COMPARISON OF DIFFERENT SELECTION METHODS IN OKRA (*Abelmoschus esculentus* (L.) Moench)

by

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Thesis submitted to the Chaudhary Charan Singh Haryana Agricultural University in partial fulfilment of the requirements for the degree of:

DOCTOR OF PHILOSOPHY

IN

VEGETABLE CROPS

COLLEGE OF AGRICULTURE
Chaudhary Charan Singh Haryana Agricultural University
HISAR

1993

DEDICATED

TO

MY RESPECTED PARENTS

ACKNOWLEDGEMENTS

I take this opportunity to express my profound regards and deep sense of gratitude to Dr. B.S. Dhankhar, Professor and Head, Department of Vegetable Crops, CCS Haryana Agricultural University, Hisar, the Chairman of my Advisory Committee, for his valuable, constant and unfailing guidance, for providing necessary facilities and the encouragement evinced during the course of the present investigation and in the preparation of this manuscript.

I express most sincere and heartfelt thanks to Dr. Partap Singh Partap, Scientist, Vegetable Crops, Co-Major Advisor; Dr. B.S. Dahiya, Professor and Head, Seed Technology Centre; Dr. J.P. Singh, Senior District Extension Specialist (Plant Pathology) and Dr. R. Yamdagini, Professor of Horticulture, all the members of my Advisory Committee, for their useful discussion, constructive suggestions and elderly advice from time to time during the period of experimentation, and in the preparation of the manuscript.

I gratefully extend my sincere thanks to ex-member Advisory Committee, Dr. Kalloo, Professor of Vegetable Crops, (presently Project Director, Directorate of Vegetable Research, Varanasi, UP), for his guidance, help and encouragement during the tenure of my work.

My sincere thanks are to all other faculty and staff members of the Department of Vegetable Crops, CCS Haryana Agricultural University, Hisar, for their timely help and encouragement.

I am greatly indebted and thank to my friends Sh. A.K. Goyal, Om Parkash Saini and Rajesh Malik for rendering valuable help and encouragement during the investigation.

I am especially thankful to Professor and Head, Department of Statistics and all other members working in the Computer Centre for providing necessary computation facilities.

I thank and appreciate Mr. D.V. Hooda for typing this manuscript.

In the end with all reverance, I express my deep gratitude to my parents, brothers, sisters and all other family members for their silent sacrifice, affection and everlasting inspiration in this endeavour.

The financial help provided by the University as Merit Fellowship for one trimester is also thankfully acknowledged.

HISAR

MARCH, 1993

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CERTIFICATE -I

This is to certify that this thesis entitled "Comparison of different selection methods in okra (Abelmoschus esculentus (L.) Moench.)" submitted for the degree of Doctor of Philosophy, in the subject of Vegetable Crops of the Chaudhary Charan Singh Haryana Agricultural University, is a bonafide research work carried out by Sh. Phool Singh under my supervision and that no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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16.6.93

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16/6/93.

EXTERNAL EXAMINER

HEAD OF THE DEPARTMENT

21/6

DEAN, POST-GRADUATE STUDIES

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INTRODUCTION

Okra (Abelmoschus esculentus (L.) Moench), a member of the family Malvaceae and grown for its tender green fruits, is one of the important summer vegetable crops of India. Its fruits are generally used as cooked or fried and occasionally for processing as dehydrated and canned products. Immature fruits are also used for making soups, stews and pickles. Fruits of okra contain vitamins A, B, C and minerals calcium and magnesium in appreciable amounts. Protein and oil contents of okra seeds have been reported to be 26.0 and 18.1 per cent, respectively (Martin et al., 1979). Besides its medicinal value, the stems and roots of okra plants are used for clearing the cane juice during the process of making gur or cane sugar (Chauhan, 1972).

The information on the extent of genetic variation and type of gene effects is required for the success of any breeding programme. Further, the prediction of the genetic advance during selection is also desirable in a crop improvement programme. Basically the breeding of self pollinated crops involves two phases, (i) the hybridization, and (ii) selection in segregating generations. The main difficulty in the improvement of most of the self pollinated crops like okra lies in the selection phase. This is because the handling of unmanageably large segregating population through routine method of pedigree selection is quite laborious, time consuming and expensive.

Nilsson-Ehle (1908) used bulk method to overcome the difficulty of single plant selections of pedigree method. In this method, large population is sown and harvested as bulk from F_2 onwards until sufficient amount of homozygosity

is achieved, and then followed the individual plant selection. However, natural selection operating during bulking period may increase the frequency of undesirable types and also the inadequate sampling in each generation may reduce genetic variability.

Goulden (1939) proposed single seed descent (SSD) method to overcome the slowness of pedigree and problem of inadequate sampling of the bulk method. In SSD, single seed from each plant is taken from the F_2 generation onwards. After reaching homozygosity, individual plant selection is performed. Byth et al. (1979) used single pod descent (SPD) method as a modification of SSD, where, single pod instead of single seed is taken from each plant.

As regards studies on genetic advance, there is hardly any work with particular reference to okra crop. Besides, the varieties Pusa Makhmali, Pusa Sawani, Punjab Padmini, Parbhani Kranti and P7 etc. had been developed through pure line and the labour intensive pedigree methods only (Singh and Sikka, 1955; Singh et al., 1962; Thakur and Arora, 1986). Considering the importance of the crop, there is a further need and scope of genetic improvement of its fruit yield and component characters. Therefore, keeping these facts in view, the present study of comparison of different selection methods in okra was planned with the following objectives:

1. to examine comparative performance of different selection methods in terms of high yielding potential lines, and
2. to estimate heritability and genetic advance for various characters under different selection methods.

REVIEW OF LITERATURE

Most of the breeding programmes are aimed at improving the genetic potential of the cultivars for economic yields. However, it is very difficult to improve yield through simple selection methods as yield is a complex character with low heritability. The ability to isolate a plant with high yield potential in segregating populations is one of the most difficult tasks faced by breeders. Many a times it is difficult to judge whether the observed variability is genetic or environmental in nature.

Generally, while dealing with vegetable crops like okra, the single crosses are made between certain chosen pure lines and their segregating progenies are handled by pedigree selection. Yield testing is done in F_5 or F_6 generations when sufficient level of homozygosity is attained. Some times, breeders follow some deviation in selection methods where, segregating generations are advanced by single seed descent (SSD), bulk or some other methods of selection. For many years, breeders have been interested in determining the most effective methods of breeding for yield improvement and have carried out a number of studies on breeding methods in various crops. However, in vegetable crops and particularly in okra, the literature regarding comparative performance of different selection methods is very scanty. Therefore, here the information on selection methods viz., single seed descent (SSD) or single seed per fruit (SSF), pedigree method (PM) and bulk population (BP) employed for the improvement of self fertilizing crops have been reviewed.

Single seed descent method (SSD)

Single seed per fruit or single seed descent selection is a method of handling segregating populations in self pollinated crops. It was first proposed by Goulden (1939) and further elaborated by Grafius (1965) and Brim (1966) in oats and soybean, respectively. This method consists of advancing each plant in F_2 and succeeding generations by a single random seed until homozygosity is achieved. Many generations can be had in a year in green house as no selection is done. Thus, F_2 genetic spectrum in homozygous form is obtained in a very short time. Once the lines have reached the stage of near homozygosity, they can be evaluated and selection is practised.

Compton (1968) suggested a selection procedure which allowed breeders of self pollinated crops to conduct selection recurrently in a population without large numbers of pollinations. The procedure was based on the use of the "single seed descent" method, but with each derived line being a descendent of a different F_1 rather than from different F_2 plants within an F_1.

Single seed descent method has been experimentally found comparable or better than traditional methods in developing superior pure lines in self pollinated crops (Empig and Fehr, 1971; Boerma and Cooper, 1975a, 1975b). Empig and Fehr (1971) also reported SSD method to be the least influenced by natural selection in soybean. Hence they recommended it as the most suitable and useful method for green house and winter nursery environments where a genotype may perform differently. Further they found that single seed descent was most effective method in maintaining earliness and large seeded lines in soybean.

The comparison of two methods of plant improvement (Casali and Tigchelaar, 1972) showed that for earliness and fruit production in tomato, single seed descent method was more efficient under green house conditions. Snape and Riggs (1975) reported and discussed theoretical changes in the mean and variances of segregating populations under single seed descent method. The direction and magnitude of these changes were shown to depend on the genetical architecture of the character under consideration.

Using computer simulation, they showed that for situations where heterosis was exhibited, few homozygous lines exceeded the mean of the F_2 distribution from which they were derived.

Knott and Kumar (1975) in wheat observed that mean yield of the pedigree advanced lines was significantly higher, mainly because there were fewer, very low yielding lines. The correlations between the F_3 and F_5 yields of these lines were significant, but were not particularly large (0.29 and 0.14). The yield of the F_5 pedigree derived lines from the highest yielding 20 per cent of the F_3 lines, was compared with the highest yielding 20 per cent of F_6 SSD lines. In each cross, the SSD lines were atleast as good as the pedigree derived lines.

Boerma and Cooper (1975a) reported that in soybean, single seed descent method proved as the most efficient as it required less selection effort than the early generation testing and pedigree selection procedures. Tee and Qualset (1975) reported an accelerated generation increase programme for establishing near homozygous lines and evaluated by both single seed descent (SSD) and random bulk population (BP) methods for different characters. The results indicated that selection for certain highly heritable characters was practical in an accelerated

generation programme. The SSD and BP methods were generally comparable except for plant height. Tall plants increased in the BP method, due to significantly changing gene frequencies. In a system of rapid generation turnover where only a few seeds per plant were produced, the BP method could be applied more efficiently than SSD, thus, the random bulk method was recommended unless competition effects were important, where upon single seed descent became the preferred method.

The mean values of tomato lines derived from 2 or 3 generations of pedigree selection followed by single seed descent (SSD) to F_6 or F_7 were similar to their corresponding pedigree lines and approximately 50 per cent of SSD lines derived following selection to F_4 surpassed pedigree lines in weighted value. Early generation pedigree selection to F_4 followed by selection among F_6 SSD derived lines appears to be the most rapid and effective means of sampling variability in segregating populations (Casali and Tigchelaar, 1975a).

Further in a computer simulation study, Casali and Tigchelaar (1975b) mentioned that SSD method offers the greatest benefits in tomato where simultaneous selection is required for many characters under different heritabilities. Wright and Thomas (1976) reported that SSD and pedigree methods produced a similar number of lines worthy of inclusion in advanced trials from the same crosses, however, SSD method was rated poor due to the labour involved and susceptibility of lines to diseases like Puccinia and Erysphe in wheat.

Peirce (1977) reported that single seed descent (SSD) produced generally inferior fruit size, earliness and total yield among tomato progenies as compared with pedigree selection alone and single seed descent following one cycle of

pedigree selection (PDSD). The latter two systems were essentially equal in performance, but the PDSD system provided increased efficiency of time and space. Progeny tests generally reflected the superiority, regardless of selection system. In each system, acceptable performance was obtained in atleast one line. The data suggested that chances of recovering high performance lines were reduced in SSD as compared to other two methods.

Riggs and Snape (1977) reported that in the absence of linkage no differences between the populations for genetic means and variances for characters were observed, but when linkage was present, recombination was more frequent in the SSD populations as indicated by the relative differences in variances between these and the diploidizing haploid populations. In addition, differences in mean between the populations derived by the two methods were observed when non-allelic interaction was present. It was concluded that SSD method was to be preferred from theoretical considerations although in practice the choice of method will also depend upon practical and technical factors.

Experimentally it was confirmed that the SSD method retains more genetic variability than bulk method as it minimizes the effects of natural selection in soybean (Ivers and Fehr, 1978). The extent of plant loss (due to lack of germination, plant death, and failure of plants to produce even a single seed) from generation to generation affects the genetic make up of SSD population (Martin et al., 1978). They reported the plant loss of as much as 55 per cent of the original population at high density in soybean at the end of four generations. At low density, however, the loss was 19 per cent. Tee et al. (1979) suggested single seed descent approach for improvement of tomato in tropics.

In another simulation study (Muehlbauer et al., 1981), SSD and BP methods were compared with hypothetical crop having seven chromosomes with six loci on each and various degrees of linkages. In that case, it was found that additive genetic variance was more for SSD than BP method. In SSD method, all the additive genetic variance must originate from between line variance.

Haddad and Muehlbauer (1981) studied three lentil populations advanced from F_2 to the F_4 generations by single seed descent (SSD) and bulk population (BP) breeding methods to compare the relative efficiency of these methods for maintaining genetic variation and selection opportunities. SSD maintained more genetic variation (σ_g^2) in 15 or 21 comparisons of characters that were made. Genetic variances were significantly higher with SSD for plant height, days to maturity and yield in population 1; height of lowest pod in population 2; and days to blooming, height of lowest pod, plant type, and yield in population 3. SSD compared with BP derived populations had 10, 9 and 13 per cent more erect lines in three populations, respectively. The BP method maintained 14, 2 and 4 per cent more taller types in the three populations, respectively, and 16 and 33 per cent more segregants that carried their pods higher from the ground. This indicated a reduced frequency of short plant with low flowers as a result of natural selection operating within BP against less competitive short types. The SSD method as an efficient cost saving method of advancing populations was recommended for lentil breeding.

Bedo and Balla (1984) opined that greater unformity of SSD lines permitted more efficient scoring of characters. Ntare et al. (1984) compared two breeding procedures in two cowpea crosses. Both procedures were started from the same selected F_2 plants in each cross. For early generation evaluation, the F_3 lines

were yield tested and pedigree and bulk methods were followed in F_4 and F_5. Each of F_5 lines were bulked to provide seeds for a yield test in F_6. In the single seed descent (SSD) procedure, a single seed was taken from each F_2 plant to produce the F_3 generation. The procedure was repeated for the F_4 and F_5. The F_6 SSD lines and the F_6 yield testing lines were compared in yield trials. The results showed that differences in yielding ability of F_3 lines persisted over generations indicating that the selection was effective. This was confirmed by the significant correlations between F_3 yields and those of later generations which ranged from $r = 0.51$ to 0.85. The grain yields of lines derived by the single seed descent procedure were as good as those derived from early generation yield testing.

Blaha (1984) set out the respective merits and limitations of pedigree selection, bulk population selection, single seed descent and the pure line family method, with reference to the particular problems associated with the breeding of self pollinated crops. Visual assessment may be used to shorten the selection process in all but the first approach. When a mixture of genotypes is needed to overcome complex environmental problems, bulk population selection was the most effective approach. With pedigree selection, the procedure may be sensitive to the range of diversity of the initial materials, the number of characters being selected for and the generation in which selection commences, while genotype x site and genotype x year interactions may also be important. Interaction with years may be crucial in selecting for disease resistance. It is pointed out that some conclusions which have been drawn from fundamental investigations in this field are controversial and even contradictory.

Singh and Dahiya (1986) reviewed mass selection and single seed descent selection methods for breeding of autogamous crops and described these in the light of current literature. Almost in all the studies reported in literature both these methods have been found comparable to the conventional pedigree method of breeding. In an experiment on mungbean, both these methods were found superior to pedigree selection in terms of producing high yielding progenies.

Three selection methods, viz. single seed descent (SSD), mass selection and selective intermating were applied simultaneously to a highly heterogeneous and broad based population of green gram. Progenies developed after two cycles of selection were evaluated for yield and seven other economic characters. The relative efficacy of each selection method was judged on the basis of the number of high yielding progenies, mean yield of top 10 per cent progenies, and mean of the highest yielding progeny. Selection after two cycles of selective intermating was found to be the best method for generating productive progeny, although mass selection favouring smaller seeds was an equally efficient method. Both these methods were found superior to SSD selection (Dahiya and Singh, 1986).

Genetic variance studies, conducted by Chen and Chen (1987) revealed a predominance of additive effects in population derived through SSD method. Dahiya et al. (1987) subjected a broad base population of green gram developed from composite crosses of 15 varieties representing a wide spectrum of genetic variability to the single seed descent and single plant selections and reported the superiority of former over the later for the production of high yielding progenies and maintaining high variability. They suggested that single seed descent selection method would be useful for handling the segregating materials.

In field peas single seed descent method was found more suitable to breed for earliness (Ram Niwas, 1989). Dahiya and Singh (1990) reported that single seed descent (SSD) method consists of advancing segregating populations by taking single seed from each plant till the attainment of near homozygosity. SSD method has been found to be comparable to or better than traditional methods for developing superior pure lines in crops like soybean, wheat, barley, pigeonpea, oats and green gram.

Thus from the foregoing reports the SSD method looks to be quite appealing for handling segregating generations of autogamous crops, but at the same time, it has certain limitations also. Firstly, selection for traits with low heritability (h^2) is ineffective on single plant basis (Brim, 1966). Secondly, once a superior genotype is lost from a breeding stream, it will be lost for ever. Thirdly, there may be random genetic drift if sample drawn is small.

Pedigree method (PM)

In pedigree method, a detailed record of the relationship between the selected plants and their progenies is maintained. As a result, each progeny in every generation can be traced back to the F_2 plant from which it originated. Such a record is known as a pedigree record or simply pedigree. The pedigree may be defined as a description of the ancestors of an individual and it generally goes back to some distant ancestor or ancestors in the past. The pedigree is helpful in finding out if two individuals are related by descent, i.e., have a common parent in their ancestry, and thus, are likely to have some genes in common.

The pedigree method is the most commonly used method of selection from the segregating generations of crosses in self pollinated crops. This method

is often used to correct some specific weaknesses of an established variety (combination breeding). Pedigree method is also useful in the selection of new superior recombinant types. It is almost always hoped that some transgressive segregants would be recovered (transgressive breeding). Thus, the method is suitable for improving specific characteristics, such as disease resistance, plant height, maturity time etc., as well as yield and quality characteristics.

Mahmud and Kramer (1951) tested sixty four soybean families, each comprising the F_3 lines, the bulk progeny of seven plants of the F_3 lines, and three individual F_3 plant progenies from a cross in a replicated yield trial in 1949 and showed that under the conditions of this test, genetic segregation for yield, height and maturity could have been detected among F_6 to F_8 lines. Using the variance component for generations families as a measure of environmental variability a slight evidence for dominance deviation and epistasis was found for yield but none for height or maturity.

Heritability values ranged from 69 to 77 per cent for yield, 74 to 91 per cent for height and 92 to 100 per cent for maturity, when such estimates were based on generations grown in the same season, but were negligible for yield and ranged from 35 to 50 per cent for height and maturity when different spacing and seasons were involved. It appeared that F_3 lines would provide good segregates when some attempt is made to control genetic shift and interactions of generations with environmental factors. Raeber and Weber (1953) suggested that greatest genetic advance in selecting for yield could be made by a combination of pedigree testing and concurrent phenotypic selection.

Frey (1954) while handling barley crosses suggested a scheme of plant breeding, in which besides, a scope for wider base of germ plasm investigation,

the great deal of time and effort spent in pedigree selection could be eliminated. Van der kley (1955) suggested that pedigree, bulk and mass pedigree methods were not the most efficient ones because of small frequency of desired genotypes and the possible loss of valuable genotypes by a misdirected natural or human selection.

Johnson et al. (1955) studied twenty four characters in 2 populations of soybeans in the F_4 and F_5 generations. Estimates of genetic variance obtained in different environments were less consistant, and the estimates of genotype x environment interactions were higher for yield than for other important characters.

Lupton and Whitehouse (1957) while discussing the limitations of pedigree and mass selection methods emphasised the value of quantitative data in early generation selection for the improvement of self pollinated cereal crops. They illustrated the use of F_2 progeny method and pedigree methods of selection with reference to wheat hybrids. Torrie (1958) reported non significant differences in plant height, lodging index, bacterial blight reaction, oil and protein contents of seeds between soybean lines developed by the pedigree and bulk methods. Except for the two exceptions, in which the bulk lines showed superiority, mean seed yields also were similar for the two methods of breeding. The mean maturity time of lines was similar for the two methods of breeding with the exception of the early group in which the bulk lines were late.

Voigt and Weber (1960) reported that F_5 lines selected by early generation (F_4) testing in 5 soybean crosses were superior in yield to those selected by bulk and pedigree methods. The lines selected by the early generation methods were similar in maturity and height and superior or equal in lodging resistance to selected by the bulk and pedigree methods of breeding. Heyne and Finney (1965)

while evaluating F_2 progeny method of studying segregating generations in wheat recorded high heritability for quality as analysed with data from the F_6 bulk and F_8 lines. Genetic correlation indicated that selection for one trait accomplished automatic selection to a certain degree for the other traits. Thus, early testing was suggested to serve as adequate guide for quality in making pure line selections in later generations.

