Kasetsart J. (Nat. Sci.) 45 : 780 - 792 (2011)

Variability of French Bean in the Western Mid Hills of Nepal

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ABSTRACT

Variability was studied among 18 exotic and indigenous French bean (*Phaseolus vulgaris* L.) genotypes collected from research centers, agro-vets and traditional farming villages of the western hills of Nepal. The collected genotypes were field evaluated at the Agriculture Research Station, Malepatan, Pokhara at 848 m above sea level during the summer season of 2010 with the objectives to assess the variability in the exotic and indigenous genotypes and their potential for utilization in improvement programs. The results of the study showed that the variability was higher in adaptation, vegetative growth, floral and pod characteristics. The plant survival at harvest was higher in pole-type than in bush-type beans ranging from 97.92 to 54.17% with means of 83.71% and 79.80%, respectively. Bush-type beans were earlier in flowering than pole-type beans ranging from 32 to 174.33 d with a mean of 35.76 and 76.61 d, respectively. Pod length and width were higher in pole- type beans than in bush-type beans ranging from 20.45 to 7.67 cm in length and 33.53 to 7.37 mm in width. The variability indicated that the collected genotypes were distinctly different. The results revealed that the French bean genotype in the mid hills of Nepal is highly diverse and could be considered as the secondary center of genetic diversity. The diverse genotypes should be conserved and utilized for varietal improvement.

Keywords: French bean, pole, bush, genotypes, variability

INTRODUCTION

French bean (*Phaseolus vulgaris* L.), a native of central and South America (Swaider *et al*., 1992) has one of the longest histories of cultivated plants and is widely cultivated in the temperate and subtropical regions and in many parts of the tropics. It is the most important legume worldwide for human consumption (Singh, 1999). Nepal is one of the world's richest centers of crop genetic diversity because of diverse agro-climatic conditions and socioeconomic and cultural variation. About 400 species of food and horticultural crops have been reported in Nepal and about 200 species are in the vegetable category (Pandey *et al.,* 2000). Fifty species of vegetables are domesticated in Nepal including the French bean. It is an important vegetable and is cultivated in a wide range of agro-climatic conditions from plains at 300 m above sea level (asl) to the high hills at 2,500 m asl in different seasons (Neupane *et al.,* 2008). Beans, the "meat of the poor", contribute essential protein to the undernourished people living in the hills. In Nepal, beans are grown

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Received date : 25/01/11 Accepted date : 20/07/11

for their green pods as a fresh vegetable and the dried seeds are used as pulse and for seed purposes, while the foliage is consumed as fodder and is used to restore soil fertility.

Different ethnic groups have their own ways of preparing beans and there are special occasions and festivals when the products are relished. Red kidney beans are cultivated during the winter season on the plains (below 500 m asl) and are an integral part of the cuisine as a socio-cultural identity in the plains of Nepal. Different Indian rajma (red kidney bean) genotypes have been introduced in production areas and the predominant cropping pattern is as a mono crop. In the mid hills, fresh green pods are important and widely consumed as a vegetable. Both pole- and bush-type French beans are cultivated for green pods in the hills (500–1600 m asl) during summer to autumn. Most of the genotypes growing in the hills were introduced from India and China. Green stringless French bean (snap bean) is a very popular vegetable crop among the hill people. These beans are grown as a mono crop in the commercialized peri-urban areas using staking for pole beans. Pole beans are also cultivated or inter cropped with maize as a rain-fed crop in the hills. Dried shelling beans are usually produced from summer to autumn in the high hills and mountains (1,600–2,500 m asl). These beans are long duration vegetables, which are grown either with maize or in apple orchards. In the high hills, they are the major source of protein for households and are also a cash-generating crop. Dried beans produced in the high hills are considered to be high quality beans and find their way to distant markets and cities. Farmers regard beans as a cash-generating crop in the hills and grow a number of landraces with varying morphologies (Neupane and Vaidya, 2002). The current research was initiated with the objectives of collection, evaluation and characterization of available exotic and indigenous germplasms so that they can be utilized for varietal improvement and commercial cultivation.

