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Earliness and developmental characteristics of snap bean (*Phaseolus vulgaris* L.) genotypes in two growing seasons, pre-winter and winter

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Abstract

The aim of present research on snap bean (*Phaseolus vulgaris*), which was carried out in the years 2014-2016, to assess the performance of nine varieties/genotypes in two growing seasons of North Indian plains at ICAR-IIVR, Varanasi, UP. In early season (pre-winter), shorter days of first pod-picking (47.5 days), higher picking period index (60.0%), stable and better pod bearing capacity (>21), smaller pod width (<0.85 cm), more pod yield (>110 q/ha), higher genotypic potential realization (92.5%) and greater responsiveness to short day length (4.0-5.5 hr) by genotype VRFBB-91 make it a unique genotype whose genetic potential could be utilized in breeding programmes to widen the genetic variability towards shorter day length, to increase the genotypic adaptability and to harness the potential of earliness in snap bean.

Keywords: Snap bean (*Phaseolus vulgaris*); earliness; picking period index (PPI); genotypic potential realization (GPR); pod yield; photoperiod.

Introduction

Snap bean (*Phaseolus vulgaris* L.), a type of common bean (dry bean, shell bean and edible podded bean) whose fresh fleshy tender pods with reduced fibre content in pod-wall, is an important legume vegetable usually used for cooking or canning. It is also known as French bean, garden bean, green bean, string bean, fresh bean or vegetable bean. As the name implies, snap bean breaks easily when the pod is bent, giving off a distinct audible snap sound. The pods (green, yellow and purple in colour) are harvested when they are rapidly growing, fleshy, tender (not tough and stringy), bright in colour, and the seeds are small and underdeveloped (Singh and Singh 2015, Singh *et al*. 2014, Singh *et al*. 2011). In India, snap bean is generally grown in the hilly parts of Maharashtra, Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Odisha, Chhatishgarh, Jharkhand, Madhya PradishTamil Nadu, Kerala, Karnataka and West Bengal; Tarai regions of Uttar Pradesh and Bihar; parts of Rajasthan, Haryana and Punjab; and all the parts of North Eastern regions (Singh et al. 2011). The hilly regions of India possess wider genetic variability.

Snap bean is a winter season vegetable in North Indian plains which bears tender pods for a narrow period i.e. mid-January to March first week because it is very sensitive to temperature and photoperiod. Northern Indian plains have problems with cold temperature stress during germination and emergence of the crop, high temperature particularly night-time, occurrence of frost, and short day length during reproductive developments which limit the pod yield of snap bean. High day-time temperature too causes pollen and ovule abortion ultimately affecting pod setting and development. High temperature also enhances stringiness of pods. In order to adapt to high temperature stress, plants employ various physiological adaptive mechanisms *viz.* earliness, dense canopies, long stay-green, high transpiration rate and reduced photosynthetic rates (Reynolds et al. 1998).

Earliness is the ability of plants to grow and develop rapidly which is determined by how rapid a state of biological and economic ripeness is attained. It has biological as well as economic significance. Biologically, early maturity provides an escape mechanism under incidence of high temperature stress and has been suggested as a good approach for crop breeding for the regions which suffers from terminal high temperature stress (Gur et al. 2010; Mondal et al. 2013); and economically, it provides premium price of product. Temporal meaning of earliness in snap bean could be defined as adaptability of genotype in the preceding growing conditions or the number of days from sowing to the appearance of the first pod. The variation in earliness can be due to an earlier switch from vegetative

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to reproductive growth or due to faster development of pods. Earliness plays a central role in genotype adaptation to current and new environments; diversifyies the cropping systems; has powerful effect on yield and yield stability; and protects the crops from various abiotic and biotic stresses. As a result, early maturity is an imperative horticultural trait for snap bean breeding. Experiencing the sensitivity of snap bean productivity to temperature and photoperiod requirement, the present study was undertaken to evaluate the performance of nine high yielding varieties/genotypes on plant growth, pod development and yield cultivated under field conditions during two growing seasons in the climes of northern Indian plains at ICAR-IIVR, Varanasi, UP.

