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Research Article

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Evaluation of French Bean (*Phaseolus Vulgaris* L.) Genotypes for Spring Season Planting in Mid Hills of Nepal

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Abstract

An experiment was conducted at National Horticulture Research Centre (NHRC), Khumaltar, Lalitpur, Nepal from March to July of 2019 and 2020 to identify suitable bean genotypes for spring season planting. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications having seven genotypes as treatments viz. Semi Light Long, Long Green Bean, Trishuli, Four Season, LB-37, Pahelo Gheusimi, and Khairo Gheusimi. Observations were recorded on morphological characters, yield, and yield contributing attributes. All genotypes under study showed significant differences among each other. Pahelo Gheusimi was found to be early maturing (81 days after sowing) whereas genotype Four Season had the longest harvesting duration (29 days). Similarly, pod length (20.52 cm) and pod weight (16.60 g) was recorded highest in Long Green Bean, while the highest pod diameter was recorded in Pahelo Gheusimi (12.59 mm). A significantly highest number of pods (92/plant) was observed in Four Season whereas the highest fresh pod yield (1030.3 g/plant) was observed in Long Green Bean which was at par with Four Season (997.1 g/plant). The calculated yield per hectare was 2.5 times higher in Long Green Bean (28.66 t/ha) as compared to the national average in 2020. Both rust incidence and Yellow Bean Mosaic Virus susceptibility were found less in Long Green Bean and Four Season. Based on the two-year observations, Long Green Bean and Four Season were found to be promising for spring season planting.

Keywords: Legumes, Flower, Pod, Yield

Introduction:

French bean (*Phaseolus vulgaris* L.) native of Central and South America is widely cultivated and one of the most important legume vegetables grown worldwide (Singh, 1999). The French bean genotype in Nepal's mid hills is highly diverse and it might be considered as a secondary center of genetic diversity (Pandey et al., 2011). The green pods of the French bean are used for fresh vegetables, the dried seeds are used as pulses, and the leaves are utilized as animal fodder. Its cultivation is also useful for restoring soil fertility, and it provides a low-cost protein source for the poor (Pandey et al., 2011). It is a tender, warm-season vegetable that cannot tolerate frost. A mean air temperature of 20 °C -25 °C is ideal for its growth and development. Extreme high temperature causes poor pod filling, while low temperature limits vegetative growth (ICAR, 2003). The total area, production, and productivity of pole-type French bean in Nepal was 4,714 ha, 51,794 t, and 10.99 t/ha respectively during the year 2020 (MoALD, 2020). Due to the lack of high-yielding improved varieties, a lack of package of cultivation practices and

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the susceptibility of available genotypes to disease and pests, Nepal's national average productivity of French bean is quite low as compared to neighboring nations (Dhakal et al., 2020).

Despite the significant genetic diversity of French bean in mid hills of Nepal, varietal evaluation and selection have received little attention. Only three French bean varieties namely; Trishuli, Long Green Bean, and Semi Light Long were recommended for commercial cultivation in mid hills of Nepal. Similarly, French bean cultivation in mid hills of Nepal is limited to the summer (June-March) planting but it can be successfully cultivated throughout the year. Four Season, also known as Chaumase Simi, is a popular genotype among farmers that is suitable for all-season production. However, it has some disadvantages such as small pod size, low yield, and short harvest duration. It has also been cultivated in farmer's fields for a long time but has yet to be registered to the National Seed Board (Dhakal et al., 2020). Farmers have very little varietal option for spring season planting therefore; the current research was conducted to identify suitable bean genotypes for spring season planting under mid hills of Nepal.

Materials and Methods:

An experiment was conducted at National Horticulture Research Centre, Khumaltar, Lalitpur, Nepal for the spring seasons (March-July) of 2019 and 2020. Khumaltar, Lalitpur is located in the hilly region of Nepal with a subtropical climate with a range of average temperature of 13.7 °C- 25.7 °C during the experimental period. The soil of the experiment site contains around 2.84% organic matter, 0.13% total nitrogen, 181.79 mg/kg available P2O5, 92.86 mg/kg exchangeable K2O, and 5.90 soil pH. The experiment was laid out in Randomized Block Design with seven treatments (Semi Light Long, Long Green Bean, Trishuli, Pahelo Gheusimi, Khairo Gheusimi, LB-37 and Four Season) and three replications. Out of seven genotypes Trishuli is a released variety while Semi Light Long and Long Green Bean are registered one likewise, Four Season also called as Chaumase Simi is a popular variety but it is neither released nor registered. The seeds of these varieties were collected from National Horticulture Research Centre, Khumaltar, Lalitpur. Similarly, the seeds of LB-37 were collected from Directorate of Agriculture Research, Gandaki Province, Lumle, Kaski as it is a promising line of that locality. Pahelo Gheusimi and Khairo Gheusimi are also promising genotypes of that Dolakha district and their seeds were collected from farmers' fields of Gaurishankar Rural Municipality of Dolakha district.