Thorne et al. (1970) evaluated homogeneous F_5 derived soybean lines tracing through an F_3 selection to a single F_2 plant. Similarity of performance of genetically related lines indicated appreciable fixation of agronomic and chemical characters in the F_2 generation with further fixation occuring in the F_3. F_2 and F_3 derived lines were simulated by mixing equal amounts of seed from each related F_5 sister lines. Yield evaluation indicated that testing F_2 derived lines in advanced generations may be useful procedure in selecting superior homozygous lines of soybeans. Baker (1971) proposed modified pedigree selection as a method for improving self pollinated species. The theoretical variance of response was expected to be more variable with higher selection intensity or greater genetic variance, and less variable with larger population size or decreased environmental variance.

Tigchelaar and Casali (1972) suggested that pedigree method for more advanced generations should give maximum advance under selection in tomato. Casali and Tigchelaar (1975a) estimated breeding progress in tomato populations subjected to 4 generations of pedigree selection and revealed significant generation differences for 5 to 12 variables measured. Cross effects were greater in magnitude than generation effects with response to pedigree selection measurable only for highly heritable characters. Mean value of lines derived from 2 or 3

generations of pedigree selection followed by single seed descent (SSD) to F_6 or F_7 were similar to their corresponding pedigree lines and approximately 50 per cent of SSD lines derived following selection to F_4 surpassed pedigree lines to weighted value. Early generation pedigree selection to F_4 followed by selection among F_6 SSD derived lines appears to be the most rapid and effective means of sampling variability in segregating populations.

Park et al. (1976) compared the performance of 52 double haploid barley lines developed by pedigree (PD) and the single seed descent (SSD) methods over 2 years at two locations. There were no differences in grain yield, heading date and plant height between the DH populations and the populations derived by the other two breeding methods. Similar means and ranges, genetic variances and frequencies of desirable genotypes were obtained in the population produced by the three breeding methods for grain yield, heading date and plant height.

Seitzer and Evans (1978) in wheat compared the efficiency of (1) The standard pedigree method of selection (2) the early generation (F_3) hill test and (3) the early generation adjacent control test. They observed no significant yield differences between methods, but between methods in line performance compared to a control variety in two crosses. In cross-I, all methods were effective in recovering lines outyielding the control but the early generation tests had eliminated more of the lower yielding lines. In cross III, the hill test isolated more superior lines than the other two methods.

In self pollinated cereals Valentini (1984) demonstrated an accelerated pedigree selection (APS) which was based on the assessment of lines rather than individual plants. Unlike single seed descent (SSD), line selection by accelerated

generation procedure could begin in an early generation. The length of the APS breeding cycle was shorter than pedigree selection (PS) or SSD and combined their best features. Besides its higher efficiency of selection for yield, which being an offset against the need for greater resources, APS was expected to retain valuable genotypes with desirable combinations of characters.

Ntare (1984) compared two breeding procedures in two cowpea crosses. Both procedures were started from the same selected F_2 plants in each cross. For early generation evaluation the F_3 lines were yield tested and pedigree and bulk methods were followed in F_4 and F_5. Significant linear correlation between visual rating of F_3 and F_6 yields with actual yields revealed that it is possible to identify promising lines of cowpea visually.

Dahiya and Singh (1985) applied selective intermating and pedigree selection methods simultaneously to highly heterogeneous and heterozygous base populations of green gram in order to compare their relative efficacy in terms of evolving the number of productive lines as well as their production potential. Selection after two cycles of selective intermating was found better than traditional pedigree selection.

Dahiya and Lather (1990) evaluated selection methods in chickpea breeding and found low magnitude of differences in the mean yield of lines developed by different methods probably due to low heritability of yield and component characters. They observed frequency of the superior lines developed by bulk method almost double as compared to the pedigree method. In their opinion, to achieve higher genetic advance while selecting for yield, a combination of bulk testing in F_2 and F_3 over locations and advancing the best crosses by pedigree method may be followed in chickpea improvement programme.

Bulk population method (BP)

The bulk method of breeding was first used by Nilsson-Ehle in 1908 at Swalof. This method is also known as mass method or the population method of breeding. In the bulk method, the F_2 and subsequent generations are harvested in mass or as bulks to raise the next generation. At the end of the bulking period, individual plants are selected and evaluated in a similar manner as in the pedigree method of breeding.

Considering laborious nature of the pedigree selection, the most commonly used method, one of its alternatives is to carry a considerable number of lines to a later generation through mass pedigree (Harrington, 1937) or single seed descent method (Goulden, 1939).

In mass pedigree method of selection, segregating material is advanced in bulk for few generations and then selection is applied after attaining some level of homozygosity. This method is suited to conditions when season is not favourable for few years. This can also save labour during early stages, say in F_2, F_3 and/or F_4 where, plants are not approached individually and book keeping is avoided.

One fundamental issue in choosing a breeding method is the nature of relationship between competitive ability of yield and yield attributing characters. Competition studies in cultivar mixtures showed that competition ability was not necessarily related to yielding ability. Agronomically poor types were found to be poor competitors in barley (Harlan and Martini, 1938; Suneson, 1949; Suneson and Wiebe, 1942; Suneson and Stevens, 1953), whereas with wheat (Jensen and Federer, 1965; Khalifa and Qualset, 1974), soybeans (Mumaw and Weber, 1957) and rice (Jennings and de Jesus, Jr., 1968) the survival in mixtures was not related to yielding ability.

Genetic shifts in bulk population can take place in favour of highly competitive types because they have higher seed set and reduced seed weight as compare to poor competitors (Khalifa and Qualset, 1974). Because of unequal fertility, highly competitive types are represented in higher frequencies in successive generations resulting in decreased variability in the population and increased frequency of closely related genotypes. The genetic shifts and natural selection due to inadequate sampling and intergenotypic competition can reduce genetic variability and alter gene frequency in an undesirable direction (Haddad and Muehlbauer, 1981). To overcome the complex environmental problems, bulk population selection proved to be a more effective approach than SSD (Blaha, 1984).

At present, the most common use of bulk method is to obtain homozygous lines with less efforts and expenses. The duration of bulking depends on genetic considerations and can, thus be specified quite precisely. In general we expect a sufficiently higher amount of homozygosity by F_6 generation of selfing irrespective of segregating genes. Hence, in the species where little cross fertilization occurs, selection made in F_6 to F_8 generation are expected to breed true and subsequent evaluation is not likely to be seriously complicated by segregation. A few plant breeders have chosen to emphasize natural selection in bulk breeding progenies by continued bulking for an extended number of generations, in some instances, twenty five generations or even more (Allard, 1960).

Florell (1929) employed population or bulk population method to handle hybrid material and reported that number of generations required before selection

depended on the number of character differences involved. Ordinarily, seven or eight generations were sufficient. He further suggested that the area required for a bulk population should be large enough to include all combinations expected in a cross. The method was reported effective in self fertilized crops for the development of strains possessing winter hardiness, rust resistance, smut resistance, etc.

Sakai (1951) derived formula for proportion of homozygotes when genes were linked and suggested that selection was likely to be ineffectual in the early generations. Individual selection should, therefore, be delayed until later generations and a large bulk population be carried over through F_2 and F_3 until selection efficiency improved in the later generations. Atkins (1953) observed variability and increased yield in the selected lines as compared to the bulk lines. Greater variation in yield among bulk lines was indicated for two crosses while greater variation among selected lines and no difference in variability for yield between the bulk and selected populations was apparent in one cross each.

Studying autogamous plants Sakai (1954) derived formulae for the variance of a given character, for heritability in the F_4 generation, and for the effect of antecedent selection in the F_4 generation of hybrid bulk populations. He concluded that the method of individual selection in the F_2 and subsequent generations is inadvisable when breeding for yield, and recommended bulk breeding till about F_6 and then progeny selection.

Mumaw and Weber (1957) reported that composites of pure line varieties of soybean grown at the same location showed marked varietal changes during

5 seasons. Varieties having taller height, later maturity, more lodging and greater branching habit increased in proportion suggesting a limitation in the bulk hybrid method of plant breeding. Composites of unlike varieties exceeded the mean yield of their pure lines by more than composites of similar varieties. Seed number was more important than seed size in the yield advantage of composites. Branching types yielded more than non branching types in composites.

Soybean lines selected from populations advanced by the pedigree, early generation (F_4 and F_5) testing, and 2 bulk methods were evaluated in F_6 and F_7 (Luedders et al., 1973). Differences in the yield of these lines due to method of generation advance were not significant. However, with selection on 2 year means and in each individual years, the complete bulk (CB) and early generation testing (EGT) methods retained a few more lines than the maturity bulk (MB) and pedigree (P) methods. Methods of generation advance were highly significant for four character population combinations but these appeared to occur at random except for seed quality and later maturity which were significantly correlated in 14 out of 24 cases. Heritability estimates ranged from 10 to 40 per cent for yield, 29 to 98 per cent for height, and 23 to 72 per cent for lodging. They suggested that plant breeders discard approximately 75 per cent of their yield tested lines each year. This would permit larger population to be evaluated and should result in the retention of more stable high yielding lines.

In beans Hamblin (1977) studied the effect of bulk breeding on yield and its components in two high yielding and two low yielding crosses until the F_6 generation. It was found that bulk breeding on the whole did not alter the mean values in the high yielding crosses, but that there was a steady increase in the mean values of the low yielding crosses with generation. Besides mean

values, the use of variance as a determinant of cross potential was also studied. It was found for characters markedly influenced in their expression by the environment, of which grain yield is the prime example, that progeny variance did not differ significantly from parental variance. It was concluded that interplant competition was the factor of the environment responsible for this effect.

Busch and Luizzi (1979) studied the effect of intergenotypic competition in F_2 through F_5 bulk generations in spring wheat crosses advanced in competitive yield plots. They found that grain yield of each of the six crosses across generations did not differ significantly. Correlations of the F_2 bulk yields with yields of F_3 through F_6 bulks remained positive with no appreciable decrease. Apparently, changes in bulk populations for plant height and heading were due primarily to genetic segregation, coupled with intergenotypic competition having only minor, but significant, effects.

Rosielle (1983) used computer simulation techniques to examine the effect of variation of genetic variance and correlation between mean and genetic variance on the efficiency of bulk yield testing procedures. Assessment of the effect of variation in various parameters was made by comparing genetic gains with the maximum potential gain. The maximum potential gain was defined as that gain which would be achieved if the particular bulk which maximizes genetic advance, were chosen for selection. Maximum potential gains increased with increasing mean genetic variance within bulks but showed only slight response to increasing variation of the within bulk genetic variance. Negative correlations between bulk mean and genetic variance reduced maximum potential gains and positive correlations increased them but the effects were not large.

Virupakshappa (1984) in his studies with cowpea found that F_6 lines derived through SSD and bulk methods gave equal yields. He also reported that yield increase with bulk method of selection over generations was high in low x high yielding cross but not in high x high yielding cross.

Dahiya et al. (1984) in a comparative evaluation of mass selection for seed size, pedigree selection and selection on yield per se in terms of evolving number of more productive lines of green gram as well as their production, found the former best among these three methods. Two cycles of mass selection favouring smaller seed produced 45 per cent progenies which yielded significantly higher than check. On the other hand, only 8 and 9 per cent progenies developed through yield per se, pedigree selection, respectively out yielded the check. Mean seed yield of 10 per cent top yielding plants was also highest (8.3 g) in case of small seeded progenies as compared to those of pedigree selection (7.7 g) and selection on yield per se (7.0 g).

In field peas bulk population (BP) method was found to have the highest mean for yield and its component characters. Single pod descent (SPD) method was found best in one cross but both SSD and BP were superior to the SPD in the another cross. The BP method also contributed highest percentage of lines superior to the check for most of the characters (Ram Niwas, 1989).

Yonezawa (1988) viewed that a selection method for plant breeding which did not produce greatest genetic advance may, however, provided a better probability of success in obtaining desirable genotypes. Selection strategies based on these two approaches (genetic advance and choice of success) were described using theoretical models.

Pesek (1989) conducted a theoretical analysis of selection gain predictions and their reliability. He reported that whereas an increase in the number of repetitions reduced the reliability of selection gain estimations, an increase in the number of genotypes in the source population decreased estimation error. Population sizes required in recurrent breeding programmes for self-fertile plant species depended on the frequency of the advantageous alleles and the heritability of the desired trait.

MATERIALS AND METHODS

The present study was carried out at Vegetable Research Farm, Chaudhary Charan Singh Haryana Agricultural University, Hisar during summer and rainy seasons of 1988-1990 (Fig. 1). The experimental material for the present study consisted of F_5 progenies of single plant selections from the F_4 generation of two crosses namely Lam Sel-1 x Parbhani Kranti and HB57 x P7, derived through three selection methods viz., single seed per fruit (SSF) same as single seed descent (SSD); pedigree method (PM) and bulk population (BP). The parents involved in crossing were selected on the basis of their genetic diversity for earliness, fruit size, plant height, fruit yield and resistance to yellow vein mosaic virus disease. The source and distinguishing characters of the parents are given in Table 1.

Table 1 Source and important morphological characters of the parental lines of okra

S. No.	Variety	Source	Characteristics
1.	Lam Sel-1	Lam (Andhra Pradesh)	Early, medium tall, leaves deeply lobed, fruits long green, susceptible to yellow vein mosaic disease.
2.	Parbhani Kranti	Parbhani (Maharashtra)	Tall, leaves deeply lobed, fruits long green, resistant to yellow vein mosaic disease.
3.	HB57	HAU, Hisar (Haryana)	Early, medium tall, leaves shallow lobed, fruits medium long and thick with blunt tip, susceptible to yellow vein mosaic disease.
4.	P7 (Punjab 7)	PAU, Ludhiana (Punjab)	Medium tall, leaves shallow lobed, fruits medium long with blunt tips, resistant to yellow vein mosaic disease.

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Dean. P.G.S.

Selection procedure

In case of single seed per fruit (SSF) from the F_2 population of each cross, one seed from each fruit of 5000 individual plants was taken. These seeds were kept separately and used to grow F_3 generation, where selection similar to F_2 generation was adopted. In F_4 generation single plant selection was practised and of the 5000 plants the thirty top yielders were selected in each cross to grow F_5 single plant progenies for evaluation (Fig. 1).

In pedigree method (PM), instead of taking single seed, random sample of seeds of individual selected F_2 plants were taken separately and their pedigree records were maintained. This seed was used to grow next generation. The population size as that of F_2 was maintained in F_3 and F_4 generations also. Visual selection and selection for yield per se was practised in F_4 as in SSF method.

In bulk population method (BP), all the plants from F_2 were harvested as bulk and a random sample of seeds was used to grow 5000 plants in next generation. the same procedure was adopted in F_3 population also. In F_4 generation visual selection and selection for yield per se was practised as per the earlier two methods.

The seeds of 30 selected lines under each method along with their parents and standard check (Pusa Sawani) were sown on July 26, 1990 in a complete randomized block design with three replications. Progenies, their parents and standard check were grown in 3 m long single rows each accomodating 15 plants. A distance of 45 cm and 20 cm between and within rows was maintained. The recommended package of practices were adopted for raising a healthy crop of okra. Observations were recorded on five randomly selected competitive plants from each plot for the following characters:

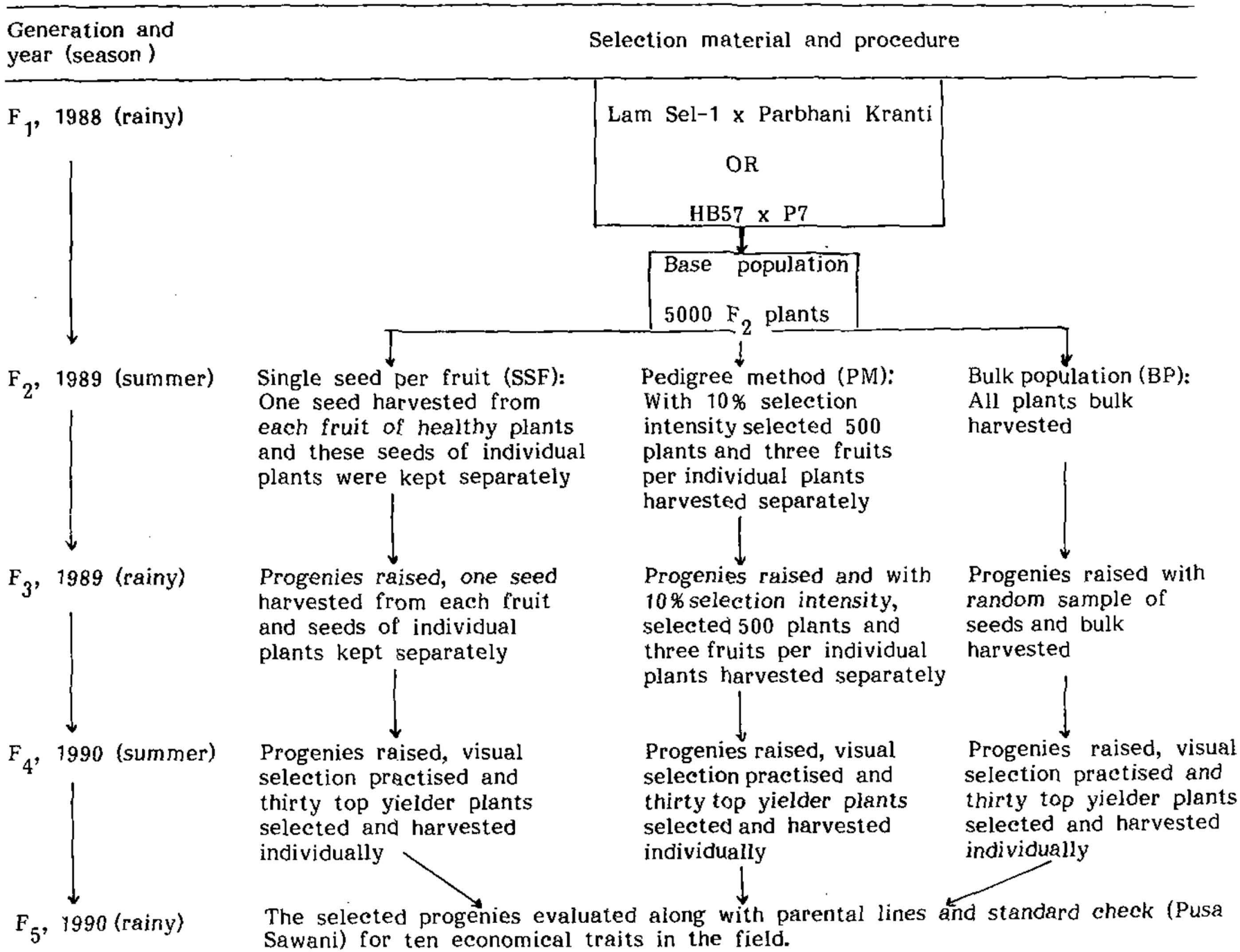

Fig. 1 Selection scheme in two crosses of okra

Observations recorded

1. **Days to first flowering:** *The number of days taken from the date of sowing* to the date of opening of the first flower was recorded.

2. **Days to first picking:** The number of days taken from the date of sowing to the date of first picking of marketable fruits was recorded.

3. **First fruiting node:** Nodes of individual plants from the base to the node bearing first fruit were counted and then average per plant was worked out.

4. **Plant height (cm):** At the time of final picking plant height was measured from ground level to the apex of the main shoots of plants to work out average per plant.

5. **Number of branches per plant:** Total number of productive branches of selected plants was counted at the time of last picking to find out the average number of branches per plant.

6. **Number of fruits per plant:** Fruits harvested from selected plants of individual genotypes at each picking were counted, added and average per plant was worked out.

7. **Fruit length (cm):** It was recorded from five marketable fruits taken randomly at three different pickings of sampled plants. Mean length of the fruit was calculated.

8. **Fruit diameter (cm):** Fruits taken for recording length were also used to measure their diameter from the centre with the help of Vernier Calliper and then average fruit diameter was estimated.

9. **Internode length (cm):** *Internode length of lower, middle and upper internodes* of randomly selected plants was recorded at final harvest and then average was worked out.

10. Total yield per plant (g): Weight of fruits harvested from the selected five plants was recorded at each picking and from total of all pickings the average per plant was worked out.

Statistical Method

The statistical analysis was done using mean of five plants taken from each plot. The experimental data obtained from three replications for all the characters were analysed for both the crosses separately, following statistical analysis as given below:

Analysis of variance

The analysis of variance carried out for the simple randomized complete block design was based on the following model (Panse and Sukhatme, 1967):

$$Yij = m + ai + bj + eij$$

where,

Yij = Observation in the ith treatment and jth replication,

m = general mean ,

ai = ith treatment effect,

bj = jth replication effect, and

eij = random error associated with ith treatment and jth block.

The assumptions of the model are:

a) All the observations should be independent.

b) Error involved in the population should be normally and independently distributed with mean zero and variance σ_e^2.

