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Research Article

Evaluation of different Pole French Bean genotypes in Lamjung, Nepal

Anubhav Tripathi*, Mamata Pandey

Institute of Agriculture and Animal Science, Lamjung Campus, Tribhuvan University, 33600, Nepal.

***Correspondence**
Anubhav Tripathi
tripathianuvav@gmail.com

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Background: Yield, being a quantitative trait, is influenced by multiple yield-related traits and environmental factors. The objective of this research is to have an effective comparison of the different released, registered, popular, and local bean varieties at different growth stages, as well as to determine their yield potential for commercial production in Sundarbazar, Lamjung, and similar mid-hill conditions.

Methods: Consequently, twelve varieties of pole-type French bean, viz., Trishuli, Chaumase, Semi Light Long, Green Long Bean, LB-31, LB-37, Madhav, Chinese Long, Rato Makai Simi, Khairo Makai Simi, Kalo Makai Simi, and Kalo Simi, were evaluated in a randomized complete block design with three replications at the Institute of Agriculture and Animal Science (IAAS), Sundarbazar, Lamjung, Nepal.

Results: The varieties under study showed significant differences in morphological, phenological, and yield parameters. Semi Light Long had the highest pod number per plant (44.76), yield per plant (289.13 g), and yield per plot (5726.83 g), at par with Chaumase Simi for pod number per plant (42.03) and yield per plant (244.48 g). The highest pod weight was observed in LB-31 (6.75 g) at par with Semi Light Long (6.38 g), Green Long Bean (6.33 g), Chinese Long (5.96 g), Madhav (5.94 g), and Chaumase (5.76 g). Kalo Simi had the earliest flowering (41 DAS), the earliest harvest (67 DAS), and the greatest harvest duration (16 days). Green long bean had the highest plant height (187.64 cm), at par with Semi Light Long (178.23 cm) and LB-31 (174.31 cm), and the highest pod length (13.98 cm) at par with LB-31 (13.82 cm).

Conclusion: Based on the results obtained, Semi Light Long would be the best variety to recommend for commercial cultivation in Sundarbazar, Lamjung, and other similar mid-hill environments.

Keywords: *commercial, comparison, local varieties, vegetable bean, yield*

Introduction

French bean (*Phaseolus vulgaris* L. 2n = 2x = 22), a native leguminous crop originating from Central America and the Peruvian Andes in South America, has been a staple in temperate, subtropical, and tropical regions globally (Pandey et al. 2011; Neupane et al. 2008). The cultivation of French beans expanded from Europe to the United States, the West Indies, India, and various other parts of the world (State et al., 1991). Annually, about 25 million metric tons of beans are cultivated worldwide, with China as the leading producer of green beans (19 million metric tons) and India leading in dry beans (62 million metric tons) (FAOSTAT, 2020). In Nepal, French beans occupy 4070 hectares of land, yielding 42,289 metric tons with a productivity of 10.39 metric tons per hectare (MoALD, 2020/2021).

French beans are warm-season vegetables sensitive to frost, requiring an optimal mean temperature of 20–25°C for growth and productivity (Dhakal et al., 2020). Based on growth habits, pole (indeterminate) and bush

(determinate) type beans are found (Chaudhary et al., 2008; Raggi et al., 2019). Pole beans are widely cultivated across Nepal, ranging from Terai at 300 masl to high hills at 2500 masl in different seasons (Pandey et al. 2011; Neupane et al. 2008). Beans, often referred to as "poor man's meat" in Nepalese villages, serve as a low-cost, high-quality protein source. Fresh pods (1.7% protein content) are used as vegetables, while dried seeds (21.1% protein content) are used as pulses (Alice et al., 2019; Luitel et al., 2021). Rich in vitamins A, B, and C, folates, and minerals (iron, calcium, potassium, and selenium), beans promote the growth of healthy gut bacteria, exhibit carminative properties, and reduce the risk of chronic and degenerative diseases, including cancer, obesity, diabetes, and cardiovascular diseases (Reynoso-Camacho et al., 2006; Alice et al., 2019; Pandey et al., 2011).