The size of the experimental plot was 7.2 m², the space between experimental plots and within replication was 0.5m each. A total of four rows were made at the spacing of 1.2m. The recommended doses of manure and fertilizers were applied at the rate of 15 t/h FYM and 80:120:60 NPK kg/ha. Half dose of nitrogen, full dose of potash, and phosphorus fertilizers was incorporated at sowing time and the remaining half dose of nitrogen fertilizer was top-dressed at 35 days after sowing. Seeds were sown on 1st March in an experimental plot accommodating 20 plants per plot (four rows with five plants per row) at a spacing of 120 cm x 30 cm. Staking, weeding, irrigation, and plant protection measures were applied as per recommendation.

Data recording and observation were taken from eight plants of middle rows. Observations were recorded on various parameters like days to 50% germination, days to 50% flowering, days to first harvest, harvest duration, plant height, pod length, pod diameter, single pod weight, number of pods per plant, yield per plant, and yield per hectare. Flower color, seed color, pod appearance, pod shape, and pod color were also recorded by visual observation. Maturity characters viz. days to 50% germination was recorded when 50% of plants emerges, days to 50% flowering was recorded when 50 % of plants had set flowers in each plot, and duration from seed sowing to that date was expressed in days after sowing (DAS), number of days to first harvesting was counted from days of sowing and expressed as DAS. Harvest duration was recorded from the date of the first pod harvest to the last harvest. Plant height was measured at the green pod maturity stage from the base of the plant to the highest. Similarly, pod weight, pod length, and pod diameter of 20 sample pods from each experimental plot were recorded by using digital weighing balance and Vernier caliper, respectively. Likewise, yield and yield attributing parameters like, the number of pods per plant and fresh pod yield per plant were recorded from each sample plant from each harvest, and the average number of pods and yield per plant was computed. The yield of net plot was calculated by adding the yield of each sample plant. The total pod yield per hectare was obtained by converting the yield of the net plot area into a hectare. Morphological characteristics were recorded based on visual observation as per the guideline of IBPGR (International Board for Plant Genetic

Resources) descriptors (IBPGR, 1982). Similarly, rust scoring (1-5) scale and virus scoring (1-5) was done at 110 DAS by a senior pathologist. The recorded data were compiled in Ms-Excel 2010 and analyzed by using Gen Stat software.

Results:

Days to 50% germination and 50% flowering

The results showed significant variations among different genotypes for days taken to 50% germination and 50% flowering (**Table 1**). The result of tested genotypes from the mean of two-year data showed the shortest days to germination (15 days after sowing) in Khairo Gheusimi which was at par with Pahelo Gheusimi (16). However, the highest days to 50% emergence was recorded in genotypes Trishuli (25). Similarly, days taken to 50% flowering differed significantly among tested genotypes in both the years and over mean years. Among different genotypes lowest days to 50% flowering was recorded in genotypes Pahelo Gheusimi (57) which significantly differed with remaining genotypes so, it can be considered as early flowering genotypes. Khairo Gheusimi (68) and Semi Light Long (67) are reported to be mid flowering genotypes while, the highest days to 50% flowering was reported in Trishuli (71) which was at par with Long Green Bean (70), Four Season (71) and LB-37 (71). Despite its earliest germination, Khairo Gheusimi showed mid-flowering; this might be attributed to GXE interaction.