MATERIALS AND METHODS

French bean germplasms were collected from government farms, markets and farm households during February–March 2010. A total of 19 landraces were collected and of them, 11 were pole and 8 were bush types. Special attention was given to collect the genotypes which were generally grown for fresh vegetable (stringless). The collected genotypes were Samjhana, Madhav, Chinese Long (Run Long), Four Season, Trishuli, Syangja, LB-39, Tarbare, LB-31, Myagdi and Makwanpur (pole type) and Mandir, Arka Komal, S-9, LB-27, Pant Anupma, Mallika and Arka Suvidha (bush type).

The genotypes were evaluated at the Agriculture Research Station (Horticulture), Malepatan, Pokhara and the agro-morphological characteristics were recorded. The station is situated at a latitude of 28°13′6.18″ N and a longitude of 83°58′27.72″ E at an elevation of 848 m asl and is characterized by a sub-tropical climate. The maximum temperature range during the crop growing period was 33.7 °C in June to 20.0 °C in November and the minimum temperature range was from 23.7 °C in June to 11.6 °C in November. For characterization, the experiment was conducted from April to November 2010. The experiment was arranged in a randomized complete block design with three replications. Spacing was maintained at 75 × 45 cm for pole-type beans and at 60 × 30 cm for bush-type beans. Experimental plot sizes were 3.6 × 1.1 m for pole types and 3.6 × 0.9 m for bush types. The crop was planted on 27 April 2010. Manure and fertilizer were applied as compost (20 t/ha) and 40:60:50 kg.ha^{-1} N, P, and K, respectively. Scoring of agro-morphological characters was done according to the procedures given in the IBPGR (International Board for Plant Genetic Resources) descriptors for *Phaseolus vulgaris* (IBPGR, 1982). The data were analyzed using Genstat software (version 12.1, VSN International, Hemel Hempstead, UK).

Plant survival was recorded as a percentage at the three different stages of 15 d, flowering and harvest. Plant vigor was recorded twice by visual observation at full emergence and flowering by a team of scientists using grades of very poor, poor, acceptable/medium, good and very good. Plant vigor was measured by visual observation as a combination of active growth, and plants appearing to be healthy and strong. The scale rating of very poor was defined as inactive growth with weak and unhealthy plants, whereas very good was defined as active growth with healthy and strong plants. Days to flowering was recorded when 50% of plants had set flowers. Node number was recorded after flower set from base to first axillary inflorescence in the indeterminate type and from base to terminal inflorescence in the determinate type. Means were averaged from 10 randomly selected plants. The number of flower buds per inflorescence was recorded from terminal inflorescence in the determinate type and from the lateral (third inflorescence from the apex) in the indeterminate type. Means were averaged from 10 randomly selected plants. Flower color was recorded as white, green, lilac, white with carmine stripes, white with red stripes, purple or other. The number of branches was recorded from the base to the first inflorescence and averaged based on measurements from five randomly selected plants. Leaf color was recorded after flower set on measurements from five randomly selected plants as pale green, medium green or dark green. Plant height was measured at the green pod maturity stage from the cotyledon scar to the highest tip of the plant. Height was recorded in centimeters and the measurements from five randomly selected plants were averaged.

Pod length in centimeters and pod width in millimeters were measured on the largest, fully expanded, immature, green pod and measurements were averaged from 10 randomly selected plants. Pod beak orientation was measured at the largest, fully expanded, immature, green pod as upward, straight or in a downward position. Pod curvature was measured on the largest fully expanded immature green pod as straight, slightly curved, curved or recurved. Pod color was recorded on the fully expanded immature pods as normal green, shiny green, dull green, dark pink, pale red stripe on green or other. Pod appearance was recorded from randomly selected plants as very attractive, attractive, medium, less attractive or not attractive. Seed color was recorded from matured dry seeds as black, brown, pure white, whitish, red, pink, purple or other. The qualitative characters/traits were measured by a team of 15–20 scientists and consumers. The characters/traits were measured individually and later compiled.

Statistical testing was carried out using Duncan's new multiple range text at the $P < 0.05$ level.