Despite Nepal contributing only about 0.4% to the global area and production capacity for pulse cultivation, it remains a significant center of diversity for French beans (Aryal et al., 2020). Various bean landraces with diverse morphologies are cultivated in Nepal (Neupane and Vaidya, 2002). However, the research gap in Nepal is evident, with few released varieties of pole beans, despite the hills being considered secondary centers of diversity (Pandey et al., 2011). Notably, the popular genotype Four Season, or Chaumase Simi, suitable for year-round production, is characterized by small pod size, low yield, and a short harvest duration, highlighting the need for improved varieties (Dhakal et al., 2020). Thus, understanding agronomic characteristics of different genotypes is crucial for identifying suitable varieties that meet the needs of marginalized farmers (Sheikh et al., 2017). Despite the challenges faced in French bean cultivation in Nepal—such as, lack of high-yielding varieties, limited knowledge of cultivation practices, and susceptibility to diseases and pests (Bhattarai et al., 1997)—the importance of the crop cannot be overstated. Compared to its neighbors, Nepal's national productivity of French beans is relatively low (Dhakal et al., 2020). Furthermore, the productivity of pole beans has remained stagnant, despite the potential of a few newly released and registered varieties (Thapa et al., 2022).

Given that, yield is a complex quantitative trait influenced by multiple yield-related traits (Alemu et al., 2017), this research aims to effectively compare different germplasms of released, registered, popular varieties, and local landraces at various growth stages in the mid-hill conditions of Nepal, specifically Lamjung. This comparison contributes valuable insights for recommending the best varieties for commercial, semi-commercial, and subsistence bean growers in the region. Furthermore, the research served as a learning platform for farmers to gain scientific knowledge in the production package of practices.

Materials and Methods

Research site

The field investigation was conducted at the Institute of Agriculture and Animal Science (IAAS), Sundarbazar, Lamjung, located at coordinates 20.2765°N, 84.3542°E, and at an elevation of 857 m above sea level. This research was carried out in the summer–rainy season, specifically covering the period from March to June, in the significant year of 2023.

Experimental design and treatments

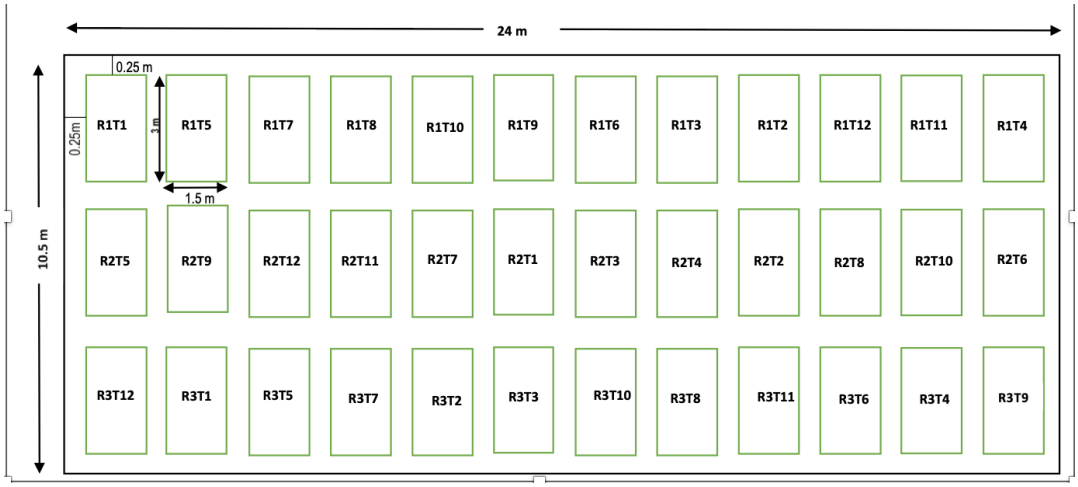

Figure 1. Experimental layout in field condition

The experiment was conducted in a randomized control block design (RCBD) with twelve varieties of pole French beans and three replications as shown in Figure 1. Therefore, thirty-six raised plots were present in the entire field of