Materials and Methods

The field experiments were carried out at the Research Farm, ICAR-IIVR, Varanasi, UP during two consecutive years i.e. 2014-15 and 2015-2016. The Farm is located at 25°10'55" N latitude and 82°52'36" E longitude with an altitude of 85 m above the mean sea level, and receives an annual rainfall of 1050-1100 mm. Mean weekly meteorological parameters such as minimum and maximum temperature (Tmin and Tmax), minimum and maximum relative humidity (RHmin and RHmax) and sunshine hour, and total weekly rainfall during the cropping period are summarized (Table 1) for better understanding and interpretation of data of seasons and genotypes. The plot size was kept as 3.2×2.5 m and seeds were sown in eight lines in each plot at a spacing of 40×5-6 cm. The experiment was laid-out in randomized block design (RBD) with three replications. The experiment comprised nine high yielding varieties and genotypes, namely Kashi Sampann, VRFBB-2, VRFBB-16, VRFBB-91, Arka Komal, Arka Suvidha, Swarnaprya, Pant Anupama and Arka Anoop; and sown during 3-6th day of October and November i.e. pre-winter (early season) and winter (main season), respectively both years. The fertilizers such as N:P_2O_5:K_2O @ 80:40:40 kg/ha were supplied by urea, single super phosphate (SSP) and muriate of potash (MOP), respectively. The half dose of N, and full dose of P_2O_5 and K_2O was applied as basal at final plot dressing; and rest half N was top dressed at flowering stage.

Harvesting period index (HPI), more specifically picking period index (PPI) for snap bean has been calculated by multiplying days from first to last picking to 100 and divided by total cropping period (days from first to last

Table 1: Mean weekly meteorological parameters at ICAR-IIVR, Varanasi, UP from September to March (2014-15 and 2015-16)

Month and date	Standard week number (ith)	Temperature (°C)			Sunshine (hr)	Relative humidity (%)		Total rainfall (mm)
		Max	Min	Mean		Max	Min	
Sept 03-09	36	34.5	26.5	30.5	7.7	84	59	17.5
Sept 10-16	37	34.1	27.3	30.7	5.2	88	68	5.5
Sept 17-27	38	34.9	27.5	31.2	6.2	89	64	14.6
Sept 24-30	39	34.8	25.3	30.0	9.0	86	51	1.1
Oct 01-07	40	34.0	24.1	29.0	7.8	82	56	0.0
Oct 08-14	41	33.6	23.2	28.4	6.9	89	56	25.4
Oct 15-21	42	32.2	21.4	26.8	7.0	87	57	12.6
Oct 22-28	43	31.5	19.8	25.7	6.7	84	52	3.1
Oct 29-Nov 04	44	29.9	18.5	24.2	5.9	88	51	14.1
Nov 05-11	45	28.7	17.9	23.3	5.9	90	42	0.0
Nov 12-18	46	29.4	15.9	22.7	5.3	75	36	0.0
Nov 19-25	47	28.2	15.1	21.7	5.3	90	38	0.0
Nov 26-Dec 02	48	28.8	14.3	21.5	5.1	82	49	0.5
Dec 03-09	49	24.9	13.5	19.2	4.8	91	53	0.3
Dec 10-16	50	22.8	11.5	17.1	3.9	95	52	1.4
Dec 17-23	51	21.0	9.4	15.2	3.8	94	47	0.0
Dec 24-31	52	20.6	7.4	14.0	4.8	91	50	0.0
Jan 01-07	1	21.1	8.1	14.6	3.6	97	65	17.8
Jan 08-14	2	21.9	9.3	15.6	4.1	97	60	0.0
Jan 15-21	3	21.2	9.4	15.3	5.1	91	76	4.3
Jan 22-28	4	22.1	9.5	15.8	5.3	92	63	5.5
Jan 29-Feb 04	5	24.5	10.9	17.7	6.9	94	49	1.3
Feb 05-11	6	24.8	11.8	18.3	5.8	88	49	0.0
Feb 12-18	7	27.6	13.1	20.4	6.2	94	46	0.0
Feb 19-25	8	30.3	15.8	23.0	7.1	86	39	0.0
Feb 26-Mar 04	9	29.0	16.8	22.9	7.3	82	53	6.3
Mar 05-11	10	30.1	16.9	23.5	8.7	86	40	0.3
Mar 12-18	11	30.3	17.2	23.7	7.1	85	55	4.8
Mar 19-25	12	32.8	18.1	25.5	9.8	77	33	0.5
Mar 26-Apr 01	13	36.1	20.8	28.5	8.3	74	36	0.0