RESULTS AND DISCUSSION

Plant stand

Plant survivability was distinctly different in the pole and bush beans (Tables 1 and 2, respectively). For pole types, the plant survival percentage at 15 d was 100% in Four Season, Madhav, Chinese Long, Samjhana, Syangja and LB-31 whereas it was highest in Chinese Long, Tarbare and Samjhana at flowering (97.92%) and in Chinese Long at harvest (97.92%). The lowest percentage of plant survival was in LB-39 at 15 d (89.58%) and flowering (70.83%) whereas LB-39 and Myagdi at harvest had 64.58% survival. For bush types, the highest plant survival percentage was found in S-9, Mandir and Arka Komal at 15 d (100%), and in S-9 at flowering (100%) and harvest (91.67%). The lowest survival percentage was found in Pant Anupma at 15 d (86.11%) and in LB-27 at flowering (69.4%) and harvesting (54.17%). Plant survival of the crop varieties is one of the important parameters for seasonal and off-season production of vegetables, which determines the resistance and tolerance of the variety to a particular environment. The result revealed that the average plant survival percentage was better in pole beans compared with bush beans at all plant growth stages. Similar findings have been reported by other researchers. Pandey (2004) reported that the survivability of a particular variety of cauliflower is affected by adverse climatic conditions and it is obvious that the

Table 1 Plant survivability and morphological characters of different pole bean genotypes.

Varieties	Plant survival at 15 days (%)	Plant survival at flowering (%)	Plant survival at harvest (%)	Number of nodes	Number of branches
Four Season	100.00[a1]	95.83[ab]	91.67[ab]	27.00[fg]	3.60[fg]
LB-39	89.58[b]	70.83[c]	64.58[d]	24.67[h]	3.50[g]
Madhav	100.00[a]	93.75[ab]	85.42[b]	26.33[fg]	4.37[e]
Trishuli	97.92[a]	93.75[ab]	89.58[ab]	25.67[gh]	3.83[f]
Chinese Long	100.00[a]	97.92[a]	97.92[a]	34.00[c]	5.27[d]
Myagdi	97.92[a]	75.00[c]	64.58[d]	45.33[ab]	8.93[a]
Makwanpur	97.92[a]	91.67[ab]	87.50[b]	27.67[ef]	4.60[e]
Tarbare	97.92[a]	97.92[a]	93.75[ab]	45.70[a]	6.33[c]
Samjhana	100.00[a]	97.92[a]	91.67[ab]	29.00[e]	5.27[d]
LB-31	100.00[a]	89.58[ab]	77.08[c]	32.00[d]	5.07[d]
Syangja	100.00[a]	87.50[b]	77.08[c]	44.00[b]	8.40[b]
CV %	2.4	5.8	5.5	2.8	3.4
F-test[2]	**	**	**	**	**

[1] Mean values in the same column followed by a common letter are not significantly different at the $P < 0.05$ level by Duncan's new multiple range test.

[2] ** = Highly significant at $P < 0.01$.

Table 2 Plant survivability and morphological characters of different bush bean genotypes.

Variety	Plant survival at 15 days (%)	Plant survival at flowering (%)	Plant survival at harvest (%)	Number of nodes	Number of branches
S-9	100.00[a1]	100.00[a]	91.67[a]	31.67[a]	7.93[a]
LB-27	97.22[a]	69.40[d]	54.17[c]	26.33[d]	7.33[bc]
Mandir	100.00[a]	97.20[a]	84.72[a]	32.00[a]	5.20[d]
Mallika	98.61[a]	91.70[ab]	87.50[a]	27.33[cd]	6.87[c]
Arka Komal	100.00[a]	90.30[ab]	83.33[a]	30.00[b]	7.40[b]
Pant Anupma	86.11[b]	77.80[cd]	73.61[b]	28.33[c]	7.20[bc]
Arka Suvidha	98.61[a]	83.30[bc]	83.33[a]	26.67[cd]	7.53[ab]
CV %	2.0	6.4	5.9	3.2	3.6
F-test[2]	**	**	**	**	**

[1] Mean values in the same column followed by a common letter are not significantly different at the $P < 0.05$ level by Duncan's new multiple range test.

[2] ** = Highly significant at $P < 0.01$.

genetic characters show resistance and susceptibility to a particular environment. Al-Soqeer (2010) reported that plant survival of jojoba clones was affected by the genotype and growing season ranging from 91.7 to 98%. NeSmith (2003) also reported that the plant survival and vigor of southern highbush blueberry were highly affected by the genotype and growing environment.