area 252 m^2 (24×10.5 m^2) with a 0.5 m gap between the replications and within the replications. A plot of 4.5 m^2 dimension (3 m×1.5 m) was designed. Each plot had four rows, 75 cm apart, with five plants/row at a distance of 30 cm. Five sample plants were tagged for each experimental plot. The list of pole bean genotypes used in the experiment and their collection sites is shown in Table 1.

Table 1. List of pole French bean genotypes and collection site

Treatment Number (T)	Variety	Collection site
1.	Trishuli	NARC, Khumaltar
2.	Chaumase (Four season)	NARC, Khumaltar
3.	Semi Light Long	NARC, Khumaltar
4.	Green Long Bean	NARC, Khumaltar
5.	LB-31	Lumle Regional Agricultural Research Center
6.	LB-37	Lumle Regional Agricultural Research Center
7.	Madhav	Lumle Regional Agricultural Research Center
8.	Chinese Long	Lumle Regional Agricultural Research Center
9.	Rato Makai Simi	Ghanpokhara Seed Bank, Lamjung
10.	Khairo Makai Simi	Ghanpokhara Seed Bank, Lamjung
11.	Kalo Makai Simi	Ghanpokhara Seed Bank, Lamjung
12.	Kalo Simi	Farmer´s field, Humla

Cultural practices

The field was tilled using a tractor-drawn cultivator on March 9, 2023. The plots were then raised. Following the national recommendation of 15t/ha FYM and 80:120:60 kg NPK/ha, 6.75 kg of FYM, 117.2 g DAP, and 45 g MOP were applied to each plot after tillage and then mixed thoroughly. Seed sowing was performed later in the evening with two seeds/hill. Thinning out and gap filling were performed 15 days after sowing (DAS). G-Sunami (Chlorpyrifos 50% + Cypermethrin 5% EC) at 2 g/L water was applied to the field at 19 DAS because of the infestation of white-spotted leaf beetles and aphids. 32.4 g of urea was later topdressed at 35 DAS, and hoeing was performed. At the same time, staking with a bamboo stick of about two meters in length was performed on each plant. Periodic irrigation and hand weeding were performed whenever necessary. The lower leaves, infested with rust, were manually trimmed at regular intervals.

Data collection and analysis

The time for 50% germination was recorded, denoting the period at which 50% of seedlings emerged from the ground level as days after sowing (DAS). Similarly, the emergence of vines in 50% of the plants marked the number of days to 50% vining as DAS. Additionally, the onset of flowering in half of the plants within each experimental plot led to the documentation of days to 50% flowering (DAS). The initiation of the first flowering instance within a plot was observed and documented as days to first flowering (DAS). Furthermore, the interval from sowing to the first harvesting event was noted for the sampled plants, reflecting the number of days to first harvesting (DAS). The overall duration between the initial and final pod harvest dates was the harvest duration. The plant height (cm) was measured from the base to the highest point at the tender pod stage. Pod characteristics, such as length (cm), diameter (mm), and weight (g), were quantified using a scale, digital Vernier caliper, and digital weighing balance, respectively from 20 sample pods taken from five sample plants in different harvests. Similarly, yield and yield-attributing factors: the number of pods per plant and pod yield per plant (g) were noted from each sample plant at each harvest, and the average number of pods and yield per plant was calculated. Furthermore, the cumulative yield of 20 plants within a specific plot was the net plot yield (g). Morphological characteristics were recorded based on visual observation as per the guideline of IBPGR (International Board for Plant Genetic Resources) descriptors (IBPGR, 1982). Data entry was done into MS-Excel Version 16.74. The data were analyzed statistically by analysis of variance and standard errors using R version 1.4.1106.