Table 1. Mean performance of genotypes on days to germination and days to 50% flowering at Khumaltar, Lalitpur during 2019-2020

Genotypes	Days to 50% Germination			Days to 50% Flowering		
	2019	2020	Mean	2019	2020	Mean
Semi Light Long	23^{de}	21^{b}	22^{c}	67^{b}	67^{b}	67^{b}
Long Green Bean	19^{bc}	19^{b}	19^{b}	71^{c}	70^{c}	70^{c}
Trishuli	25^{e}	24^{c}	25^{d}	72^{c}	71^{c}	71^{c}
Four Season	21^{cd}	20^{b}	20^{c}	71^{c}	71^{c}	71^{c}
LB-37	18^{bc}	19^{b}	18^{b}	71^{c}	70^{c}	71^{c}
Khairo Gheusimi	15^{a}	15^{a}	15^{a}	68^{b}	67^{b}	68^{b}
Pahelo Gheusimi	16^{ab}	16^{a}	16^{a}	58^{a}	57^{a}	57^{a}
Mean	20	19	19	68	68	68
LSD (0.01)	2.471	1.948	1.434	2.511	2.132	1.432
SEM	1.134^{***}	0.894^{***}	0.705^{***}	1.152^{***}	0.979^{***}	0.704^{***}
CV%	7.1	5.8	6.3	2.1	1.8	1.8

*Note: Means in the column followed by the same letter in each treatment do not differ significantly at (p= 0.05) by DMRT. SEM= Standard error of mean, LSD = Least significant difference, CV = Coefficient of variance and *** highly significant at P <0.001*

Number of days to first harvest and the harvest duration

Days to first harvest and harvest duration of different genotypes differ significantly from each other (**Table 2**). From the mean of two years' data, Pahelo Gheusimi was found to be the earliest for harvesting (81) followed by Khairo Gheusimi (85). The genotypes Semi Light long and Four Season are statistically at par with first harvesting days of 89 and 90 respectively. The result revealed that genotypes Long Green Bean, Trishuli and LB-37 are late maturing and are statistically at par with the same days to first harvesting (92). Harvest duration varies from 24 days to 29 days with an overall mean of 24 days. The highest harvest duration was recorded in Four Season (29 days) which was at par with Trishuli (28 days). Genotypes Semi Light Long, Long Green Bean, Pahelo Gheusimi, and Khairo Gheusimi are statistically at par for harvest duration. However, the shortest harvest duration was found in genotypes LB-37 (20).

Plant Height

The plant height differed significantly among the genotypes (Table 3) for both years. Plant height ranged from 2. 69 m to 3.40 m in 1st year while, in 2nd year the tallest and the shortest plants were of 2.72 m to 3.41 m height respectively. The mean data showed highly

Table 2. Mean performance of genotypes on days to first harvesting and harvest duration at Khumaltar, Lalitpur during 2019-2020

Genotypes	Days to first harvesting			Harvest duration		
	2019	2020	Mean	2019	2020	Mean
Semi Light Long	90^{c}	89^{c}	89^{c}	24^{ab}	25^{bc}	25^{b}
Long Green Bean	92^{c}	91^{d}	92^{d}	24^{ab}	25^{bc}	24^{b}
Trishuli	92^{c}	92^{d}	92^{d}	28^{b}	28^{cd}	28^{c}
Four Season	91^{c}	90^{cd}	90^{c}	28^{b}	29^{d}	29^{c}
LB-37	92^{c}	91^{d}	92^{d}	20^{a}	20^{a}	20^{a}
Khairo Gheusimi	86^{b}	85^{b}	85^{b}	24^{ab}	24^{ab}	24^{b}
Pahelo Gheusimi	81^{a}	81^{a}	81^{a}	24^{ab}	23^{ab}	24^{b}
Mean	89	88	89	25	25	24
LSD (0.001)	2.551	1.973	1.470	5.342	3.972	2.713
SEM	1.171***	0.906***	0.723***	2.452*	1.823**	1.333***
CV%	1.6	1.3	1.4	12.1	9	9.3

*Note: Means in the column followed by the same letter in each treatment do not differ significantly at (p= 0.05) by DMRT. SEM= Standard error of mean, LSD = Least significant difference, CV = Coefficient of variance and * significant at P=0.05, ** highly significant at P= 0.01, *** highly significant at P <0.001*

significant results on plant height with the highest plant height in Semi Light Long (3.40 m) followed by Four Season (3.13 m) while the lowest plant height was recorded in LB-37 (2.71 m) which was at par with Khairo Ghuesimi (2.76 m). Dhakal et al. (2020) also reported the highest plant height in Semi Light Long in their findings. A similar variation on plant height of bean varieties was also reported by Yadav et al. 2015; Meena et al. (2018)