Analysis of variance tables for all the characters under study in both the crosses were constructed separately as follows:

Source	df	MS	EMS	F calculated
Replications	(r-1)	MS r	$\sigma_e^2 + g\,\sigma_r^2$	
Genotypes	(g-1)	MS g	$\sigma_e^2 + r\,\sigma_g^2$	MS g/MS e
Error	(r-1)(g-1)	MS e	σ_e^2	
Total	(rg-1)			

where,

r = number of replications,

g = number of genotypes,

MS r = mean sum of square due to replication,

MS g = mean sum of square due to genotypes,

MS e = mean sum of square due to error,

σ_g^2 = genotypic variance of character X and

σ_e^2 = error variance of character X.

The genotypic, phenotypic and error variances were calculated as follows:

Genotypic variance of character X = $\sigma_g^2 = \dfrac{MS\ g - MS\ e}{r}$

Phenotypic variance of character X = $\sigma_p^2 = \sigma_g^2 + \sigma_e^2$

Error variance of character X = σ_e^2 = MS e

Analysis of covariance: Analysis of covariance tables were constructed for all possible combinations taking two characters at a time in the following manner:

Source	df	MSP	EMSP
Replications	(r-1)	MSP r	Cov e. xy + g Cov r. xy
Genotypes	(g-1)	MSP g	Cov e. xy + r Cov g. xy
Error	(r-1)(g-1)	MSP e	Cov e. xy
Total	(rg-1)		

where,

r = number of replications,

g = number of genotypes,

Cov g. xy= genotypic covariance of character X and character Y,

Cov e. xy= error covariance of character X and Y.

The genotypic and phenotypic covariance were calculated as follows:

$$\text{Genotypic covariance} = \text{Cov g. xy} = \frac{\text{MSP g} - \text{MSP e}}{r}$$

Phenotypic covariance = Cov p. xy = Cov g. xy + Cov e. xy

where, MSP g and MSP e are the mean sum of products due to treatments and error, respectively from analysis of covariance between character X and character Y, respectively and Cov p. xy is the phenotypic covariance between character X and character Y.

Parameters of variability

Mean ($\bar{x}$): The mean value of each character was worked out by dividing the totals by corresponding number of observations.

$$\bar{X} = \frac{\sum X_{ij}}{N}$$

where,

X_{ij} = any observation in ith genotype and jth replication,

N = total number of observations,

Range: The lowest to the highest mean values for each character were recorded.

$$\text{Range Index (RI)} = \frac{\text{Highest mean} - \text{Lowest mean}}{\text{General mean}} \times 100$$

Standard error: Standard error of difference of two means were calculated with the help of error mean square from the analysis of variance table.

$$\text{Standard Error (SE d)} = \sqrt{\frac{2\ \text{EMS e}}{r}}$$

where,

EMS e = error mean sum of square,

r = number of replications.

Critical difference (CD): Critical differences for all the characters were calculated to compare the treatment means. Critical differences were calculated with the help of standard error for the differences of two means and tabulated value of 't' at 5 per cent and 1 per cent level of significance and at error degrees of freedom,

Critical difference (CD) = SE d x t at 5% or 1% probability at error degrees of freedom.

Coefficient of variation: Genotypic and phenotypic coefficients of variation were estimated by the formula suggested by Burton (1952) for each character as:

$$\text{Genotypic coefficient of variation (GCV)} = \frac{\sqrt{g}}{\bar{x}} \times 100$$

$$\text{Phenotypic coefficient of variation (PCV)} = \frac{\sqrt{p}}{\bar{x}} \times 100$$

$$\text{Simple coefficient of variation (CV)} = \frac{\sqrt{e}}{\bar{x}} \times 100$$

where, $\bar{x}$ is the mean of that particular character.

Heritability: Heritability in broad sense was calculated according to the formula suggested by Hanson et al. (1956) for each characetr as:

$$\text{Heritability in broad sense } (h^2 \text{ b.s.}) = \frac{\sigma^2_g}{\sigma^2_p} \times 100$$

Genetic advance: Estimates of appropriate variance components were substituted for the parameters to predict expected genetic gain as suggested by Lush (1940). The expected genetic advance was calculated at 5 per cent selection intensity for each character as:

$$\text{Genetic advance (GA)} = k.\ \sigma_p.\ h^2, \text{ and}$$

$$\text{Genetic advance (\%age of mean)} = \frac{k.\ \sigma_p.\ h^2}{\bar{x}} \times 100$$

where, k is the selection differential expressed in terms of phenotypic standard deviations σ_{pi}. Using 5 per cent selection in a large sample from a normally and independently distributed population, the value of selection intensity (k) is equal to 2.06 (Allard, 1960).

h^2 is the heritability in broad sense, and

$\bar{x}$ is the mean value for that character over all the genotypes.

Genotypic, phenotypic and error correlation coefficients

Correlation coefficients at phenotypic, genotypic and environmental levels were calculated from the variance and covariance tables already obtained, using the Cross 1 and Cross 2 data separately.

$$\text{(i) Phenotypic correlation} = rij\ (p) = \frac{\text{Cov p. xy}}{\sqrt{\text{Var p. x} \cdot \text{Var p. y}}}$$

where,

Cov p. xy = phenotypic covariance of character x and character y,

Var p. x = phenotypic variance of character x and

Var p. y = phenotypic variance of character y.

(ii) Genotypic correlation rij (g) = $\frac{\text{Cov g. xy}}{\sqrt{\text{Var g. x} \cdot \text{Var g. y}}}$

where,

Cov g. xy = genotypic covariance of character x and y,

Var g. x = genotypic variance of character x and

Var g. y = genotypic variance of character y.

(iii) Environmental correlation = rij (e) = $\frac{\text{Cov e. xy}}{\sqrt{\text{Var e. x} \cdot \text{Var e. y}}}$

where,

Cov e. xy = error or environmental covariance of characters x and y,

Var e. x = error variance of character x and

Var e. y = error variance of character y.

Phenotypic correlations were tested at 5 per cent and 1 per cent levels of significance against the expected values from Fisher's table at (n-2) degrees of freedom, where n represents number of varieties under study.

EXPERIMENTAL RESULTS

The populations of two crosses of okra were advanced through F_4 generation by adopting three selection methods viz., single seed per fruit (SSF), pedigree method (PM) and bulk population method (BP). Finally on the basis of yield per se the visually appearing superior 180 plants i.e. 30 plants with each method were selected and evaluated in the field during rainy season of 1990-91 for various metric traits of economic importance. The results of this study have been described as under:

A. Analysis of variance

The analysis of variance for the design of experiment with respect to three methods of selection was done for ten metric traits (Table 2) for both the crosses i.e. Lam Sel-1 x Parbhani Kranti (Cross 1) and HB57 x P7 (Cross 2). The analysis of variance showed that except for number of fruits per plant, fruit and internode length (SSF); fruit length, diameter and internode length (PM); number of branches per plant, fruit length, diameter and internode length (BP) in cross Lam Sel-1 x Parbhani Kranti (Cross 1), and days to first picking, number of branches per plant, number of fruits per plant and internode length (SSF) in cross HB57 x P7 (Cross 2) the mean squares due to lines were significant for all the characters.

The significance of mean squares due to replications in some cases could be attributed to soil heterogeneity in fertility, sampling error etc. From these results it is obvious that lines selected from both the crosses under three methods of selection were significantly variable for most of the characters

S. No.	Characters	Crosses	Mean squares								
			Single seed per fruit (SSF)			Pedigree method (PM)			Bulk population method (BP)		
			Replications	Genotypes	Error	Replications	Genotypes	Error	Replications	Genotypes	Error
		df.	2	32	64	2	32	64	2	32	64
1.	Days to first flowering	Cross 1	20.17**	4.53**	1.19	19.60**	4.74**	0.88	10.13**	5.48**	1.24
		Cross 2	53.74**	4.67**	1.89	52.77**	6.73**	1.85	71.77**	7.55**	2.70
2.	Days to first picking	Cross 1	3.68	6.83*	3.74	4.03	6.21*	3.62	1.85	6.56**	3.10
		Cross 2	11.38	6.83	6.45	7.85	19.39**	7.74	11.06	16.56*	9.41
3.	First fruiting node	Cross 1	2.51*	1.14**	0.56	0.33	1.36*	0.74	0.38	1.40**	0.50
		Cross 2	1.04	1.60**	0.60	8.78**	1.38**	0.66	3.47**	2.14**	0.56
4.	Plant height (cm)	Cross 1	1053.84**	475.36**	161.27	0.29	824.82**	133.15	927.98**	462.51**	169.82
		Cross 2	233.32	270.55**	95.11	1230.14**	299.11**	104.09	292.15*	353.17**	85.60
5.	Number of branches/ plant	Cross 1	11.75**	0.91*	0.47	0.84	0.84*	0.43	0.32	0.91	0.64
		Cross 2	2.78*	0.70	0.68	0.69	1.21**	0.56	4.55**	1.20*	0.69
6.	Number of fruits/ plant	Cross 1	31.82**	8.41	5.34	3.26	10.71**	3.90	9.61	9.05*	4.91
		Cross 2	36.74**	7.15	6.51	17.57*	9.38*	5.46	17.70	12.08*	7.50
7.	Fruit length (cm)	Cross 1	4.11	3.19	2.22	7.07*	3.55	2.24	0.67	2.24	1.86
		Cross 2	5.01	4.09*	2.29	3.45	6.93**	2.23	2.45	5.02**	1.91
8.	Fruit diameter (cm)	Cross 1	0.02	0.02**	0.01	0.04	0.02	0.01	0.01	0.01	0.01
		Cross 2	0.08**	0.03**	0.01	0.01	0.06**	0.01	0.02	0.03**	0.01
9.	Internode length (cm)	Cross 1	55.05**	1.69	1.83	21.65**	1.84	1.16	9.51**	1.68	1.55
		Cross 2	5.58**	1.35	1.06	18.10**	3.09**	1.36	1.09	2.95**	1.33
10.	Total yield/plant (g)	Cross 1	6743.74**	1425.53*	875.15	1038.80	2075.02**	576.72	1501.84	1718.61**	636.76
		Cross 2	2790.37*	1561.25*	782.61	2035.97	1387.72*	764.25	2715.95	1726.56*	1078.92

*,** $P \leqslant 0.05$ and 0.01, respectively as tested against error mean square.

observed. This was further supported by the two factor pooled analysis (Table 3) where methods, lines and their interaction effects were found highly significant for different characters in both the crosses. The method differences were found significant for all the characters except days to first picking, number of fruits per plant, fruit diameter and total yield per plant in Cross 1, and non significant for all the characters except fruit length and diameter in Cross 2.

The lines were found significantly variable for all the characters except number of branches per plant, fruit and internode length in Cross 1 and for all the characters except number of fruits per plant and total yield per plant in Cross 2. However, in both the crosses the interaction effects were found highly significant for all the characters except days to first picking, fruit diameter and internode length in Cross 1. The results presented in Tables 2 and 3 suggested that methods differed in their efficiencies to select the superior lines, also different from each other. Further the selection of lines with particular method depended on their interactions and the differences in methods for selecting desirable lines appeared to be the function of base material used in selection programme. Here, for the selection of superior lines perhaps a particular method appeared appropriate while for others the another method of selection might be suitable. This is also evident that in both these crosses the methods appeared to be character specific for improvement programme in okra.

B Mean performance of selection lines

The mean performance of lines developed through the three methods of selection along with their parents and a standard check, 'Pusa Sawani' for the ten characters studied in both the crosses are presented in Table 4a-e.

Table 3 ANOVA of lines and selection methods for different characters in two okra crosses - Lam Sel-1 x Parbhani Kranti (Cross 1) and HB57 x P7 (Cross 2)

S. No.	Characters	Crosses	Mean squares			
			Methods	Lines	Methods x Lines	Error
		df.	2	32	64	196
1.	Days to first flowering	Cross 1	12.72**+	8.78**++	2.99**	1.10
		Cross 2	1.33	9.11**+	4.92**	2.11
2.	Days to first picking	Cross 1	1.71	15.95**++	1.83	3.43
		Cross 2	7.73	12.04*	15.37**	8.00
3.	First fruiting node	Cross 1	3.29**	1.64**	1.12**	0.61
		Cross 2	1.12	1.28**	1.92**	0.62
4.	Plant height (cm)	Cross 1	4755.72**++	904.39**++	429.15**	158.89
		Cross 2	50.48	278.48**	322.17**	96.21
5.	Number of branches/plant	Cross 1	2.19*	0.90	0.88**	0.55
		Cross 2	0.96	1.16**	0.98*	0.64
6.	Number of fruits/plant	Cross 1	1.31	12.55**+	7.81**	4.80
		Cross 2	0.63	7.52	10.54**	6.46
7.	Fruit length (cm)	Cross 1	8.34*	2.51	3.23*	2.11
		Cross 2	11.13**	6.99**	4.52**	2.11
8.	Fruit diameter (cm)	Cross 1	0.02	0.02**++	0.01	0.01
		Cross 2	0.09**	0.04**	0.04**	0.01
9.	Internode length (cm)	Cross 1	17.89**++	2.22	1.50	1.61
		Cross 2	1.22	2.36**	2.51**	1.29
10.	Total yield/plant (g)	Cross 1	905.00	2323.32**+	1447.92**	711.77
		Cross 2	44.68	1030.05	1510.19*	951.26

*, ** $P \leqslant 0.05$ and 0.01, respectively as tested against error mean square, and
+, ++ $P \leqslant 0.05$ and 0.01, respectively as tested against interaction mean square.

Days to first flowering

The mean performance of progenies and parents for both the crosses, and standard check differed markedly for days taken to first flowering. The range for parents being 45 days in Lam Sel-1 to 47.3 days in Parbhani Kranti in Cross 1 population, while 40.4 days in HB57 to 43.7 days in P7 of Cross 2 under all the three methods of selection (Table 4a).

Parbhani Kranti was late in flowering compared to standard check, Pusa Sawani (45.7 days) in Cross 1. On the other hand parent HB57 was early in flowering, while Pusa Sawani with mean value of 46 days was late in Cross 2.

In case of SSF the variation for days to flowering among progenies ranged between 41.6 to 45.3 days in Cross 1 and 41.5 to 46.4 days in Cross 2. The lines 17, 27, 9, 10 and 14 of Cross 1 and 7, 3, 14, 21 and 27 of Cross 2 were found early flowering selections as compared to their parents (except HB57) and the standard check, Pusa Sawani.

Under PM of selection the range for days taken to flowering among progenies varied between 41 to 45.2 days for Cross 1 and 41 to 46.5 days in Cross 2. The lines 7, 14, 15 27, 28 in Cross 1 and lines 5, 9, 11, 17 and 30 in Cross 2 were also marked early flowering selections.

In selections generated through BP the days taken to flowering ranged from 41 days to 44.3 days in Crsos 1 and 41.5 days to 46.7 days in Cross 2. The lines 6, 1, 4, 9 and 11 in Cross 1 and lines 7, 4, 11, 14 and 29 in Cross 2 were the earliest flowering genotypes. The Line No. 5 with mean days of 46.7 was late than all selections in BP method. Apparently the selections of late parents in Cross 1 were found early and that of early parents in Cross 2 were late flowering types.

Table 4a Mean performance of selected okra lines along with their parents and standard check for different characters under three methods of selection

Selected lines, Parents and Standard Check	Characters/Crosses*/Methods											
	Days to first flowering						Days to first picking					
	Cross 1			Cross 2			Cross 1			Cross 2		
	SSF	PM	BP	SSF	PM	BP	SSF	PM	BP	SSF	PM	BP
Line No. 1	43.9	46.1	41.3	44.7	45.5	45.4	**48.3**	51.0	51.0	53.3	55.3	**51.0**
" 2	43.3	44.7	42.7	43.5	42.7	43.4	51.0	52.0	51.0	**51.0**	**51.0**	51.0
" 3	44.3	43.5	44.1	42.1	42.9	44.5	51.0	52.0	51.0	51.0	59.3	51.0
" 4	43.3	44.0	41.3	**46.4**	42.5	42.0	51.0	52.0	51.0	53.0	51.0	51.0
" 5	43.7	43.0	43.9	43.3	41.9	**46.7**	51.0	51.0	51.0	**55.7**	51.0	**58.0**
" 6	44.3	44.3	**41.0**	44.1	43.7	45.1	51.0	51.0	51.0	51.0	51.0	58.0
" 7	43.0	42.4	42.7	**41.5**	44.9	**41.5**	51.0	52.0	**48.3**	54.7	51.0	51.0
" 8	43.3	43.0	42.4	43.5	43.5	44.7	51.0	51.0	51.0	54.0	58.0	54.7
" 9	41.7	44.3	41.5	45.0	42.0	45.3	51.0	51.0	51.0	51.0	51.8	54.3
" 10	42.5	44.6	43.9	45.1	43.7	42.1	51.0	51.0	52.0	53.0	56.7	51.0
" 11	45.2	44.3	41.3	44.1	**41.0**	42.1	51.0	51.0	51.0	53.3	52.0	51.0
" 12	43.5	43.9	43.9	45.3	44.8	42.9	51.0	51.0	51.0	53.0	51.0	55.7
" 13	43.3	**45.2**	42.5	45.3	45.0	45.1	51.0	51.0	51.0	54.0	52.0	54.0
" 14	42.4	42.1	42.3	42.5	45.5	42.0	51.0	51.0	51.0	51.0	57.0	51.0
" 15	42.7	42.1	44.1	44.3	45.3	46.4	51.0	51.0	**54.3**	53.0	53.0	52.5
" 16	43.9	43.8	42.2	44.4	43.0	42.6	51.0	51.0	51.0	52.0	51.0	51.0
" 17	**41.6**	43.9	41.9	45.3	41.6	43.5	51.0	52.0	51.0	53.0	51.0	52.0
" 18	43.7	44.3	42.7	43.5	44.8	45.6	51.0	51.0	51.0	52.0	52.5	53.3
" 19	42.6	43.8	42.9	43.4	44.5	43.7	51.0	51.0	51.0	52.0	52.5	52.0
" 20	43.3	44.6	**44.3**	44.1	45.2	45.5	51.0	51.0	51.0	51.0	**59.5**	55.7
" 21	45.1	42.8	43.2	42.3	**46.5**	44.1	**53.3**	51.0	51.0	51.0	52.5	56.7
" 22	44.3	44.1	43.4	43.7	44.6	44.0	51.0	51.0	51.0	55.3	53.0	54.7
" 23	43.2	43.3	42.7	44.5	42.9	43.1	51.0	51.0	51.0	52.0	51.0	51.0
" 24	42.7	43.5	42.6	44.8	44.0	42.8	51.0	51.0	51.0	54.7	51.0	51.0
" 25	42.7	44.2	42.4	44.1	43.3	44.5	51.0	52.0	51.0	55.7	51.0	52.0
" 26	**45.3**	42.5	44.3	44.5	42.4	44.9	51.0	51.0	51.0	51.0	51.0	54.7
" 27	41.7	41.7	43.9	42.7	44.3	45.3	48.3	51.0	51.0	51.0	51.0	58.0
" 28	43.8	**41.0**	43.6	44.3	45.3	45.8	51.0	**48.3**	51.0	52.0	52.0	53.0
" 29	44.2	44.1	43.0	44.1	44.1	41.7	51.0	51.0	51.0	52.5	52.0	51.0
" 30	44.0	42.5	42.3	43.6	42.1	43.9	51.0	**53.3**	51.0	51.0	51.0	52.0
Lam Sel-1/HB57 (P1)			45.0			40.4			53.3			51.0
Parbhani Kranti/P7 (P2)			47.3			43.7			58.0			52.5
Pusa Sawani (S. Check)			45.7			46.0			51.0			52.0
General mean	43.7	43.8	43.1	43.9	43.7	44.0	51.2	51.5	51.3	52.5	52.7	53.1
C.D. at 5%	1.5	1.8	2.2	2.2	2.6	2.6	3.1	2.8	4.1	NS	4.9	4.9
C.D. at 1%	2.0	2.4	2.9	2.9	3.5	3.5	4.0	3.7	5.4	NS	6.5	6.5

* Cross 1 = Lam Sel-1 x Parbhani Kranti and Cross 2 = HB57 x P7,

NS = Not significant

Days to first picking

The mean performance of parents, progenies and standard check differed significantly for days taken to first picking in both the crosses except under SSF in Crsos 2. The range being 53.3 days (Lam Sel-1) to 58 days (Parbhani Kranti) in Cross 1 and 51 days (HB57) to 52.5 days (P7)in Cross 2 under all the three methods of selection. Pusa Sawani took 51 and 52 days for first picking while comparing Cross 1 and Cross 2, respectively (Table 4a).

Among progenies under SSF the Line No. 1 and 27 were early yielder with mean values of 48.3 days and Line No. 21 was late yielder (53.3 days) in Cross 1 while in Cross 2 the majority of the lines were picked in 51 days and Line No. 25 gave first harvest in 55.7 days in Cross 2, however, statistically the differences among lines under SSF method were not significant for this cross.

