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Development of new promising varieties of faba bean through traditional pedigree method for commercial cultivation in plain zone of India

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A long term experiment was carried out in MAP Section (GPB), CCS HAU, Hisar from 2005-2019, beginning with evaluation of germplasm identification of superior parental lines, hybridization and selections as per the traditional pedigree method for development of high yielding varieties of Faba bean. In the present investigation, a number of germplasm lines were screened for seed yield and other related traits including a national check Vikrant during 2004-05. As a result, ten elite genotypes were identified. These selected genotypes were inter-mated to produce a series of F_1 hybrids followed by raising of F_2 to F_6 progenies for selection of superior recombinants during 2007-08 to 2011-12. This rigorous evaluation and selection process resulted in identification of 20 superior transgressive segregant progenies which could be used as new entries. During 2012-2013, these superior entries were evaluated at Hisar center against Vikrant and were found to be promising. Consequently, these 20 genotypes were evaluated in Small Scale Trial during 2013-14, Large Scale Trial during 2014-15 and Final Yield Trial during 2015-16. On the basis of the above evaluations, five genotypes i.e., HB12-8 (47.77 q/ha), HB12-42 (47.70 q/ha), HB12-15 (46.70 q/ha), HB12-34 (46.14 q/ha) and HB12-37 (45.31 q/ha) were found to be promising. These were further evaluated in multi-location trials for seed yield, quality and resistance against insect pest and disease in IVT and AVT during 2016-17 and 2017-18, respectively. Out of these, HB 12-8 and HB12-34 exhibited yield superiority over national checks, Vikrant and HFB-1 and free from insect pest and disease as well as low vicine-convicine and high protein content. Therefore, HB 12-8 and HB 12-34 may be recommended for commercial cultivation in plain zone at national level.

Keywords: Elite genotypes, Faba bean, Hybridization, Pedigree method, Seed yield

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India supports nearly 16.8% of total human population and 20% of world's cattle with about 2.3% of the world's geographical area. India is one of the leading countries in rearing cattle and buffaloes for dairy products. The total contribution of livestock sector is approximately 32% of the total agricultural output. This accounts for around 22% of the total Gross Domestic Product in India[1]. To achieve the anticipated level of livestock production, deficiency in feed as well as fodder has been recognized as one of the major hurdles[1]. Faba bean (*Vicia faba* L.) is a prospective legume fodder crop. Although, it belongs to the family Fabaceae; it is an often cross-pollinated crop. The cross-pollination generally depends on the genotype, row spacing, environment and number and frequency of visiting insects during flowering[2]. It is mainly a winter season (*Rabi* season) crop and performs well under moist and cool environments. It

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Abbreviations: MAP, Medicinal aromatic and potential crops; AICRN, All India Coordinated Research Network; PDI value, digestible protein in the intestine; SST, Small Scale Trial; LST, Large Scale Trial; FYT, Final Yield Trial; IVT, Initial Varietal Trial; AVT, Advance Varietal Trial; AMEn, nitrogen corrected apparent metabolisable energy; CP, crude protein; VC, vicine-convicine fixes atmospheric N_2 in the soil due to the presence of *Rhizobium* bacteria in its root nodules and minimises the use of chemical fertilizers and economises the cost of cultivation of the following crops[3]. Therefore, it can also be used in crop rotation.

In developed countries, faba bean is mainly utilised as animal feed, however it is also used as food for humans in developing countries[4]. According to Lapierre and coworkers 2003[5], the substitution of all the soybean meal of cow diets by mixing one-third rapeseed meal and two-thirds of laminated faba bean in the feed for dairy cows does not change the feed intake, the milk production (higher than 30 kg/cow/day) or the milk nutritional quality. Similar results were reported by Brunschwig and Lamy 2002[6] on feeding of cows on 30% of crushed faba bean. The replacement of soybean with faba bean in lamb diet does not reduce the consumption as well as growth of animal. Nevertheless, only crushed faba bean is used after mixing with the cereals[7]. The N_2 fraction of faba bean seed is easily digestible and readily soluble in rumen[8]. A finer grinding of faba bean seeds leads to higher N_2 degradability which results in a lesser value of digestible protein (PDI)[9]. The other methods such as extrusion may be used to protect nitrogen from degrading in the rumen[10]. Due to high starch content of the seeds, the faba bean seeds energy values for ruminants are high and similar to that of cereals[9]. The higher starch content is also responsible for beneficial effects of pelleting as in other legumes such as field pea[11].The young chicks fed on pellets made of faba bean seeds show a positive significant effect on the AMEn value[12]. As compared to the unpelleted faba bean, the AMEn value was 12% higher, *i.e.*, 1.23 MJ/kg DM, for the pelleted faba bean[13]. Similarly, the seeds of faba bean containing low tannin and vicine-convicine has additive positive significant effect on AMEn values in young broilers[14,15].