Results

Days to 50% germination

The significant difference was seen among the varieties for days to 50% germination in Table 2. Earliest germination in 50% of the plant population was found in Trishuli (7.33) which was at par with Green Long Bean (7.66), Chaumase (8.33), Semi Light Long (8.33), LB-31 (8), LB-37 (8.66), Madhav (8.66) and Chinese Long (8.33). The highest days to

50% germination were found in Kalo Makai Simi (13.66). Kalo Simi (11.66) followed Kalo Makai Simi which was statistically at par with Khairo Makai Simi (10.66) and Rato Makai Simi (9.66).

Days to 50% vining

Days to 50% vining varied among the varieties of French bean, contrasting with the findings of Chalise et al. (2017) who found it to be non-significant. Among these twelve evaluated varieties, Kalo Makai simi took the longest days for the 50% vining (43 DAS), whereas the earliest 50% vining was seen in LB-31 (32 DAS), Semi light long and Kalo simi (31.67 DAS) which is significantly at par with Trishuli, Chaumase, Green Long Bean, Madhav and Chinese Long as shown in Table 2.

Days to 50% flowering

Days to 50% flowering varied significantly among the varieties of French bean. The earliest flowering among 50% of the plant population was obtained in Kalo Simi (49 DAS). Kalo Makai Simi took the highest days for 50% flowering (62 DAS) which was found to be statistically at par with Trishuli (59.33 DAS) as shown in Table 2.

Table 2. Days to 50% germination, Days to 50% vining and Days to 50% flowering of different genotypes of pole French bean tested at Sundarbazar, Lamjung

Treatment	Days to 50% Germination	Days to 50% Vining	Days to 50% Flowering
Trishuli	7.33^{e}	32.67^{de}	59.33^{ab}
Chaumase	8.33^{de}	32.67^{de}	55.33^{cd}
Semi Light Long	8.33^{de}	31.67^{e}	54.66^{cd}
Green Long Bean	7.66^{e}	32.67^{de}	54.66^{cd}
LB-31	8^{e}	32^{e}	56.33^{cd}
LB-37	8.66^{de}	34.67^{cd}	56^{cd}
Madhav	$8..66^{de}$	32.67^{de}	54.66^{cd}
Chinese long	8.33^{de}	32.33^{de}	56.33^{cd}
Rato Makai Simi	9.66^{cd}	37^{bc}	57^{bc}
Khairo Makai Simi	10.66^{bc}	38.33^{b}	54^{d}
Kalo Makai Simi	13.66^{a}	43^{a}	62^{a}
Kalo Simi	11.66^{b}	31.67^{e}	49^{e}
LSD (0.05)	1.62	2.58	2.81
Standard Error of Mean (SE_m)	0.55	0.88	0.96
F- Probability	***	***	***
CV (%)	10.35	4.44	2.98
Grand Mean	9.25	34.28	55.77

*Note: LSD = Least significant difference, CV = Coefficient of variance and *** signifies significant at P<0.001 level.*

Plant height

Plant height at the green pod maturity stage varied significantly among the varieties from 153.9-187.64 cm as shown in Table 3. The highest plant height was seen for Green Long Bean (187.64) which is at par with Semi Light Long (178.23) and LB-31 (174.31). The smallest plant height was recorded for Rato Makai Simi (131.46).