picking*100/total cropping period). The yield contributing economic parameters such as days to first picking, PPI, number of pods per plant, single pod weight, pod length, pod width (measuring through ventral and dorsal sutures), pod weight per plant, pod yield per hectare and genotypic potential realization (GPR) as early crop (pod yield in early season*100/ pod yield in main season) were taken. Number of pods/ plant was calculated by averaging all the pods harvested from inner four rows. Single pod weight, pod length and pod width was calculated from a random sample of 60 pods from 20 plants from four rows. The mean data were analysed statistically using MS Excel. Mean values of both years for the parameters measured for the tested genotypes were compared with standard error bars with $p<0.05$ to identify homogeneity of data between both seasons and among various varieties/ genotypes.

Results and Discussion

The response of different genotypes for various traits of economic importance (days to first picking, relative picking period, number of pods/plant, single pod weight, pod length, pod width, pod weight/plant, pod yield and GPR as early crop) in both growing seasons, pre-winter and winter (Early season and main season) for two consecutive years 2014-2016 are given in Table 2. However, the trait-wise values pertaining to mean of years for early and main season are presented in various histograms (Figure 1 to Figure 9). By and large, there is significant difference for various parameters between two seasons i.e. pre-winter and winter season, but values don't differ considerably during both years.

Snap bean sown in pre-winter (early season) had shorter days to first pod-picking than in winter (main season) for all the genotypes and it was decidedly shorter for VRFBB-91, Arka Suvidha, Swarnaprya, Pant Anupma and Arka Anoop (Figure 1). Among genotypes, VRFBB-91 was found responsive to earliness and also had shortest duration (47.5 days) followed by Arka Suvidha (61.5 days) to bear pods i.e. two weeks earlier to next best genotype. This indicates a very strong reaction of VRFBB-91, being earliest and shortest in duration, to different types of growing conditions in the both years of cultivation. Inter-racial and inter-gene pool crosses have been made in Mexico to combine different drought tolerance traits and lines derived from crosses appear to have promise based on earliness, disease resistance and seed yield in the highlands (Rosales-Serna *et al.* 2002).

Moreover, the PPI was calculated to find period of

Table 2: Mean performance of various varieties/genotypes in two growing seasons, pre-winter and winter

Early season (Pre-winter)