Along with its different uses, faba bean also has excellent seed production potential, and its seed is rich in required nutritional quality. Faba bean has wide adaptability to thrive over a range of soil and environmental circumstances, thus, it is fit for sustainable cultivation and it has gained more consideration in the present era at a global level. However, its full potential through hybrid breeding and through transgressive segregants is not yet explored mainly due to its distinctive pollination behaviour and variation in seed production performance[4]. Faba bean bears protein-rich seeds and it is highly adapted to European climatic conditions and chiefly utilised as feed and food. Even though the seed is high in nutritional components, the prevailing genetic variability for seed configuration presents opportunities for genetic enhancement of this trait through breeding[16]. ICARDA also developed some new varieties of faba bean for cultivation[17]. In 2010, Kopke and Nemecek reviewed the utilisation of faba bean seeds in animal as well as human nutrition[18]. They promoted faba bean as a possible crop of numerous positive environmental services in production and animal husbandry. Therefore, by considering the above facts, the prominent entries were exploited in crossing program to evolve new cultivars by pedigree breeding scheme.

Methodology

Germplasm evaluation

In the present investigation, 155 germplasm lines of faba bean (*Vicia faba* L.) were screened including national check Vikrant under AICRN on Potential Crops project in augmented block design at the Research Area of Medicinal, Aromatic Plants and Potential Crops Section (GPB), CCS Haryana Agricultural University, Hisar situated 215.2 m above the mean sea level at 29° 10’ N latitude and 75° 46’ E longitude. The soil of the experimental site was sandy loam (Typic Ustochrepts) in texture, low in organic carbon (0.46%), low in available nitrogen (191 kg/ha), medium in phosphorus (14 kg/ha) and high in available potassium (340 kg/ha). During *Rabi* 2004-05, in germplasm screening, the top 10 elite genotypes *viz*., EC117755, EC117799, EC248710, EC329675, HB123, HB180, HB430, HB204, HB 430, HB 502, HB 503 and check variety, Vikrant were identified superior in seed yield and its attributes along with resistance to abiotic as well as biotic stresses (Table 1).

Hybridisation

These elite genotypes were utilised in crossing programmes. Hybridisation work was done during *Rabi* 2005-06 by using the hand emasculation and pollination technique with the help of forceps. For emasculation, premature flower buds likely to open the next day were selected and immature anther were removed before bursting from the flower without injuring the female part of the flower. After emasculation, the flowers were covered with parchment paper bag and next morning pollination was done with the pollen collected from male parent and bagging and tagging was done. The crosses were

Table 1 — Yield performance and economic traits of selected parental lines

Sr. No.	Parents	Distinct identified characters	Seed yield (g/plant)
1.	EC 117755	High seed yield, highly tolerant to insect pest	41.6
2.	EC 117799	Medium plant height, higher number of pods per plant	41.2
3.	EC 248710	Short to medium plant height, more number of pods per plant	40.5
4.	EC 329675	Tall plant with more number of pods per plant	40.0
5.	HB 123	Creamy white flower, light green seeds, highly tolerant to insect pest	32.5
6.	HB 180	Higher seed yield, green pod yield, test weight, protein. Moderately tolerant to shattering	30.0
7.	HB 204	Higher test weight, resistance to insect pest, disease and shattering	32.7
8.	HB 430	Higher seed yield, medium maturity, resistance to disease	37.4
9.	HB 502	Medium plant height, higher yielder, slightly tolerant to salinity.	36.5
10.	HB 503	Medium plant height, higher yielder and early maturing	39.7
11	Vikrant	Only release variety in the country, Tolerant to insect pest, disease and lodging and also good seed and pod yielder	35.0
		Mean of selected genotypes	37.0
		Overall mean of germplasm (155 genotypes)	24.6
		Range	8.7 – 41.6

Table 2 — Pedigree details of promising transgressive segregants utilised in the study