Table 3. Plant height at green pod maturity stage of 1st harvest of different genotypes of pole French bean tested in Sundarbazar, Lamjung

Treatment	Plant height at green pod maturity stage (cm)
Trishuli	160.65^{c}
Chaumase	163.33^{bc}
Semi Light Long	178.23^{a}
Green Long Bean	187.64^{a}
LB-31	174.31^{ab}
LB-37	155.37^{c}
Madhav	153.9^{c}
Chinese long	154.3^{c}
Rato Makai Simi	131.46^{d}

Khairo Makai Simi	159.6[c]
Kalo Makai Simi	159.43[c]
Kalo Simi	163.13[bc]
LSD (0.05)	13.42
Standard Error of Mean (SE_m)	4.57
F- Probability	***
CV (%)	4.90
Grand Mean	161.81

*Note: LSD = Least significant difference, CV = Coefficient of variance and *** signifies significant at P<0.001 level.*

Days to first flowering

Days to first flowering varied significantly among the varieties from 41-53 days as shown in Table 4. Earliest flowering was seen in Kalo Simi (41) while flowering was observed in Kalo Makai Simi (53) which was statistically at par with Chinese Long (50.66), LB-37 (50.33) and Trishuli (49.66).

Days to first harvest

Days to first harvest were seen moderately significant among the varieties ranging from 63-75 days as shown in Table 4. Earliest harvest was taken for Kalo Simi (63.33) which was statistically at par with Semi Light Long (65.66), Chinese Long (66.66) and LB-31 (67.33). Kalo Makai Simi had its 1st harvest at last (75.33).

Table 4. Days to first flowering and Days to first harvest of different genotypes of pole French bean tested in Sundarbazar, Lamjung

Treatment	Days to first Flowering	Days to first harvest
Trishuli	49.66[abc]	70.33[b]
Chaumase	49.33[bcd]	68[bc]
Semi Light Long	47.33[bcd]	65.66[cd]
Green Long Bean	46.66[cd]	70[b]
LB-31	46.33[cd]	67.33[bcd]
LB-37	50.33[ab]	69.33[bc]
Madhav	48[bcd]	68.33[bc]
Chinese long	50.66[ab]	66.66[bcd]
Rato Makai Simi	46[d]	68.33[bc]
Khairo Makai Simi	47.33[bcd]	69.66[bc]
Kalo Makai Simi	53[a]	75.33[a]
Kalo Simi	41[e]	63.33[d]
LSD (0.05)	3.35	4.12
Standard Error of Mean (SE_m)	1.14	1.41
F- Probability	***	**
CV (%)	4.13	3.55
Grand Mean	47.97	68.53

*Note: LSD = Least significant difference, CV = Coefficient of variance, *** signifies significant at P<0.001 level and ** signifies significant at P< 0.01 level.*

Pod Length

Genotypes showed significant differences for pod length ranging from 9.83-13.98 cm as shown in Table 5. The highest pod length was found in Green Long Bean (13.98) statistically at par with LB-31 (13.82). The least pod length was recorded for Rato Makai Simi (9.83) which was statistically at par with Kalo Simi (10.13).

Pod weight

Pod weight varied significantly among the French bean varieties from 3.31-6.75 gm as shown in Table 5. LB-31 showed the greatest single pod weight (6.75), statistically at par with Semi Light Long (6.38), Green Long Bean (6.33), Chinese

Long (5.96), Madhav (5.94) and Chaumase (5.76). Rato Makai Simi had the lowest single pod weight (3.31) and was statistically at par with Kalo Makai Simi (3.79) and Khairo Makai Simi (3.88).

Pod diameter

Significant variation was seen for pod diameter among the varieties ranging from 8.49-11.06 mm as shown in Table 5. The greatest pod diameter was seen for Kalo Simi (11.06), the lowest pod diameter was seen for Chaumase (8.49) that was statistically at par with Chinese Long (8.62), Trishuli (8.87), LB-37 (9.12), Madhav (9.17) and Semi Light long (9.20).