Parameter	Days to first picking		Picking period index (PPI %)		No. of pods/ plant		Single pod weight (g)		Pod length (cm)		Pod width (cm)		Pod weight (g/ plant)		Pod yield (q/ha)	
Variety	14-15	15-16	14-15	15-16	14-15	15-16	14-15	15-16	14-15	15-16	14-15	15-16	14-15	15-16	14-15	15-16
Kashi Sampann	61.0	63.0	21.3	23.8	4.6	5.1	7.1	7.0	15.9	15.8	0.97	0.98	32.4	35.6	26.3	29.0
VRFBB-2	65.0	64.0	13.8	21.9	6.9	10.1	7.1	7.1	14.8	14.8	0.86	0.83	49.1	71.3	39.9	57.9
VRFBB-16	68.0	71.0	8.8	9.9	5.0	5.6	6.6	6.6	16.2	16.2	0.94	0.93	33.2	36.8	27.0	29.9
VRFBB-91	47.0	48.0	57.4	62.5	21.5	20.7	6.6	6.5	15.5	15.4	0.84	0.79	141.7	134.3	115.1	109.2
Arka Komal	63.0	64.0	17.5	21.9	4.5	5.0	6.8	6.8	16.2	16.3	1.17	1.16	30.8	34.0	25.0	27.6
Arka Suvidha	61.0	62.0	21.3	25.8	8.8	9.5	7.2	7.1	17.2	17.2	1.19	1.19	63.3	67.8	51.4	55.1
Swarnaprya	62.0	63.0	19.4	23.8	6.4	7.4	7.2	7.2	16.0	15.9	1.22	1.21	46.1	53.4	37.5	43.4
Pant Anupma	62.0	62.0	19.4	25.8	5.7	7.3	6.9	6.8	15.1	15.0	0.95	0.94	39.3	49.7	31.9	40.4
Arka Anoop	63.0	64.0	17.5	21.9	6.3	6.2	7.3	7.3	16.2	16.1	1.16	1.17	46.1	45.1	37.4	36.6
Mean	61.3	62.3	21.8	26.4	7.7	8.5	7.0	6.9	15.9	15.9	1.03	1.02	53.5	58.7	43.5	47.7

Main season (Winter)

Parameter	Days to first picking		Picking period index (PPI %)		No. of pods/ plant		Single pod weight (g)		Pod length (cm)		Pod width (cm)		Pod weight (g/ plant)		Pod yield (q/ha)		GPR as early crop (%)	
Variety	14-15	15-16	14-15	15-16	14-15	15-16	14-15	15-16	14-15	15-16	14-15	15-16	14-15	15-16	14-15	15-16	14-15	15-16
Kashi Sampann	68.0	67.7	35.3	36.7	26.2	25.9	7.2	7.2	16.0	15.8	0.96	0.94	187.9	186.9	152.6	151.9	17.3	18.2
VRFBB-2	71.0	69.9	29.6	33.6	28.7	28.3	7.2	7.0	15.0	14.6	0.88	0.87	206.4	198.3	167.7	161.1	23.8	30.6
VRFBB-16	77.0	75.1	19.5	25.8	24.9	25.0	6.8	6.6	16.3	15.8	0.96	0.94	168.1	166.4	136.6	135.2	19.8	21.0
VRFBB-91	59.0	57.2	55.9	65.9	22.8	23.1	6.6	6.5	15.5	15.1	0.87	0.86	151.4	149.2	123.0	121.2	93.6	92.5
Arka Komal	71.0	68.5	29.6	39.3	28.6	28.0	7.0	6.9	16.3	16.1	1.18	1.19	198.8	193.8	161.5	157.5	15.5	16.7
Arka Suvidha	70.0	69.3	31.4	34.1	29.1	28.2	7.3	7.4	17.3	17.0	1.21	1.20	211.3	208.9	171.7	169.7	29.9	31.4
Swarnaprya	72.0	70.2	27.8	34.5	26.7	26.3	7.5	7.6	16.0	15.8	1.26	1.25	200.0	199.9	162.5	162.4	23.1	24.9
Pant Anupma	71.0	69.6	29.6	35.0	24.8	25.0	7.0	6.9	15.3	15.3	0.96	0.94	173.8	172.0	141.3	139.8	22.6	25.9
Arka Anoop	71.0	74.9	29.6	16.7	30.3	30.8	7.4	7.2	16.4	16.5	1.14	1.13	223.0	220.6	181.2	179.2	20.7	20.7
Mean	70.0	69.2	32.0	35.7	26.9	26.7	7.1	7.0	16.0	15.8	1.05	1.04	191.2	188.4	155.3	153.1	29.6	31.3

GPR: genotypic potential realization

economic return available to farmers i.e. longer PPI favours the growers. The PPI estimates for various genotypes were generally higher in main season as compared to early season because of longer crop duration in main season and narrow adaptability of genotypes in early season (Figure 2). Further, a genotype VRFBB-91 showed outstanding performance having highest PPI values in both seasons which was at par in both early and main seasons i.e. 60.0 and 60.9%; nevertheless next best genotype in respective season showed only 23.6 and 36.0% PPI.