Sr. No.	New Genotypes	Pedigree details	Sr. No.	New Genotypes	Pedigree details
1.	HB12-1	EC248710 x HB 123	11.	HB12-28	EC248710 x HB 204
2.	HB12-5	EC248710 x HB 430	12.	HB12-29	HB180 x HB 123
3.	HB12-8	EC248710 x HB 503	13.	HB12-30	Vikrant x HB 123
4.	HB12-9	Vikrant x EC248710	14.	HB12-31	EC329695 x Vikrant
5.	HB12-11	Vikrant x EC117799	15.	HB12-34	EC117755 x HB 430
6.	HB12-12	EC248710 x HB 180	16.	HB12-36	EC117799 x HB 204
7.	HB12-13	EC248710 x HB 502	17.	HB12-37	HB204 x HB123
8.	HB12-14	EC248710 x EC117755	18.	HB12-38	EC117755 x HB 180
9.	HB12-15	Vikrant x EC117755	19.	HB12-39	EC117755 x HB 204
10.	HB12-26	EC 248710 x Vikrant	20	HB12-42	EC117799 x HB 204

made in all possible combinations. But, due to dropping of crossed flowers of female parent, success remained confined only to 20 F_1 hybrids. The details of successful F_1 hybrids with their pedigree are presented in Table 2. All the 20 F_1 hybrids were grown under protected condition during 2006-07 and F_2 progenies were harvested separately (Fig. 1).

Generation advancement and selection of transgressive segregants

During *Rabi* 2007-08, F_2 progenies of all the F_1crosses were raised and single superior plants identified & selected and self-pollinated by using muslin cloth bags and harvested separately avoiding any kind of genetic and mechanical admixture. According to traditional pedigree breeding method, F_3 to F_6 generations were evaluated to identify the superior transgressive segregants through the process of critical selection or rejection during *Rabi* 2008-09 to 2011-12. At last, in F_6, superior progenies of 20 crosses (Table 1) were bulked and evaluated in PRT for yield performance against Vikrant during *Rabi* 2012-13.

Station trials

In station trials, the 20 promising genotypes, along with check variety Vikrant were also evaluated at Hisar in different station trials *i.e.*, SST, LST and FYT during 2013-14, 2014-15 & 2015-16, respectively. The trials were planted in plots of 6.0 x 0.6 m^2 with plant spacing 30 x 10 cm^2 in RBD with three replications. Each genotype was dibbled in two rows of six meter length. All the suggested cultural practices were followed to achieve best results. The data on five competitive selected plants was noted for days to maturity, plant height (cm), branches/plant, number of pods/plant, pod length (cm), seeds/pod, 100 seed weight (g) and seed yield (kg/ha). Statistical analysis was carried out as per standard procedure[19].

Coordinated trials

The identified superior genotypes *viz.*, HB12-8, HB12-15, HB12-34, HB-12-37, HB-12-42 with check varieties, Vikrant and HFB-1 were assessed during 2016-17, 2017-18 & 2018-19, respectively. In multi-location trials at seven locations *i.e.*, Ambikapur, Delhi, Faizabad, Faridkot, Hisar, Ludhiana and

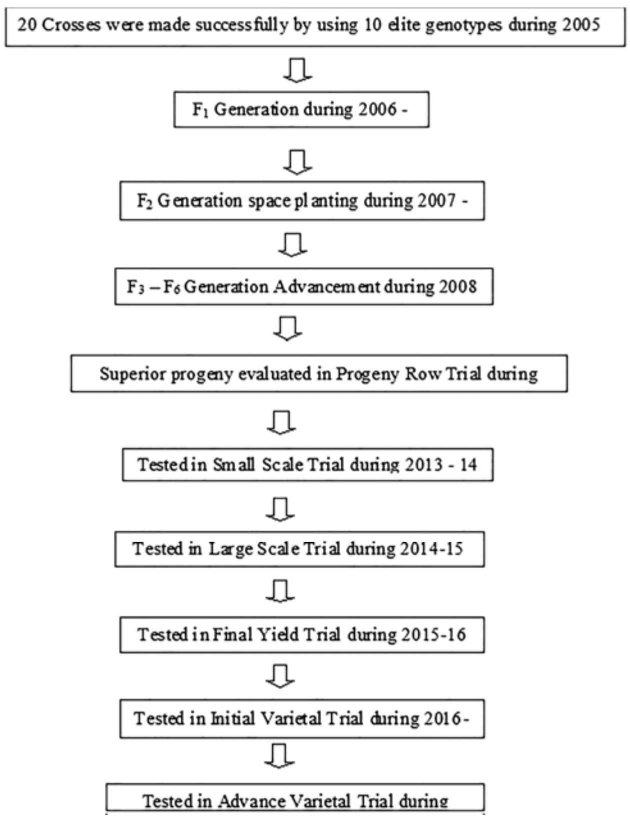

Fig. 1 — Flow Chart from crossing to evaluation in the coordinated trials

Ranchi to recognise the maximum seed-producing varieties for the plain zones of the country. The trials were planted in RBD having three replications. The plot dimensions were kept 3.0 x 6.0 m^2 with plant spacing 30 x 10 cm^2 apart. Each entry was sown in two rows of six meter row length. All the suggested cultural practices were followed to raise a good healthy crop. The data was recorded on five competitive plants for days to maturity, plant height (cm), branches/plant, number of pods/plant, pod length (cm), seeds/pod, 100 seed weight (g) and seed yield (q/ha).

