both years were presented in Table 8. The pooled results from both years showed that the cauliflower genotypes differ significantly (P<0.001) with each other in terms of plant height. From pooled results, the maximum height at the maturity stage was recorded in Khumal Jyapu (67.6 cm) which was followed by Agheni (51.9 cm). However, the lowest plant height was reported in Terai 2 (26.8 cm).

Significant (P<0.001) differences among genotypes were observed in terms of leaf number. From pooled results, the maximum leaf number was reported in Khumal Jyapu (25 leaves) followed by Terai 1 (18 leaves). However, the lowest leaf number was recorded in genotype Sarlahi Deepali (15 leaves) which was at par with Terai 2 (15 leaves) (Table 8).

Table 8. Effect of different cauliflower genotypes on plant height and leaf number during 15th July planting of 2019 and 2020 at Khumaltar, Lalitpur

Genotypes	Plant height (cm)			Leaf number		
	2019	2020	Mean	2019	2020	Mean
Chinese	42.9bc	45.9b	44.4bc	18c	16ab	17cd
PusaKatiki	37.1ab	44.3b	40.7b	16a	15ab	15abc
SarlahiDeepali	39.2abc	43.5b	41.4b	15a	14a	15a
Taichun	38.0ab	48.5b	42.8b	19c	17bc	18d
PusaSarad	46.6bc	46.7b	44.1bc	18bc	15ab	16abcd
Agheni	50.4cd	53.4b	51.9c	19c	15ab	17bcd
Terai 1	35.0ab	43.2b	39.1b	19c	17bc	18d
Terai 2	28.4a	25.2a	26.8a	16a	14a	15ab
KhumalJyapu	61.1d	67.6c	64.4d	24d	26d	25e
Cold Queen	37.6ab	48.1b	42.9b	16ab	18c	17cd
Mean	41.6	46.6	43.9	17	17	17
F test	***	***	***	***	***	***
LSD (0.05)	11.02	10.96	7.176	1.78	2.041	2
CV%	15.4	13.7	15.1	5.8	7.1	10

***P<0.001, Figures with same letter (s) within the same column do not differ significantly by Duncan Multiple Range Test at 0.05 level.

Root weight and shoot weight

Root weight and shoot weight of different cauliflower genotypes for both years were presented in Table 9. The mean results from both years showed that the cauliflowers genotypes differ significantly (P<0.001) with each other in terms of Root weight. From pooled results, the maximum root weight was recorded in Khumal Jyapu (91.8 g) followed by Cold Queen (63.1 g). However, the lowest root weight was recorded in Terai 2 (25.8 g). Significant (P<0.001) differences among genotypes were observed in shoot weight during both years. The maximum shoot weight was recorded in genotype Khumal Jyapu (1658.1 g) followed by genotype Chinese (1132.8 g) and the minimum shoot weight was recorded in genotype Sarlahi Deepali (481.5 g) which was at par with PusaKatiki (524.2) (Table 9).

Table 9. Effect of different cauliflower genotypes on root weight and shoot weight during 15th July planting of 2019 and 2020 at Khumaltar, Lalitpur

Genotypes	Root weight (g)			Shoot weight (g)		
	2019	2020	Mean	2019	2020	Mean
Chinese	45.15a	41.1ab	43.1abc	1259.5	1005.7ab	1132.8c
Pusa Katiki	29.73a	42.7ab	36.2ab	453.5	594.8a	524.2a
Sarlahi Deepali	31.63a	38.6ab	35.1ab	502.5	460.5a	481.5a
Taichun	38.87a	64.4bc	51.6bc	982.4	1269.6b	1126.0c
Pusa Sarad	31.78a	48.1ab	39.6ab	909.7	915.5ab	912.6abc
Agheni	31.01a	46.0ab	38.5ab	924.2	971.2ab	947.7bc
Terai 1	29.85a	31.4a	30.6ab	740.0	810.8ab	775.0abc
Terai 2	29.28a	22.4a	25.8a	680.1	512.0a	596.1ab
Khumal Jyapu	72.02b	111.5d	91.8d	1375.5	1940.7c	1658.1d
Cold Queen	40.92a	85.4cd	63.1c	685.9	1394.9b	1040.4c
Mean	38	53.1	45.5	851	988.0	911
F test	***	***	***	0.011	***	***
LSD (0.05)	15.13	27.59	19.8	476.7	533	371.7
CV%	23.2	30.3	37.6	32.6	31.5	35.1

***P<0.001, Figures with same letter (s) within the same column do not differ significantly by Duncan Multiple Range Test at 0.05 level.

