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GENETIC DIVERGENCE STUDIES IN FABA BEAN - AN OVERVIEW

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SUMMARY

Faba bean (*Vicia faba*) is a winter season legume crop. The seeds of faba bean are known as a good source of protein (29.4%), carbohydrate (51 - 68%) and fat (1.5%). In 100 g of edible portion, it contains 7.2 g carbohydrate, 4.5 g protein, 0.1 g fat, 0.08 mg thiamine, 12.0 mg ascorbic acid, 50mg calcium and 1.4mg iron. Faba bean have many medicinal values as it is used as ingredients and applications to soften stiff limbs. The seeds of faba bean are good source of L-DOPA, a precursor dopamine, which is used as a medicine for the treatments of Parkinson's disease. It also has antioxidant activities. As we know that variability is perquisite for any crop improvement programme. If in any crop, sufficient genetic variability is present, help in further improvement as well as development of superior cultivars. Genetic variability and genetic diversence is the primary consideration of many investigators. This study has paramount role in breeding for wide adaptation. It helps in selection of desirable parents for an efficient hybridization program. Further, the knowledge of inter-relationships among different characters is helpful because the selection of one trait may directly affect the performance of another, which is determining the components of complex characters like yield. Therefore, keeping the importance of these studies in faba bean, this effort is made to collect the available information from the different sources for further utilization for researchers' working in this field.

Keywords : Faba bean, *Vicia faba*, genetic variability, divergence, character association

Faba bean (*Vicia faba* L.; 2n = 2x = 12, 14; Family: *Fabaceae*) is known by many names like broad bean, horse bean, winter bean, windsor bean, pigeon bean and popularly known as bakla and kalamatar in India (Singh *et al*., 2013). It is a hardy plant, which can tolerate extreme cold temperature. Faba bean is the only bean which grown as winter crop. It is widely believed to have originated in the North Africa and South Caspian Sea (Tanno and Willcox, 2006) and introduced in India by Arab traders. In 2018-19, faba bean ranked 6th with respect to production worldwide, after the common bean, pea, chickpea, cowpea and lentil with total production of 4.5 M tons, while the area harvested was 2.5 M ha (Khazaei and Vandenberg, 2020). China is a leading growing country of faba bean with respect to area and production. In India, the area and production of faba bean is low and that is why it is still categorized as minor crops. The statics of faba bean with respect to area and production in India is not available(Pradhan and Sinha, 2012). It is a traditional legume crop ofBihar that is why in India, faba bean have maximum area in Bihar. In India, faba bean cultivated in Madhya Pradesh, Odisha and Uttar Pradesh (mainly eastern part) (Singh *et al.*, 2012, Arya *et al.*, 2020).

Faba bean have limited area in Haryana state as compared to other legume crops because of lack of suitable high yielding varieties as well as improper pest management. In Haryana and Northern states of India, faba bean is grown during November to April (*rabi* season). Faba bean have great role in world agriculture due to its high performance with respect to yield, compared to alternative grain legumes. It can also be used as break crop in area where cereal based mono-cropping system is dominated. It is a very much beneficial crop because of its naturally nitrogen fixation capacity and helpful to control weed and disease in subsequent crops (Preissel *et al*., 2015).

Faba bean is an annual herb. The faba bean has large and white flowers that originate on short pedicles in clusters. The fruit of faba bean is known as pod which is leathery, green maturing to blackish-brown (Lindemann and Glover, 2003). Faba bean is a dual purpose crop, green pod are used as vegetable, whereas, dry seed are used as grain legume (Raiger *et al.*, 2021). The seeds of faba bean are good source of protein (29.4%), carbohydrate (51 to 68%) and fat

(1.5%) (Cerning *et al.,* 1975). Among the commonly cultivated legume crops, faba bean has the highest crude protein content as well as has the highest yield of protein per hectare. In 100 g of edible portion, it contains 7.2 g carbohydrate, 4.5 g protein, 0.1 g fat, 0.08 mg thiamine, 12.0 mg ascorbic acid, 50 mg calcium and 1.4 mg iron (Hazara and Som, 2006). The Indian Council of Agriculture Research (ICAR) recognised faba bean as a potential grain legume crop and included it in AICRP programme. The Consultative Group of International Agricultural Research (CGIAR) ranked the faba bean as 8th major grain legumes on priority basis (Sharifi, 2015).