Node number

The number of nodes per plant produced by different genotypes was significantly different (Tables 1 and 2). The highest number of nodes was produced by Tarbare (45.70) and the lowest by LB-39 (24.67). Among bush types, the highest number of nodes was produced by Mandir (32.0) and the lowest by LB-27 (26.33). Growth, development and yield of vegetable crops are the result of each variety's genetic potential interacting with the environment and farming practices. The results showed that the node number of different varieties was affected by the genotype and the growing environment. Genotypes Tarbare, Myagdi and Syangja did not enter into the reproductive phase as early as other genotypes, and produced more nodes and vegetative growth. These genotypes produced more nodes due to the long vegetative period and the effects of photoperiod and temperature. Long days and high temperatures changed the growth habit of the normally determinate lablab bean (*Lablab purpureus*) plant to indeterminate (Kim and Okubo, 1995). They also reported that the plants of indeterminate growth habit showed an increased number of nodes and a greater length of internodes with high temperature and day length (13 h at 25 °C or 10–11 h at 30 °C). The results also showed that the average node number was greater in pole beans with an average of 32.85 compared with bush beans with an average of 28.90. Similar results have been reported by Luitel *et al*. (2009) who noted that the ground coverage and stem number of potatoes were directly influenced by the genotype. Islam *et al*. (2010) reported that the genotypes of hyacinth bean showed considerable variation for most morpho-physical traits. They found that the number of nodes per raceme ranged from 2.33 to 14.1 in different genotypes.

Branches

The number of branches per plant in different genotypes differed significantly (Tables 1 and 2). The highest number of branches was produced by Myagdi (8.93) and the lowest by LB-39 (3.5). Among bush types, the highest number of branches was produced by S-9 (7.93) and the lowest by Mandir (5.2). Plant growth including the number of branches is the result of a variety's genetic potential interacting with the environment and farming practices. The results showed that the number of branches of different varieties was affected by the genotype and growing environment. As with the number of nodes, the genotypes Myagdi, Syangja and Tarbare did not enter into the reproductive phase as early as other genotypes and so produced more branches and vegetative growth. Environmental conditions (mainly air temperature and rainfall) greatly affect the growth and development of bean plants. Brewster (1983) reported that temperature influences the responses of many plant species to photoperiod, growth, tuber development and flowering. The temperature is just as important as day length in influencing growth and flowering (Herath and Ormrod, 1979). However, the results of the current study showed that the average number of branches was greater in bush beans with an average of 7.07 compared to pole beans with an average of 5.38. Alghamdi (2007) also reported in a study of faba beans that the genotypes differed significantly for all traits. He found that the number of branches per plant was significantly different. Similar findings have been reported by Al-Soqeer (2010) where the number of branches of jojoba clones was affected by genotype and growing season ranging from 11.9 to 58.7 branches.

Days to flowering

Days to 50% flowering of a particular variety describes whether the variety is early, medium or late to mature. The flowering days in different genotypes differed significantly (Tables 3 and 4). The earliest flowering genotypes were Makwanpur (37.67 d) and S-9 (32 d) for pole- and bush-type beans, respectively. The latest flowering genotypes were Myagdi (174 d) and Mandir (47 d) for pole- and bush-types, respectively. The flowering and fruiting days were influenced by genotype, day length and temperature. In most of

Table 3 Plant height, days to flowering, floral and pod characters of different pole bean genotypes.

Genotype	Plant height (cm)	Days to 50% flowering	No. of flower buds	Pod length (cm)	Pod width (mm)
Four Season	247.20^{bcd1}	44.00^{f}	4.70^{ef}	18.17^{e}	9.13^{fg}
LB-39	239.60^{d}	44.33^{ef}	4.90^{de}	18.47^{d}	10.10^{d}
Madhav	229.30^{e}	45.33^{e}	5.70^{a}	18.97^{c}	9.83^{de}
Trishuli	240.70^{d}	47.33^{d}	5.17^{c}	16.23^{g}	9.60^{e}
Chinese Long	275.40^{a}	42.33^{g}	5.43^{b}	20.47^{a}	8.97^{g}
Myagdi	245.40^{cd}	174.33^{a}	4.70^{ef}	13.27^{h}	27.60^{c}
Makwanpur	247.40^{bcd}	37.67^{h}	5.53^{ab}	18.13^{e}	8.37^{h}
Tarbare	266.73^{a}	162.33^{b}	3.43^{g}	11.57^{i}	33.53^{a}
Samjhana	256.70^{b}	42.00^{g}	5.40^{b}	20.13^{b}	9.57^{ef}
LB-31	214.20^{f}	42.67^{g}	5.07^{cd}	17.17^{f}	9.07^{g}
Syangja	255.47^{bc}	160.33^{c}	4.67^{f}	7.67^{j}	32.83^{b}
CV %	2.2	0.8	2.5	0.9	1.7
F-test[2]	**	**	**	**	**