Curd diameter and Curd height

The curd diameter and curd height of different cauliflower genotypes for both years were presented in Table 10. The mean results from both years showed that the cauliflower

genotypes differ significantly (P<0.001) with each other in terms of Curd diameter. From pooled results, the maximum curd diameter was recorded in Khumal Jyapu (14.6 cm) which was at par with genotype Chinese (14.2 cm). However, the minimum curd diameter was recorded in Sarlahi Deepali (8.3 cm). Significant (P<0.001) differences among genotypes were observed from both years in terms of Curd height. The maximum curd height was recorded in genotype Khumal Jyapu (11.6cm) and the minimum curd height was recorded in genotype Sarlahi Deepali (7.3 cm) which was at par with Pusa Katiki (7.5 cm) (Table 10).

Table 10. Effect of different cauliflower genotypes on curd diameter and curd height during 15th July planting of 2019 and 2020at Khumaltar, Lalitpur

Genotypes	Curd Diameter (cm)			Curd height (cm)		
	2019	2020	Mean	2019	2020	Mean
Chinese	14.64	13.7cd	14.2bc	10.07	8.6bc	9.4b
PusaKatiki	8.83	9.5ab	9.2a	7.59	7.5abc	7.5ab
SarlahiDeepali	9.10	7.4a	8.3a	8.17	6.4a	7.3a
Taichun	12.87	13.8cd	13.3bc	8.08	8.3abc	8.2ab
PusaSarad	11.95	12.9cd	12.4bc	7.69	8.1abc	7.9ab
Agheni	12.58	12.2bc	12.4b	8.97	8.8bc	8.9ab
Terai 1	12.48	14.0cd	13.2bc	9.11	9.0c	9.1ab
Terai 2	12.62	11.6bc	12.1b	10.67	6.8ab	8.7ab
KhumalJyapu	13.92	15.3d	14.6c	11.14	12.0d	11.6c
Cold Queen	13.34	13.8cd	13.6bc	8.76	8.6bc	8.7ab
Mean	12.23	12.4	12.3	9.03	8.4	8.7
F test	ns	***	***	ns	***	***
LSD (0.05)	3.16	2.596	1.9	2.40	1.842	1.6
CV%	15.1	12.2	13..4	15.5	12.7	16.0

Ns: non significant, ***P<0.001, Figures with same letter (s) within the same column do not differ significantly by Duncan Multiple Range Test at 0.05 level.

Cauliflower yield

Curd weight and Yield (t/ha) of different cauliflower genotypes for both years were presented in Table 11. The mean result shows that the cauliflower genotypes differ significantly (P<0.001) with each other in terms of Curd weight.

Table 11. Effect of different cauliflower genotypes on curd weight and yield mt ha^{1} during 15th July planting of 2019 and 2020 at Khumaltar, Lalitpur

Genotypes	Curd weight (g)			Yield mt ha^{-1}		
	2019	2020	Mean	2019	2020	Mean
Chinese	666.1g	427.3e	546.7c	41.6g	26.7e	34.2c
PusaKatiki	80.3a	112.7b	96.5a	5.0a	7.0a	6.0a
SarlahiDeepali	98.6a	97.3a	97.9a	6.2a	6.1a	6.1a
Taichun	347.1ef	431.5e	389.3b	21.7ef	27.0e	24.3b
PusaSarad	298.8cd	305.5bc	302.1b	18.7cd	19.1bc	18.9b
Agheni	273.7c	312.4c	293.1b	17.1c	19.5c	18.3b
Terai 1	336.8ef	367.3d	352.1b	21.1ef	23.0d	22.0b
Terai 2	315.3de	264.1b	289.7b	19.7de	16.5b	18.1b
KhumalJyapu	233.2b	482.3f	357.8b	14.6b	30.1f	22.4b
Cold Queen	365.3f	756.4g	560.8c	22.8f	47.3g	35.1c
Mean	301.5	355.7	329.0	18.8	22.2	20.5
F test	***	***	***	***	***	***
LSD (0.05)	36.01	43.12	112.1	2.25	2.695	7.006
CV%	7	7.1	29.4	7	7.1	29.4

***P<0.001, Figures with same letter (s) within the same column do not differ significantly by Duncan Multiple Range Test at 0.05 level.