Quality test

The seeds of the promising entries were evaluated for quality traits *i.e.*, crude protein[20] (%), vicine-convicine[21] (%) and phenol[20] (%) in phytochemistry laboratory at Hisar center as per standard procedures[20,21].

Screening for disease resistance

Screening of faba bean promising genotypes for disease resistance was carried out at Hisar Centre. During *Rabi* 2017-18, Alternaria leaf blight percentage severity) was assessed according to Behairy *et al.*[22] and root rot disease percentage incidence) following the procedure developed by Habtegebriel and Boydom[23] under natural field conditions. The genotypes were classified as resistant (R), moderately resistant (MR), moderately susceptible (MS) and susceptible (S).

Statistical analysis

Augmented block design was used in germplasm evaluation, however, randomized block design was used in station as well as coordinated trials for analysis. Statistical analysis was done using per standard procedure[19].

Results

Germplasm evaluation

The success of any breeding programme depends on the selection of superior parents possessing several agronomic characters so that the desirable upgradation could be gained in the earliest possible time. In the present investigation, a number of faba bean genotypes were evaluated for seed yield and its attributes against national check Vikrant and top 10 genotypes were identified, which were superior in yield and its attributes as well as tolerant to abiotic and biotic stresses. The performance detail of top 10 selected genotypes and one check variety is given in Table 1.

Hybridisation

In the present study, the identified superior genotypes/parental lines were utilised to carry out crosses through hand emasculation technique during 2005-06. The hybridisation work was carried out in all 90 possible cross combinations to obtain the desirable transgressive segregants. But, due to dropping of crossed female flowers, success remained confined to 20 F_1 hybrids. The details of successful F_1 hybrids with their pedigree are presented in Table 2. The genotype EC 248710 with more number of pods per plant, with short-medium height and Vikrant having tolerance to insect pests, disease, lodging and also good seed and pod yielder are better combiners than the others. Similarly, the genotype EC 117755 with high seed, highly tolerant to insect pest was also found to be good combiner as compared to the other genotypes. The F_1 seeds were limited to 5-12 seeds only. The F_2 population size varied from 800 to 1500 which was restricted to 600-700 in the later segregating generations as the number of families increased up to 42.

Generation advancement and selection of transgressive segregants

During *Rabi* 2006-07, the seeds of all the 20 F_1 hybrids were planted in single row and self-pollinated to get F_2 seeds. In next year (2007-08), space planting of F_2 population was done of each individual cross in separate plots and self seeds were harvested from each plant of each cross separately. Later on, evaluation of progenies continued from F_3 to F_6 generations during 2008-09 to 2011-12. These segregating generation populations had hundreds of plants of each cross which were evaluated on visual basis and desirable superior plants selected, because, it was not possible to measure the characteristics of all the plants. Therefore, selection was carried out on quick visual evaluation of all the plants on the basis of easily observable characters like number of pods/plant, days to maturity, plant height, leaf size and shape, number of branches/plant, and disease resistance. During advancement, the progenies were evaluated for seed yield performance and other desirable agronomic traits. The weak progenies as well as plants were discarded and only superior high seed yielding progenies were advanced till the stabilisation of plant population. After that, only the stabilised plant progenies were bulked and evaluated in PRT for yield and its contributing traits during *Rabi* 2012-13 (Fig. 2). The results revealed that the genotype HB12-8 was top yielder with seed yield 61.20 g/plant followed by HB12-34 (57.80 g/plant), HB12-42 (55.5 g/plant), HB12-37 (54.60 g/plant), HB12-15 (54.60 g /plant), HB12-38 (54.10 g/plant), HB12-13 (53.10 g/plant), HB12-36 (51.80 g/plant), HB12-1 (50.00 g/plant), HB12-5 (50.00 g/plant), Vikrant (50.00 g/plant), HB12-9 (47.80 g/plant), HB12-11 (47.30 g/plant), HB12-31 (45.80 g/plant HB12-14 (40.7 g/plant), HB12-12 (40.6 g/plant), HB12-30 (36.9 g/plant), HB12-28 (33.8 g/plant), HB12-39 (31.6 g/plant), HB12-29 (28.6 g/plant), HB12-26 (28.1 g/plant). Only 10 genotypes were found superior or comparable in seed yield performance.