Table 3. Mean performance of genotypes on plant height at Khumaltar, Lalitpur during 2019-2020

Genotypes	Plant height (m)		
	2019	2020	Mean
Semi Light Long	3.40^{c}	3.41^{c}	3.40^{d}
Long Green Bean	2.76^{ab}	2.86^{ab}	2.81^{ab}
Trishuli	2.87^{ab}	2.77^{a}	2.82^{ab}
Four Season	3.05^{b}	3.22^{bc}	3.13^{c}
LB-37	2.74^{ab}	2.72^{a}	2.73^{a}
Khairo Gheusimi	2.69^{a}	2.84^{a}	2.76^{a}
Pahelo Gheusimi	2.93^{ab}	3.00^{abc}	3.00^{bc}
Mean	2.92	2.98	2.95
LSD (0.001)	0.294	0.338	0.195
SEM	0.135**	0.155**	0.095***
CV%	5.7	6.4	5.6

*Note: Means in the column followed by the same letter in each treatment do not differ significantly at (p= 0.05) by DMRT. SEM= Standard error of mean, LSD = Least significant difference, CV = Coefficient of variance and ** highly significant at P= 0.01, *** highly significant at P <0.001*

Pod length and pod diameter

The length and diameter of a pod of different bean genotypes were statistically highly significant in both of the study years (**Table 4**). During both study years, the highest pod length was recorded in Long Green Bean, whereas the lowest pod length was found in Pahelo Gheusimi. The mean value for pod length was also found to be highly significant with the highest pod length in Long Green Bean (20.63 cm) followed by Khairo Gheusimi (17.94 cm), while the lowest pod length was recorded in Pahelo Gheusimi (15.76 cm). Pod diameter of different genotypes during 1st year ranged from 9.28 mm in Four Season to 12.65 mm in Pahelo Gheusimi. Pod diameter during the 2nd year was also similar as in the 1st year (Table 4). The result of both years showed the highest pod diameter in genotype Pahelo Gheusimi (12.59 mm) which was at par with Long Green Bean (12.24) while the lowest pod diameter was found in Four Season (9.22 mm) followed by Semi Light Long (10.54 mm) which was at par with Trishuli (10.53 mm).

Table 4. Mean performance of genotypes on pod length and pod diameter at Khumaltar, Lalitpur during 2019-2020

Genotypes	Pod length (cm)			Pod diameter (mm)		
	2019	2020	Mean	2019	2020	Mean
Semi Light Long	17.57^{b}	17.88^{cd}	17.73^{de}	10.63^{b}	10.45^{b}	10.54^{b}
Long Green Bean	20.41^{c}	20.63^{e}	20.52^{f}	12.24^{cd}	12.24^{d}	12.24^{d}
Trishuli	16.57^{ab}	16.33^{ab}	16.45^{b}	10.68^{b}	10.38^{b}	10.53^{b}
Four Season	16.60^{ab}	17.11b^{cd}	16.85^{bc}	9.28^{a}	9.16^{a}	9.22^{a}
LB-37	17.28^{b}	17.05^{bc}	17.17^{cd}	11.14b^{c}	11.33^{c}	11.24^{c}
Khairo Gheusimi	17.91^{b}	17.97^{d}	17.94^{e}	11.01^{b}	11.04b^{c}	11.02^{bc}
Pahelo Gheusimi	15.61^{a}	15.89^{a}	15.76^{a}	12.65^{d}	12.52^{d}	12.59^{d}
Mean	17.42	17.55	17.48	11.09	11.09	11.05
LSD (0.001)	1.349	0.849	0.666	1.127	0.743	0.550
SEM	0.619***	0.390***	0.327***	0.517***	0.743***	0.270***
CV%	4.4	2.7	3.2	4.4	3.8	4.2

*Note: Means in the column followed by the same letter in each treatment do not differ significantly at (p= 0.05) by DMRT. SEM= Standard error of mean, LSD = Least significant difference, CV = Coefficient of variance and *** highly significant at P <0.001*

Single pod weight

The mean performance of different genotypes on single pod weight was presented in table 5. The result revealed that there exist significant differences among genotypes for single pod weight. During both years of study highest pod weight was recorded in Long Green Bean and the lowest pod weight was recorded in Four Season. The mean of two years showed the highest pod weight in Long Green Bean (16.60 g) followed by Khairo Gheusimi (14.14 g). However, the lowest pod weight was recorded in Four season (11.08 g).