[1] Mean values in the same column followed by a common letter are not significantly different at the $P < 0.05$ level by Duncan's new multiple range test.

[2] ** = Highly significant at $P < 0.01$.

Table 4 Plant height, days to flowering, floral and pod characters of different bush bean genotypes.

Genotype	Plant height (cm)	Days to 50% flowering	No. of flower buds	Pod length (cm)	Pod width (cm)
S-9	37.00^{c1}	32.00^{c}	4.40^{a}	13.49^{c}	8.23^{cd}
LB-27	26.80^{f}	35.33^{b}	4.70^{a}	14.10^{b}	8.60^{bc}
Mandir	102.07^{a}	47.00^{a}	3.83^{b}	15.71^{a}	9.30^{a}
Mallika	35.27^{d}	35.00^{b}	4.57^{a}	10.73^{e}	7.37^{e}
Arka Komal	40.67^{b}	33.00^{c}	4.43^{a}	12.39^{d}	7.77^{de}
Pant Anupma	29.73^{e}	35.00^{b}	3.67^{b}	10.93^{e}	7.43^{e}
Arka Suvidha	34.53^{d}	33.00^{c}	4.37^{a}	13.99^{b}	8.83^{ab}
CV %	1.8	2.1	4.2	1.3	3.9
F-test[2]	**	**	**	**	**

[1] Mean values in the same column followed by a common letter are not significantly different at the $P < 0.05$ level by Duncan's new multiple range test.

[2] ** = Highly significant at $P < 0.01$.

the vegetable crops, early flowering and maturing genotypes are considered preferable. Three pole bean genotypes (Myagdi, Syangja and Tarbare) were very late in flowering. These genotypes were shelling type beans for grain purposes and are generally used as dry beans, which have a long duration, and therefore, the flowering time was influenced by the season or photoperiod and temperature. White and Laing (1989) reported that adaptation of the common bean is strongly affected by photoperiod and there is considerable genetic variation for photoperiod response in bean species. The results revealed that flowering was earlier in bush beans than pole beans ranging from 32 to 47 d. Neupane *et al*. (2008) reported that the flowering days in beans were influenced by the genotype. They reported that flowering varied from 40 to 84 d depending on the bean genotype. Similar results have been reported by other researchers. Adams *et al*. (1985) and Wallace *et al*. (1991) reported that with the common bean, the days to flowering and the length of flowering period vary depending on the cultivar and environmental conditions. Imrie and Lawn (1990) reported that the time of flowering of mung bean crops varies appreciably depending on the genotype, day length and temperature prevailing during the period after sowing. Al-Soqeer (2010) reported that the days to flowering in jojoba clones were affected by genotype, with early and late flowering occurring. Islam *et al*. (2010) also reported that the genotypes of hyacinth bean had days to first flower ranging from 47.6 to 136.3 d, indicating the presence of an early variety.

Flower buds

The number of flower buds per inflorescence was significantly different among the genotypes (Tables 3 and 4). The highest number of flower buds was produced by Madhav (5.70) and LB-27 (4.70) pole and bush beans, respectively. The lowest number of flower buds was produced by Tarbare (3.43) and Pant Anupma (3.67) pole and bush beans, respectively. The result revealed that the number of flower buds was greater in pole beans with an average of 4.97 per inflorescence than in bush beans with an average of 4.28. The number of flower buds produced was influenced by the genotype. Neupane *et al*. (2008) reported that the number of flower buds per inflorescence in bean was influenced by the genotype. All the genotypes were planted on the same date and varied in the number of flower buds from 1.8 to 18 depending on the bean genotype. Peksen (2007) also reported that large differences were found among common bean genotypes for the number of flowers per plant.