Performance in station trials

In different station trials, all the genotypes were evaluated for 3 years for yield performance (Tables 3, 4 & 5 and Fig. 3). During *Rabi* 2013-14, all the

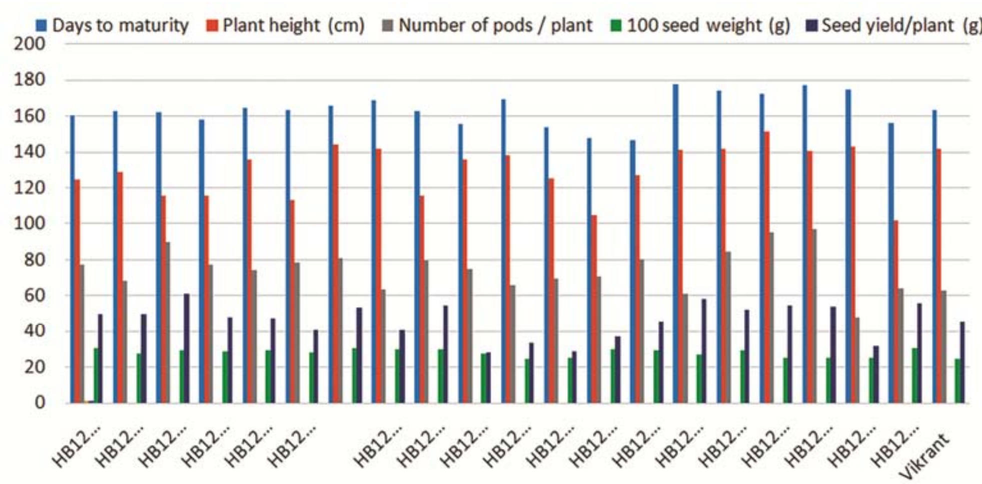

Fig. 2 — Performance of faba bean promising transgressive segregants at Hisar during 2012-13

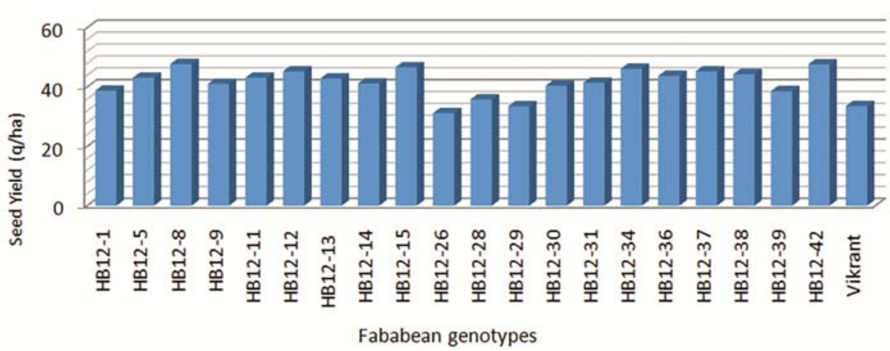

Fig. 3 — Mean seed yield (q/ha) over the years in station trials at Hisar

20 newly developed entries of faba bean were tested in a small-scale trial and 18 of them produced significantly higher yield than check Vikrant (33.33 q/ha), highest seed yield was produced by HB12-8 (48.75 q/ha) followed by HB12-15 (48.61 q/ha), HB12-42 (48.09 q/ha), HB12-34 (46.53 q/ha). During *Rabi* 2014-15, all the genotypes were again evaluated in a large-scale trial and 17 of them produced significantly higher yield than check Vikrant (33.50 q/ha) and HB12-42 produced highest seed yield (47.51 g/ha) followed by HB12-8 (47.27 q/ha), HB12-34 (46.61 q/ha), HB12-15(46.39 q/ha) and the minimum was HB12-26 (30.28 q/ha). During *Rabi* 2015-16, an experiment was planted as final yield trial (FYT) and 16 of them produced significantly higher yield than check Vikrant (34.00 q/ha). The genotype HB12-42 exhibited maximum seed yield (47.50 q/ha) followed by HB12-8 (47.28 q/ha), HB12-12 (46.11 q/ha), HB12-37 (45.56 q/ha), HB12-34 (45.28 q/ha), with a minimum of HB12-26 (31.11 q/ha). Based on the average of three years results of station trials, (Supplementary Information, Table 1 - 3) only the top performing five genotypes *viz*., HB12-8 (47.77 q/ha), HB12-42 (47.70 q/ha), HB12-15 (46.70 q/ha), HB12-34 (46.14 q/ha) and HB12-37 (45.31 q/ha) were submitted for further testing their seed yield performance at multilocation trials under AICRN (PC).