Number of pods/plant is one of the most important yield contributing factors in snap bean that ranged wider 4.6-21.5 in early season and narrow 22.8-30.8 in main season for both years (Table 2). In early season, it was highest for VRFBB-91 (21.1) followed by Arka Suvidha (9.2); while in main season, it was maximum for Arka Anoop (30.6), VRFBB-2 (28.5), Arka Suvidha (28.7) and Arka Komal (27.3) and minimum for VRFBB-91 (23.0) [Figure 3]. Wider range along with highest number of pods for VRFBB-91 in pre-winter season indicates the genotypic ability to bear more number of pods i.e. earliness trait. Further, single pod weight, another important yield contributing factor, was not significantly affected by growing conditions; but among various genotypes, it was considerably higher for Swarnaprya (7.6 g), Arka Suvidha (7.4 g) and Arka Anoop (7.2 g), and minimum 6.5 g for VRFBB-91 (Figure 4). Non-significance of pod weight in both seasons reveal that pod yield in early season doesn't contributed by pod weight.

Pod length is a desirable trait has noteworthy association especially with yield and consumers' preference. As like single pod weight, pod length was not meaningfully influenced by growing conditions that indicates that pod yield in early season doesn't contributed by pod length (Figure 5). Among different genotypes, it was substantially higher for Arka Suvidha (17.0 cm) and Arka Anoop (16.5 cm). Non-significance of pod weight in both seasons reveal that pod yield in early season doesn't contributed by pod weight. The pod width, directly associated with sieve size i.e. thinness, is also a desirable trait that have inverse relationship with consumers' preference as well as pod yield (Singh and Singh 2015). As like single pod weight and pod length, pod width was not significantly influenced by growing conditions that indicates that pod yield in early season doesn't contributed by pod width (Figure 6). Thinnest pod in early season was produced by VRFBB-91 followed by VRFBB-2 (0.82 cm), VRFBB-16 (0.85 cm), Pant Anupma (0.95 cm) and Kashi Sampann (0.98 cm), and other genotypes had pod thickness of more than 1.00 cm with maximum for Swarnaprya (1.22 cm). The pod width in snap bean ranged from 0.50-1.50 cm, and round in pod shape if width is <0.95 cm and semi-round in shape for width ranging from 1.00-1.25 cm. Round pod shape is one of the chief quality trait and main breeding objective of snap bean i.e. vegetable type French bean (Singh and Singh 2015).

Pod weight (g/plant) was significantly higher in main season crop as compare to early season crop for all the varieties/genotype except VRFBB-91, and the values ranged from 149.2-208.9 g and 32.4-138.0 g, respectively (Figure 7). In early season, pod weight was maximum for VRFBB-91 (149.2 g) followed by Arka Suvidha (65.6 g) and VRFBB-2 (60.2 g), and minimum for Arka Komal (32.4 g). Non-significance of pod weight/plant in early and main season for VRFBB-91 indicates its stable performance in both seasons. Moreover, in main season, pod weight was maximum for Arka Anoop (220.6 g) followed by Arka Suvidha (208.9 g), Swarnaprya (199.9 g), VRFBB-2 (198.3 g), Arka Komal (193.8 g), Kashi Sampann (186.9 g), Pant Anupma (172.0 g), VRFBB-16 (166.4 g) and VRFBB-91 (149.2 g).