From pooled analysis among ten genotypes, the maximum curd weight was recorded in genotype Cold Queen (560.8 g) which was at par with Chinese (546.7 g). However, the

minimum curd weight was recorded in genotype Pusa Katiki (96.5 g) which was at par with Sarlahi Deepali (97.9 g). Significant (P<0.001) differences were observed among genotypes in both years in terms of Yield (mt ha^{-1}). From pooled analysis, the maximum Yield (t ha^{-1}) was recorded in genotype Cold Queen (35.1 mt) which was at par with genotype Chinese (34.2 mt). However, the minimum Yield (mt ha^{-1}) was recorded in genotype Pusa Katiki which was at par with Sarlahi Deepali (6.1 mt) (Table 11).

Planting date August 5

Curd initiation days and Maturity days

The days to 50% curd initiation of different cauliflower genotypes for both years were presented in Table 12. The mean from both years showed that the cauliflower genotypes differ significantly (P<0.001) with each other in terms of curd initiation days. From pooled results, the maximum days to curd initiation days was recorded in genotype Cold Queen (65 Days after transplanting) which was at par with Khumal Jyapu (60 DAT). However, the minimum days to curd initiation was recorded in Terai 2 (34 DAT). It shows earliness in harvesting. Significant differences among genotypes were observed on maturity days during both years. The highest maturity days was recorded in genotype Cold Queen (79 DAT) which was followed by Agheni (70 DAT) and the lowest maturity days was recorded in genotype Terai-2 (46 DAT) (Table 12).

Table 12. Effect of different cauliflower genotypes on curd initiation, maturity days and plant height during 5thAugust planting of 2019 and 2020 at Khumaltar, Lalitpur

Genotypes	Curd initiation days			Maturity days		
	2019	2020	Mean	2019	2020	Mean
Chinese	40ab	32ab	36ab	54b	66^{bc}	60bc
Pusa Katiki	41abc	39b	40ab	56b	59^{b}	57b
Sarlahi Deepali	44c	41b	43bc	50ab	64^{bc}	57b
Taichun	45c	52c	48c	68c	66^{bc}	67cd
Pusa Sarad	42abc	41b	41b	54b	64^{bc}	59bc
Agheni	44bc	52c	48c	69c	71^{c}	70d
Terai 1	41abc	40b	40ab	54b	72^{c}	63bcd
Terai 2	39a	28a	34a	47a	45^{a}	46a
Khumal Jyapu	59d	61d	60d	71c	63^{bc}	67cd
Cold Queen	70e	60cd	65d	86d	72^{c}	79e
Mean	47	45	46	61	64	63
F test	***	***	***	***	***	***
LSD (0.05)	3.28	7.953	6	5.207	8.994	8
CV%	4.1	10.4	11	5.1	8.2	11

***P<0.001, Figures with same letter (s) within the same column do not differ significantly by Duncan Multiple Range Test at 0.05 level.

Plant height and leaf number

Plant height and leaf number of different cauliflower genotypes for both years were presented in Table 13. The mean results from both years showed that the cauliflower genotypes differ significantly (P<0.001) with each other in terms of Plant height. From pooled results, the maximum plant height was recorded in genotype Khumal Jyapu (56.2 cm) which was at par with genotype Agheni (50.8 cm). However, the minimum plant height was recorded in Terai 2 (21.2 cm). Significant differences were observed between the genotypes of cauliflower or both years in terms of Leaf number. From the pooled results it showed that the maximum Leaf number was recorded in genotype Khumal Jyapu (19 leaves) which was followed by Cold Queen (18 leaves) and the minimum leaf number was recorded in genotype Sarlahi Deepali (14 leaves) which was at par with Terai 2 (14 leaves) (Table 13).

Table 13. Effect of different cauliflower genotypes on plant height and leaf number during 5th August planting of 2019 and 2020at Khumaltar, Lalitpur