Faba bean have many medicinal values as it is used as ingredients and applications to soften stiff limbs. The seeds of faba bean are good source of L-DOPA, a precursor dopamine, which is used as a medicine for the treatments of Parkinson's disease. It also has antioxidant activities. Faba bean is an excellent dietary source of natural antioxidant for prevention of chronic disease and health promotion (Oomah *et al.*, 2006). Faba bean also contain certain anti-nutritional factors in fresh pods as well as in immature seeds such as polyphenols which impart beany flavour (Bjerg *et al.*, 1988) which known to cause astringency. The seed of faba bean contain vicine and co-vicine that causes hemolytic anemia due to oxidation of erythrocytes. However, the activity of anti-nutritional factors may reduce by heat treatment in boiling water as well as presoaking (Batra *et al.*, 1990).

Faba bean is a self-pollinated crop, having partial allogamous nature (5-20 *per cent*). Due to the partial allogamous nature, high degree of genetic variability prevails in this crop (Hanelt and Mettin, 1989).The presence of the adequate variability in the basic genetic material of any crop is prerequisite for initiating a systemic breeding programme for the improvement of a crop. Study of such variability among different germplasm of a crop help the breeders in identification the most potential genotypes by using various genetic parameters like heritability, genetic advance and genetic coefficient of variation (Panchta *et al.*, 2021). Since many economic characters are quantitative in nature and highly influenced by the environment, so the progress of any breeding programme is governed by the nature of both genetic as well as non-genetic variation. Therefore, it is necessary to partition the overall variability into its heritable and non-heritable components.

The genetic variability study has paramount role in breeding for wide adaptation. It helps in selection of desirable parents for an efficient hybridization program. Due to hybridization divergent groups are develop, which is the main aim of plant breeding programme. Mahalanobis's D^2 techniques (based on multivariate analysis), is a powerful tool for accessing genetic divergence and serves to be a good index of genetic diversity. In faba bean genotypes great extent of diversity is present for various quantitative characters suggested decent scope for improvement. Further, the knowledge of inter-relationships among different characters is helpful because the selection of one trait may directly affect the performance of another, which is determining the components of complex characters like yield. However, correlation studies do not provide an exact picture of the direct influence of each of the components characters towards the yield. Path coefficient proves helpful in partitioning the correlation coefficient into direct and indirect effects. In the present investigation, the available latest information from different sources on genetic variability, heretibilty, genetic advance, genetic divergence, correlation and path analysis is complied herewith for further utilization for the researchers.

Genetic Variability

As we know that variability is perquisite for any crop improvement programme. If in any crop, sufficient genetic variability is present, help in further improvement as well as development of superior cultivars. Genetic variability is the primary consideration of many investigators. Vavilov (1951) realized first that if in a crop wider range of variability is present, provides a better chance for selecting the desirable genotypes. Apart from genetic variability, their mode of transmission to the next generation is also an important factor. In a population, genetic variability is the true measure for access the variability.

Kalia *et al*. (2003) and Kalia and Sood (2004) studied the divergent genotypes for interrelationship and variability analysis. They found that sufficient variability was present for pod yield and quality characters. There was negligible differences were present in phenotypic and genotypic coefficients of variation for characters like ascorbic acid, protein content and pod yield; indicated that environment have little influence on these characters. For pod yield, heritability was 97 *per cent* while genetic advance was 126 *per cent*. Keneni *et al.* (2005) conducted an investigation on 160 random germplasm accessions in an alpha lattice design. Total 12 characters were

taken for evaluation the variability. He observed that except number of pods per podding nodes the germplasm accessions for most of the characters had significant differences, which indicated the presence of sufficient variability.

Mustafa and El-Zaher(2007)conducted a study on 9 Egyptian cultivars of faba bean to evaluated genetic variation present among cultivar. He took several characters for evaluation, like100-seed weight and albumin and globulin seed protein content. The result of investigation revealed that sufficient diversity was present for 100-seed weight and albumin and globulin seed protein content. Alghamdi and Kh (2007) studied 6 faba bean genotypes in order to access the genetic behaviours of genotypes. He found except for plant height, all genotypes differed significantly for all characters taken under investigation, which indicated the presence of sufficient variability. In the first season, the highest value of broad sense heritability was for flowering date which 98.60 *per cent* followed by number of pods 96 *per cent*. The data of second season revealed that highest broad sense heritability was for flowering date which was 99.9 *per cent*.