Plant height

The plant height differed significantly among the genotypes (Tables 3 and 4). The tallest and the shortest plants were found in Chinese Long (275.40 cm) and LB-31 (214.20 cm), respectively. In bush beans, the tallest and the shortest plants were found in Mandir (102.07 cm) and LB-27 (26.80 cm), respectively. Mandir is an imported genotype from India. It behaved like a bush bean in flowering and fruiting, while the plant height was like a pole bean. It was categorized as a bush bean. All pole beans were tall (longer than 2 m). Plant height ranged from 214.2 to 275.4 cm in pole types, while it was from 26.8 to 102.07 cm in bush types. Neupane *et al*. (2008) reported that the plant height in beans was influenced by the genotype. They recorded that the plant height ranged from 28 to 144 cm in different bean genotypes that were planted on the same date. Similar results were also reported by other researchers. Alghamdi (2007) reported that faba bean genotypes significantly differed in flowering date and plant height. Al-Soqeer (2010) reported that the plant height in jojoba clones was affected by the genotype and the growing season ranging from 30.5 to 52.8 cm.

Pod length

The pod length among the genotypes was

significantly different (Tables 3 and 4). Chinese Long produced the longest (20.47 cm) pods and the shortest (7.67 cm) pods came from Syangja. For bush types, the longest pods (15.71 cm) were produced by Mandir and the shortest pods (10.73 cm) by Mallika. The results revealed that the pod length was influenced by the genotype. Snap bean genotypes produced longer pods and shelling beans (Tarbare, Syangja and Myagdi) produced shorter pods. The pod length was greater in pole beans (average 16.38 cm) than in bush beans (average 13.05 cm). Neupane *et al*. (2008) reported that the pod length in beans was influenced by the genotype. They found that all the genotypes planted on the same date produced varying pod lengths ranging from 6.7 to 17.4 cm. Similar results were also reported by other researchers. Islam *et al*. (2010) reported that the genotypes of hyacinth bean showed considerable variation in pod length varying from 3.96 cm to 18.20 cm. Pengelly and Maass (2001) also reported that the pod length in lablab bean ranged from 2.5 to 14 cm among 249 genotypes.

Pod width

The pod width among the genotypes differed significantly (Tables 3 and 4). Tarbare produced the widest pods (33.53 mm) and the narrowest pods came from Makwanpur (8.37 mm). For bush types, the widest pods (9.30 mm) were produced by Mandir and the narrowest pods (7.37 mm) by Mallika. Shelling beans (Tarbare, Syangja and Myagdi), which are indigenous and cultivated in the mid to high hills, produced wider pods while the snap bean genotype produced narrower pods. These shelling beans have shorter but wider pods which produce bigger dry beans. The average pod width was greater in pole beans with an average of 15.33 mm than in bush beans with an average of 8.22 mm. Neupane *et al*. (2008) reported that the pod width in beans was influenced by the genotype. They recorded pod widths ranging from 10 to 30 mm in different genotypes which were planted on the same date. Islam *et al*. (2010) also reported that the genotypes of hyacinth bean showed considerable variation in pod width that ranged from 1.5 cm to 4.46 cm. Pengelly and Maass (2001) reported that the pod width in lablab bean showed high variation among 249 genotypes.

Plant vigor

The plant vigor in most genotypes was either very good or good (Table 5). Excellent plant vigor was found in Four Season at full emergence and in Four Season and LB-39 at flowering. The poorest vigor was found in Myagdi at full emergence and flowering. In bush types, excellent plant vigor was found in Arka Suvidha, S-9 and Arka Komal at full emergence and flowering. The poorest vigor was found in Mallika and Mandir at full emergence and flowering. Plant vigor is directly related to the strength of plant growth. An extreme value for this variable could be an indicator of a lack of adaptation. Plant vigor is a feature of plant physiology. NeSmith (2003) reported that the plant survival and vigor of southern highbush blueberry was highly affected by the genotype and growing environment. Qiu and Mosjidis (1993) also reported that substantial variability of plant vigor was found among 54 varieties of sericea lespedeza.