Number of pods per plant

From both study years, highly significant variation was recorded among genotypes for the number of pods per plant (**Table 5**). During both years the highest number of pods per plant was recorded on Four Season (91 and 93) and lowest in Pahelo Gheusimi (43 and 44). Similarly, the two-year mean data showed the highest number of pods in Four Season (92) followed by Trishuli (65). The least number of pods per plant was recorded in Pahelo Gheusimi (44) and LB-37 (44) which are at par with Semi Light Long (47) and Khairo Gheusimi (48).

Morphological Characteristics

Morphological characteristics on flower, pod and the seed of different genotypes were presented in table 6. Among seven genotypes Semi Light Long and Four Season showed the same flower color i.e. purplish-pink while Long Green Bean showed Yellowish white flower color and the remaining all genotypes showed cream white colored flower. Pod color of Semi Light Long, Long Green Bean, and LB-37 were Light Green whereas Trishuli, Four Season, Pahelo Gheusimi, and Khairo Gheusimi had green color pod. Similarly, the shape of pods of all genotypes was slightly curved except Trishuli.

Table 5. Mean performance of genotypes on single pod weight and number of pod per plant at Khumaltar, Lalitpur during 2019-2020

Genotypes	Single pod weight (g)			Number of pods per plant		
	2019	2020	Mean	2019	2020	Mean
Semi Light Long	11.82^{a}	11.61^{a}	11.72^{b}	46^{a}	48^{a}	47^{ab}
Long Green Bean	16.94^{c}	16.26^{d}	16.60^{e}	61^{b}	61^{b}	61^{c}
Trishuli	11.57^{a}	11.22^{a}	11.40^{ab}	64^{b}	66^{b}	65^{d}
Four Season	11.13^{a}	11.03^{a}	11.08^{a}	91^{c}	93^{c}	92^{e}
LB-37	11.94^{a}	11.61a	11.78^{b}	44^{a}	45^{a}	44^{a}
Khairo Gheusimi	14.29^{b}	13.99^{d}	14.14^{d}	48^{a}	48^{a}	48^{ab}
Pahelo Gheusimi	13.28^{c}	13.27^{c}	13.28^{c}	43^{a}	44^{a}	44^{a}
Mean	13.00	12.71	12.87	57	58	57
LSD (0.001)	1.078	0.602	0.559	4.997	4.449	3.406
SEM	0.495***	0.276***	0.275***	2.293***	2.042***	1.674***
CV%	4.7	2.7	3.7	4.9	4.3	5.1

*Note: Means in the column followed by the same letter in each treatment do not differ significantly at (p= 0.05) by DMRT. SEM= Standard error of mean, LSD = Least significant difference, CV = Coefficient of variance and *** highly significant at P <0.001*

Among seven genotypes Four Season has an attractive pod appearance while Semi Light Long and Long Green Beans have a smooth appearance whereas the remaining all genotypes have a medium pod appearance. Similarly, the seed color of different genotypes also varied, Semi Light Long and Four Season had the same color seed i.e. black while Long Green Bean and Pahelo Gheusimi have white and yellowish seed color respectively, however, remaining all genotypes have Brown colored seed. Dhakal et al. (2020); Kalauni et al. (2019) and Pandey et al. (2011) also reported similar variation in morphological characters of different genotypes of French bean.

Table 6. Visual observation on flower, pod, and seed characteristics of different bean genotypes at Khumaltar, Lalitpur during 2019-2020

Genotypes	Flower color	Pod Color	Pod Shape	Pod Appearance	Seed Color
Semi Light Long	Purplish pink	Light green	Slightly curved	Smooth	Black
Long Green Bean	Yellowish white	Light green	Slightly curved	Smooth	White
Trishuli	Cream White	Green	Curved	Medium	Brown
Four Season	Purplish pink	Green	Slightly curved	Attractive	Black
LB-37	Cream white	Light green	Slightly curved	Medium	Brown
Khairo Gheusimi	Cream white	Green	Slightly curved	Medium	Brown
Pahelo Gheusimi	Cream white	Green	Slightly curved	Medium	Yellowish