Genotypes	Plant height (cm)			Leaf number		
	2019	2020	Mean	2019	2020	Mean
Chinese	40.85^{bc}	40^{b}	40.6^{cd}	15	16^{a}	15^{abc}
PusaKatiki	38.37b	35.8^{b}	37.1^{bc}	15	15^{a}	15^{ab}
SarlahiDeepali	35.60b	38.4^{b}	37.0^{bc}	14	14^{a}	14^{a}
Taichun	39.40b	36.5^{b}	38.0^{c}	15	19^{c}	17^{bcd}
PusaSarad	34.48b	40.0^{b}	37.2^{bc}	14	16^{a}	15^{ab}
Agheni	48.59c	53.1^{c}	50.8^{e}	14	16^{ab}	15^{ab}
Terai 1	26.58a	36.5^{b}	31.5^{b}	17	18^{bc}	17^{cde}
Terai 2	21.15a	21.3^{a}	21.2^{a}	14	14^{a}	14^{a}
KhumalJyapu	61.21d	51.3^{c}	56.2^{e}	17	20^{c}	19^{e}
Cold Queen	48.78^{c}	41.8^{b}	45.3^{d}	16	20^{c}	18de
Mean	39.50	39.5	39.5	15	17	16
F test	***	***	***	0.063	***	***
LSD (0.05)	7.28	5.809	5.5	2.42	1.997	2
CV%	11.6	8.6	12.0	9.4	6.9	11

***P<0.001, Figures with same letter (s) within the same column do not differ significantly by Duncan Multiple Range Test at 0.05 level

Root weight and shoot weight

The root weight and shoot weight of different genotypes for both years were shown in Table 14. The mean results from both years showed that the cauliflower genotypes differ significantly (P<0.001) in terms of root weight. From the pooled results the maximum root weight was recorded in genotype Cold Queen (65 g) which was followed by Khumal Jyapu (62 g). However, the minimum root weight was recorded in genotype Terai 2 (16 g). Significance difference was reported in genotypes from both years in terms of shoot weight. From the pooled results the maximum shoot weight was recorded in genotype Cold Queen (1595.1 g) which was followed by Taichun (1127.2 g). However, the minimum shoot weight was recorded in genotype Terai 2 (306.9 g) (Table 14).

Table 14. Effect of different cauliflower genotypes on root weight and shoot weight during 5th August planting of 2019 and 2020 at Khumaltar, Lalitpur

Genotypes	Root weight (g)			Shoot weight (g)		
	2019	2020	Mean	2019	2020	Mean
Chinese	24.09abc	37.5ab	31ab	808.4bc	884.2b	846.3cde
Pusa Katiki	17.82ab	38.6ab	28ab	400.7ab	407.4a	404.0ab
Sarlahi Deepali	20.60abc	38.2ab	29ab	319.8a	437.6a	378.7ab
Taichun	36.43c	57.0bcd	47bc	1057.7c	1196.8bc	1127.2e
Pusa Sarad	18.77abc	55.3bcd	37b	517.2ab	772.5ab	644.8bc
Agheni	32.63bc	55.2bcd	44b	825.1bc	1155.3b	990.2de
Terai 1	17.25ab	44.4bc	31ab	489.3ab	1024.4b	756.8cd
Terai 2	9.78a	21.6a	16a	244.6a	369.2a	306.9a
Khumal Jyapu	62.88d	61.8cd	62cd	1261.2cd	897.6b	1079.4de
Cold Queen	60.92d	68.5d	65d	1605.2d	1584.9c	1595.1f
Mean	30.1	47.8	39	753	873.0	813.0
F test	***	0.002	***	***	***	***
LSD (0.05)	16.1	18.71	17	423	403.3	297.8
CV%	31.2	22.8	37	32.7	26.9	39.6

***P<0.001, Figures with same letter (s) within the same column do not differ significantly by Duncan Multiple Range Test at 0.05 level

Curd diameter and curd height

The curd diameter and curd height of the cauliflower genotype for both years were shown in Table 15. The mean results from both years showed that the cauliflower genotypes differ

significantly (P<0.001) with each other in terms of curd diameter. From pooled results, the maximum curd weight was recorded in genotype Cold Queen (15.38 cm) which was followed by genotype Agheni (14.6 cm). However, the minimum curd weight was recorded in genotype Pusa Katiki (8.4 cm) which was at par with genotype Sarlahi Deepali (8.5 cm). Significant (P<0.001) differences were observed from both years in terms of curd height. From the pooled results among various genotypes of cauliflower, the maximum curd height was recorded in genotype Khumal Jyapu (11.5 cm) which indicates a high yield. Similarly, minimum curd height was recorded in genotype Terai 2 (6.0 cm) which was at par with Pusa Katiki (6.6 cm) (Table 15).