Similar to pod weight, pod yield (q/ha) was extensively higher in the crop grown in main season as compare to early season for all the genotype excluding VRFBB-91, and the respective yield potential varied to the tune from 121.2-179.2 q/ha and 26.3-112.1 q/ha (Figure 8). In early season, pod yield potential was realized highest for VRFBB-91 (112.1 q/ha) followed by Arka Suvidha (53.3 q/ha) and VRFBB-2 (48.9 q/ha), and lowest for Arka Komal (26.3 q/ha). In main season, however, pod yield was harvested maximum for Arka Anoop (179.2 q/ha) followed by Arka Suvidha (169.7 q/ha), Swarnaprya (162.4 q/ha), VRFBB-2 (161.1 q/ha), Arka Komal (157.5 q/ha), Kashi Sampann (151.9 q/ha), Pant Anupma (1139.8 q/ha), VRFBB-16 (135.2 q/ha) and VRFBB-91 (121.2 q/ha). Non-significance of pod yield between early and main season crop of a genotype VRFBB-91 indicates its wider adaptability and stable performance which is a main criterion to breed new varieties in present impending climate change scenario.

GPR as early crop in percentage is a ratio of pod yield in early season to pod yield in main season of a genotype which was computed with the aim to find out the outstanding genotypes specifically suitable to early season. The higher the GPR-value, the greater is earliness responsiveness. The estimates of GPR as early crop (Figure 9) were highest for VRFBB-91 (92.5%) thereafter Arka Suvidha (31.4%), VRFBB-2 (30.6%), Pant Anupma (25.9%), Swarnaprya (24.9%), VRFBB-16 (21.0%), Arka Anoop (20.7%), Kashi Sampann (18.2%) and lowest for Arka Komal (16.7%). This

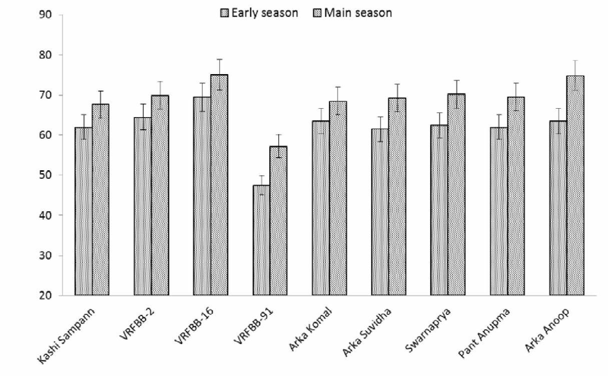

Figure 1: Response of various genotypes for days to first pod-picking in two growing seasons

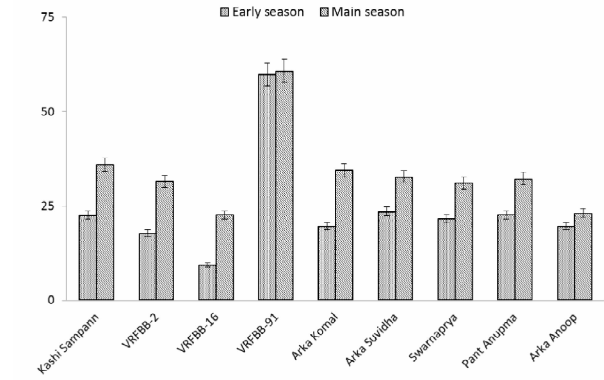

Figure 2: Response of various genotypes to picking period index (%) in two growing seasons

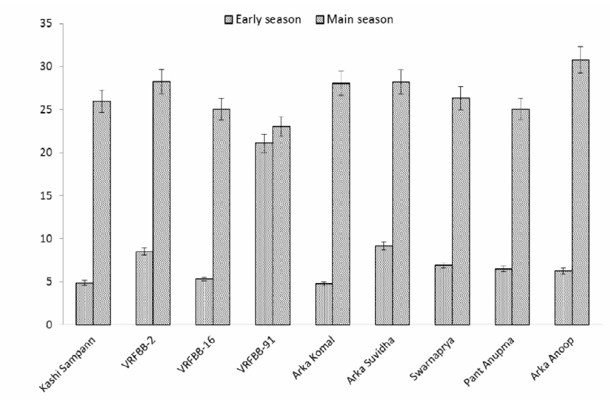

Figure 3: Response of various genotypes for number of pods/ plant in two growing seasons