In PM progeny range observed for first picking was 48.3 days (Line No. 28) to 53.3 days (Line No. 30) and 51 days for fourteen of the lines to 59.5 days (Line No. 20) for the Cross 1 and Cross 2, respectively. Twenty one lines under this method were also picked in 51 days in Cross 1.

Under BP method the porgeny range for days to first picking varied from 48.3 days (Line No. 7) to 54.3 days (Line No. 15) and 51 days for twelve of the lines to 58 days (Line No. 5, 6 and 27) for Cross 1 and Cross 2, respectively. Further, in Cross 1 twenty seven out of thirty selections became ready for first picking at 51 days. The pattern of late parents producing early selections and early parents producing late yielding selections was also obvious from these results.

First fruiting node

Among parental lines of Cross 1, Lam Sel-1 and that of Cross 2, HB57 produced fruits at lower nodes. Parbhani Kranti, P7 and Pusa Sawani produced fruits at higher nodes under all the three methods of selection (Table 4b).

In Cross 1, the range of first fruiting node among progenies was 5.1 (Line No. 27) to 7.7 (Line No. 11) under SSF; 4.9 (Line No. 15) to 7.9 (Line No. 18) under PM and 5.2 (Line No. 1) to 7.5 (Line No. 26) under BP method. While, in Cross 2 first fruiting node among progenies ranged from 5.4 (Line No. 7) to 8.1 (Line No. 10) in SSF; 5 (Line No. 8) to 7.9 (Line No. 1) in PM and 5 (Line No. 24) to 8.3 (Line No. 30) under BP method.

Plant height (cm)

Among parents Parbhani Kranti (68.5 cm) followed by Lam Sel-1 of Cross 1 and P7 followed by HB57 in Cross 2 recorded the maximum to minimum plant height. The standard check Pusa Sawani, had more height than the female parents of both the crosses (Table 4b).

Among progenies the height of plant ranged from 58.7 cm in Line No. 21 to 102.4 cm in Line No. 11 in Cross 1 and 41 cm (Line No. 17) to 77.3 cm (Line No. 10) of Cross 2 under SSF method of selection.

Under PM the plant height of progenies varied from 61.6 cm (Line No. 4) to 111.5 cm (Line No. 22) in Cross 1 and 28 cm (Line No. 9) to 74.5 cm (Line No. 23) in Cross 2.

In case of BP method the plant height of progenies dispersed from 66.7 cm in Line No. 28 to 103.2 cm in Line No. 9 of Cross 1 while, 36.2 cm in Line No. 15 to 75.4 cm in Line No. 4 of Cross 2.

An examination of mean plant height data of selected progenies under different methods of selection though did not show specific pattern, however it appeared that the progenies of taller plants tended to be tall and in no case the plant height reduced than the shorter female parent in Cross 1. However, in case of Cross 2 some selected progenies became still dwarfer than their shortest female parent, HB57. It was also visible that pedigree and bulk population methods tended to retain selection lines with tall stature in Cross 1 while these two methods selected more number of short statured lines in Cross 2. The SSF, which is rather more vigrous selection method, mainly tended to select the plants of tall nature. In general PM in Cross 1 selected majority of the tall selection lines.

Number of branches per plant

Number of branches per plant differed significantly among parents, progenies and standard check in both the crosses except for selections developed under BP in Cross 1 and SSF in Cross 2. Both the female parents possessed lesser, branches while, both the male parents had more branches as compared to standard check used in both the crosses (Table 4c).

In Cross 1 the Line No. 13, 30 and 5 had the minimum and Line No. 8, 12 and 18 recorded the highest number of branches per plant among selected lines in SSF, PM and BP methods, respectively. Similarly, Line No. 27, 1 and 21 gave minimum branches while, Line No. 13, 7 and 3 exhibited highest branching in Cross 2 selections under SSF, PM and BP methods of selection, respectively. In general, SSF in Cross 1 and BP in Cross 2 showed more branching tendency in selected lines.

Table 4c Mean performance of selected okra lines along with their parents and standard check for different characters under three methods of selection

Selected lines, Parents and Standard Check	Characters/Crosses*/Methods											
	Number of branches/plant						Number of fruits/plant					
	Cross 1			Cross 2			Cross 1			Cross 2		
	SSF	PM	BP	SSF	PM	BP	SSF	PM	BP	SSF	PM	BP
Line No. 1	1.8	1.5	1.3	0.8	0.3	1.3	8.3	10.0	8.8	5.7	4.7	8.5
" 2	2.3	1.1	2.4	0.8	1.0	0.7	12.2	8.7	12.7	6.0	9.3	7.9
" 3	1.8	1.9	1.1	1.2	1.0	3.1	11.1	9.1	10.8	7.5	5.9	9.9
" 4	1.7	1.0	1.5	1.1	1.7	1.4	12.4	7.0	12.1	4.9	9.7	9.4
" 5	1.4	1.6	0.3	1.3	0.8	0.3	10.3	9.9	8.0	5.5	7.7	5.3
" 6	2.4	1.7	0.7	0.8	0.6	1.0	10.7	12.5	10.3	5.3	6.6	5.8
" 7	0.9	1.1	0.9	1.7	2.3	1.6	9.1	10.2	8.9	8.7	7.6	8.7
" 8	3.4	0.5	1.3	1.4	0.3	0.6	11.9	8.6	9.3	8.0	7.3	3.4
" 9	1.3	2.0	1.4	1.3	1.0	1.3	11.2	9.8	10.8	7.3	3.5	4.5
" 10	1.3	1.6	1.7	1.7	0.6	1.1	10.1	10.7	10.3	8.4	4.2	8.0
" 11	1.7	1.0	1.9	1.0	1.9	1.2	10.3	11.3	13.1	4.9	8.8	8.6
" 12	1.5	2.5	1.9	0.7	1.8	1.1	10.0	12.5	8.5	4.7	9.4	5.0
" 13	0.2	1.1	0.5	2.2	0.8	0.9	7.3	10.3	9.0	8.3	4.4	5.0
" 14	1.6	1.7	1.1	1.7	0.5	1.3	10.5	12.9	10.3	10.0	3.9	11.9
" 15	1.1	1.1	0.7	1.1	0.7	1.2	10.1	10.9	8.7	7.1	4.6	5.7
" 16	1.4	0.7	1.1	1.2	1.6	1.8	10.8	10.5	11.1	6.3	8.8	8.7
" 17	1.4	2.3	1.3	1.5	0.9	0.7	10.3	13.2	10.5	6.7	7.8	5.2
" 18	1.4	1.8	2.4	1.7	0.7	1.7	8.0	9.4	11.8	8.3	5.6	6.2
" 19	1.5	1.0	1.9	1.5	0.7	0.9	11.4	8.2	13.6	11.3	7.8	5.2
" 20	1.0	1.9	1.1	1.7	0.7	1.3	8.5	10.6	9.8	7.7	5.6	4.5
" 21	1.3	1.7	0.5	1.9	0.3	0.2	7.5	11.6	10.0	8.9	6.5	8.6
" 22	1.4	1.5	2.1	0.8	1.8	0.8	10.4	9.6	12.4	7.1	8.6	5.7
" 23	1.4	2.1	1.3	0.9	1.3	1.1	9.4	11.1	10.7	7.4	7.7	9.6
" 24	2.3	1.3	0.7	0.9	1.9	1.4	11.4	11.4	9.3	5.7	8.7	7.6
" 25	2.4	0.7	1.3	0.7	1.1	1.3	12.0	9.6	11.1	4.3	6.4	6.6
" 26	1.8	0.9	1.9	1.0	0.5	2.3	9.1	10.7	11.9	6.2	6.7	8.6
" 27	1.9	1.1	0.7	0.3	2.3	0.4	12.3	10.2	8.8	6.6	9.1	3.6
" 28	1.5	1.8	1.9	0.8	1.5	1.1	8.7	14.0	8.7	7.8	8.2	7.1
" 29	1.7	2.2	1.3	1.7	0.8	1.4	8.4	9.9	9.5	6.7	6.9	9.0
" 30	2.0	0.4	1.2	2.0	0.5	2.1	11.6	6.3	11.6	7.8	4.5	7.1
Lam Sel-1/HB57 (P1)			1.3			0.9			7.1			7.5
Parbhani Kranti/P7 (P2)			2.1			2.1			6.2			6.7
Pusa Sawani (S. Check)			1.2			0.5			8.0			7.9
General mean	1.6	1.4	1.3	1.2	1.0	1.2	9.9	10.1	10.1	7.1	6.9	7.1
CD at 5%	1.1	1.3	NS	NS	1.3	1.3	NS	3.5	4.1	NS	4.4	4.4
CD at 1%	1.4	1.7	NS	NS	1.7	1.8	NS	4.7	5.4	NS	5.8	5.8

*Cross 1 = Lam Sel-1 x Parbhani Kranti and Cross 2 = HB57 x P7,

NS = Not significant

Number of fruits per plant

Number of fruits per plant was 7.1 in Lam Sel-1, 6.2 in Parbhani Kranti, 7.5 in HB57 and 6.7 in P7. Standard check had 8.0 and 7.9 fruits per plant when compared with Cross 1 and Cross 2 selections, respectively (Table 4c). For both the crosses the selection lines developed under SSF did not show significant differences among them for number of fruits per plant. The other two methods were quite effective in retaining large variability.

The number of fruits among progenies varied from 6.3 in Line No. 30 to 14 in Line No. 28 and 3.5 in Line No. 9 to 9.7 in Line No. 4 under PM of selection in Cross 1 and Cross 2, respectively. The other promising lines were No. 6, 12, 14 and 17 in Cross 1, No. 2, 12, 16 and 27 in Cross 2.

Fruit length (cm)

The mean fruit length of Lam Sel-1 and Parbhani Kranti was 8.5 cm and of Pusa Sawani was 10 cm in comparison to Cross 1 selections. HB57 had fruits of average length of 9.8 cm while P7 had the longest fruits of 13 cm size. Pusa Sawani in comparison with Cross 2 lines had 9.3 cm long fruits.

The differences in fruit length of selected progenies by three methods were not significant for the cross Lam Sel-1 x Parbhani Kranti. The average fruit lengths of Line No. 3, 6,9,12, 14 and 24 in Cross 1 and that of Line No. 1, 3, 18, 21 and 28 in Cross 2 under SSF method of selection were more than 10·5cm. The Line No. 22 and 17 produced fruits of minimum length in Cross 1 and Cross 2, respectively (Table 4d).

Under pedigree method of selection the average fruit length of lines varied from 7.8 cm (Line No. 30) to 12.1 cm (Line No. 27) in Cross 1 and 7 cm

Table 4d Mean performance of selected okra lines along with their parents and standard check for different characters under three methods of selection

Selected lines, Parents and Standard Check	Characters/Crosses*/Methods											
	Fruit length (cm)						Fruit diameter (cm)					
	Cross 1			Cross 2			Cross 1			Cross 2		
	SSF	PM	BP	SSF	PM	BP	SSF	PM	BP	SSF	PM	BP
Line No 1	10.3	7.9	10.8	**11.3**	9.3	10.5	1.3	1.2	1.3	**1.6**	1.4	1.4
" 2	8.7	8.4	8.2	8.2	10.3	10.1	1.3	1.2	1.3	1.3	1.3	1.4
" 3	10.9	9.6	8.4	10.6	**7.0**	10.3	1.3	1.3	1.2	1.5	**1.1**	1.3
" 4	9.4	10.1	8.2	9.9	10.2	9.7	1.4	1.4	1.2	1.3	1.4	**1.5**
" 5	9.7	11.7	7.9	9.8	9.2	8.8	1.3	1.4	1.2	1.5	1.4	1.4
" 6	10.8	9.3	9.8	10.1	9.5	10.0	1.3	1.3	1.3	1.3	1.3	**1.6**
" 7	9.0	8.7	9.6	10.2	8.6	8.9	1.2	1.3	1.3	1.4	1.4	1.3
" 8	10.6	9.0	8.7	7.9	10.7	8.0	1.3	1.3	1.3	1.3	1.5	1.3
" 9	9.2	9.5	9.0	10.4	10.7	7.5	1.2	**1.1**	1.2	1.3	1.5	1.3
" 10	10.4	11.2	8.6	8.7	**13.8**	10.1	1.3	1.4	1.2	1.4	**2.0**	1.3
" 11	10.3	9.5	9.1	9.8	10.3	9.0	1.3	1.3	1.2	1.3	1.5	1.2
" 12	10.7	8.5	**11.0**	8.1	10.1	8.4	1.4	1.3	1.3	1.4	1.3	1.3
" 13	7.9	9.4	10.9	9.3	8.6	8.7	1.3	1.3	1.4	**1.2**	1.4	1.2
" 14	10.7	9.0	9.6	9.5	9.0	9.9	1.5	1.2	1.4	1.5	1.3	1.3
" 15	9.6	9.4	8.1	8.4	8.9	7.7	1.4	**1.4**	1.3	1.3	1.4	1.3
" 16	9.1	10.7	9.6	10.0	9.6	7.5	1.2	1.4	1.3	1.3	1.5	1.3
" 17	9.1	9.1	8.7	**7.0**	10.4	9.4	1.3	1.2	1.2	1.3	1.6	1.4
" 18	10.0	9.8	9.2	11.2	9.9	9.6	1.3	1.2	1.3	1.4	1.3	1.5
" 19	8.5	10.4	9.9	9.5	9.2	9.7	1.3	1.3	1.3	1.4	1.3	1.4
" 20	10.2	10.8	8.2	10.1	10.7	8.7	1.3	1.2	1.2	1.3	1.4	1.3
" 21	8.4	10.8	9.7	10.8	13.7	8.5	1.2	1.3	1.2	1.4	1.5	1.3
" 22	**7.3**	9.7	10.0	9.8	11.7	10.7	**1.1**	1.3	1.3	1.3	1.5	1.4
" 23	9.0	9.4	8.3	9.7	12.4	9.9	1.3	1.3	**1.2**	1.4	1.5	1.2
" 24	**11.8**	10.5	8.9	9.6	10.1	11.1	1.3	1.3	1.2	1.6	1.3	1.4
" 25	9.3	10.8	8.8	7.8	9.1	9.9	1.4	1.3	1.3	1.3	1.3	1.3
" 26	8.6	9.0	10.1	9.6	8.6	**12.5**	1.3	1.2	1.3	1.4	1.4	1.4
" 27	8.6	**12.1**	9.7	10.3	10.5	**7.0**	1.4	1.3	1.3	1.4	1.4	1.4
" 28	8.0	9.9	**7.9**	10.9	9.9	8.8	1.2	1.3	1.4	1.5	1.5	1.2
" 29	8.7	11.6	9.0	10.0	12.1	9.9	1.3	1.2	1.3	1.5	1.5	1.3
" 30	9.5	**7.8**	8.6	10.5	8.5	9.6	1.3	1.2	1.3	1.4	1.4	1.3
Lam Sel-1/HB57 (P1)			8.5			9.8			1.3			1.5
Parbhani Kranti/P7 (P2)			8.5			13.0			1.2			1.6
Pusa Sawani (S. Check)			10.0			9.3			1.4			1.4
General mean	9.4	9.7	9.1	9.7	10.1	9.5	1.3	1.3	1.3	1.4	1.4	1.4
CD at 5%	NS	NS	NS	2.4	2.2	2.2	0.2	NS	NS	0.2	0.2	0.2
CD at 1%	NS	NS	NS	3.2	2.9	2.9	0.2	NS	NS	0.2	0.2	0.2

*Cross 1 = Lam Sel-1 x Parbhani Kranti and Cross 2 = HB57 x P7,

NS = Not significant

(Line No. 3) to 13.8 cm (Line No. 10) in Cross 2. The five top ranking of selections for length of fruit in Cross 1 were Line No. 5, 10, 21, 27 and 29 while, Line No. 10, 21, 22, 23 and 29 in Cross 2. In general, the average fruit length of top selections was better in Cross 2 as compared to Cross 1 selections developed under pedigree method.

The average fruit length of selections of BP method from Cross 1 varied from 7.9 cm (Line No. 28) to 11 cm (Line No. 12) and those from Cross 2, the fruit length varied from 7 cm in Line No. 27 to 12.5 cm in Line No. 26. This method tended to select lines with longer fruits than the parents more in the Cross 1 than in Cross 2 where none of the selected lines could surpass the better parent for this character.

Fruit diameter (cm)

The average fruit diameter of parents was 1.2, 1.3 and 1.4 cm for Parbhani Kranti, Lam Sel-1 and Pusa Sawani (check) and 1.6, 1.5 and 1.4 cm for P7, HB57 and Pusa Sawani as check, respectively. The differences among selected lines for fruit diameter were not significant for Cross 1 under both PM and BP methods (Table 4d).

Under SSF method the fruit diameter of selections ranged from 1.1 cm (Line No. 22) to 1.5 cm (Line No. 14) in Cross 1 and from 1.2 cm (Line No. 13) to 1.6 cm (Line No. 1) in Cross 2. Fruit diameter varied from 1.1 cm to 1.4 cm among selections from Cross 1 under PM and BP methods. However, in case of Cross 2 the average fruit diameter of selections under PM varied from 1.1 cm (Line No. 3) to 2.0 cm (Line No. 10) whereas, it ranged from 1.2 cm (LIne No. 28) to 1.6 cm (Line No. 6) under BP method of selection. In general, under all the three methods of selection, the lines selected from parents having thick fruits

also tended to produce fruits with increased diameter in Cross 2.

Internode length (cm)

Parbhani Kranti had average internode length of 7.4 cm while standard check had 8.5 cm long internodes. Minimum internode length of 7.1 cm was observed in HB57 and the standard check, Pusa Sawani, had 6.9 cm long internodes when compared with Cross 1 and Cross 2 selection (Table 4e).

Under SSF method among progenies the Line No. 7 was having minimum internode length in Cross 1 whereas, it was minimum (4.6) in Cross 2 for Line No. 17. Line No. 23 (9.4) in Cross 1 and Line No. 19 (7.7) in Cross 2 had the longest internodes among SSF selected progenies.

In PM of selection the internode length of selected progenies varied from 6.8 cm (Line No. 7) to 9.8 cm (Line No. 26) and 3 cm (Line No. 9) to 8.1 cm (Line No. 28) in Cross 1 and Cross 2, respectively. In Cross 1, only Line No. 7 recorded internodes shorter in length than either parents and the standard check, however, in Cross 2 atleast ten lines recorded internode length shorter than the standard check.