Performance in coordinated trials

The newly developed and identified as the best performing five genotypes *viz*., HB12-8, HB12-42, HB12-15, HB12-34 and HB12-37 (Fig. 4) along with checks (HFB-1 and Vikrant) were evaluated in coordinated trials at seven locations *i.e*., Ambikapur, Delhi, Ayodhaya, Faridkot, Hisar, Ludhiana & Ranchi in IVT during 2016-17 and AVT during 2017-18. During this period, seed yield and its contributing traits, quality parameters and reaction against insect pest and diseases were recorded.

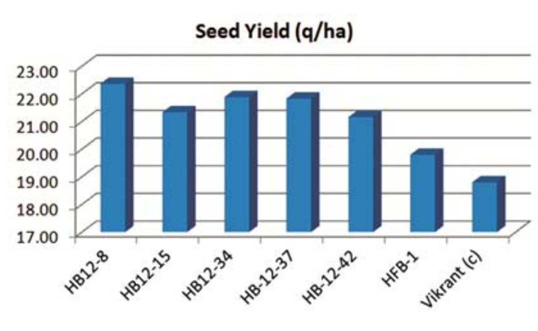

Fig. 4 — Mean seed yield (q/ha) over the years in Coordinated trials

Seed yield performance

The results of the present investigation (Table 3) revealed that the yield performance of various genotypes varied over the years as well as locations due to variation in soil and climatic conditions as well as irrigation and fertilizer management. During 2016-17, the average seed yield over the locations revealed that the genotype HB-12-37 had maximum yield of 24.62 q/ha followed by HB12-8 (23.50 q/ha), HB12-34 (22.42 q/ha), HB-12-42 (22.81 q/ha), Vikrant (c) (22.08 q/ha), HFB-1 (21.97 q/ha), HB12-15 (21.34 q/ha) in plain zone at national level. Likewise, during 2017-18, the average seed yield over the locations revealed that the genotype HB12-34 was recorded maximum yield of 21.35 q/ha followed by HB12-8 (21.24 q/ha), HB-12-42 (19.51 q/ha), HB-12-37 (19.04 q/ha), HFB-1 (17.63 q/ha) and Vikrant (c) (15.53 q/ha) in plain zone at national level.

The Fig. 4, on the basis of 2 years data (2016-17 & 2017-18) depicted that the average seed yield of HB12-8 was found maximum (22.37 q/ha) and followed by HB12-34(21.89 q/ha), HB12-37(21.83 q/ha), HB12-15 (21.34 q/ha) and HB-12-42 (22.16 q/ha), against national check Vikrant (18.81) and HFB-1 (19.80). The genotype HB12-8 exhibited 12.98% and 18.96% and the genotype, HB12-34 exhibited 10.56% and 16.37% yield superiority over national checks, HFB-1 and Vikrant, respectively in plain zone at national level. The pattern of genotypic response of faba bean genotypes was not similar in all the environments due to variation in date of sowing, soil fertility and agro-climatic conditions. Moreover, seed yield is governed by polygenes which are directly influenced by crop environmental conditions like soil moisture, fertility and temperature during the plant growth and chiefly during pod filling.

Quality parameters

On the basis of mean, the Table 4 on quality parameters revealed that the genotypes HB12-42 had highest protein content (26.58%) followed by HB12-15 (26.43%), HB12-34 (26.13%), HFB-1 (25.46%), Vikrant (25.41%), HB12-8 (25.23%) and HB12-37 (25.12%). The genotypes HB12-8 (0.70%) had the lowest vicine-convicine content followed by HB12-37 (0.72%), HB12-34 (0.78%), Vikrant (0.83%), HB12-42 (0.85%), HFB-1 (0.86%), and HB12-15 (0.94%). The genotypes HB12-37 (0.22%) had the lowest phenol content followed by Vikrant (0.23%), HB12-42 (0.24%), HB12-8 (0.24%), HFB-1 (0.24%), HB12-34 (0.25%) and HB12-15 (0.28%).