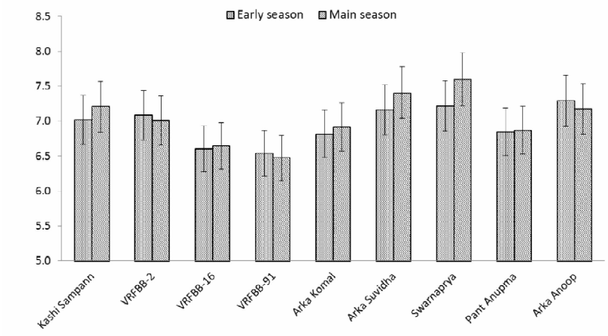

Figure 4: Response of various genotypes for single pod weight (g) in two growing seasons

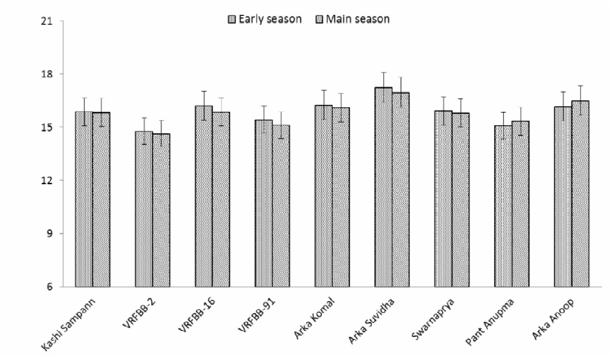

Figure 5: Response of various genotypes for pod length in two growing seasons

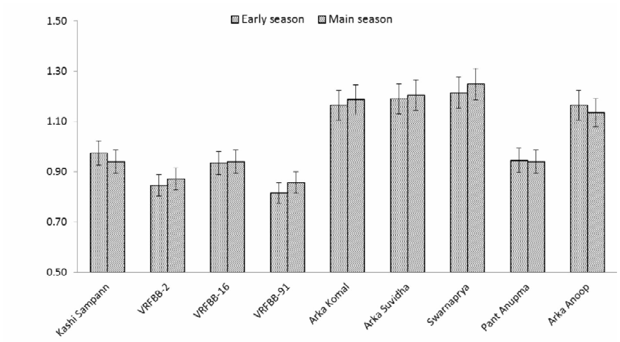

Figure 6: Response of various genotypes for pod width (cm) in two growing seasons

indicates the ability of VRFBB-91 for successful cultivation in early season.

The mean weekly meteorological parameters of ICAR-IIVR, Varanasi, UP during September to March (36th to 13th standard week) for years 2014-2016 ranged from 18.2-36.1 °C for Tmax, 7.4-27.5 °C for Tmin, 3.6-9.8 hr for sunshine hour, 74-97% for RHmax, 33-76% for RHmin and 0-25.4 mm total rainfall (Table 1). Further, during pod picking period of early season (47th to 51st standard week) and main season (3rd to 9th standard week), the meteorological values ranged from 9.4-15.9 °C for Tmin, 21.0-29.4 °C for Tmax and 3.8-5.3 hr sunshine during early season, and 9.4-16.8 °C for Tmin, 21.2-30.3 °C for Tmax and 5.1-7.3 hr sunshine during main season. This indicates that the temperatures during both seasons were around 9.5-16.5 °C for Tmin and 21.0-30.0 °C for Tmax, nevertheless sunshine exposure clearly different in both seasons i.e. around 4.0-5.5 hr

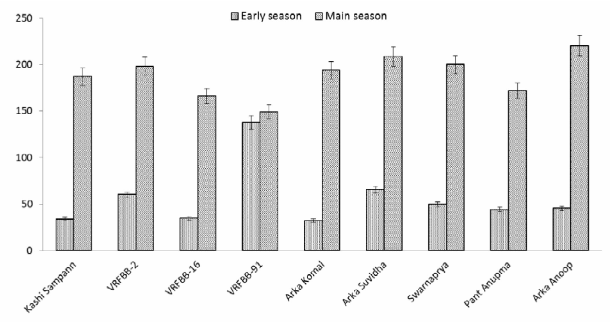

Figure 7: Response of various genotypes for pod weight (g/plant) in two growing seasons