The internode length of progenies generated through BP method ranged between 7.4 cm (Line No. 18) and 10.6 cm (Line No. 16) in case of Cross 1 while it varied from 4.1 cm (Line No. 15) to 8.4 cm (Line No. 5) in Cross 2. Similar to PM, all except one line produced more lengthy internodes than either parents and the standard check in Cross 1 while, atleast fourteen lines had internode length shorter than the standard check in Cross 2. Majority of the lines selected from Cross 2 segregants had shorter internodes than the parental lines and standard check. The results with regard to internode length have been

Table 4e Mean performance of selected okra lines along with their parents and standard check for different characters under three methods of selection

Selected lines, Parents and Standard Check	Characters/Crosses*/Methods											
	Internode length (cm)						Total yield/plant (g)					
	Cross 1			Cross 2			Cross 1			Cross 2		
	SSF	PM	BP	SSF	PM	BP	SSF	PM	BP	SSF	PM	BP
Line No. 1	9.2	8.7	9.0	7.2	7.5	8.1	95.8	118.0	101.0	70.0	56.0	102.7
" 2	8.4	8.5	8.0	7.3	6.9	8.0	146.0	112.0	159.3	73.9	116.0	99.3
" 3	7.6	8.1	8.6	6.8	7.2	7.3	130.7	111.3	131.3	87.3	68.1	121.3
" 4	8.1	8.5	8.2	6.0	7.7	7.8	152.0	83.3	149.3	59.3	118.0	117.7
" 5	8.5	8.9	9.3	6.6	7.5	8.4	124.8	128.7	100.0	62.1	90.0	67.5
" 6	8.3	9.3	9.5	7.4	7.5	6.4	130.0	162.7	130.0	66.0	83.3	70.0
" 7	6.2	6.8	9.1	6.6	7.2	7.0	114.5	119.7	104.7	96.5	90.1	102.4
" 8	9.0	8.9	9.4	7.0	5.2	5.3	141.3	101.9	113.3	97.0	87.5	45.7
" 9	9.1	7.5	9.3	7.4	3.0	8.0	133.7	122.8	131.3	87.8	45.0	54.0
" 10	8.0	8.1	8.5	7.3	7.3	7.1	127.3	137.3	126.0	99.7	54.0	99.3
" 11	8.3	9.7	8.5	7.0	7.6	6.5	135.3	119.7	163.3	59.3	112.7	106.8
" 12	8.3	8.9	9.8	6.5	7.7	6.6	128.0	157.3	109.3	58.7	112.7	56.8
" 13	8.6	9.6	9.3	7.2	7.6	7.5	83.2	124.0	118.0	105.0	56.0	62.3
" 14	8.3	9.6	9.2	6.2	7.0	7.0	130.7	168.7	132.7	119.5	50.4	143.0
" 15	7.3	9.2	8.1	6.2	7.9	4.1	116.7	141.3	78.2	89.4	52.5	61.7
" 16	7.1	8.8	10.6	5.9	6.6	6.0	128.0	129.3	140.0	75.6	109.6	109.3
" 17	7.4	9.6	9.7	4.6	7.4	5.9	127.3	167.3	126.0	86.7	95.6	65.9
" 18	7.7	8.3	7.4	7.4	5.4	5.2	92.0	108.7	154.0	102.7	68.1	81.7
" 19	8.8	9.1	7.6	7.7	5.9	5.6	138.0	100.0	168.8	131.7	97.5	64.3
" 20	8.1	9.4	8.5	6.9	5.5	5.9	95.0	128.0	118.0	92.5	73.8	54.8
" 21	7.7	8.4	8.8	7.1	7.6	6.0	86.9	150.0	121.3	102.7	82.1	94.4
" 22	7.4	9.8	8.6	7.1	7.2	6.9	114.3	126.0	143.3	87.7	110.0	70.7
" 23	9.4	9.3	8.1	6.9	7.7	8.0	110.3	145.3	128.7	91.1	94.7	119.7
" 24	7.0	9.1	7.5	6.3	6.5	7.0	133.3	150.7	108.7	68.2	108.5	93.7
" 25	7.2	9.5	9.4	6.6	6.6	7.7	137.7	124.0	137.6	53.3	76.9	86.3
" 26	8.5	9.8	8.6	5.7	7.1	6.4	111.3	134.0	141.3	74.3	81.7	105.0
" 27	7.2	8.9	8.7	7.1	6.2	5.3	156.7	121.3	106.0	84.2	108.7	48.7
" 28	7.1	7.8	8.8	6.5	8.1	6.4	100.0	172.0	102.7	93.3	98.9	83.3
" 29	7.7	7.5	7.9	5.7	6.6	7.3	105.6	120.7	112.0	88.3	84.0	110.0
" 30	7.8	9.8	7.7	5.8	7.6	7.3	139.8	75.7	142.7	94.3	54.7	82.7
Lam Sel-1/HB57 (P1)			8.9			7.1			83.9			89.3
Parbhabi Kranti/P7 (P2)			7.4			7.2			73.3			80.0
Pusa Sawani (S. Check)			8.5			6.9			92.2			90.2
General mean	8.0	8.8	8.7	6.7	6.9	6.8	118.7	124.6	122.7	85.4	84.7	86.1
CD at 5%	NS	NS	NS	NS	1.9	1.9	38.4	40.4	51.0	44.2	52.6	52.6
CD at 1%	NS	NS	NS	NS	2.4	2.4	50.6	53.2	67.2	58.2	69.2	69.2

*Cross 1 = Lam Sel-1 x Parbhani Kranti and Cross 2 = HB57 x P7,

NS = Not significant

described as above, however, the differences among lines for all the three methods in Cross 1 and SSF in Cross 2 were statistically non significant.

Total yield per plant (g)

The yield per plant was 83.9 g of Lam Sel-1, 73.3 g of Parbhani Kranti and 92.2 g of standard check in comparison to the progenies of Cross 1. It was 89.3 g for HB57, 80 g for P7 and 91.2 g for standard check as compared with Cross 2 progenies (Table 4e).

The yield performance of progenies of Cross 1 under SSF varied from 83.2 g (Line No. 13) to 156.7 g (Line No. 27). The other promising lines from this cross selected using SSF method were Line No. 2, 4, 8 and 30. Similarly yield performance of selections from Cross 2 ranged from 53.3 g (Line No. 25) to 131.7 g (Line No. 19). Twenty seven lines from Cross 1 and only eleven lines from Cross 2 were found to exceed the parents and standard check for their yield performance under this method.

The mean yield performance of lines selected through PM in Cross 1 ranged from 75.7 g (Line No. 30) to 172 g (Line No. 28) where all except Line No. 4 and 30 exceeded the parents and standard check. In case of Cross 2 derived lines the yield performance varied from 45 g (Line No. 9) to 118 g (Line No. 4) with only eleven lines surpassing the parental stock. The most promising lines yielding almost double than the parents were Line No. 6 (162.7 g), Line No. 12 (157.3 g), Line No. 14 (168.7 g) and Line No. 17(167.3 g) besides the highest yielding Line No. 28 (172 g) among the progenies of Cross 1.

The yield of BP lines ranged from 78.2 g (Line No. 15) to 168.8 g (Line No. 19) in Cross 1 and 45.7 g (Line No. 8) to 143 g (Line No. 14) in Cross 2. All the

lines of Cross 1 except Line No. 15 exceeded parental lines for yield per plant while, fourteen lines of Cross 2 gave higher yields than the parents and standard check. Mostly under all the three methods of selection the selected progenies were superior to parents and standard check in Cross 1, however, approximately 50 per cent of the lines from Cross 2 could excel the respective parents.

The three selection methods under study were compared on the basis of mean of thirty progenies mean of five top yielding progenies, mean of best performing progenies, per cent progeny superior to better parent or standard check and range index (%) for both the crosses which are presented in Tables 5 and 6.

The data for the cross Lam Sel-1 x Parbhani Kranti (Table 5) indicated that the overall mean of progenies developed through SSF was the highest for number of branches per plant (1.6) and fruit diameter (1.3 cm). This method showed the lowest and desirable mean for days to first flowering (42.0), days to first picking (50.9), internode length (8.0 cm) while undesirable poor values for plant height (78.1 cm) and total yield per plant (122.2 g).

Pedigree method was found superior for plant height (93.1 cm), fruit length (9.8 cm), total yield per plant (128.7 g) and poor for internode length (8.9 cm). BP method was found important for improving first fruiting node (6.3), number of fruits per plant (10.4) and also the total yield per plant (126.0 g).

In the cross HB57 x P7 (Table 6), the SSF progenies had the highest mean values for plant height (57.1 cm), number of branches per plant (1.3), number of fruits per plant (7.0) and the next highest yield per plant (85.3 g). The progenies of this method recorded the overall lowest average for days to first picking

Table 5 Comparison of three selection methods for various characters in okra Lam Sel-1 x Parbhani Kranti (Cross 1)

S. No.	Parameters compared	Selection methods employed*	Characters scored									
			Days to first flowering	Days to first picking	First fruiting node	Plant height (cm)	Number of branches/ plant	Number of fruits/ plant	Fruit length (cm)	Fruit diameter (cm)	Internode length (cm)	Total yield/ plant (g)
1.	Mean of all thirty progenies	SSF	42.00	50.90	6.49	78.13	1.63	10.17	9.47	1.30	7.98	122.21
		PM	43.56	51.19	6.63	93.07	1.42	10.35	9.79	1.28	8.85	128.72
		BP	42.81	51.06	6.24	88.23	1.31	10.41	9.15	1.27	8.72	126.63
2.	Mean of top five progenies	SSF	41.97	49.93	5.55	95.82	2.56	12.14	10.97	1.42	6.91	147.17
		PM	41.85	50.47	5.60	109.15	2.22	13.00	11.49	1.39	7.54	165.60
		BP	41.28	50.47	5.38	100.80	2.16	12.78	10.55	1.36	7.62	158.96
3.	Mean of top most performing progeny	SSF	41.60	48.33	5.07	102.40	3.40	12.40	11.81	1.45	6.16	156.67
		PM	41.00	48.33	4.93	111.53	2.53	14.00	12.07	1.43	6.80	172.00
		BP	41.00	48.33	5.18	103.20	2.40	13.61	10.95	1.41	7.37	168.83
4.	Per cent progeny superior to better parent	SSF	90.00	100.00	3.33	76.67	16.67	100.00	83.33	76.67	23.33	96.67
		PM	93.33	100.00	3.33	90.00	13.33	93.33	90.00	63.33	3.33	93.33
		BP	100.00	96.67	3.33	96.67	10.00	100.00	73.33	60.00	3.33	96.67
5.	Per cent progeny superior to standard check (Pusa Sawani)	SSF	100.00	96.67	83.33	100.00	86.67	90.00	36.67	13.33	73.33	93.33
		PM	100.00	76.67	80.00	100.00	56.67	93.33	36.67	16.67	26.67	93.33
		BP	100.00	93.33	90.00	100.00	60.00	96.67	13.33	6.67	33.33	96.67
6.	Range Index (RI) (%)	SSF	8.88	9.82	40.06	55.93	195.09	50.65	48.05	23.85	40.85	60.14
		PM	9.64	9.77	44.34	53.70	152.82	74.01	43.62	24.22	34.24	74.84
		BP	7.78	11.75	36.70	41.40	158.02	53.89	33.11	18.90	36.70	71.59

* *SSF = Single seed per fruit, PM = pedigree method and BP = bulk population*

(52.7) and internode length (6.7 cm). The selection lines of PM were having highest averages for fruit length (10.1 cm) and fruit diameter (1.4 cm), while the lowest mean value was recorded for days to first flowering (43.8). The BP method showed highest mean values of progenies for number of fruits per plant (7.0), total yield per plant (86.0 g) and lowest value for first fruiting node (6.5).

Efficiency of selection methods as compared through mean of top five progenies for various characters showed that SSF progenies for days to first picking (49.93), number of branches per plant (2.56), fruit diameter (1.42) and internode length (6.9cm)were found superior in Cross 1 (Table 5). Similarly in Cross 2, the SSF generated progenies exhibited superiority for plant height (72.36 cm).

Pedigree method selected progenies were better for plant height (109.2 cm) number of fruits per plant (13.00), fruit length (11.5cm)and total yield per plant (165.6g) in Cross 1, while in Cross 2, the progenies were found superior for days to first flowering (41.72), fruit length (12.7cm), fruit diameter (1.6cm)and internode length (4.99cm,Table 6).

The BP progenies were found superior for days to first flowering (41.28) and first fruiting node (5.38) in Cross 1,and for first fruiting node (5.35), number of branches per plant (2.17), number of fruits per plant (9.97) and total yield per plant (122.3g) in Cross 2 (Table 6). The progenies developed through SSF, PM and BP were having the same mean value of 51 days for first picking in this Cross.

On the basis of mean of top most performing progeny, PM was found superior to other methods in Cross 1, while in Cross 2, BP followed by SSF appeared superior for most of the characters studies.

Table 6 Comparison of three selection methods for various characters in okra HB57 x P7 (Cross 2)

Sr. No.	Parameters compared	Selection methods employed*	Characters scored									
			Days to first flower	Days to first picking	First fruiting node	Plant height (cm)	Number of branches/ plant	Number of fruits/ plant	Fruit length (cm)	Fruit diameter (cm)	Internode length (cm)	Total yield / plant (g)
1.	Mean of all thirty progenies	SSF	44.00	52.67	6.77	57.05	1.24	7.03	9.62	1.38	6.66	85.27
		PM	43.78	52.76	6.70	56.35	1.03	6.88	10.07	1.41	6.90	84.56
		BP	44.00	53.17	6.54	55.48	1.22	7.03	9.34	1.35	6.73	86.04
2.	Mean of top five progenies	SSF	42.25	51.00	5.75	72.36	1.90	9.46	10.95	1.55	5.51	112.30
		PM	41.72	51.00	5.73	70.38	2.03	9.29	12.70	1.61	4.99	113.87
		BP	41.85	51.00	5.35	72.05	2.17	9.97	11.00	1.50	5.09	122.34
3.	Mean of top most performing progeny	SSF	41.53	51.00	5.35	77.27	2.20	11.33	11.33	1.62	4.58	131.67
		PM	41.00	51.00	5.00	74.47	2.27	9.73	13.75	1.95	3.00	118.00
		BP	41.47	51.00	4.98	75.40	3.05	11.94	12.50	1.55	4.11	143.00
4.	Per cent progeny superior to better parent	SSF	0.00	36.67	10.00	43.33	3.33	36.67	0.00	3.33	63.33	43.33
		PM	0.00	46.67	6.67	53.33	6.67	46.67	6.67	3.33	43.33	46.67
		BP	0.00	40.00	20.00	43.33	6.67	46.67	0.00	0.00	60.00	46.67
5.	Per cent progeny superior to standard check (Pusa Sawani)	SSF	96.67	50.00	46.67	53.33	96.67	26.67	73.33	43.33	53.33	40.00
		PM	96.67	66.67	46.67	56.67	90.00	30.00	63.33	56.67	33.33	40.00
		BP	93.33	53.33	50.00	46.67	86.67	43.33	56.67	36.67	46.67	46.67
6.	Range Index (RI) (%)	SSF	11.07	8.87	41.07	63.58	150.81	99.57	44.70	28.26	46.40	91.87
		PM	12.58	16.11	43.73	82.47	194.17	90.55	67.03	58.16	74.20	86.33
		BP	11.95	13.17	50.76	70.62	222.95	121.19	58.89	29.63	64.04	113.12

* SSF = Single seed per fruit, PM = pedigree method and BP = bulk population

The per cent progeny lines showing superior performance over better parent, and standard check, Pusa Sawani, for different characters are also given in Table 5 and 6.

For days to first flowering BP method had the highest percentage of early lines (100) over better parent, whereas all the three methods had highest percentage of early lines (100) over standard check in Cross 1. In Cross 2, none of the three methods could develop superior lines over better parent, whereas SSF and PM had equal number of lines (96.67%) superior to standard check. SSF and PM had equal number of early yielding lines (100%) over better parent and when compared with standard check, SSF was having more early yielding lines (96.67%) followed by BP (93.33%) in Cross 1. However, in Cross 2, PM showed 46.67 per cent early yielding lines over better parent and 66.67 per cent over standard check.

For first fruiting node all methods (SSF, PM and BP) had equal number of lines (3.33%) superior to better parent, whereas BP method was superior to the other two methods in per cent early lines selected over the standard check in Cross 1. In Cross 2 for first fruiting node the BP method was found superior to both the methods.

The BP had more lines taller in height (96.67%) than the better parent, however, all the three methods (SSF, PM and BP) had equal number of lines taller in height (100%) than the standard check in Cross 1 (Table 5). In Cross 2, PM was having more number of lines taller in height (53.33% and 56.67%) than better parent and standard check over both the methods, respectively.

For number of branches per plant PM was found superior to the other methods showing 16.67 and 86.67 per cent superior progenies over better parent and standard check, respectively in Cross 1. However, in Cross 2, PM and BP method had equal number of progenies (6.67%) superior to better parent whereas 96.67 per cent superior lines over standard check were found in SSF.

For number of fruits per plant in Cross 1, the SSF and PM had high and equal percentage of superior lines (100) than better parent. Superior lines to the extent of 96.67 per cent were found in BP method of selection (Table 5). In Cross 2, pedigree and BP had equal percentage of superior lines (46.67) for fruits per plant over better parent, while BP method had higher percentage of superior lines (43.33) over standard check for this trait (Table 6).

For fruit length, PM had higher percentage of superior lines (90.00) over better parent (Table 5). SSF and PM had equal number of superior lines (36.67) over the standard check in Cross 1. However, BP method had higher percentage of superior lines (6.67) over better parent, and SSF had higher percentage of superior lines (73.33) over standard check in Cross 2 (Table 6). SSF method had higher percentage of superior lines (76.67) over better parent for fruit diameter and PM had higher percentage of superior lines (16.67) over standard check in Cross 1, while in Cross 2 PM was found better than other methods.

For internode length SSF method with higher percentage of superior lines 23.33 and 73.33 in Cross 1 and, 63.33 and 53.33 in Cross 2 over better parent and standard check, respectively was found superior to other two methods.

For yield per plant SSF and BP methods had equal number of higher yielding lines (96.67%) over better parent, and BP had higher percentage of yielding lines

(96.67) over standard check in Cross 1 (Table 5), whereas in Cross 2 PM and BP method had equal number of higher yielding lines (46.67) over better parent and BP had higher percentage of such yielding lines (46.67) over the standard check (Table 6).

The range index (RI) in SSF was found higher for plant height (55.93), number of branches per plant (195.09), fruit length (48.05) and internode length (40.85) in Cross 1 (Table 5), while in Cross 2, SSF was having low range index values than other two methods for all the characters (Table 6). In Cross 1, PM recorded high values of range index for days to first flowering (9.64), first fruiting node (44.34), number of fruits per plant (74.01), fruit diameter (24.22) and total yield per plant (74.84), while in Cross 2, high range index values were observed for days to first flowering (12.56), days to first picking (16.11), plant height (82.47), fruit length (67.03) fruit diameter (58.16) and internode length (74.20). The BP method showed high range index value only for days to first picking (11.75) in Cross 1. In Cross 2 high range index values were recorded for first fruiting node (50.76), number of branches per plant (222.95), number of fruits per plant (121.19) and total yield per plant (113.12).

C. Genetic variability and comparison of selection methods

The comparative performance of selection methods for all the characters under study have been given in Table 7 and 8. The coefficient of variation (CV %) in Cross 1 under SSF method was higher for days to first picking (3.78), plant height (16.59), number of fruits per plant (23.37), fruit length (15.80), internode length (16.89) and total yield per plant (24.93) (Table 7). This method exhibited high CV only for fruit length (15.57) in Cross 2 (Table 8). The PM accounted high CV for first fruiting node (13.03) in Cross 1 and for first fruiting

Table 7 Comparison of three selection methods for different genetic parameters of various characters in okra cross - Lam Sel-1 x Parbhani Kranti (Cross 1)

S. No.	Genetic parameters compared	Selection methods employed*	Characters scored									
			Days to first flowering	Days to first picking	First fruiting node	Plant height (cm)	Number of branches/ plant	Number of fruits/ plant	Fruit length (cm)	Fruit diameter (cm)	Internode length (cm)	Total yield plant (g)
1.	*Coefficient of variation (CV)*	SSF	2.50	3.78	11.57	16.59	42.31	23.37	15.80	7.69	16.89	24.93
		PM	2.14	3.70	13.03	12.80	45.86	19.67	15.40	7.81	12.25	19.28
		BP	2.58	3.43	11.33	15.20	60.15	21.92	14.94	7.87	14.34	20.57
2.	Genotypic coefficient of variation (GCV)	SSF	2.42	1.98	6.75	13.37	23.69	10.22	6.03	3.02	2.81	11.42
		PM	2.59	1.80	6.89	16.85	25.76	14.98	6.81	2.72	5.42	17.94
		BP	2.76	2.09	8.78	11.52	22.74	11.62	3.87	1.60	2.39	15.48
3.	Phenotypic coefficient of variation (PCV)	SSF	3.48	4.27	13.42	21.31	48.59	25.50	16.90	8.74	16.68	27.42
		PM	3.36	4.12	14.73	21.16	52.62	24.69	16.84	9.06	13.40	26.33
		BP	3.78	4.02	14.29	19.08	64.44	24.79	15.44	8.57	14.55	25.74
4.	Heritability in broad sense h^2 (b.s.)	SSF	48.47	21.62	25.33	39.37	23.67	16.05	12.72	11.91	4.55	17.33
		PM	59.50	19.18	21.89	63.39	23.96	36.82	16.37	9.03	16.36	46.41
		BP	53.24	27.15	37.73	36.49	12.45	21.97	6.27	7.48	2.70	36.16
5.	Genetic advance (GA)	SSF	1.52	0.97	0.45	13.23	0.39	0.83	0.42	0.03	0.17	11.62
		PM	1.80	0.84	0.44	24.90	0.37	1.88	0.55	0.02	0.40	31.36
		BP	1.79	1.15	0.69	12.29	0.22	1.14	0.18	0.02	0.07	23.52
6.	GA as per cent of mean	SSF	3.47	1.90	7.00	17.28	23.79	8.43	4.43	2.14	1.88	9.79
		PM	4.12	1.63	6.40	27.64	25.97	18.72	5.68	1.69	4.52	25.17
		BP	4.14	2.25	11.10	14.34	16.53	11.22	2.00	1.14	0.81	19.17

* SSF = Single seed per fruit, PM = pedigree method and BP = bulk population

Table 8 Comparison of three selection methods for different genetic parameters of various characters in okra cross - HB57 x P7 (Cross 2)

S. No.	Genetic parameters compared	Selection methods employed*	Characters scored									
			Days to first flowering	Days to first picking	First fruiting node	Plant height (cm)	Number of branches/ plant	Number of fruits/ plant	Fruit length (cm)	Fruit diameter (cm)	Internode length (cm)	Total yield plant (g)
1.	Coefficient of variation (CV)	SSF	3.13	4.84	11.53	17.17	67.04	36.14	15.57	7.19	15.37	32.76
		PM	3.11	5.28	12.22	18.17	71.95	33.77	14.76	7.04	16.88	32.62
		BP	3.74	5.78	11.50	16.71	70.40	38.84	14.61	7.35	17.06	38.16
2.	Genotypic coefficient of variation (GCV)	SSF	2.19	2.68	8.61	13.47	36.46	26.53	7.98	5.48	4.67	16.18
		PM	2.92	3.74	7.37	14.36	44.81	16.53	12.37	8.38	10.99	17.01
		BP	2.90	2.91	11.13	17.06	35.03	17.47	10.77	6.15	10.86	17.07
3.	Phenotypic coefficient of variation (PCV)	SSF	3.82	4.89	14.39	21.82	67.47	36.71	17.48	10.15	16.03	36.85
		PM	4.26	6.47	14.24	23.15	84.45	37.58	19.25	11.45	20.11	36.80
		BP	4.73	6.47	16.03	23.88	78.37	42.61	18.15	9.98	20.23	41.80
4.	Heritability in broad sense h^2 (b.s.)	SSF	32.91	21.92	35.82	38.08	20.92	23.16	20.81	29.13	8.49	22.72
		PM	46.83	33.40	26.77	38.44	28.15	19.34	41.28	53.62	29.87	21.38
		BP	37.50	20.21	48.18	51.03	19.98	16.81	35.19	37.90	28.83	16.67
5.	Genetic advance (GA)	SSF	1.14	0.10	0.71	9.72	0.02	0.17	0.73	0.09	0.19	11.76
		PM	1.80	2.35	0.52	10.30	0.51	1.04	1.66	0.18	0.86	13.73
		BP	1.61	1.43	1.04	13.90	0.38	1.04	1.24	0.11	0.81	12.36
6.	GA as per cent of mean	SSF	2.59	0.19	10.62	17.12	1.28	2.39	7.50	6.09	2.80	12.07
		PM	4.11	4.45	7.86	18.34	48.98	14.97	16.37	12.65	12.38	16.21
		BP	3.65	2.70	15.91	25.10	32.25	14.75	13.16	7.80	12.01	14.36

* SSF = Single seed per fruit, PM = pedigree method and BP = bulk population

node (12.22), plant height (18.17) and number of branches per plant (71.95) in Cross 2. The BP method showed high CV for days to first flowering (2.58), number of branches per plant (60.15) and fruit diameter (7.87) in Cross 1, whereas in Cross 2, high CV was observed for days to first flowering (3.74), days to first picking (5.78), number of fruits per plant (38.84), fruit diameter (7.35), internode length (17.06) and total yield per plant (38.16).