Table 3 — Seed yield performance of newly developed elite genotypes in coordinated trials

Sr. no.	Genotypes	Seed Yield performance (q/ha)							
		Ambikapur	Delhi	Ayodhaya	Faridkot	Hisar,	Ludhiana	Ranchi	Mean
IVT *Rabi* 2016-17									
1.	HB12-8	18.07	9.44	24.67	26.48	45.66	20.93	19.28	23.50
2.	HB12-15	17.26	10.12	17.67	26.91	39.93	16.90	20.58	21.34
3.	HB12-34	19.25	10.49	18.63	29.95	40.63	15.51	22.45	22.42
4.	HB-12-37	17.60	9.85	26.17	32.55	45.14	20.37	20.65	24.62
5.	HB-12-42	18.84	9.78	19.63	26.48	46.11	16.90	21.90	22.81
6	HFB-1(c)	16.04	6.76	26.50	27.13	37.88	19.91	19.58	21.97
7	Vikrant (c)	16.93	8.02	27.50	29.08	34.34	19.44	19.25	22.08
	Mean	18.66	9.34	25.74	28.37	37.50	18.89	20.85	22.76
	CD (0.05)	0.95	3.11	3.34	7.01	2.32	2.96	1.31	-
	CV (%)	6.26	14.48	18.44	8.05	10.77	11.28	6.19	-
AVT *Rabi* 2017-18									
1.	HB12-8	8.21	13.15	25.79	-	40.84	19.44	20.00	
2.	HB12-15	-	-	-	-	-	-	-	
3.	HB12-34	8.82	8.80	24.63	-	43.16	19.27	23.43	
4.	HB-12-37	7.17	6.33	24.49	-	38.59	17.71	19.97	
5.	HB-12-42	7.43	7.38	24.12	-	43.96	13.19	20.97	
6.	HFB-1(c)	6.44	11.62	21.62	-	31.68	15.03	19.40	
7.	Vikrant (c)	6.55	6.51	21.30	-	29.83	15.10	13.90	
	Mean	7.53	8.81	25.00	-	37.09	15.10	19.82	
	CD (0.05)	1.78	2.67	4.15	-	3.09	1.69	1.20	-
	CV (%)	12.56	31.58	7.59		15.66	15.40	16.02	-

Source: Progress Report of AICRN on Potential Crops 2016-17 & 2017-18)

Table 4 — Quality parameters of fababeangenotypes tested in IVT & AVT

Sr. No.	Genotypes	Protein (%)			Vicine- convicine (%)			Phenol (%)		
		2016-17	2018-19	Mean	2016-17	2018-19	Mean	2016-17	2018-19	Mean
1	HB12-8	24.17	26.29	25.23	0.77	0.62	0.70	0.25	0.23	0.24
2	HB12-15	26.43	-	26.43	0.94	-	0.94	0.28	-	0.28
3	HB12-34	24.83	27.42	26.13	0.81	0.75	0.78	0.26	0.23	0.25
4	HB12-37	24.43	25.81	25.12	0.75	0.68	0.72	0.23	0.21	0.22
5	HB12-42	25.20	27.96	26.58	0.80	0.89	0.85	0.26	0.21	0.24
6	Vikrant(c)	25.00	25.82	25.41	0.80	0.85	0.83	0.26	0.20	0.23
7	HFB-1(c)	25.57	25.35	25.46	0.85	0.87	0.86	0.25	0.22	0.24
	Mean	25.09	26.44	25.77	0.82	0.78	0.80	0.26	0.22	0.24
	Range	24.17 – 26.77	25.35 - 27.96	25.12-26.43	0.75 – 0.94	0.62 - 0.89	0.70-0.86	0.23 – 0.28	0.20- 0.23	0.22-0.28
	CD (0.05)	0.72			0.04			0.02		
	CV (%)	3.00			7.66			5.91		

Screening for disease resistance

Screening of faba bean entries for disease resistance against root rot and alternaria leaf blight disease revealed that, only HB 12-34 entry and HFB-1 (check) exhibited multiple resistance against both the diseases. In addition to this, HB 12-42 was moderately susceptible against alternaria leaf blight and moderately resistant to root rot disease (Table 5). The entry HB12-15 was found moderately resistant to root rot and moderately susceptible to alternaria blight disease. HB12-8 and HB12-37 were found moderately resistant to alternaria blight.

Discussion

In the present investigation, a number of faba bean genotypes were evaluated for seed yield and their attributes and top 10 genotypes were identified for seed yield and their attributes as well as resistance to abiotic and biotic stresses. Likewise, the entries were also tested for seed yield and other related characters by Arya *et al.* in 2019[25], 2020[26] and Raiger *et al.*[27] also evaluated the germplasm of faba bean and reported similar findings. In the present study, hybridisation work among the identified superior genotypes/parents (EC117755, EC117799,

Table 5 — Screening of faba bean in AVT (2017-18) against Alternaria leaf blight and root rot disease