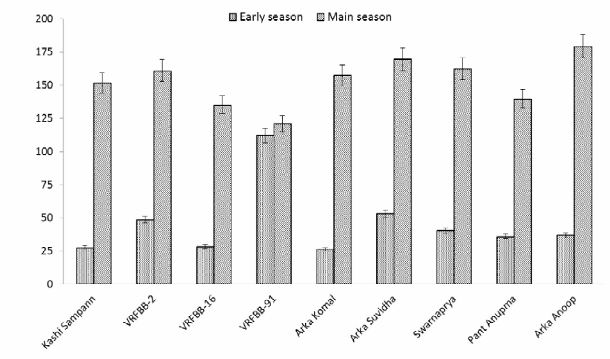

Figure 8: Response of various genotypes for pod yield (q/ha) in two growing seasons

and 5.0-7.5 hr respectively during early and main season. By critically analyzing the meteorological data and response of all genotype in both seasons, it is clear that genotype VRFBB-91 is also responsive to short day length of early season. Most wild *P. vulgaris* genotypes are photoperiod sensitive; the trait is more accentuated in late maturity accessions (Acosta-Gallegos *et al.* 2007).

In conclusion, shorter days of first pod-picking, higher picking period index, better and stable pod bearing capacity, smaller pod width, higher genotypic potential realization and greater responsiveness to short day length in pre-winter (early season) by a genotype VRFBB-91 make it a unique genotype whose genetic potential could be utilized in breeding programmes to widen the genetic variability towards shorter day length, to increase the genotypic adaptability and to harness the potential of earliness in snap bean.

सारांश

स्नैपबीन (फैजियोलस बल्गेरिस) के वर्तमान अध्ययन वर्ष 2014–2016 दौरान 9 प्रजातियों/जीन प्ररूपों को सम्लित कर उत्तर भारत के मैदानी भाग के दो मौसमों में किया गया। अगेती मौसम (सर्दी पूर्व) फल तुड़ाई के लिए छोटा दिनमान (47.5 दिन), अधिकतम तुड़ाई समय गुणांक (60 प्रतिशत), स्थिर तथा उत्कृष्ट फली धारण क्षमता (>21), फली की कम चौड़ाई, (<0.85 सेन्टी मीटर), अधिक फली उपज (>110 कुन्तल/हेक्टेयर) अधिकतम प्रभेद क्षमता प्राप्ति

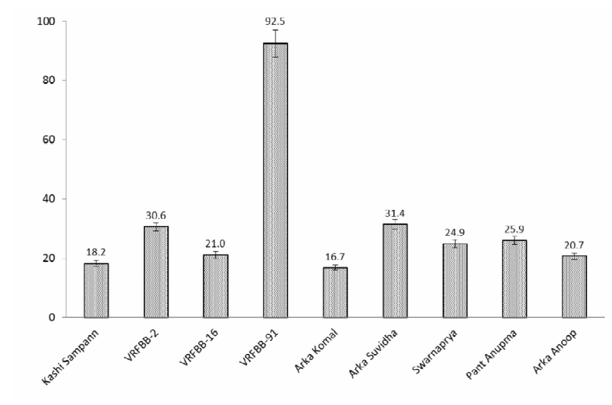

Figure 9: Response of various genotypes for genotypic potential realization (GPR) as early crop

(92.5 प्रतिशत) तथा कम दिनमान लम्बाई के प्रति उत्तरदायी (4.0–5.5 घण्टे) प्रभेद वी.आर.एफ.बी.बी.–91 को एक उत्कृष्ट प्रभेद बनाता है। जिसकी अनुवांशिक क्षमता को प्रजनन कार्यक्रम में शामिल कर कम दिनमान के प्रति अधिक अनुवांशिक विविधता, अधिक अनुवांशिक अनुकूलन क्षमता एवं अगेतीपन क्षमता का दोहन हेतु किया जा सकता है।

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