Table 15. Effect of different cauliflower genotypes on curd diameter and curd height during 5thAugust planting of 2019 and 2020at Khumaltar, Lalitpur

Genotypes	Curd diameter (cm)			Curd height (cm)		
	2019	2020	Mean	2019	2020	Mean
Chinese	14.31cd	13.0cd	13.6cd	8.74ab	8.0bc	8.4bcd
PusaKatiki	9.23a	7.6a	8.4a	7.39ab	5.9a	6.6ab
SarlahiDeepali	8.77a	8.2ab	8.5a	7.87ab	6.2a	7.1abc
Taichun	15.01d	13.6cd	14.3d	8.45ab	8.6bcd	8.5bcd
PusaSarad	11.122ab	12.4cd	11.8bc	6.45ab	7.2ab	6.8ab
Agheni	14.19cd	14.6d	14.6d	9.69b	9.9d	9.8de
Terai 1	12.20bc	15.1d	13.6cd	7.98ab	10.0d	9.0cd
Terai 2	10.48ab	9.7abc	10.1ab	6.08a	5.9a	6.0a
KhumalJyapu	15.99d	11.7bcd	13.85cd	13.57c	9.5cd	11.5e
Cold Queen	15.75d	15.0d	15.38d	9.97b	9.9d	9.9de
Mean	12.73	12.1	12.4	8.62	8.1	8.4
F test	***	***	***	***	***	***
LSD (0.05)	2.32	3.58	2.2	3.13	1.490	1.8
CV%	10.6	17.3	15.1	21.2	10.7	18.9

***P<0.001, Figures with same letter (s) within the same column do not differ significantly by Duncan Multiple Range Test at 0.05 level

Curd weight and Yield

Curd weight and yield (t/ha) of different cauliflower genotypes for both years were shown in Table 16. The mean results from both years showed that the cauliflower genotypes differ significantly (P<0.01) in terms of curd weight. From the pooled results the maximum curd weight was recorded in genotype Cold Queen (842.1 g) which was followed by Taichun (718.8 g). However, the minimum weight was recorded in genotype Sarlahi Deepali (82 g) which was at par with Pusa Katiki (94.5 g). The yield of cauliflower was also influenced by different genotypes during both years.

From pooled among ten genotypes of cauliflower the maximum yield was recorded in genotype Cold Queen (52.6 mt ha^{-1}) which was followed by Taichun (44.9 mt ha^{-1}). However, the minimum yield was recorded in genotype Sarlahi Deepali (5.1 mt ha^{-1}) which was at par with genotype Pusa Katiki (5.9 mt ha^{-1}) (Table 16).

Table 16. Effect of different cauliflower genotypes on curd weight and yield (mt ha^{1}) during 5th August planting of 2019 and 2020 at Khumaltar, Lalitpur

Genotypes	Curd weight (g)			Yield mt ha^{1}		
	2019	2020	Mean	2019	2020	Mean
Chinese	433.2e	456.1d	444.6c	27.1e	28.5d	27.8c
Pusa Katiki	101.3ab	87.8a	94.5a	6.3ab	5.5a	5.9a
Sarlahi Deepali	65.5a	98.6a	82a	4.1a	6.2a	5.1a
Taichun	531.3f	906.4f	718. 8d	33.2f	56.7f	44.9d
Pusa Sarad	209.1c	365.7c	287.4b	13.1c	22.9c	18.0b
Agheni	350.9d	436.3d	393.6c	21.9d	27.3d	24.6c
Terai 1	327.1d	576.9e	452c	20.4d	36.1e	28.3c
Terai 2	131.9b	211.1b	171.5a	8.2b	13.2b	10.7a
Khumal Jyapu	398.7e	398.1c	398.4c	24.9e	24.9c	24.9c
Cold Queen	807.1g	877f	842.1e	50.4g	54.8f	52.6e
Mean	335.6	441.4	388	21.0	27.6	24.28
F test	***	***	***	***	***	***
LSD (0.05)	40.04	32.94	104.4	2.503	2.059	6.525
CV%	7	4.4	23.2	7	4.4	23.2

**P<0.01, ***P<0.001, Figures with same letter (s) in the column do not differ significantly by Duncan Multiple Range Test at 0.005 level.