Sr. No.	Genotype	Alternaria blight (% severity)	Disease reaction	Root rot incidence (%)	Disease reaction
1	HB 12-8	14.20	MR	22.00	S
2	HB 12-15	27.20	MS	13.40	MR
3	HB 12- 34	8.25	R	4.25	R
4	HB 12-37	12.50	MR	23.00	S
5	HB 12-42	28.75	MS	12.25	MR
6	Vikrant (c)	21.40	MS	14.30	MR
7	HFB-1(c)	6.40	R	4.20	R

EC248710,EC329675, HB123, HB180, HB430, HB204, HB 430, HB 502, HB 503 & Vikrant) was carried out in order to find elite genotypes. Similarly, the hybridisation work was also carried out by Bishnoi *et al*. in 2015[4]. Arya *et al.*[24] also carried out hybridisation for assimilating higher seed yield and resistance to biotic and abiotic stress, among the identified superior genotypes/parents (HB180, HB123, EC329675, EC47755, HB430, HB204, EC248710, PRT12, HB85 and Vikrant).

The newly developed genotypes having potential for high seed production were evaluated in station trials (Tables 3, 4 & 5). Based on the average of 3 years results of station trials, only the top performing five genotypes i.e., HB12-8 (47.77 q/ha), HB12-42 (47.70 q/ha), HB12-15 (46.70 q/ha), HB12-34 (46.14 q/ha) and HB12-37 (45. 31 q/ha) were further tested for adaptability over a broad range of climatic conditions and their seed yield at multiple locations under AICRN PC (Table 3). Likewise, faba bean newly developed entries were evaluated earlier in station trial by Arya in 2018[3].

The quality parameters study revealed that the genotype HB12-42 had high protein content (26.58%) followed by HB12-15 (26.43%) and HB12-34 (26.13%). The genotype HB12-8 (0.70%) had lowest vicine-convicine content followed by HB12-37 (0.72%) and HB12-34 (0.78%). The seed of faba bean (HB12-34) had high nutritional quality and was low in anti-nutritional factors. Though the quality factors are also governed by the genetic makeup of genotypes, these are also subject to ecological factors and management practices[28,29]. High protein content and low content of vicine-convicine makes HB 12-34 and HB 12-8 genotypes suitable to use as feed for animals. Further, the results on disease showed that HB 12-34 and HFB-1 have multiple resistances towards both diseases. The resistance against the biotic stress is a highly required characteristic for a cultivar. Therefore, HB-12-34 may be suggested for crop cultivation in plain zone at national level. Likewise, HFB-1 was also developed and evaluated in multilocation trials and released for commercial cultivation[30,31].

Similarly, Arya *et al.*[24] developed transgressivesegregants of faba bean namely HB11-12, HB11-15 and HB11-32, which are high yielding genotypes. Subsequently, these were further tested in diverse agroecological conditions prevailing at various sites for seed yield, quality and resistance against insect pest and disease. Based on mean seed yield over all the sites, HB11-12 revealed 14.95% seed yield superiority. In addition to this, no disease and insect pests were noticed in HB 11-12. Also, Dahiya *et al.*[32] reported that the genotypes, HB 15-41 and HB 15-21 were observed to be resistant against alternaria leaf blight. Contrasting to this, HB 15-55 was moderately resistant to root rot disease and HB 15-51 was found resistant. Thereafter, HB11-12 was recommended for commercial cultivation in the name of HFB-2 for plain zones of country. This genotype was developed by crossing EC117755 and HB180 genotypes of faba bean.

Conclusion

The new genotypes HB 12-8 and HB 12-34 of faba bean developed as a result of transgressive segregation of cross EC 248710 x HB 503 and EC 117755 x HB 430, respectively, were evaluated over the years at multiple locations and were seen to be promising in performance and other agronomic characters, nutritional (protein content) and anti-nutritional content (vicine-convicine) and resistance to major disease, like alternaria leaf blight and root rot. HB 12-8 and HB12-34 exhibited more than 10% yield superiority over national checks HFB-1 and Vikrant. Therefore, HB 12-8 and HB 12-34 are suitable for commercial cultivation in plain zone at national level.

Supplementary Data

Supplementary data associated with this article is available in the electronic form at http://nopr.niscpr.res.in/jinfo/ijtk/IJTK_21(04)891-900(2022)_SupplData.pdf

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Conflict of Interest

The authors declare that there are not any conflicts of interest.

Authors' Contributions

RKA, JSH, SKK, HLR and GSD conceived the study and designed the experiment. RKA, JSH, GSD and SK, RKG, JLM, JKT, CBY, RK, RP performed the experiments. RKA, GSD, HLR, RK, JMS, PK analysed data and interpreted results and co-wrote and edited the manuscript. All authors reviewed the manuscript.

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