Table 5. Pod Length, Pod Weight and Pod Diameter of different genotypes of pole French bean tested in Sundarbazar, Lamjung

Treatment	Pod Length (cm)	Pod Weight (g)	Pod Diameter (mm)
Trishuli	13.11^{c}	5.58^{bc}	8.87^{bc}
Chaumase	13.00^{c}	5.76^{ab}	8.49^{c}
Semi Light Long	13.23^{bc}	6.38^{ab}	9.20^{bc}
Green Long Bean	13.98^{a}	6.33^{ab}	9.71^{b}
LB-31	13.82^{ab}	6.75^{a}	9.67^{b}
LB-37	12.90^{c}	5.63^{bc}	9.12^{bc}
Madhav	13.27^{bc}	5.94^{ab}	9.17^{bc}
Chinese long	12.85^{c}	5.96^{ab}	8.62^{c}
Rato Makai Simi	9.83^{e}	3.31^{e}	9.69^{b}
Khairo Makai Simi	10.72^{d}	3.88^{de}	9.56^{b}
Kalo Makai Simi	10.6^{d}	3.79^{de}	9.05^{bc}
Kalo Simi	10.13^{de}	4.62^{cd}	11.06^{a}
LSD (0.05)	0.71	1.04	0.84
Standard Error of Mean (SE_m)	0.24	0.35	0.29
F- Probability	***	***	***
CV (%)	3.39	11.49	5.32
Grand Mean	12.28	5.33	9.35

*Note: LSD = Least significant difference, CV = Coefficient of variance and *** signifies significant at P<0.001 level.*

Pods per plant

Pods per plant varied significantly among the tested varieties ranging from 18.33-44.76 as shown in Table 6. Semi Light Long showed the greatest pod number per plant (44.76) which was statistically at par with Chaumase (42.03). The least pod number per plant was observed in Kalo Makai Simi (18.33) statistically at par with Rato Makai Simi (23.16).

Harvest duration

Harvest duration varied significantly among the varieties tested ranging from 7.33-16.67 days as shown in Table 6. Kalo Makai Simi showed the shortest harvest duration (7.33) that was statistically at par with Trishuli (9.67), Khairo Makai Simi (10.33), LB-67 (10.67) and Green Long bean (10.67). The highest harvest duration was observed for Kalo Simi (16.67) statistically at par with Semi Light Long (14.33), Chinese Long (13.33) and LB-31 (12.67).

Table 6. Pods per plant and Harvest duration of different genotypes of pole French bean tested in Sundarbazar, Lamjung

Treatment	Pods per Plant	Harvest Duration
Trishuli	38.53^{abc}	9.67^{cd}
Chaumase	42.03^{ab}	12^{bc}
Semi Light Long	44.76^{a}	14.33^{ab}
Green Long Bean	36.56^{abc}	10.67^{bcd}
LB-31	31.33^{cd}	12.67^{abc}
LB-37	33.66^{bc}	10.67^{bcd}
Madhav	31.2^{cd}	11.67^{bc}
Chinese long	36.7^{abc}	13.33^{abc}
Rato Makai Simi	23.16^{de}	11.67^{bc}

Khairo Makai Simi	39.33^{abc}	10.33^{bcd}
Kalo Makai Simi	18.33^{e}	7.33^{d}
Kalo Simi	39.8^{abc}	16.67^{a}
LSD (0.05)	8.9	4.28
Standard Error of Mean (SE_m)	3.04	1.46
F- Probability	***	*
CV (%)	15.18	21.53
Grand Mean	34.62	11.75

*Note: LSD = Least significant difference, CV = Coefficient of variance and *** signifies significant at P<0.001 level and * signifies significant at P<0.05 level*

Yield per plant and yield per plot

Yield per plant and yield per plot was seen to vary significantly among the bean varieties as shown in Table 7. Yield per plant was seen highest for Semi Light Long (289.13) and lowest for Kalo Makai Simi (70.72). Yield per plant of Chaumase (244.48) was statistically at par with Semi Light Long. Similarly, Rato Makai Simi (79.03) had a statistically similar yield per plant with Kalo Makai Simi. Likewise, the highest yield per plot was recorded in Semi Light Long (5726.83) and the lowest in Kalo Makai Simi (1401.21). Yield per plot in Rato Makai Simi (1607.64) was statistically at par with Kalo Makai Simi.