Ibrahim (2010) investigated 7 faba bean varieties in the diallele cross set to determine the variability present among the parents and F_1 genotypes. He made 21 crosses in in season and evaluated these crosses with their parents in next season. He found wide genetic variability was present for the studied characters. He also observed that narrow sense heritability was found maximum for short plant height and100-seed weight, while it was recorded lowest for grain yield per plant. Abu-Amer *et al.* (2011) analyzed 11 Jordanian faba bean landraces and five imported cultivars to determine the genotypic and phenotypic variation. They found sufficient diversity was present among the landraces. They also observed that significant location effects were present for most of the characters except for plant height and seeds per plant. Germplasm varied significantly over locations for all characters.

Fikreselassie and Seboka (2012) investigated 25 faba bean elite genotypes for determination of genetic variability for seed yield and other related characters. They found significant variability for seed yield and most of the character. The value of genotypic coefficient of variation was maximum for seed yield followed by number of seeds per plant while minimum value was for number of seeds per pod. The genetic gains varied from 12.32 *per cent* for number of seeds per plant to 35.46 *per cent* for seed yield.

Mulualem *et al.* (2013) conducted a study on 10 faba bean genotypes to check the variability present among the genotypes. The result of study showed that significant amount of variability is present among the genotypes. The value ofphenotypic coefficient of variation values was closer to corresponding value of genotypic coefficient of variation values indicating environment have little effect on the expression characters. Verma*et al.* (2013) studied 96 germplasm lines and three check genotypes viz., PRT 7, PRT 12 and Vikrant of faba bean for accessing the variability using augmented block design. Result showed that significant degree of variability was available for most of the traits under study. They also reported that mean squares due to replication were highly significant for days to 50% flowering, number of pods per plant, seed yield per plant and biological yield per plant.

Solieman and Ragheb (2014) conducted an investigation on genotypes of faba bean to determine the genetic variability. They found sufficient variability was present among the 11 studied characters. The range for broad sense heritability varies between 80.19% for pod diameter to 99.83% for pods number per plant. The value heritability recorded high for most characters such as, plant height, branches number per plant, pods number per plant, pod weight, and total yield per plant which associated with high genetic advance, indicating the presence of additive gene effects. Sharifi (2014) conducted an investigation on 10 genotypes of faba bean to access variability in two regions of Iran.The results indicated that the genotypes under investigation differed significantly for all of the characters, which indicated the presence of sufficient variability. He also reported that highest value of heritability was ≥0.98 for pod length and 100-seed weight while lowest value of heritability was0.37 and 0.25 for number of stems and pods per plant respectively.

Sheelamary and Shivani (2015) studied 50 faba bean germplasm accessions to determine variability. For this purpose, data took on 10 morphological characters. They observed that the significant variability is present among germplasm accessions. They also found that the phenotypic coefficient of variation was higher than the genotypic coefficient of variation for most of the characters but there was very little difference between them for the characters studied. Sharifi (2015) conducted an investigation to find most successful genotype and heritability of some of the important characters. He observed significant difference among different characters, which indicated the presence of sufficient variability. The value for broad sense heritability ranges

from 95-98 *per cent* for most of the characterswhich suggested that the environmental factors had a small effect on the inheritance of characters. Also the high value of heritability suggested that selection based on mean would be successful in improving these characters.

Singh *et al.* (2017) studied diversity analysis of faba bean germplasm of Bihar. Twenty traits were studied to determine the variability in the germplasm. Maximum amount of variability was found in qualitative traitss having >30% CV, reasonable amount was observed in seed starch and protein contents. Results on frequency distribution indicated that most of germplasm falls under medium category. Kumar *et al.* (2017) studied 65 germplam lines in RBD with three replications. Analysis of variance revealed that lines differed significantly for all of the studied traits, which suggested the presence of sufficient variability. Arya (2018) evaluated faba bean genotypes for seed yield under Haryana condition. He used 22 newly developed genotypes of faba bean including checks. He observed wide genetic variability for plant height (cm), days to maturity, number of branches/plant, pod length (cm), seeds/pod, clusters/plant and seed yield (kg/ ha). Jain *et al.* (1999) and Vu *et al.* (2017) supported that for selecting the superior genotypes, heritability estimates along with genetic advance was found a better approach rather than heritability estimates alone.