On the basis of genotypic coefficient of variation (GCV) the SSF was found better for fruit diameter (3.02) in the cross Lam Sel-1 x Parbhani Kranti. PM had higher GCV for plant height (16.85), number of branches per plant (25.76), number of fruits per plant (14.98), fruit length (6.81), internode length (5.42) and total yield per plant (17.94) in this cross. Bulk population method was better in terms of GCV for days to first flowering (2.76), days to first picking (2.09) and first fruiting node (8.78). Thus GCV was high in Lam Sel-1 x Parbhani Kranti under SSF, PM and BP for one, six and three characters, respectively.

In the cross HB57 x P7, the SSF was found to record better GCV for number of fruits per plant (26.53) (Table 8). PM had more GCV for days to first flowering (2.92), days to first picking (3.74), number of branches per plant (44.81), fruit length (12.37) fruit diameter (8.38), internode length (10.99) and total yield per plant (17.01). The BP method was better in terms of GCV for first fruiting node (11.13), plant height (17.06) and total yield per plant (17.07). Thus GCV was high in SSF, PM and BP for one, seven and three characters, respectively.

On the basis of phenotypic coefficient of variation (PCV) the SSF method was found better for days to first picking (4.27), plant height (21.31), number

of fruits per plant (25.50), fruit length (16.90), internode length (16.68) and total yield per plant (27.42). PM had high PCV for first fruiting node (14.73) and fruit diameter (9.06). The BP method was better for days to first flowering (3.78) and number of branches per plant (64.44) in the cross Lam Sel-1 x Parbhani Kranti.

In the cross combination HB57 x P7, on the basis of PCV, SSF method showed low values for all the characters than the other two methods. PM was found better for days to first picking (6.47), number of branches per plant (84.45), fruit length (19.25) and fruit diameter (11.45). The BP method was found better for days to first flowering (4.73), first fruiting node (16.03), plant height (23.88), number of fruits per plant (42.61), interonde length (20.23) and total yield per plant (41.80).

The highest heritability (h^2) values in broad sense (Table 7) were observed for days to first flowering (48.47, 59.50 and 53.24) for SSF, PM and BP methods, respectively. The next character with high heritability was plant height (39.37, 63.39 and 36.49) for SSF, PM and BP, respectively. On the other hand branches per plant (23.77, 23.96 and 12.45), total yield per plant (17.33, 46.41 and 36.16), days to first picking (21.62, 19.18 and 27.15), and number of fruits per plant (16.05, 36.82 and 21.97) for SSF, PM and BP, respectively in Lam Sel-1 x Parbhani Kranti exhibited low heritability values. Thus, progenies developed through SSF, PM and BP method showed high heritability for one, seven and two characters, respectively.

In the cross HB57 x P7, the highest heritability was observed for plant height (38.08, 38.44 and 51.03) in SSF, PM and BP methods, respectively (Table 8).

The other characters with high heritability were days to first flowering (32.91, 46.83 and 37.50) and first fruiting node (35.82, 26.77 and 48.18) in SSF, PM and BP, respectively. On the other hand, low heritabilities were recorded for number of branches per plant (20.92, 28.15 and 19.98), number of fruits per plant (23.16, 19.34 and 16.81) and total yield per plant (22.72, 21.38 and 16.67) in SSF, PM and BP methods, respectively. Concludingly the progenies developed through SSF, PM and BP methods recorded high heritabilities for two, six and two characters, respectively.

SSF was found to have comparatively larger values of genetic advance (Table 7) for number of branches per plant (0.39) and fruit diameter (0.03) than other methods, while it was higher in PM for days to first flowering (1.80), plant height (24.90), number of fruits per plant (1.88), fruit length (0.55), interonde length (0.40) and total yield per plant (31.36). It was higher in BP for days to first picking (1.15) and first fruiting node (0.69) in Lam Sel-1 x Parbhani Kranti. In cross HB57 x P7, SSF recorded low genetic advance values for all the characters when compared with other two methods (Table 8). Pedigree method had higher genetic advance values for days to first flowering (1.80), days to first picking (2.35), number of branches per plant (0.51), number of fruits per plant (1.04), fruit length (1.66), fruit diameter (0.18), internode length (0.86) and total yield per plant (13.73) while, genetic advance was higher for the progenies developed through BP method for first fruiting node (1.04), plant height (13.90) and number of fruits per plant (1.04). It has been observed that genetic advance was higher for the characters having high heritability when generation advanced through PM and BP methods (Tables 7 and 8).

It is obvious from the data that genetic advance as per cent of mean also showed a trend similar to heritability and genetic advance for most of the characters in both the crosses (Tables 7 and 8).

D. Correlation coefficients

The correlation coefficients at genotypic, phenotypic and environmental levels were worked out to find out the association between different characters contributing to yield per plant under three methods of selection in both the crosses. These estimates are presented in Tables 9, 10 and 11, respectively.

In general, the magnitude of correlation coefficients at genotypic level was higher than the corresponding phenotypic or environmental correlations, indicating a strong inherent association between different characters under different methods of selection in both the crosses.

In Cross 1 under SSF method yield was found positively correlated with number of fruits per plant, number of branches per plant and plant height while it was negatively correlated with days to first flowering. In Cross 2, yield was positively correlated with number of fruits per plant, plant height, number of branches per plant and internode length, whereas negatively correlated with days to first picking and days to first flowering. Number of fruits per plant was positively correlated with yield per plant, number of branches per plant and plant height and it was negatively correlated with days to first flowering in Cross 1. Similarly, in Cross 2, fruits per plant was positively correlated with yield per plant, number of branches per plant, plant height and internode length and none of the characters was found negatively correlated. Fruit length was positively correlated with fruit diameter in both the crosses. Plant height was

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Table 9 Genotypic (above diagonal) and phenotypic (below diagonal) correlations among different characters under three methods of selection in cross *Lam Sel-1 x Parbhani Kranti*

S. No.	Characters	Methods	Days to first flowering	Days to first picking	First fruiting node	Plant height (cm)	Number of branches / plant	Number of fruits/ plant	Fruit length (cm)	Fruit diameter (cm)	Internode length (cm)	Total yield/ plant (g)
1.	Days to first flowering	SSF	1.000	1.116	0.489	-0.266	0.131	-1.011	-0.329	-0.712	0.080	-0.964
		PM	1.000	0.884	0.732	-0.261	0.318	-0.631	-0.251	-0.474	-0.289	-0.566
		BP	1.000	0.931	0.556	-0.680	0.198	-0.834	-0.247	0.240	-1.077	-0.758
2.	Days to first picking	SSF	0.311	1.000	-0.102	-0.564	-0.164	-1.420	-0.731	-0.984	-0.095	-1.350
		PM	0.367*	1.000	-0.427	-0.819	-0.064	-1.238	-0.836	-0.430	-0.088	-1.079
		BP	0.380*	1.000	-0.194	-0.908	0.224	-1.006	-1.038	-0.060	-1.313	-0.852
3.	First fruiting node	SSF	0.219	0.179	1.000	0.539	0.435	0.462	0.622	-0.055	0.260	0.456
		PM	0.249	0.166	1.000	0.019	0.223	-0.162	-0.278	-1.477	-0.273	-0.229
		BP	0.370*	0.150	1.000	-0.100	0.461	-0.069	-0.440	0.230	-0.474	-0.110
4.	Plant height (cm)	SSF	-0.196	-0.089	0.270	1.000	0.876	1.052	0.633	0.734	0.586	1.107
		PM	-0.179	-0.167	0.052	1.000	0.388	0.907	0.314	-0.083	0.828	0.857
		BP	-0.352*	-0.151	0.029	1.000	0.035	0.745	0.126	0.460	0.702	0.743
5.	Number of branches/plant	SSF	0.016	0.101	0.250	0.193	1.000	0.309	0.904	0.416	-0.106	0.333
		PM	0.109	0.030	0.171	0.050	1.000	0.344	-0.170	-1.440	-0.321	0.375
		BP	0.088	0.157	0.269	-0.220	1.000	0.372	0.031	-0.030	0.457	0.418
6.	Number of fruits/plant	SSF	-0.377*	-0.153	-0.002	0.359*	0.586*	1.000	0.685	0.708	0.210	0.968
		PM	-0.306	-0.335	0.045	0.518*	0.477*	1.000	0.096	-0.331	0.493	1.007
		BP	-0.401*	-0.154	0.058	0.369*	0.433*	1.000	0.340	-0.090	0.263	1.028
7.	Fruit length (cm)	SSF	-0.050	-0.058	0.061	0.126	0.174	0.170	1.000	0.295	0.402	0.728
		PM	-0.140	-0.190	-0.005	0.195	0.139	0.201	1.000	-0.297	-0.491	0.066
		BP	-0.134	-0.082	0.099	0.201	-0.056	-0.052	1.000	0.600	1.198	0.401
8.	Fruit diameter (cm)	SSF	-0.130	-0.172	0.042	0.108	0.176	0.215	0.325*	1.000	0.260	0.921
		PM	-0.148	-0.175	-0.179	0.095	-0.001	0.145	0.372*	1.000	-0.201	-0.293
		BP	-0.001	-0.086	0.182	0.061	-0.080	-0.109	0.349*	1.000	0.300	0.380
9.	Internode length (cm)	SSF	0.009	-0.108	0.125	0.352*	-0.189	-0.184	0.101	0.155	1.000	0.260
		PM	-0.190	-0.201	-0.059	0.479*	-0.317	0.019	0.045	0.088	1.000	0.403
		BP	-0.166	-0.198	-0.005	0.478*	-0.456*	-0.221	0.232	0.274	1.000	0.244
10.	Total yield/plant (g)	SSF	-0.377*	-0.154	0.012	0.424*	0.545*	0.979*	0.177	0.235	-0.160	1.000
		PM	-0.363*	-0.333	0.025	0.579*	0.490*	0.949*	0.239	0.177	0.092	1.000
		BP	-0.435*	-0.233	0.033	0.430*	0.438*	0.939*	-0.009	-0.077	-0.143	1.000

* $P \leqslant 0.05$

Table 10 Genotypic (above diagonal) and phenotypic (below diagonal) correlations among different characters under three methods of selection in cross HB57 x P7

S. No.	Characters	Methods	Days to first flowering	Days to first picking	First fruiting node	Plant height (cm)	Number of branches/ plant	Number of fruits/ plant	Fruit length (cm)	Fruit diameter (cm)	Internode length (cm)	Total yield/ plant (g)
1.	Days to first flowering	SSF	1.000	0.491	0.890	0.267	-0.858	-1.341	-0.293	-0.360	-0.340	-0.326
		PM	1.000	0.487	0.939	0.351	-0.049	-0.214	0.185	-0.131	0.182	-0.208
		BP	1.000	0.901	0.651	-0.112	-0.262	-0.907	-0.284	-0.007	-0.281	-0.894
2.	Days to first picking	SSF	0.176	1.000	0.244	-0.180	1.160	-1.986	-1.281	0.260	-0.078	-0.428
		PM	0.110	1.000	0.098	-0.264	-0.606	-0.614	0.036	0.113	-0.185	-0.568
		BP	0.424*	1.000	0.667	-0.532	-1.021	-1.530	-0.483	0.293	-0.458	-1.588
3.	First fruiting node	SSF	0.276	0.033	1.000	0.595	-2.444	-0.689	-0.076	-0.593	0.589	-0.260
		PM	0.252	0.143	1.000	0.741	-0.277	-0.587	0.205	0.122	0.389	-0.525
		BP	0.319	0.166	1.000	0.245	0.170	-0.248	-0.394	-0.280	0.124	-0.269
4.	Plant height (cm)	SSF	-0.029	-0.197	0.278	1.000	0.994	-0.323	-0.061	-0.556	0.874	0.760
		PM	0.057	-0.299	0.249	1.000	0.751	0.345	0.322	0.194	0.652	0.365
		BP	-0.164	-0.315	0.204	1.000	0.458	0.779	0.435	-0.340	0.856	0.771
5.	Number of branches/plant	SSF	-0.102	-0.092	0.060	0.130	1.000	-0.317	1.735	0.258	-1.822	0.642
		PM	-0.093	-0.177	0.092	0.293	1.000	0.787	0.163	-0.033	0.424	0.750
		BP	-0.135	-0.248	0.236	0.447*	1.000	0.387	0.535	-0.397	0.140	0.344
6.	Number of fruits/plant	SSF	-0.208	-0.235	-0.046	0.381*	0.540*	1.000	0.221	0.332	-0.795	0.930
		PM	-0.192	-0.363*	-0.167	0.392*	0.624*	1.000	-0.061	-0.340	0.128	1.000
		BP	-0.330	-0.309	-0.069	0.524*	0.441*	1.000	0.569	-0.401	0.495	0.995
7.	Fruit length (cm)	SSF	-0.249	-0.208	-0.019	0.123	0.155	0.136	1.000	0.316	0.391	0.600
		PM	0.022	-0.009	-0.014	0.299	0.030	0.164	1.000	0.783	-0.211	0.019
		BP	-0.137	-0.195	-0.114	0.384*	0.356*	0.313	1.000	0.381	0.526	0.598
8.	Fruit diameter (cm)	SSF	-0.236	-0.055	-0.103	-0.067	0.087	0.069	0.663*	1.000	-0.398	0.326
		PM	-0.100	0.007	0.014	0.131	-0.044	-0.006	0.744*	1.000	0.120	-0.287
		BP	-0.011	0.022	-0.032	0.027	0.186	0.128	0.546*	1.000	-0.107	-0.359
9.	Internode length (cm)	SSF	-0.206	-0.098	0.249	0.707*	0.037	0.343*	0.298	0.141	1.000	0.409
		PM	-0.015	-0.204	0.149	0.706*	0.232	0.280	0.049	0.005	1.000	0.076
		BP	-0.160	-0.209	-0.024	0.677*	0.136	0.322	0.252	0.081	1.000	0.523
10.	Total yield/plant (g)	SSF	-0.426*	-0.510*	-0.308	0.610*	0.530*	0.890*	0.340	0.261	0.348*	1.000
		PM	-0.194	-0.362*	-0.154	0.415*	0.633*	0.988*	0.203	0.027	0.274	1.000
		BP	-0.354*	-0.300	-0.069	0.554*	0.477*	0.986*	0.326	0.155	0.349*	1.000

* $P \leq 0.05$

found positively correlated with yield per plant, number of fruits per plant and internode length in Cross 1, whereas in Cross 2, it was positively correlated with internode length, number of fruits per plant and yield per plant. Days to first flowering was observed negatively correlated with yield per plant and fruits per plant in Cross 1, while found negatively correlated with yield per plant in Cross 2 (Table 10).

Under PM of selection the significant and positive correlation coefficients were observed between yield and number of fruits per plant, plant height and branches per plant. The yield was having negative correlation with days to first flowering in Cross 1, while in Cross 2, it exhibited positive significant correlation with fruits per plant, branches per plant and plant height, and negative correlation with days to first picking but with low magnitude. Number of fruits also showed positive correlation with yield per plant, plant height and branches per plant in both the crosses. It also showed negative correlation with days to first picking in Cross 2. Fruit length expressed significant positive correlation with fruit diameter in both the crosses. Plant height was positively correlated with yield per plant, fruits per plant and internode length in Cross 1, while magnitude of its positive correlation in Cross 2 with internode length, yield per plant and fruits per plant was in decreasing order. Days to first flowering had positive association with days to first picking and negative with yield per plant with low magnitude in Cross 1. None of the characters showed correlation with days to first flowering in Cross 2 under pedigree method of selection(Table 10).

Significant positive correlation coefficients were observed between yield and other characters namely fruits per plant, branches per plant and plant height under BP method of selection. Yield recorded negative correlation with

days to first flowering in Cross 1. It was positively correlated with fruits per plant, plant height, branches per plant and internode length, while negatively with days to first flowering with low magnitude in Cross 2. Fruits per plant showed positive correlation with yield per plant, branches per plant and plant height and negative correlation with days to first flowering in Cross 1 (Table 9). Significant and positive correlation of fruits per plant with yield per plant, plant height and branches per plant was in that order of decreasing magnitude in Cross 2. Fruit length was positively correlated with fruit diameter in Cross 1 and with fruit diameter, plant height and branches per plant in Cross 2. Plant height showed positive association with internode length, yield per plant and fruits per plant, whereas negative association with days to first flowering in Cross 1. Plant height exhibited positive correlations with internode length, yield per plant, fruits per plant, branches per plant and fruit length in Cross 2. Days to first flowering showed positive correlation with days to first picking, fruiting node having moderately low magnitude, and negative correlation with yield per plant, fruits per plant and plant height in Cross 1, while it had positive correlation with days to first picking and negative with yield per plant but for lower magnitude in Cross 2 (Tables 9 and 10).