Table 7. Yield per plant and Yield per plot of different genotypes of pole French bean tested in Sundarbazar, Lamjung

Treatment	Yield per plant (g)	Yield per plot (g)
Trishuli	209.96^{bcd}	4246.71^{b}
Chaumase	244.48^{ab}	4629.21^{b}
Semi Light Long	289.13^{a}	5726.83^{a}
Green Long Bean	233.73^{bc}	4672.19^{b}
LB-31	210.07^{bcd}	4341.17^{b}
LB-37	193.18^{bcd}	3914.22^{bc}
Madhav	184.63^{cd}	3844.67^{bc}
Chinese long	221.43^{bc}	4446.79^{b}
Rato Makai Simi	79.03^{e}	1607.64^{d}
Khairo Makai Simi	158.95^{d}	3140.43^{c}
Kalo Makai Simi	70.72^{e}	1401.21^{d}
Kalo Simi	186.43^{cd}	3786.65^{bc}
LSD (0.05)	51.93	1032.71
Standard Error of Mean (SE_m)	17.71	352.11
F- Probability	***	***
CV (%)	16.12	15.99
Grand Mean	190.15	3813.15

*Note: LSD = Least significant difference, CV = Coefficient of variance and *** signifies significant at P<0.001 level.*

Qualitative traits

Cream white flower color was observed in Trishuli, LB-37 and Rato Makai Simi while a yellowish white colored flower was seen in Green Long Bean. The remaining varieties displayed purple- violet colored flower petals. Normal Green colored pods were observed in Trishuli, Chaumase, Khairo Makai Simi and Chinese Long. Light Green color was seen in Semi Light Long, Green Long Bean, LB-37 and Madhav while dull green color was seen in Kalo Makai Simi. Purple stripes on green pod of LB-31 were noticed while a red tinge at the base on the green pod was seen in Rato Makai Simi. Only Kalo Simi had curved pods while pods of remaining varieties were semi-curved. The pods of Trishuli and Green Long Bean were attractive in appearance whereas the pods of remaining varieties were medium. Only the beaks of LB-37 and Madhav were oriented upward. The pod beak has been considered an identifying feature for a particular genotype (Pandey et al., 2011).

Table 8. Flower color, Pod color, Pod shape, Pod appearance and Beak orientation of different genotypes of pole French bean tested in Sundarbazar, Lamjung

Genotypes	Flower color	Pod color	Pod shape	Pod appearance	Beak Orientation
Trishuli	White	Green	Semi-Curved	Attractive	Downward
Chaumase	Purple	Green	Semi-Curved	Medium	Downward
Semi Light Long	Purple	Light Green	Semi-Curved	Medium	Downward
Green Long Bean	Yellowish White	Light Green	Semi-Curved	Attractive	Downward
LB-31	Purple	Purple stripe on green pod	Semi-Curved	Medium	Downward
LB-37	White	Light Green	Semi-Curved	Medium	Upward
Madhav	Purple	Light Green	Semi-Curved	Medium	Upward
Chinese Long	Purple	Green	Semi-Curved	Medium	Downward
Rato Makai Simi	White	Green with red tinge	Semi-Curved	Medium	Downward
Khairo Makai Simi	Purple	Green	Semi-Curved	Medium	Downward
Kalo Makai Simi	Purple	Dull Green	Semi-Curved	Medium	Downward
Kalo Simi	Purple	Purple	Curved	Medium	Downward

Discussion

The variation in days to 50% germination, as explained by Meena et al. (2018) and Subedi et al. (2022) can be attributed to differences in genetic makeup, soil conditions (such as soil type, temperature, and moisture), seed storage quality, and their interactions. Similar variations in days to 50% flowering have been observed in many studies, possibly due to differences in genotypes, photoperiod, and temperature during the growing period (Whantake et al., 2021; Dhakal et al., 2020; Neupane et al., 2008).