Genetic divergence

Genetic divergence is used to differentiate a well-defined population to select suitable parental genotypes for obtaining better progenies.Genetic divergence is the process in which two or more populations of an ancestral species accumulate independent genetic changes, through time, often after the populations have become reproductively isolated for some period of time. To estimate genetic divergence Mahalanobis (1936) provided a statistical procedure 'D^2 statistic' in a given population. To access the degree of genetic divergence in different crops Rao (1952) provided a procedure known as multivariate analysis.While clustering, genetically divergent population dividing into different groups thus enabling selection of better parents. The geographic distributions of genotypes are compared with genetic diversity, very often these exhibits parallelism.

Chaieb*et al.* (2011) conducted a study on the 13 faba bean genotypes to access the intraspecific diversity. They took 5 characters for studied viz. plant height, branch number per plant, pod number per plant, seed number per pod and yield per plant. They found significant diversity for most of the characters. Highest Yield per plant were observed for genotype G10 which is 215.14 g followed by the land race G13 which is 137.37 g. In addition to this, the genotypes have different behaviours with sowings location and season. Sharifi and Aminpane (2014) used hierarchical cluster analysis method for grouping 10 genotypes having 28 characters into three main groups. The finding of this study indicated that days to flowering, hundred seed weight, plant height, weight of pods per plant before physiological maturity stage and days to harvesting were the characters that closely correlated to dry seed weight per meter square.

Kumar *et al.* (2017) conducted an investigation using 65 genotypes of faba bean. They used Mahalonobis's D^2 statics for genetic divergence study. Total 9 clusters were formed for 65 genotypes. The maximum intra-cluster distance were observed for cluster IX, whereas maximum inter-cluster distance were observed between cluster V and VII, which suggested that the genotypes present in these clusters were most diverged. De-Moraes *et al.* (2019) studied eight accessions of faba bean from Germplasm Bank of the Federal University of Piauí. With the help of Grouping method of Trocher, he found that accessions UFPI 799 and UFPI 817 most divergent. The accessions UFPI 817 and UFPI 797 can be used in crossings, as they are genetically distant and complementary in their characteristics.

Chaurasia (2020) grouped 53 genotypes of faba bean into 6 clusters using Tocher's method as per suggestion given by Murty and Arunachalam in 1966. The pattern of clustering of genotypes revealed that there was substantial diversity presented among the genotypes for the characters under investigation. The knowledge of sufficient amount of diversity will helpful in the selection of diverse and better parents for any hybridization programme for isolating the better segregates. According to Vu *et al.* (2017) the constellation of group of the genotypes from the different sources were also present together in same cluster revealed that geographical diversity, though important, but is not a necessary parameter of group constellation. Therefore, selections of parents merely on the basis of geographical diversity are not essentially a rewarding performance for any hybridization programme.

Correlation Coefficient Analysis

As the name indicates, correlation is a measure that determine the mutual relationship among various plant characters as well as it also determines the components on which selection will lead to the improvement. For increase the efficiency of selection, a plant breeder must have knowledge about correlations between different characters. With the knowledge of significant correlation coefficients among various plant characters, the selection procedure to improve the yield is simplified. Yield is a quantitative character, so it is greatly influenced by changing environmental conditions. So, performance of yield is not a true measure of selection of superior genotypes. Hence, the breeder should have performed selection on phenotypic expression for selection of superior genotypes.

Keneni and Jarso (2002) observed positive and significant association of number of pods per plant and days to 50 *per cent* flowering with yield per plant. Ulukan*et al.* (2003) reported significant positive correlation between numbers of seed per plant with seed yield per plant in faba bean. There was a positive and significant correlation between biological yield and plant height. Kalia and Sood (2004) observed that genotypic correlation coefficients among all contributing traits were higher than the corresponding phenotypic ones.

Alan and Geren (2007) observed significant association between yield components, pods/plant with plant height and grains/pod with number of stems in faba bean crop plants. They also point out that grain yield had significant positive correlation with grains/ pod. Bhushan *et al.* (2007) carried out the association analysis for seven yield contouring traits in 441 exotic germplasm lines of Faba bean. They reported that grain yield/plant had positive and significant association with number of pods/plant, pod length and 100- grain weight. They also revealed that number of pods/plant had positive and significant correlations with plant height, pod length and days to maturity. They also observed that in faba bean days to maturity had positive and significant association with plant height.