Yield per plant and yield per hectare

There exist significant differences among beans genotypes for yield per plant and yield per hectare (**Table 7**). Yield per plant of bean genotypes ranged from 517.9 g to 1031.7 g with a mean value of 720.7 g. The combined analysis over the years showed that the fresh pod yield/plant was the maximum in Long Green Bean (1031.7 g/plant) followed by Four Season (997.1 g/plant) and the minimum was in LB-37 (517.9 g/plant) followed by Pahelo Gheusimi (575.5 g/plant). The two years mean data showed that the yield per hectare was highly significant with the highest yield in Long Green Bean (28.66 t/ha) followed by Four Season (27.70 t/ha) and the least was in LB-37 (14.39 t/ha) followed by Semi Light Long (15.12 t/ha).

Table 7. Mean performance of genotypes yield per plant and yield per hectare at Khumaltar, Lalitpur during 2019-2020

Genotypes	Yield per plant (g)			Yield per hectare (t)		
	2019	2020	Mean	2019	2020	Mean
Semi Light Long	543.5^{ab}	545.0^{a}	544.3^{ab}	15.10^{ab}	15.14	15.12^{ab}
Long Green Bean	1033.0^{e}	1030.3^{c}	1031.7^{e}	28.69^{e}	28.62	28.66^{e}
Trishuli	752.0^{d}	686.2^{b}	719.1^{d}	20.89^{d}	29.06	19.97^{d}
Four Season	993.3^{e}	1001.0^{c}	997.1^{e}	27.59^{e}	27.81	27.70^{e}
LB-37	517.3^{a}	518.6^{a}	517.9^{a}	14.37^{a}	14.40	14.39^{a}
Khairo Gheusimi	639.9^{c}	678.1^{b}	659.0^{c}	17.77^{c}	18.84	18.31^{c}
Pahelo Gheusimi	576.6^{b}	574.8^{a}	575.7^{b}	16.02^{b}	15.97	15.99^{c}
Mean	722.2	719.1	720.7	20.06	19.98	20.02
LSD	53.560	67.680	39.64	1.488	1.880	1.101
SEM	24.58***	31.06***	19.48***	0.683***	0.863***	0.541***
CV%	4.2	5.3	4.7	4.2	5.3	4.7

*Note: Means in the column followed by the same letter in each treatment do not differ significantly at (p= 0.05) by DMRT. SEM= Standard error of mean, LSD = Least significant difference, CV = Coefficient of variance and *** highly significant at P <0.001*

Disease intensity

Rust and Virus scoring

From two years of experiment, a significant difference among the varieties was obtained in the case of rust disease incidence (**Table 8**). During both years Rust incidence was observed more in Semi Light Long (3.00) followed by Trishuli (2.33) whereas the least intensity was observed in Long Green Bean (1.16). However, Dhakal et al. (2020) reported high rust intensity in Long Green Bean and less rust intensity in Four Season; such variation might be due to different growing conditions. Similarly, two years' results against scoring of Yellow Bean Mosaic Virus |(YBMV) showed significant variation among tested genotypes (Table 7). Among seven genotypes, Pahelo Gheusimi was found to be highly susceptible for YBMV followed by Khairo Gheusimi while Trishuli showed less incidence of YBMV which was at par with Semi Light Long, Long Green Bean, and Four Season.

Table 8. Mean performance of genotypes on days rust and virus scoring at Khumaltar, Lalitpur during 2019-2020

Genotypes	Rust scoring (1-5)			Virus scoring (1-5)		
	2019	2020	Mean	2019	2020	Mean
Semi Light Long	2.66^{b}	3.33^{b}	3.00^{c}	0.00^{a}	0.67^{a}	0.33^{a}
Long Green Bean	1.33^{a}	1.00^{a}	1.16^{a}	0.33^{ab}	0.67^{a}	0.50^{a}
Trishuli	2.00^{ab}	2.67^{b}	2.33^{bc}	0.00^{a}	0.33^{a}	0.16^{a}
Four Season	1.33^{a}	2.00^{ab}	1.66^{ab}	0.00^{a}	0.33^{a}	0.17^{a}
LB-37	2.00^{ab}	2.33^{ab}	2.16^{b}	1.00^{bc}	1.33^{ab}	1.16^{b}
Khairo Gheusimi	2.00^{ab}	2.00^{ab}	2.00^{b}	1.66^{c}	2.00^{b}	1.83^{c}
Pahelo Gheusimi	1.66^{a}	2.00^{ab}	1.83^{ab}	3.00^{d}	3.33^{c}	3.16^{d}
Mean	1.87	2.19	2.02	0.85	1.24	1.04
F-test	**	*	***	***	***	***
LSD (0.05)	0.792	1.335	0.732	0.760	0.938	0.571
SEM	0.363**	0.613*	0.360***	0.348***	0.430***	0.280***
CV%	24	34.3	30.8	49.8	42.6	46.4