Leaf color

The leaf color in beans was categorized as pale green, medium green or dark green. In most genotypes, the leaf color was medium green (Table 5). Trishuli, Tarbare and Four Season had dark green leaves whereas all other pole-type genotypes had medium green leaves while Syangja and Myagdi had pale green leaves. All the bush bean genotypes had medium green leaves except for Pant Anupma which had pale green leaves. Similar findings have been reported by other researchers. Islam *et al*. (2010) reported that the color of different plant parts of hyacinth bean varied among the genotypes. They found that leaf color intensity

Table 5 Plant, leaf, flower and pod characteristics of different French bean genotypes.

Genotype	Plant vigor		Flower color	Leaf color	Pod beak orientation	Pod curvature	Pod color	Pod appearance	Seed color
	Full emergence	Flowering							
Pole bean									
Chinese Long	Good	Good	Lilac	Medium green	Downward	Slightly curved	Normal green	Medium	Black
Four Season	Very good	Very good	Lilac	Dark green	Downward	Slightly curved	Normal green	Attractive	Black
LB-31	Medium	Medium	Purple	Medium green	Downward	Slightly curved	Red stripes on green	Medium	Mottled
LB-39	Good	Very good	White	Medium green	Upward	Slightly curved	Dark green	Attractive	White
Madhav	Good	Good	Lilac	Medium green	Upward	Slightly curved	Light green	Very attractive	Black
Makwanpur	Good	Good	White	Medium green	Upward	Straight	Light green	Very attractive	White
Myagdi	Medium	Poor	Lilac	Pale green	Straight	Straight	Light green	No attractive	Mottled
Samjhana	Good	Good	White	Medium green	Downward	Slightly curved	Light green	Attractive	White
Syangja	Good	Good	White	Pale green	Upward	Straight	Dark green	No attractive	Mottled
Tarbare	Good	Good	White	Dark green	Downward	Slightly curved	Light green	No attractive	White
Trishuli	Good	Good	White	Dark green	Straight	Curved	Normal green	Medium	Brown
Bush bean									
Arka Komal	Very good	Very good	White	Medium green	Straight	Slightly curved	Normal green	Attractive	Light brown
Arka Suvidha	Very good	Very good	White	Medium green	Straight	Slightly curved	Normal green	Attractive	Brown
LB-27	Good	Good	White	Medium green	Straight	Slightly curved	Normal green	Attractive	White
Mallika	Medium	Good	White	Medium green	Straight	Straight	Dark green	Attractive	Red
Mandir	Medium	Good	White	Medium green	Downward	Curved	Light green	Very attractive	Red
Pant Anupma	Good	Good	White	Pale green	Downward	Slightly curved	Normal green	Medium	Light black
S-9	Very good	Very good	Lilac	Medium green	Straight	Curved	Normal green	Medium	Brown

varied from pale green to green to dark green. Dark green leaf color was dominant among the genotypes. In contrast to that report, in the current findings, most genotypes evaluated had medium green leaves. Sultana (2001) found only green and purple vein colors among 107 hyacinth bean genotypes and leaf color intensity varied from pale green to green to dark green.

Flower color

Flower color differed among the genotypes and the majority of the genotypes produced white or purple flowers (Table 5). The results showed that the flower color was directly related to the color of seed. Most genotypes with black seed color produced lilac flowers. Four Season, Madhav and Chinese Long produced lilac flowers and black seed. Most genotypes with brown or white seeds produced white flowers. Makwanpur, LB-39, Samjhana, Tarbare and LB-27 produced white flowers and white seeds. Similarly, Trishuli, Arka Suvidha and Arka Komal with brown-colored seeds produced white flowers. Islam *et al*. (2010) reported that the genotypes of hyacinth bean showed considerable variation for most of the morpho-physical traits. They found that the color of flowers, pods and seed varied among the genotypes; flower color varied among white, violet and light pink and wing color was mostly white and violet.

Pod beak orientation

The position of the pod beak in beans is either upward, straight or downward (IBPGR, 1982). Different pod beak positions were found in different genotypes (Table 5). The pod beak was upward in Madhav, LB-39, Makwanpur and Syangja, straight in Trishuli, Myagdi, S-9, LB-27, Mallika, Arka Komal and Arka Suvidha and downward in LB-31, Four Season, Samjhana, Chinese Long, Tarbare, Mandir and Pant Anupma. The pod beak position is one of the major characters of beans used to identify a particular genotype. Most of the genotypes studied were categorized by straight or downward pod beak orientation. Islam *et al*. (2010) reported that most of the hyacinth bean genotypes had pods with a thick beak followed by long beaks and medium length beaks.