Ahmed *et al*. (2008) carried out correlation coefficient analysis for grain yield and its contributing traits in 3 faba bean (*Vicia faba* L.) crosses and observed that grain yield/plant was positively correlated with branches/plant, pods/plant day to maturity, and grains/plant under Mass Selection crop improvement technique and with days to maturity and pods/plant under Pedigree selection procedure and with grains/ plant pods/plant and under Picking- Pod selection Method. Badolay *et al*. (2009) observed that days to 50% flowering had positive and significant phenotypic association with days to maturity in s study of100 germplasm lines of faba bean. They also revealed positive and significant association for plant height, pods/plant, clusters/plant, pod length and with grain yield/ plant.

Duzdemir and Ece (2011) revealed the significant and positive association of grain yield with crop harvest index, number of grains/ pod and pod length in faba bean. Tadesse *et al*. (2011) reported significant association among the fifteen genotypes characters and reported that number of plant height, pods/plant, number of grains/pod and had positive and significant correlation with grain yield/plot at Sinana location, whereas, at Adaba, 1000-grain weight exhibited significant correlation with grain yield/ plot.

Angadi *et al.* (2012) studied correlation in twelve genotypes of faba bean and repoted that pod yield/hectare had positive and highly significant correlations with plant height, pod length, pod yield/ plant, pod weight, leaf area, leaf area index, number of ovules/pod, number of grains/pod at both phenotypic and genotypic correlation levels. Chaubey *et al*. (2012) carried out a study on genotypes of faba bean and observed highly significant and positive correlation of seed yield per plant with number of pods per plant, biological yield per plant, no. of seeds per pod, 100-seed weight and harvest index in faba bean genotypes.

Osman *et al.* (2013) evaluated four genotypes of faba bean. They observedsignificant and positive correlation of grain yield with number of pods/plant, number of grains/pod, number of grains/plant, 100 seed weight, number of branches per plant, plant height, leaf area, leaf efficiency and number of days to 50 % flowering. While working on faba bean genotypes, Cokkizgin *et al.* (2013) reported that grain yield was significantly associated with all morphological traits except plant height and 100- grain weight.

Ghareeb and Helal (2014) while conducting experiment on faba bean genotypes revealed that positive significant correlation coefficient between flowering date with number of branches per plant and hundred seed weight, similarly number of pods per plant with number of seeds per plant, seed yield per plant with number of branches per plant, number of pods per plant, number of seeds per plant and 100-seed weight. Sharifi (2014) carried out experiment on six good genotypes of faba bean and observed significant positive correlation of grain yield with grain length, grain width, pod length and 100- grain weight

during two cropping seasons at one location.

Sheelamary and Shivani (2015) observed that pod length had positive and significant correlation coefficient with number of seeds per pod and pod width; plant height with pod length followed by pod width, hundred seed weight and single plant yield. There is a negative but significant correlation was observed between days to 80 *per cent* maturity, plant height and pod length in faba bean. Verma *et al.* (2015) reported that the seed yield per plant was significantly and positively correlated with harvest index, biological yield per plant, days to 50 *per cent* flowering and number of seed per pod. However, seed yield per plant showed negative significant correlation with number of pods per plant. Biological yield per plant had significant and positive correlation with days to 50 *per cent* flowering and had significant negative correlation with days to maturity, harvest index and days to maturity in faba bean.

Ahmed *et al.* (2016) while evaluating faba bean genotype obtained highest positive correlation of plant height with number of branches/ plant and number of pods/plant. Significantly positive associatios were also revealed for days to 50 *per cent* flowering plant height, number of pods /plant, number of seeds /pod and with seed yield per plant. Tofiqi *et al.* (2016) found significant and negative correlation between 100 seed weight and seed yield whereas, significant and positive correlation were observed between number of seeds per plant and seed yield at the second season. In addition, the results of the third season indicated that the number of seeds per plant and pods per plant correlated significantly and positively with seed yield whereas, number of seeds per pod correlated significantly and negatively with seed yield.