In the case of the Kalo Simi variety of French beans collected from Humla, it might have flowered earlier in Sundarbazar, Lamjung, due to higher temperature conditions compared to Humla. The observed variation in plant height can be attributed to environmental differences in growing conditions, seasons, and genotypes (Dhakal et al., 2020; Luitel et al., 2021; Whantake et al., 2021; Thapa et al., 2022).

The time required for the first flower to appear represents early maturity and is influenced by genotype, day length, and temperature (Subedi et al., 2022). Genetic differences among varieties can also cause variations in days to the first harvest, as noted by Whantake et al. (2021). Previous studies have shown variations in pod length, indicating the influence of genotype and growing season (Neupane et al., 2008; Pandey et al., 2011; Aryal et al., 2020; Dhakal et al., 2020; Thapa et al., 2022).

Kalauni et al. (2019) and Subedi et al. (2022) suggest that the variation in single pod weight is influenced by genetic differences among genotypes, with findings from Yadav et al. (2015) and Das et al. (2014) supporting the role of genetic factors in pod characteristics. The unique genetic makeup of Kalo Makai Simi may contribute to its greater pod diameter, a characteristic that allows it to thrive at higher altitudes—shorter in length, broader in size, and curved in appearance.

In terms of genotypic variation, differences in inflorescences, pod numbers per raceme, and flower-dropping tendencies are related to the variation in pod number in a plant (Khan, 2003). The number of pods per plant plays a crucial role in determining overall yield in French bean cultivation, as emphasized by Sharma et al. (2013). The Semi Light Long variety's higher productivity may be attributed to its better sink capacity in terms of the number of pods or pod weight. Subedi et al. (2022) estimated significant variation in harvest duration as a result of genotypic differences among varieties, growing environments, or their interaction. Higher yield is achieved through a combination of high pod

number per plant, greater single pod weight, and pod weight per plant. The genetic potential of a genotype significantly influences yield traits (Luitel et al., 2021). Chalise et al. (2017) observed a significant influence of environmental conditions on yield parameters of different genotypes in a 2-year analysis of pole bean varieties in Dailekh. Chaudhary et al. (2008) found that pole bean genotypes exhibit higher pod yield and a longer production period than bush bean genotypes, highlighting the importance of extra care for pole beans to achieve better yield and quality. Their findings also concluded low fresh pod yield in pole beans during the spring season but noted a similar genotypic trend of yield. In response to the observed variations in characters, Pandey et al. (2011, 2012) proposed site-specific evaluations of French bean varieties.

Conclusion

This study shows significant differences among the genotypes for their morphological, phenological and yield attributing parameters thus, indicating a crucial role for their selection based on the environmental conditions. Semi Light long had the highest number of pods per plant, yield per plant and yield per plot statistically at par with Chaumase Simi. Similarly, the highest pod weight was observed in LB-31, followed by Semi Light Long and Chaumase. Kalo Simi was found to be an early maturing variety with the highest harvest duration. Kalo Makai Simi was late maturing, having the shortest harvest duration, and late germinating. The highest plant height and highest pod length was observed in Green Long Bean, whereas the lowest plant height and lowest pod length in Rato Makai Simi. Pod diameter was highest in Kalo Simi and lowest in Rato Makai Simi. Evidently, Semi Light Long was found suitable to suggest for cultivation in and around Sundarbazar, Lamjung although further study would be appropriate. Future research needs to focus on further evaluating these genotypes under various production systems for quantitative traits as well as to identify traits that will be useful for the crop improvement.

Author contributions

A. Tripathi: Designed & conducted experiment, data collection & analysis, and manuscript writing
M. Pandey: Conducted experiment, data collection, and manuscript writing.

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