Pod curvature

Pod curvature in beans is straight, slightly curved, curved or recurved. The curvature of pods varied among genotypes (Table 5). The pod position was straight in Makwanpur, Myagdi, Syangja and Mallika, slightly curved in Four Season, Madhav, LB-39, Chinese Long, LB-31, Samjhana, Tarbare, LB-27, Arka Komal, Pant Anupma, Arka Suvidha and curved in Trishuli, S-9 and Mandir. The results revealed that the pod curvature was slightly curved in most genotypes. Islam *et al*. (2010) reported that straight, slightly curved and curved pods were observed among the hyacinth bean genotypes. Muchui *et al*. (2008) evaluated French bean genotypes and reported that most of the genotypes had straight pods and a few had slightly curved pods.

Pod appearance

This is the major character for market appeal. Bean pods were categorized on the basis of appearance as very attractive, attractive, medium/acceptable, less attractive or not attractive. Most genotypes produced attractive pods (Table 5). The pods produced by Makwanpur, Madhav and Mandir were very attractive. Four Season, Samjhana, LB-39, LB-27, Arka Komal, Arka Suvidha and Mallika produced attractive pods whereas Trishuli, Chinese Long, LB-31, S-9 and Pant Anupma produced medium or acceptable pods. Myagdi, Tarbare and Syangja produced very poor pods which were not attractive for vegetable consumers. In general, pod appearance determines the pod quality of snap beans. Important quality determining factors considered in the evaluation (low fiber content in pod walls, absence of string in suture, shape, color, curvature, length and pod diameter) are taken into account by consumers (Cajiao, 1992). Muchui *et al*. (2008) evaluated French bean genotypes and categorized them for pod appearance as extra fine, fine or bobby. They reported that most of the genotypes were in the fine category.

Pod color

This is also a major character for market appeal. Bean pods were categorized as dark green, normal green, light green or other colors. Most of the evaluated genotypes produced normal green pods (Table 5). LB-39, Syangja and Mallika produced dark green pods. Four Season, Trishuli, Chinese Long, S-9, LB-27, Pant Anupma, Arka Komal and Arka Suvidha produced normal green pods whereas Madhav, Makwanpur, Myagdi, Tarbare, Samjhana, Mandir produced light green pods. LB-31 alone produced pods with red stripes on green. The results revealed that most of the genotypes produced normal green pods. Islam *et al*. (2010) reported that out of 44 genotypes of hyacinth bean, 23 had green-colored pods, 10 had light green color, 8 were mixed in color and 3 produced red to purple pods. Sultana (2001) also reported that most of the accessions of hyacinth bean had green pod color followed by mixed colors of green and purple. Muchui *et al*. (2008) categorized French bean genotypes into different pod colors and found that most of the genotypes had green-colored pods.

Seed color

Different genotypes produced different colored seeds that were mostly white or black (Table 5). The results showed that the seed color was directly related to the color of the flowers. Most genotypes with lilac flowers produced black-colored seed. Four Season, Madhav and Chinese Long produced black seed with lilac flowers. Most genotypes with white flowers produced brown or white seeds. Makwanpur, LB-39, Samjhana, Tarbare and LB-27 produced white seeds with white flowers. Similarly, Trishuli, Arka Suvidha and Arka Komal with white flowers produced brown-colored seeds. Islam *et al*. (2010) reported that the seed color was different in hyacinth bean genotypes and observed colors were black, red purple, rusty brown, white and mixed. Stoilova *et al*. (2005) evaluated French bean genotypes and reported that they found variability in terms of seed color and shape; most of them were white but there were also brown, red, white and red, bicolor and brownish.

CONCLUSION

The agro-morphological variation observed in the genotypes shows that there is sufficient variation for selection of suitable genotypes for various production systems. The variability observed in adaptation, vegetative growth, floral and pod characters could be utilized in variety improvement programs. Four Season, Trishuli, Makwanpur, Arka Komal and Arka Suvidha, which are already in farmers' fields, could be profitably used for scaling up in target areas. Future research work should focus on the agronomic management and evaluation of genotypes across a range of environments to identify and select location- specific and widely adaptive genotypes.

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