Kumar *et al.* (2017) investigated 65 genotypes in a randomized block design with three replications. Correlation coefficient analysis indicated that all the characters had positive significant correlation coefficient with seed yield except plant height. Arya *et al.* (2019) conducted an investigation using 80 genotypes of faba bean. The results of correlation revealed that seed yield per plant had significant and positive association with the days to 50% flowering, days to maturity, plant height, branches/plant, pods/ plant, pod length, number of grains/ pod and 100 seed weight.

Path coefficient analysis

Path analysis was proposed by Wright (1921) and was used first in plant breeding by Dewey and Lu (1959) using crested wheat grass progenies. It is simply standardized partial regression coefficient partitioning the correlation coefficients into the measures of direct and indirect effects of set of independent variables on the dependent variable. It is also famous as cause and effect relationship. The studies on correlation coefficients simply show the nature of association between two traits which alone does not gives the accurate idea about the relative effect of each parameter or trait towards the major economic product under experimentation. Knowledge of direct and indirect effects of different traits on desired traits is necessary for selection to improve the population as it may be possible that a component character may have no direct effect on concerned economic trait but it may influence through other related component traits (Reddy *et al*., 2002).

Badolay *et al*. (2009) examined correlation and path analysis in faba beans using 100 genotypes which were raised in RBD design. The maximum positive direct effect on grain yield were reported for pods/plant (0.881) followed by 100-grain weight (0.165), days to maturity (0.028), clusters/plant (0.022), seeds per pod (0.016) and pod length (0.014), whereas, plant height had highest negative direct effect, -0.066.

Azarpour *et al*. (2012) carried out path analysis study in faba bean and reported that plant height had the significant and positive association with grain yield. The value of direct effect of plant height on grain yield was found 0.677. The height amount of indirect effects was observed of pod/plant through plant height. Cokkizgin *et al*. (2013) was performed a study on six common beans genotypes under three location conditions. The results of path coefficient analysis studies revealed that seed number per plant had highest positive direct effect on the seed yield, whereas, seed weight per plant had highest negative direct on the seed yield.

Verma *et al.* (2015) investigated sixty-seven germplasm lines of faba bean. Results from investigation indicated that direct positive effects on seed yield per plant had reported for characters namely harvest index, biological yield per plant, 100 seeds weight and seeds per pod. Number of pods per plant and days to maturity exhibited positive indirect effects on seed yield via, biological yield. Tofiqi *et al.* (2016) was conducted research using seven faba bean cultivars. The highest direct effect on seed yield was reported for first node height. In second season, number of pods/plant showed maximum positive direct effect on seed yield.

Singh *et al.* (2017) evaluated 35 faba bean genotypes under mild hill conditions. The positive direct effect on seed yield were reported for the characters namely, days to 50% flowering, pod per node, nodes per plant, nodes at which first flower appear, pod length, branch per plant, seed per pod, days to maturity, seed size and 100 seeds weight, whereas, negative and direct effects were observed for the characters like, plant height, dry matter content and ascorbic acid. Kumar *et al.* (2017) investigated 65 genotypes of faba bean. The finding of path coefficient analysis indicated thatpod length,100-seed weight, number of seeds/ pod, number of pods/plant, number of branches/plant days to maturity had positive and direct effects on seed yield, while the characters like plant height, days to flowering and clusters per plant recorded direct negative effects.

El-Shal and El-Sayad (2019) studied 50 different landraces of faba bean. The results of path coefficient revealed that 100 seeds weight had indirect effects on seed yield via number of branches per plant and leaflet width. In addition to this, number of seeds per plant had the highest indirect effects on seed yield via number of branches and number of pods per plant. Dewangan *et al.* (2019) conducted an investigation using 80 genotypes of faba bean. The finding of path coefficient analysis indicated that100 seed weight, number of pods /plant, number of seeds/pod, days to 50% flowering, number of branches /plant and plant height had direct positive effect on seed yield. Chaurasia (2020) carried out combined analysis of correlation coefficient and path coefficient with this 53 genotypes of faba bean and reported that the characters, namely, number of branches/plant, number of pods cluster/ plant, number of pods/plant, number of pods/cluster, number of seeds/pod , 100 seeds weight, biological yield, pod yield/plant, and harvest index were the major seed attributing characters and hence; emphasis should be given to this characters while programming any plant breeding programme.

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