The environmental correlations observed under different methods of selection for various characters in both the crosses are presented in Table 11. Under all the three methods of selection plant height exhibited positive correlation with internode length; branches per plant had positive correlation with fruits per plant and yield per plant which in turn were found positively correlated. Fruit length and fruit diameter were also found positively correlated with each other while branches per plant showed negative environmental

Table 11 Environmental correlations among characters under three different methods of selection in two crosses of okra Lam Sel-1 x Parbhani Kranti (above diagonal) and HB57 x P7 (below diagonal)

S. No.	Characters	Methods	Days to first flowering	Days to first picking	First fruiting node	Plant height (cm)	Number of branches / plant	Number of fruits/ plant	Fruit length (cm)	Fruit diameter (cm)	Internode length (cm)	Total yield/ plant (g)
1.	Days to first flowering	SSF	1.000	-0.079	0.076	-0.143	-0.046	-0.145	0.047	0.061	-0.038	-0.150
		PM	1.000	0.120	-0.027	-0.049	-0.019	-0.021	-0.107	-0.062	-0.311	-0.140
		BP	1.000	0.045	0.224	-0.096	0.058	-0.192	-0.135	0.043	-0.055	-0.188
2.	Days to first picking	SSF	0.169	1.000	0.265	0.110	0.179	0.137	0.076	-0.017	-0.109	0.133
		PM	-0.138	1.000	0.319	0.218	0.055	-0.008	-0.050	-0.138	-0.226	-0.017
		BP	0.249	1.000	0.314	0.199	0.145	0.121	0.064	-0.045	-0.101	0.050
3.	First fruiting node	SSF	-0.045	0.016	1.000	0.148	0.190	-0.120	-0.062	0.064	0.098	-0.106
		PM	-0.129	0.162	1.000	0.084	0.156	0.130	0.059	0.034	-0.010	0.152
		BP	0.075	-0.066	1.000	0.106	0.230	0.112	0.219	0.237	0.055	0.116
4.	Plant height (cm)	SSF	-0.191	-0.232	0.092	1.000	-0.110	0.133	-0.022	-0.070	0.414*	0.190
		PM	-0.161	-0.319	0.017	1.000	-0.191	0.165	0.169	0.199	0.383*	0.257
		BP	-0.208	-0.230	0.165	1.000	-0.306	0.225	0.236	0.263	0.520*	0.251
5.	Number of branches/plant	SSF	-0.067	-0.109	0.251	0.092	1.000	0.657*	0.020	0.130	-0.362*	0.601*
		PM	-0.122	0.012	0.232	0.069	1.000	0.540*	0.216	0.253	-0.318	0.572*
		BP	-0.089	-0.053	0.285	0.480*	1.000	0.449*	-0.065	-0.166	-0.523*	0.468*
6.	Number of fruits/plant	SSF	-0.088	-0.191	0.035	0.538*	0.557*	1.000	0.084	0.136	-0.261	0.981*
		PM	-0.194	-0.282	-0.043	0.423*	0.579*	1.000	0.244	0.270	-0.140	0.915*
		BP	-0.141	-0.033	0.003	0.464*	0.452*	1.000	-0.107	-0.133	-0.277	0.920*
7.	Fruit length (cm)	SSF	-0.237	-0.144	0.003	0.201	0.089	0.134	1.000	0.557*	0.104	0.082
		PM	-0.107	-0.036	-0.126	0.285	-0.038	0.263	1.000	0.697*	0.150	0.330
		BP	-0.053	-0.092	0.084	0.354*	0.297	0.237	1.000	0.582*	0.191	-0.089
8.	Fruit diameter (cm)	SSF	-0.180	-0.090	0.131	0.179	0.088	0.045	0.782*	1.000	0.132	0.121
		PM	-0.069	-0.073	-0.055	0.080	-0.053	0.169	0.720*	1.000	0.129	0.339
		BP	-0.013	-0.083	0.154	0.319	0.419*	0.318	0.642*	1.000	0.329	-0.116
9.	Internode length (cm)	SSF	-0.192	-0.100	0.191	0.730*	0.092	0.408*	0.289	0.253	1.000	-0.226
		PM	-0.136	-0.214	0.055	0.738*	0.154	0.331	0.192	-0.076	1.000	-0.028
		BP	-0.101	-0.131	-0.116	0.590*	0.136	0.277	0.125	0.174	1.000	-0.212
10.	Total yield/plant (g)	SSF	-0.110	-0.168	0.049	0.524*	0.546*	0.985*	0.140	0.043	0.408*	1.000
		PM	-0.198	-0.291	-0.037	0.446*	0.597*	0.985*	0.290	0.206	0.343*	1.000
		BP	-0.181	-0.011	0.010	0.515*	0.507*	0.984*	0.247	0.340	0.305	1.000

* $P \leqslant 0.05$

correlations with internode length only under SSF and BP methods of selection in Cross 1.

In Cross 2, fruits per plant with plant height, branches per plant and yield per plant; internode length with plant height; fruit diameter with fruit length; yield per plant with plant height, and internode length (except BP) showed positive correlations under all the three methods of selection. Also branches per plant and fruit length with plant height; fruit diameter with branches per plant under BP method of selection, and internode length with fruits per plant under SSF method exhibited significant positive environmental correlations. The magnitude of the environmental correlations varied with methods ranging from moderately low (0.343) to very high (0.985), indicating considerably high contribution of environmental influence on characters measured on the selection lines.

DISCUSSION

In maximizing the crop productivity per unit time and space the ultimate endeavour of plant breeder is to develop varieties that are superior to the existing one in respect of certain quantitative and qualitative traits. This is achieved by the accumulation of desirable genes for productivity, adaptability, resistance to biotic and abiotic stresses and the utilization of the variability present in the germplasm through suitable plant breeding approaches.

Yield as such, is a complex character governed by a number of genetic and environmental factors and is difficult to be managed easily in a breeding programme. Consequently the reliability of selection for a character with such a complexity has been questioned. Among various methods used by the plant breeders in the past as well as at present, pedigree selection ranks first in the self pollinated crops. Though the method has been quite successful in ameliorating the yield potential of many crop species, however, there are limitations of this method like quick fixation of linkage blocks, local adaptation and the effect of g x e interactions. Moreover, it is expensive, time consuming and quite unsuitable for the characters with low heritability.

Of late, the breeders have been in search of suitable selection methods to overcome the difficulties encountered in the pedigree and other conventional methods. With the advancement in the knowledge of the plant genetics and other related disciplines as well as experience of plant breeders, new selection techniques have come into practice. Some of such techniques have been

examined for their comparative efficacy in evolving superior lines of various crops.

The genetic variability forms the basis of all crop improvement programmes and hybridization is a technique to create variability. The F_2 generation of a cross between diverse parents represents maximum spectrum of variability. One of the most important consideration in the choice of breeding method is the maintenance of this genetic variation in successive generations and improvement of population mean which is necessary guide for the success in selection programme.

The success of hybridization programmes is largely determined by the choice of parents. Since the ultimate aim is to replace the existing cultivars with a superior one, therefore, the existing variety may be taken as one of the parents. The other parent should be the one that complement the existing cultivars in most aspects. In the present study Pusa Sawani, used as standard check, is the existing variety, however, this has now become susceptible to the yellow vein mosaic (YVM) disease. The other lines viz., Parbhani Kranti and P7 possessing desirable resistance to this disease with reasonably good yield and fruit quality have been included in the hybridization programme for the development of base population.

For advancing the segregating generations the large variability is handled by different selection procedures integrating genetic principles and skill of the plant breeder. Thus, there is a need of different selection methods in handling the segregating populations. Besides pedigree method, to handle the segregating populations other methods such as bulk method, mass selection, mass pedigree, single seed descent, early generation testing and a number of modifications of

these methods have been used in green gram (Dahiya, 1983). Pedigree method based on visual selection has been reported to be effective for highly heritable characters but poorly adapted for seed yield as reported by Mahmud and Kramer (1951) in soybean; Frey (1962) in oats; Townley Smith and Hurd (1973) in wheat and Byth et al. (1979) in chickpea.

Several reasons have been advanced for the failure in isolating high yielding plants in early segregating generations. Three possible reasons, insufficient genetic variation within and between bulk population, discarding of the crosses with high variance on the basis of low mean and large g x e interactions have been given (Rosielle, 1983). Dahiya and Lather (1990) also discussed these reasons in chickpea breeding programme.

With the large genotypic variation available from wide crosses, segregating populations could no longer be handled via pedigree selection. Bulk method and SSD have been found useful (Frey, 1975). These methods have their own merits and demerits. Their comparative efficacy in vegetable crops and particularly in okra has not been evaluated. However, a few reports on comparative usefulness of different selection methods are available in soybean, some cereals, green gram and chickpea which fail to provide any definite indication about the utility of a particular selection method in a crop for any specific character.

Mating flexibilities and gene effects involved in the expression of characters of interest are the important factors determining the choice of breeding procedure and selection method. Okra is a oftenly cross fertilizing crop and additive genetic variance is more important in such species. The additive genetic variance can be easily utilized and fixed in the breeding populations. The selection methods

through which the lines have been derived for the present study try to utilize such variances and thus may suit well to the material used.

The F_2 populations of two crosses (5000 plants in each) were subjected to generation advance upto F_4 through single seed per fruit (SSF), pedigree method (PM) and bulk population (BP). In F_4, visual selection was made discarding yellow vein mosaic susceptible plants (Fig. 1). From the visually selected plants, thirty plants under each method in Cross 1 and Cross 2 were seelcted on the basis of yield per se. One hundred eighty (180) F_5 progenies thus obtained were evaluated along with their parents and the standard check, Pusa Sawani.

A. Analysis of variance

Analysis of variance indicated that every selection method employed produced progenies different from each other for most of the characters in both the crosses except for fruit length in Cross 1; days to first picking and number of branches per plant in Cross 2 and number of fruits per plant and internode length in both the crosses under SSF. For fruit length, fruit diameter and internode length under PM and BP methods and for number of branches per plant under BP in Cross 1 the progeny variances were found non significant.

A comparison of mean square values in terms of their proportionate magnitude of contribution towards total variation in different characters of genotypes in both the crosses for the three methods of selection was also made (Appendix-1). The results showed that pedigree method of selection accounted for highest proportions of variability among lines for plant height (75.59%), yield per plant (63.01%), days to first flowering (61.36%) and number of fruits per plant (57.23%), while BP method included highest variation among genotypes for days to first flowering

(63.77%), first fruiting node (57.76%) and total yield per plant (55.69%). The mean squares for all the characetrs studied under SSF were comparatively lower than the other two methods of selection, however, for days to first flowering (55.44%) and plant height (55.03%), this method also contained sufficient variability among lines in Cross 1. Similarly, Muehlbauer et al. (1981) and Haddad and Muehlbauer (1981) reported SSD method retaining more genetic variation for maximum characters in lentil. Further, Ram et al. (1985) and Dahiya and Lather (1990) also observed variation among chickpea lines within the selection methods. Reports of differences among lines in other crops are also available.

In Cross 2, the mean squares due to genotypes accounted a larger proportion to the total variation for fruit diameter (74.42%), fruit length (59.71%), days to first picking (54.84%) and days to first flowering (49.02%) under PM of selection (Appendix-1). SSF accumulated highest proportionate variation only for yield per plant (47.30%), howerver, larger than PM for first fruiting node (55.85%) and plant height (56.92%). The BP method recorded highest proportionate mean squares due to genotypes for plant height (68.08%) and first fruiting node (61.55%) as compared with other two methods.

The proportions of error mean squares accounted for more than 40 per cent to as high as 71.97 per cent (BP) for seven characters each under SSF and PM, while for the nine characters under BP method (Appendix-1). In general the replication variance estimates were apparently higher under SSF than the other two methods probably due to greater responsiveness of individuals towards soil heterogeneity or the environmental variations.

In case of SSF the error mean squares exceeded 40 per cent in proportion for all the characters except days to first flowering (32.01%) and fruit diameter (36.36%). These estimates under PM exceeded 40 per cent to as high as 51.03 per cent for five characters while under BP method for six of the ten characters studied in Cross 2 (Appendix-1).

From the above results it appeared that homozygosity of lines under SSF method was attained more rapidly than the other two methods of selection in both the crosses. Further, different selection methods accounted different proportions of genotype, and environmental mean squares for various characters in both the crosses. Generally the selection lines developed through SSF method tended to be influenced more by the environment for the respective characters measured or to say that the variation among lines was mainly of environmental nature (Ivers and Fehr, 1978).

The two factor analysis carried out for both the crosses also showed that the contribution of methods, lines and their interactions toward mean squares of characters were variable ((Appendix-2). The proportion variation due to lines was highest only for days to first picking (38.66%) followed by days to first flowering (34.77%) and plant height (29.06%) in Cross 1, while the interaction of methods and lines contributed highest proportions for all the characters in both the crosses except three characters mentioned as above in Cross 1.

The magnitude of the contribution due to methods was also comparatively large for plant height (9.55%) followed by internode length (5.37%) and days to first flowering (3.15%) in Cross 1, while it was of minor magnitude for fruit length (2.30%) and fruit diameter (2.93%) in Cross 2 (Appendix-2).

Snape and Riggs (1975) also observed similar differences in the magnitude of variances of characters and suggested this as dependent on their genetic architecture. In Cross 1 the pronounced differences for days to first flowering, first fruiting node, plant height, number of branches per plant, fruit and internode length, therefore, suggested the effectiveness of selection for these characters. In Cross 2, the selection methods appeared to be effective for fruit length and fruit diameter only. The two factor analysis also supported the differences as observed in simple RBD analysis of the lines for these characters.

The earlier reports on different crops such as soybean (Empig and Fehr, 1971; Boerma and Copper, 1975a, 1975b), barley (Park et al., 1976), tomato (Casali and Tigchelaar, 1972; Peirce, 1977; Tee et al., 1979), wheat (Knott and Kumar, 1976) showed variable superiority of selection methods in producing high yielding lines. In the present study of okra also the magnitude of variance due to genotype, and environment (error) were observed differing for the characters scored as well as the cross populations handled. The advocacy of particular method under such situation, therefore, would be misleading unless the selection objectives are well defined. The multiplicity of crosses and characters being assessed also made the conclusion to be drawn regarding superiority of methods more difficult.

B. Mean performance of selection lines

The average performance of lines under evaluation was regarded as the primary and most authentic criterion in selection programme, on which breeder can rely with confidence. In carrying out the comparison of the thirty selections each under SSF, PM and BP methods the mean performance of all the lines for

ten characters scored has been considered (Table 4a-e), however, the ultimate fruit yield is the main objective of the improvement programme in okra. The data of Lam Sel-1 x Parbhani Kranti (Cross 1) indicated that the mean of all thirty progenies developed through SSF was highest and/or desirable (lowest) for five characters (Table 5). Pedigree method was found superior for three characters including total yield per plant, while BP method was important for improving total yield per plant besides the two other characters of importance.

Progenies of cross HB57 x P7 developed through SSF were found superior for five characters including total yield per plant (Table 6). The selection lines of PM recorded superior averages for three characters and BP method resulted superior performance of all lines for first fruiting node, number of fruits per plant and total yield per plant.

In general the mean performance of thirty progenies was found almost similar in magnitude both under PM and BP methods, hence appeared to be equally efficient in improving fruit yield in okra. Besides, for characters such as plant height and fruit size the pedigree selection appeared most effective while SSF was important for improving earliness and branching capacity. Invariably in literature reports also these three methods as employed in the present study, have been shown to be almost comparable except for some characters specificity in some of the cases in different crops. The results obtained in the present study regarding mean performance are, therefore, in conformity with these earlier reports.

Viewing the results presented with regard to comparison of three selection methods in respect of mean values of the top five progenies, the top most

progeny and the per cent progenies superior to better parent and standard check, the differences in selection methods were sufficiently evident in bringing out the improvement in different characters and the ultimate fruit yield in okra. SSF and PM were superior in terms of means of top five progenies for four characters each, while BP method was important for two characters. However, PM and BP methods were comparable for one character indicating towards late bearing in Cross 1 (Table 5). The PM and BP methods were superior for five characters each, while SSF stood primising for two characters. As regards days to first picking, all the three methods were found comparable in Cross 2 (Table 6).

Similarly, the comparison of methods in producing top most yielding progenies showed SSF important for 4 characters, PM for seven characters and BP method for two characters in Cross 1, with all three methods having similar mean performance of top most lines for one character. PM and BP methods also showed comparable performance for one character. In case of Cross 2 population, the performance of methods producing top most performing lines was identical to that exhibited for the performance of the top five progenies.

Comparison of selection methods using the per cent progenies exceeding in performance over the better parent and the standard check indicated that SSF method generated lines were more in number for seven and six characters, respectively in Cross 1, while these were more in number for three and four characters under PM and five characters each under BP method in the same cross. The per cent progenies were in similar numbers under all the three methods for one and two characters over the better parent and standard check,

respectively. Per cent superior lines of SSF and PM for one character (over better parent), two characters (over standard check); SSF and BP methods for two characters and PM and BP methods for one characters over the better parent were comparable in Cross 1.

Likewise the comparison of methods producing superior progenies over better parent and standard check in case of Cross 2 indicated the superiority of PM for seven and five characters; SSF method for two and four characters, while BP method for four and three characters, respectively. All the three methods were comparable for generating late bearing progenies over the better parent, however, SSF and PM were comparable for one and three characters over better parent and standard check, respectively. SSF and BP were comparable for two characters with one showing the lowest percentage, and PM and BP were comparable over the better parent for three of the characters studied. The range index estimates as per cent proportion of the difference in the highest and lowest values of the progenies to the mean of all progenies is another measure of variation present in the population. These estimates presented in Tables 5 and 6 indicated that SSF showed wide variation for four characters, PM for five characters and BP method for one character in Cross 1 while in Cross 2, PM accumulated wide variability for six and BP for four of the characters studied. Comparatively SSF lines carried narrow range of variation in Cross 2 for all the characters as compared to other methods. In general in both the crosses PM appeared to retain more variability than the other two methods.

From the above results it can be concluded that the PM and BP tended to retain more of the progenies of extreme performance type in either of the

two crosses. While SSF also generated top performing progenies in both the crosses for a number of characters but the range of performance appeared to be narrowed down under higher selection pressure. In other words BP and PM also confound a sufficient degree of natural selection and directional selection with minimum loss of superior types in selection generations.

Empig and Fehr (1971) reported SSD method to be least influenced by the natural selection in soybean. According to Snape and Riggs (1975) the direction and the magnitude of such differences are dependent on genetical architecture of the characters under improvement. Knott and Kumar (1975) found that mean of pedigree advanced lines was significantly higher, mainly because there were fewer low yielding lines. They also found SSD lines as good as the pedigree derived lines in wheat. Tee and Qualset (1975) observed an increased frequency of tall progenies in the BP method, due to significantly changing gene frequencies. Haddad and Muehlbauer (1981) also made similar comparison of SSD and BP methods in three populations of lentil and reported variable results for their performance with different characters studied. Dahiya and Singh (1986, 1990), Dahiya et al. (1987) also adopted similar criterion for assessing SSD, mass selection and selective intermating in greengram and Ram Niwas (1989) in peas. These authors sufficiently reported the superiority of SSD method. SSF appeared important for earliness but moderately effective for the improvement of yield potential in okra.

The possible reasons for narrowing down the spectrum of variability in SSD lines may be a loss of superior genotypes from the breeding stream on account of certain random genetic drift (Brim, 1966) from the sample of population used in selection programme. It also appears that in okra crop

the population of 5000 plants per cross and the limited number of crosses being explored, i.e. two only, the conclusion in respect of SSD method applications need to be assessed with more confirmation. Further, in PM transgressive segregants are hoped to be recovered for specific characters but Van der kley (1955) argued that pedigree, bulk and mass pedigree methods are not most efficient ones because of small frequencies of desired genotypes and the possible loss of valuable genotypes by a misdirected natural or human selection. Virupakshappa (1984) compared cowpea lines derived through SSD and BP methods and reported that with bulk method of selection the yield increase over generations was high in low x high yielding cross but not in high x high yielding cross.

Hamblin (1977) while studying the effects of bulk breeding on two high and low yielding crosses in beans observed no alteration in mean values in the high yielding crosses but a steady increase in the mean value of low yielding crosses with the advancement of generations. According to Busch and Luizzi (1979) the apparent changes in bulk populations of wheat for plant height and heading date were mainly due to genetic segregation coupled with intergenotypic competition. In the present study also such a phenomenon appeared to be operative for different characters in respect of the crosses used. Atkins (1953) also reported similar differences due to the cross populations used for bulk and selection lines.

C. Variability parameters and heritability

The coefficient of variation (cv %) which is another parameter of range of variation, however, on account of the environmental factors (Tables 7 and 8)

showed that SSF and BP methods seem to be confounding more environmental variation as compared to PM in their mean performance values. Since SSF is a modification of BP breeding for rapid generation advancement, these results therefore, appeared to be identical for these two methods. However, under SSF and PM the least influence of environmental variation observed on characters in Cross 1 and Cross 2, respectively suggested for such differences on account of the genetic architecture of characters under study (Snape and Riggs, 1975), and the genotype x environment interaction (Singh et al., 1979; Naidu et al., 1988).

The genotypic coefficient of variation (GCV) was found more for SSF, PM and BP methods for one, six and three characters, respectively in Cross 1 while for one, seven and three characters, respectively in Cross 2. Similarly, the phenotypic coefficients of variation (PCV) were comparatively larger in SSF for six, in PM and BP methods for two characters each of Cross 1. In case of Cross 2, PM exhibited higher values of PCV for four characters and BP method for six characters, while unlike the range index values, SSF also recorded low PCV for all the characters in Cross 2 as compared with other methods. The critical examination of data in Tables 5, 6, 7 and 8 regarding mean performance of progenies, range index values, coefficients of variation (cv %), GCV and PCV indicated that in the present study the SSF derived selections confound more influence of environment closely followed by BP but least by the PM.

Hamblin (1977) used variance as a determinant of cross potential and found that for characters having potential variation and that are markedly influenced by the environment, the interplant competition was the

factor of environment responsible for this effect. Busch and Luizzi (1979) also observed similar intergenotypic competition having only minor but significant effect. Baker (1971) recorded less variable theoretical variance with larger population size or the decreased environment variance in modified pedigree selection method. Higher genetic variances with SSD were reported by Muehlbauer et al. (1981), Haddad and Muehlbauer (1981), Singh and Dahiya (1986), Dahiya and Singh (1986) and Chen and Chen (1987) in different crops.