DISCUSSION

Cauliflower is a thermo-sensitive plant, so it requires specific climatic conditions for the development of its vegetative as well as economic parts, i.e., curd (Giri et al 2020). Depending upon varieties, early varieties of cauliflower require a temperature of 25-27°C for curd formation. Similarly, mid varieties require 13-19°C for curd formation, whereas late varieties require a lower temperature, i.e., 10–16°C (Choudhury1967). Our results showed that planting dates significantly (P<0.001) influenced the growth and yield of cauliflower genotypes (Table 6, 11 and 16). At the 25th June planting, the genotype Sarlahi Deepali, Pusa Katki and Terai -2 were found earlier maturity and are similar to our earlier finding and recommendation by the national seed board but the yield of these genotypes are very low as compared to new genotypes (Table 2). Our results showed the genotype Chinese gave the highest curd weight (438.6 g) and yield (27.4 mt ha^{1}) with significantly same maturity days on 25th June planting. On the 15th July planting, Terai 2 had the lowest maturity days (44 DAT) but lower yield (14.6 mt ha^{1}), while Cold Queen had the highest curd weight and yield (560.8 g and 35.1 mt ha^{-1}) which was at par with Chinese (546.7 g and 34.2 mt ha^{-1}) (Table 11). These indicated that these genotypes also require a higher temperature than the normal season of cauliflowers. For the 5th August planting, the genotypes Cold Queen produced the highest curd weight and yield (842.1 g and 52.6 mt ha^{-1}), followed by Taichun (718.8 g and 44.9 mt ha^{-1}) and Terai 1 (452 g and 28.3 mt ha^{-1}). These results clearly indicated that the different genotypes have different responses to temperature and rainfall, which have been indicated by many researchers in their earlier findings and recommendations.

During early and late winter, the temperature required for curd formation might not match the size and yield of the curd. As early planting, mid-season varieties take long days to maturity and formed small size curd and low yield as compared to winter season varieties. Due to unfavorable environmental conditions like extreme temperatures and droughts, cauliflower might develop different physiological disorders like buttoning, riceyness, fuzziness, and economic loss (Singh et al 2013). Similar results were observed (SQQC 1994) in our earlier recommended variety Sarlahi Deepali and other Indian varieties as Pusa Katki.

Among three different planting dates, the vegetative growth, maturity days, yield attributing characteristics as well as yield of all genotypes was recorded as lowest in June planting, and

it increased subsequently. This might be due to prevailing high temperatures during the entire growth period. As the temperature drops from June to August, the vegetative growth, maturity days, and yield of all genotypes gradually increase. This indicates that most of the genotypes favour cool seasons for proper growth and development. Similar findings were also reported by Yadav et al (2013) and Poudel et al (2018). The findings of this research were also supported by Pandey (2003). According to Swiader et al (1992) temperatures above 25°C affect curd formation and result in defective and poor-quality curds.

From our study, growth parameters, maturity days, and yield parameters of cauliflower genotypes differ significantly ($P<0.001$) from each other. Variations in plant growth, curd initiation, curd weight, and root and shoot ratio has been reported in tested genotypes. These variabilities might be due to genotypes governed by different genes, which are greatly influenced by environmental factors and management practices. Similar results have been reported by Santhosa et al (2014). Singh et al (2010) and Mehra and Singh (2013) reported similar variations among different genotypes of cauliflower. The variation in the gene can be utilized for the selection of lines for different planting times or they can be for in inter-varietal hybridization to obtain segregating populations.

While selecting early cauliflower genotypes, plant characteristics like growth traits 50% curd initiation, maturity, number of leaves, yield and yield attributing parameters as well as curd quality parameters play an important role (Bhattarai et al 2014).

CONCLUSION

The effect of genotypes on early season production of cauliflower showed significant differences in days to maturity and yield cauliflower. The differences in days to maturity and yield could be governed by different genes, which are greatly influenced by environmental factors and management practices. Based on the two years' results following conclusion can be made:

- The Chinese genotype gave higher yield and quality production with 51 days of maturity and was found promising for 25th June planting in Kathmandu valley and similar soil and environment conditions due to higher yield and quality production.
- The genotypes Cold queen and Chinese genotypes were found to be promising for the 15th July planting. Even though the Chinese genotype is more preferred due to its 49 days maturity period against 94days in Cold queen based on two-year results.
- The genotypes Cold Queen and Taichun produces higher yield for 5thAugust planting with maturity days of 79 and 67days. These genotypes were more promising than other mid-season genotypes Terai-1, Agheni, and Khumal Jyapu in Kathmandu and similar agroecological conditions.
- Before variety release and registration, coordinate variety trials and farmer field trials are required for further confirmation in different agroecological conditions.

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Authors' contributions

NG Pradhan involved in research layout, nursery, planting, growing, data recording, compiling and analysis, and manuscript writeup. A Srivastava, AK Shrestha and IP Gautam revised protocol, field inspection, and in writing up final manuscript.

Conflicts of Interest

The authors have no relevant financial or non-financial interests to disclose.

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