*Note: Means in the column followed by the same letter in each treatment do not differ significantly at (p= 0.05) by DMRT. SEM= Standard error of mean, LSD = Least significant difference, CV = Coefficient of variance and * significant at P=0.05, ** highly significant at P= 0.01, *** highly significant at P <0.001*

Discussion:

Days to 50% germination was strongly influenced by various factors such as; soil temperature, soil moisture, seed quality, genotypes, etc. The differences in days taken to germination could be due to the genetic variability within the genotype itself or may be due to the environmental effects. Or it could be due to the storage of seeds in different conditions with different moisture content. A similar variation for days to 50% germination was reported earlier by Neupane et al., (2008) and Meena et al., (2018). Time taken to first flowering is the indication of earliness and it was highly influenced by genotypes, day length, and temperature. Early flowering genotypes have a special importance during spring season because late-flowering genotypes do not complete the life cycle due to early onset of Monsoon. The variation in harvest duration could be due to genotypes, environmental conditions, or interaction of both. The findings of this research showed the longest harvest duration (29 days) in Four Season which contradicts the findings of Dhakal et al., (2020) who reported the longest harvest duration in Semi Light Long such variation might be due to the difference in the growing season.

The differences in pod length and pod diameter among the genotypes might be due to differences in their genetic makeup. Dhakal et al., (2020); Pandey et al., (2011) also reported similar variations in pod length and pod diameter of different genotypes. Highly significant variation among varieties of bean for single pod weight was reported earlier by Kalauni et al (2019) and Muthal et al., (2018). Dhakal et al., (2020) also reported the highest pod weight in Long Green Bean during summer season planting. The findings of this research are also supported by Yadav et al (2015); Das et al (2014). The number of pods per plant is an essential yield determining factor that has a direct impact on the overall productivity of the French bean crop (Sharma et al 2013). The higher number of pods per plant is due to higher number of flower clusters per plant and the higher percentage of pods set per cluster. Dhakal et al. (2020) reported maximum pod yield per plant in Semi Light Long. Yield is a complex character and it is governed by polygenes. The variation in the yielding ability of varieties is also attributed to genetic makeup, prevailing temperature, and combinations of both. Higher productivity in Long Green Bean varieties may be due to the ability of that variety to have stronger sinks in terms of the number of pods per plant or pod weight. According to Muthal et al. (2018), pod yield per hectare exhibited a significant positive correlation with plant height, single pod weight, pod length, pod width, number of pods per plant, and yield per plant. A similar positive correlation was also obtained from the present research. Likewise, Dhakal et al., (2020) had also reported this type of genetic variation in the yield of different genotypes.

Conclusion:

The current study showed the heterogeneity among different bean genotypes in terms of morphological, yield, and yield contributing features. Both Long Green Bean and Four Season were found promising for spring season planting. However, Four Season variety was already popular among farmers but due to several limitations, its cultivation is declining. Therefore, Long Green Bean might be promising as well as it can be considered as alternative genotypes of Four Season for spring season planting in the mid-hills of Nepal. However, further verification with multi-locations and farmer's field trials is equally important before a recommendation.

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Declaration of conflict of interest and ethical approval:

S. Subedi, I.P Gautam, and N.G. Pradhan was involved in designing and implementing the experiment. S. Subedi, D. Ghimire, and S. Thapa were involved in collecting the data, analyzing the raw data, and participated in writing the manuscript. All the authors have read the manuscript before submitting it to the journal Nepalese Horticulture and declare that there is no type of competing interest regarding the current manuscript. The current article does not include any human participants or animals by the authors and has taken prior approval if applicable.

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