The heritability estimates of characetrs of the selection lines derived through SSF were comparatively higher in magnitude for one and two characters; under PM for seven and six characters and under BP method for two characters each in Cross 1 and Cross 2, respectively. In general the magnitude of heritability estimates for all the characters was on the lower side in both the crosses except for days to first flowering, plant height, first fruiting node (BP), number of fruits per plant (PM) and total fruit yield per plant (PM and BP) in Cross 1; days to first flowering, days to first picking (PM), first fruiting node (SSF and BP), plant height, fruit length and fruit diameter (PM and BP) in Cross 2. Luedders et al. (1973) in soybean also observed heritability estimates from 10-88 per cent for different characters under bulk population method. Besides, a few other workers also reported variable estimates of heritability for characters under different selection methods (Frey, 1962; Byth et al., 1979; Dahiya and Lather, 1990).

Pedigree method was found more effective for highly heritable characters (Mahmud and Kramer, 1951). Sakai (1954) advocated bulk breeding followed by progeny selection for characters with low heritability such as yield. In tomato

Casali and Tigchelaar (1975a) reported that for the highly heritable characters the cross effects were greater in magnitude than the generation effects. The results of the present study are also in close conformity with these reports.

Genetic advance was comparatively of considerable magnitude for two, six and two characters for SSF, PM and BP methods, respectively in Cross 1 and for eight and three characters (PM and BP) in Cross 2. Similar pattern was also observed for genetic advance as per cent of mean for all the characters in both the crosses. Tigchelaar and Casali (1972) in tomato also reported more genetic advance in pedigree selection.

Thus, from the above informations contained in Tables 5 to 8 suggest that the selection lines of SSF as already mentioned confounded more of environmental effects and the differences among lines were primarily of environmental nature probably due to attainment of homozygosity at earliest. Rosielle (1983) found that maximum potential gain increased with increasing mean genetic variance within bulks. Slightly more intense selection than the optimal (5%) may be an advantage where the between bulk heritability is high, the within bulk variance is high,and correlation between bulk mean and variance is high and positive. However, Blaha (1984) suggested BP method as most effective than SSD to overcome such problems.

The low heritability estimates of characters observed on SSF derived lines further supported this fact. This was because of the selection of more number of similar performing genotypes under SSF method. Brim (1966) suggested that selection for traits with low heritabilities was ineffective on single plant basis. Empig and Fehr (1971) reported SSD method least influenced by natural selection,

while Casali and Tigchelaar (1975b) suggested that SSD method offered greatest benefits where simultaneous selection was required for many characters under different heritabilities. However, according to Wright and Thomas (1976) although SSD and PM yielded a similar number of superior lines from the same crosses, but for the labour involved in the production of SSD lines and their proven susceptibility of diseases, SSD was rated a poor method. In case of tomato Peirce (1977) also reported that the chances of recovering high performance lines were less in SSD as compared to pedigree and the SSD following single cycle of pedigree selection.

Singh and Dahiya (1986) who found superiority of SSD method over the PM in green gram, later in the same year Dahiya and Singh, also reported that mass selection and selective intermating were superior to SSD selections. Yonezawa (1988) observed that selection method for plant breeding which did not produce greatest genetic advance may, however, provided a better probability of success in obtaining desirable genotypes. Therefore the selection sterategy should involve the two approaches of genetic advance and choice of success.

D. Correlation studies

The correlation estimates presented at genotypic, phenotypic and environmental levels in Tables 9, 10 and 11, respectively for the characters under study showed considerably significant magnitude for a number of combinations indicating a strong inherent association among characters under different selection methods in both the crosses.

Yield per plant was found positively correlated with number of fruits per plant, branches per plant and plant height (Majumdar et al., 1974; Singh et al., 1974; Rao and Ramu, 1975; Singh et al., 1976; Korla and Rastogi, 1978; Partap et al., 1979) under all the three selection methods in both the crosses. Besides, yield per plant was also positively correlated with internode length, fruit length and fruit diameter in both the crosses under either methods. The characters indicating earliness i.e. days to first flowering, days to first picking and first fruiting node were found negatively associated with yield per plant under almost all the three selection methods in both the cross populations.

The characters as mentioned above were also found interrelated in both the crosses and the selection methods. The examination of correlation values in Tables 9 and 10 showed that with very few exceptions the magnitude of genotypic correlations under all the three selection methods and in both the crosses was invariably higher than the corresponding phenotypic values for all the character combinations.

The majority of the character combinations exhibiting significant phenotypic correlations also showed significantly higher magnitude of environmental correlations under all the three methods of selection with few exceptions in Cross 2. These estimates indicated that except for one character combination under BP method in Cross 1 (highest negative value), their values were noted positive, significant and of highest magnitude for three, one and two combinations in Cross 1 and for six, four and three combinations in Cross 2 under SSF, PM and BP methods of selection, respectively.

The magnitude of phenotypic correlation estimates was highest for three and five combinations each under SSF and PM of selections in Cross 1 and

Cross 2, respectively. In BP method of selection the six each of the character combinations observed highest magnitude of correlations estimates in both the crosses (Tables 9 and 10).

In Cross 1 all the three methods exhibited highest magnitude of positive correlations for three combinations each, however, BP method also showed highest magnitude of negative estimates of correlations for three character combinations. Similarly in Cross 2, the two combinations under SSF and one combination under PM had highest magnitude of the negative estimates. The positive estimates were found with highest magnitude for three, four and six combinations under SSF, PM and BP methods, respectively.

Due to the effect of selection programme one combination for PM and two combinations for BP method acquired significant positive association, while one combination for SSF and three combinations for BP methods acquired significant negative association. On the other hand two combinations under SSF and one combination under PM lost the significance of positive correlation, while two combinations under SSF and three combinations under PM lost the negative association in Cross 1 (Table 9).

Similarly in Cross 2, two combinations under SSF and five combinations under BP acquired, while three combinations under SSF, six under PM and one combination under BP method lost the significant positive association. On the other hand two combinations each under SSF and PM, one combination under BP method retained and one combination each under SSF and PM and two combinations under BP method lost the significant negative association in Cross 2 (Table 10).

An examination of the simple phenotypic correlation estimates for all the character combinations on the parental lines of the two crosses (Appendix-3) and the corresponding comparison of the correlation estimates given in Tables 9 and 10 for the selection lines under three methods of selection indicated that there was significant change in the direction of correlations among characters under the selection pressure. In Cross 1; 5, 6 and 12 and in Cross 2; 8, 8 and 9 combinations changed the direction of correlation from positive to negative under SSF, PM and BP methods, respectively. Similarly, 2, 1, 1, and 1, 4 and 3 combinations each of Cross 1 and Cross 2 under SSF, PM and BP methods, respectively changed the direction from negative to positive side (Appendix-4).

A further analysis of these changes suggested that under SSF all the seven in Cross 1 and eight of the nine combinations in Cross 2 were in the desirable direction. In case of pedigree method the number of desirable changes was five of the seven in Cross 1, six of the twelve in Cross 2, while under BP method six of the thirteen in Cross 1 and seven of the twelve in Cross 2.

From the above facts it became evident that selection was effective and under the selection pressure the direction of correlations was drastically changed in the selection lines. Among the three methods assessed the SSF followed by PM appeared to be most efficient in bringing out the maximum desirable correlation changes among the important yield contributing characters. Further, SSF appeared to be effective for improving earliness, PM for plant height, branching tendency and fruit characters, while BP method could improve plant height, earliness and branching tendency in okra. Interestingly all the

three methods in both the crosses had tried to change the negative correlation of plant height into positive with the fruit diameter. In Cross 1, BP method changed the positive association of fruit length and diameter with a number of plant characters into the negative and undesirable one. Above all, the SSF was most promising, BP the poorest and PM the intermediate in respect of these correlation estimates of the characters.

The changes and improvement in the character correlations due to selection programme were also reported by several workers in different crops (Whan et al., 1981; Ntare et al., 1984). Busch and Luizzi (1979) reported positive correlation in bulk populations but without appreciable decrease. In their opinion the changes in bulk populations were due to genetic segregation coupled with intergenotypic competition effects.

SUMMARY

The study on the comparison of three selection methods viz., single seed per fruit (SSF), pedigree method (PM) and bulk population (BP) in okra was carried out from 1988 to 1990 during rainy and summer seasons at the Vegetable Research Farm, Chaudhary Charan Singh Haryana Agricultural University, Hisar using the populations of two crosses namely Lam Sel-1 x Parbhani Kranti and HB57 x P7. The results obtained during the investigation are summerized as under:

The analysis of variance showed significant differences among lines, methods and their interactions for all the ten characters observed in both the crosses. For the selection of superior lines perhaps, a particular method appeared appropriate, while for others, the another method might be suitable. The comparison of proportionate magnitude of mean squares for genotypes in both the crosses for the selection methods also indicated and confirmed such differences.

The mean performance of lines under different methods of selection for various characters showed that for specific characters particular best genotypes were selected under specific methods. None of the genotypes under specific selection methods was found important for all the characters under study. The comparison of selection methods in terms of mean of all thirty lines, mean of top performing five genotypes and mean of the topmost performing genotype suggested that the results were variable among methods with none found promising for all the characters in both the crosses. However, for majority of the important characters, SSF and PM appeared to be imporatnt in selecting the

high percentage of superior lines over the respective best parents and standard check, Pusa Sawani in both the crosses. A phenomenon of directional selection of early genotypes from the cross of late parents and late genotypes from that of early parents was also visible.

The range index and coefficient of variation showed variable magnitude of differences among lines for all the characters under three methods of selection in both the crosses, which indicated significant influence of genotypic, environmental and genotype x environment interaction in the expression of character variation. The estimates of genetic parameters GCV, PCV, heritability and genetic advance, and the comparison made among methods on these basis suggested that the pattern of variation, nature of inheritance of variation in generations and the response to selection varied with different methods for various characters in both the crosses. No consistency of these methods was observed for these parameters. However, SSF and PM appeared to mop up higher values of different parameters for characters in the two crosses.

The study of correlations among characters under three methods of selection in the two cross populations also did not show consistent results. The character correlations were significant for a number of combinations in all the three methods. In few cases the character correlations were acquired, while in some other cases the existence of correlations, whether a positive or negative, were lost under either selection methods in both the crosses. Also besides, loosing or acquiring the significance, the direction of correlations among characters was altered under all the three methods of selection. However, an examination of these changes suggested that under SSF all such alterations were in desirable direction with almost comparable performance under PM also. While under BP method most

of the direction changes of correlations were of undesirable types as compared to the correlations existing among characters in the parental lines.

All the variations with regard to mean performance, genetic parameters and correlation estimates, showed the effectivity of selection methods for different characters in both the crosses.

From the results derived and discussed in the present study for the comparison of the three selection methods in handling segregating populations of okra crosses, in generating more number of high yielding lines with high heritability estimates of characters over the generations advance, and significant response to further selection pressure, showed no consistency in the parameters assessed on the selection lines. Though, the informations brought out from these findings appeared to be controversial and contradictory or in conformity with earlier studies on different crops, yet provided a scope for crop improvement. Thus, viewing all these facts it can be safely concluded that apart from the routine pedigree method, the single seed per fruit (SSF) may be practised for the improvement of okra crop. However, its scope and usefulness with increased number of crosses and simulatneous multiplicity of selection characters should be explored and confirmed. The BP method may be utilized for random natural recombinations and to safeguard against the loss of desirable genotypes in okra, possessing oftenly cross fertilization behaviour. In selection programmes the interplay of environmental influence on these two methods may also be taken care of in judging their suitability.

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* Original

APPENDIX-1

Proportionate magnitude of mean squares (%) of okra lines from two crosses for different characters under three methods of selection

S. No.	Characters	Crosses*	Per cent magnitude of mean squares								
			Single seed per fruit (SSF)			Pedigree method (PM)			Bulk population method (BP)		
		d.f.	Replications 2	Genotypes 32	Error 64	Replications 2	Genotypes 32	Error 64	Replications 2	Genotypes 32	Error 64
1.	Days to first flowering	Cross 1	15.43	55.44	29.13	15.86	61.36	22.78	7.37	63.77	28.86
		Cross 2	28.44	39.55	32.01	24.02	49.02	26.95	25.73	43.30	30.97
2.	Days to first picking	Cross 1	1.49	44.13	54.39	1.84	45.32	52.84	0.90	50.95	48.15
		Cross 2	3.48	33.41	63.11	1.39	54.84	43.78	1.92	45.91	52.17
3.	First fruiting node	Cross 1	6.49	47.17	46.34	0.72	47.54	51.74	0.98	57.76	41.26
		Cross 2	2.27	55.85	41.88	11.89	42.48	40.63	6.24	61.55	32.21
4.	Plant height (cm)	Cross 1	7.63	55.03	37.34	0.002	75.59	24.41	6.74	53.77	39.49
		Cross 2	3.07	56.92	40.02	13.16	51.20	35.64	3.36	68.08	31.55
5.	Number of branches/ plant	Cross 1	28.42	35.21	36.37	3.00	47.93	49.07	0.90	41.18	57.92
		Cross 2	7.78	31.34	60.88	1.82	50.99	47.20	9.93	41.89	48.18
6.	Number of fruits/plant	Cross 1	9.43	39.90	50.67	1.09	57.23	41.68	3.08	46.48	50.43
		Cross 2	10.22	31.83	57.95	5.13	43.84	51.03	3.92	42.80	53.28
7.	Fruit length (cm)	Cross 1	3.26	40.45	56.30	5.22	41.90	52.88	0.70	37.32	61.98
		Cross 2	3.49	45.53	50.98	1.86	59.71	38.43	1.70	55.82	42.48
8.	Fruit diameter (cm)	Cross 1	2.72	40.96	56.32	5.88	47.06	47.06	0.35	27.68	71.97
		Cross 2	9.09	54.55	36.36	0.78	74.42	24.81	2.44	58.54	39.02
9.	Internode length (cm)	Cross 1	39.14	19.23	41.64	24.54	33.37	42.08	11.06	31.26	57.68
		Cross 2	9.13	35.35	55.52	16.30	44.52	39.19	1.20	51.95	46.85
10.	Total yield/plant (g)	Cross 1	11.72	39.63	48.66	1.97	63.01	35.02	3.04	55.69	41.27
		Cross 2	5.28	47.30	47.42	4.18	45.60	50.22	4.19	42.59	53.23

* Cross 1 = Lam Sel-1 x Parbhani Kranti; Cross 2 = HB57 x P7

APPENDIX-2

Proportionate magnitude of mean squares (%) of lines, selection methods and their interactions for different characters in two okra crosses Lam Sel-1 x Parbhani Kranti (Cross 1) and HB57 x P7 (Cross 2)

S. No.	Characters	Crosses	Per cent magnitude of mean squares				
			Replications	Methods	Lines	Methods x Lines	Error
		d.f.	2	2	32	64	196
1.	Days to first flowering	Cross 1	11.73	3.15	34.77	23.68	26.68
		Cross 2	25.73	0.19	21.17	22.87	30.03
2.	Days to first picking	Cross 1	1.29	0.26	38.66	8.87	50.92
		Cross 2	0.08	0.52	13.04	33.29	53.07
3.	First fruiting node	Cross 1	0.63	2.61	20.84	28.46	47.47
		Cross 2	6.80	0.73	13.27	39.82	39.38
4.	Plant height (cm)	Cross 1	2.54	9.55	29.06	27.58	31.27
		Cross 2	5.61	0.20	17.35	40.14	36.71
5.	Number of branches/ plant	Cross 1	7.51	2.05	13.50	26.40	50.53
		Cross 2	5.84	0.80	15.38	25.99	51.99
6.	Number of fruits/plant	Cross 1	2.82	0.14	21.16	26.33	49.56
		Cross 2	5.42	0.05	10.43	29.23	54.87
7.	Fruit length (cm)	Cross 1	1.87	2.28	10.99	28.28	56.58
		Cross 2	1.95	2.30	23.12	29.90	42.74
8.	Fruit diameter (cm)	Cross 1	0.30	1.22	19.45	19.45	59.57
		Cross 2	2.61	2.93	20.85	41.69	31.92
9.	Internode length (cm)	Crsos 1	22.13	5.37	10.67	14.42	47.40
		Cross 2	6.86	0.46	14.31	30.44	47.92
10.	Total yield/plant (g)	Cross 1	3.97	0.56	23.16	28.86	43.45
		Cross 2	5.01	0.30	9.90	29.04	56.02

APPENDIX-3

Simple phenotypic correlation coefficients among different characters observed on the parental lines in okra

S. No.	Characters	Days to first picking	First fruiting node	Plant height (cm)	Number of branches/ plant	Number of fruits/ plant	Fruit length (cm)	Fruit diameter (cm)	Internode length (cm)	Total yield/ plant (g)
1.	Days to first flowering	0.498	0.175	0.134	0.186	-0.305	-0.446	-0.593	-0.228	-0.329
2.	Days to first picking	1.000	0.249	0.658	0.484	-0.229	-0.207	-0.383	-0.158	-0.198
3.	First fruiting node		1.000	0.369	0.254	0.088	0.085	0.138	0.286	0.075
4.	Plant height (cm)			1.000	0.250	0.105	0.246	-0.123	0.394	0.132
5.	Number of branches/plant				1.000	0.109	0.195	0.160	-0.041	0.159
6.	Number of fruits/plant					1.000	0.359	0.462	0.293	0.994
7.	Fruit length (cm)						1.000	0.732	0.188	0.394
8.	Fruit diameter (cm)							1.000	0.051	0.470
9.	Internode length (cm)								1.000	0.311
10.	Total yield/plant (g)									1.000

APPENDIX-4

Changed direction of phenotypic correlations among characters under three methods of selection in two okra crosses Lam Sel-1 x Parbhani Kranti (Cross 1) and HB57 x P7 (Cross 2) compared to parental lines

Selection Methods	Character combinations exhibiting changed direction			
	Positive to negative correlations		Negative to positive correlations	
	Cross 1	Cross 2	Cross 1	Cross 2
	Plant height vs " Days to first flowering " Days to first picking Fruits/plant vs " First fruiting node " Internode length Yield/plant vs " Internode length	Plant height vs " Days to first flowering " Days to first picking First fruiting node vs " Fruits/plant " Fruit length " Fruit diameter " Yield/plant Branches/plant vs " Days to first flowering " Days to first picking	Plant height vs " Fruit diameter Days to first flowering vs " Internode length	Branches/plant vs " Internode length
	Plant height vs " Days to first flowering " Days to first picking First fruiting node vs " Fruit length " Fruit diameter " Internode length Branches/plant vs " Fruit diameter	Plant height vs " Days to first picking First fruiting node vs " Fruit length " Yield/plant Branches/plant vs " Days to first flowering " Days to first picking " Fruit diameter Fruits/plant vs " First fruiting node " Fruit diameter	Plant height vs " Fruit diameter	Plant height vs " Fruit diameter Days to first flowering vs " Fruit length Days to first picking vs " Fruit diameter Branches/plant vs " Internode length
	Plant height vs " Days to first flowering " Days to first picking " Branches/plant First fruiting node vs " Internode length Fruits/plant vs " Fruit length " Fruit diameter " Internode length Branches/plant vs " Fruit length " Fruit diameter Yield/plant vs " Fruit length " Fruit diameter " Internode length	Plant height vs " Days to first flowering " Days to first picking First fruiting node vs " Fruit/plant " Fruit length " Fruit diameter " Internode length " Yield/plant Branches/plant vs " Days to first flowering " Days to first picking	Plant height vs " Fruit diameter	Plant height vs " Fruit diameter Days to first picking vs " Fruit diameter Branches/plant vs " Internode length

COMPARISON OF DIFFERENT SELECTION METHODS IN OKRA (Abelmoschus esculentus (L.) Moench.)

by

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(An abstract of the thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy of the Chaudhary Charan Singh Haryana Agricultural University, Hisar)

A study on the comparison of different selection methods in okra was carried out during rainy and summer seasons of 1988 to 1990, at the Vegetable Research Farm, Chaudhary Charan Singh Haryana Agricultural University, Hisar using two cross populations. Thirty selection lines each under single seed per fruit (SSF), pedigree method (PM) and bulk population (BP) along with parental lines and standard check, Pusa Sawani were evaluated with respect to per se performance; mean of all thirty, top five, and topmost lines; per cent superior lines over best parents and standard check; genetic parameters and correlations among ten metric traits.

Differences among lines, due to methods employed and their interactions were significant for almost all the characters studied. There was no consistency for the parameters assessed under the three selection methods. Also none of the selected lines was found consistently superior for all the characters under either methods. Among the selection methods, though influenced by the environmental factors, SSF and BP accounted large variations. In PM the variation appeared to be due to the genetic architecture of the characters and the gene recombinations. SSF and PM resulted larger percentage of higher yielding lines; heritability estimates and the genetic advance in characters.

The character correlations with variable magnitude and directions existed under three selection methods. Some correlation combinations showed changed direction as compared to those existing in the parental lines, which all under SSF, most under PM and few under BP method were in desirable directions suggesting the superiority of SSF and PM in okra improvement programme. However, the usefulness of SSF with more number of crosses and simultaneous selection for characters may further be explored and confirmed.

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