CYTOGENETIC STUDIES ON INTERVARIETAL HYBRIDS OF SESAMUM (Sesamum indicum L.)

By

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THESIS

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Department of Agricultural Botany
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Vellayani—Trivandrum.

1984

DECLARATION

I hereby declare that this thesis entitled "Cytogenetic studies on intervarietal hybrids of sesamum (*Sesamum indicum* L.) is a bonafide record of research work done by me during the course of research and that the thesis has not been previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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INTRODUCTION

INTRODUCTION

Vegetable oils arising from tree crop species such as oil palm and coconut palm to annuals such as sunflower, safflower, castor, groundnut and sesamum form an important constituent of the diet of Indian people. The advantage of having a cafeteria of oilseed crops suited to different agroclimatic regions enable the country to cater to the different needs and tastes of the people. In spite of the large variety of crops yielding oil the Indian production has been stagnant for the last 25 years leading to acute scarcity and shortage. There has been a considerable drain in our foreign exchange resources due to import of vegetable oils. Considerable importance has been given for increasing vegetable oil production in the country which is exemplified by the high priority given to it in the new 20 point programme.

Two main approaches have been made to meet these requirements. One is the introduction of new oil seed crops such as sunflower and oil palm. Both these have been highly successful, the former in the dryland regions of Peninsular India and the latter in the monsoon tropical belt of Kerala. Another approach has been the improvement programmes of oil seed crops especially annuals. In the improvement of annuals considerable progress has been made

in the case of groundnut. Under the All India Co-ordinated Project on Oil seeds considerable work is currently being carried out in linseed, rape seed, mustard, sesamum and castor. Of these sesame is the most important annual oil seed crop as far as Kerala is concerned.

Sesamum originally a native of Africa, finds mention in the Rig Vedic and Yajurvedic scriptures and is known to have been used in the rituals of the ancient Aryans De Candolle (1886) reported that if not originally a native of the warm temperate tracts of India, it was probably brought to India before it found its way to Egypt and Europe.

Annual world production in 1978 approached 2 million metric tonnes from altogether 65 countries. India is the world's major producer with a third of the world's acreage and approximately a quarter of total global production (Anonymous, 1977, 1978). In India sesamum is cultivated in about 24 lakh hectares with an annual production of about 5 lakh tonnes. The average yield in India is about 200 kg/ha against the average yield of 300-700 kg/ha in other countries (Anonymous, 1979b). In India among the different states which cultivate sesamum Uttar Pradesh stands first for production (Anonymous, 1978). In Kerala sesamum is cultivated in about 14.75 thousand hectares with an annual production of about 3833 tonnes of which the maximum contribution is from the Alleppey District (Anonymous, 1983).

Sesamum is essentially a crop of the tropics and is a herbaceous annual growing well in sandy loam soils. Sesamum belongs to the family Pedaliaceae. A confusion still prevails in the species differentiation. Index Kewensis has so far listed 36 species. As many as 8 wild species have been reported from Africa - the original home.

Morinaga et al. (1929) first reported the chromosome number of the cultivated sesamum as 2n = 26. The available cytological data indicate the close affinity between Sesamum radiatum and Sesamum occidentale (both n = 32), S. prostratum and S. laciniatum (both n = 16) and S. indicum and S. indicum sub species malabaricum (both n = 13).

Sesamum seeds are very nutritive containing upto 60% oil and 25% protein with an exceptionally high amount of methionine. It is rich in calcium (about 1%), phosphorus (about 0.7%) and Vitamin E. The most useful property of sesamum oil is its high stability because of the presence of powerful antioxidants which prevents rancidity. The antioxidant synergistic properties are provided by sesamolin (0.3 to 0.5%) and sesamin (0.5 to 1%) in the oil (Yermanos et al., 1964; Nayar and Mehra, 1970).

The volume of research work on sesamum, especially basic studies leading to plant improvements is very limited. Khidir (1981) has rightly pointed out that sesamum is produced by small and subsistence farmers. Breeding of

better varieties in view of this could produce immediate and spectacular yield increases substantially benefitting subsistence farmers living on the fringes of the poverty line, besides improving the national production of sesamum. Seshadri (1957) while reviewing the work in India has pointed out that characters such as profuse branching habit, close setting, multipod development in leaf axils, multi loculed capsules, high oil content of seeds etc. are some of the characters that should be considered in a breeding programme. Recently with the evolution of the plant type concept, considerable stress is being made for increasing production from unit area by changing the architecture of present day cultivars. A basic understanding of the genetic factors determining the more important yield contributing characters, nature of association of different characters, combining ability of varieties and the mode of inheritance of different characters, is probably the Sine quo non for launching any plant breeding programme of consequence on sesamum. Since our knowledge on the foregoing is meagre and sketchy the present study has been found to be of top priority. The study has been therefore undertaken with the following objectives.

i) to find out the extent of varietal variation available in sesamum

ii) to find out the mechanism of inheritance of quantitative (yield attributing) characters.

iii) to find out the interrelationship among various yield attributing characters.

iv) to find out the extent of heterotic effect operating in various characters in different cross combinations.

v) to find out the combining ability among different varieties available for various characters.

vi) to find out the gene action mechanism in character expression of various quantitative traits.

vii) to find out the effects of single and double crosses in character expressions.

viii) to find out the segregation pattern of various characters in segregating populations.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

I. Variability analysis

a) Genotypic and phenotypic variability

Quantitative characters are known to be governed by the co-ordinated action of genes at many loci. Gaul (1967) reported that the individual substitution of these jointly acting genes provides small effects at the phenotypic level and on the environmental influences'. "Any change in the environment produces differences in the phenotype, of a similar order to changes in the set of genes co-operating to produce a given trait. Usually different genes co-operating to determine the same trait are kept together in blocks intermingled with genes co-operating to influence other traits. Such polygenic traits are the results of a natural selection process, but they may be broken by recombination. Therefore, one may say that in such blocks a genetic variation is stored which represents the potential to face ecological requirements at different locations and in different years, to face evolutionary trends or to provide variability for artificial selection".

Hence, the information on the type of variability available in the genetic stock and the part played by environment on the expression of characters is a pre-requisite for any crop improvement programme. Sesame is a crop showing much variability for the different morphological characters.

Osman and Khidir (1974) from their studies on forty two strains of Sesamum indicum, comprising twenty one indigenous and twenty one exotic lines, recorded that the variability present among the varieties for the fifteen characters studied showed significant differences. Number of primary branches, number of pods per plant, seeds per plant and yield showed comparatively high level of variability while oil content and days to maturity exhibited a low level. Chavan et al. (1982) studied a total of eighty two M_2 progenies derived from gamma irradiation of three varieties of sesamum for twelve yield components. The studies indicated that number of capsules per plant, seed yield per plant, number of primary branches, height up to the first branch and number of capsules on the main shoot showed the greatest variability.

The progress in breeding depends upon the magnitude of genetic variability in the population and the extent to which the desirable characters are heritable. So to explore the genetic variability the magnitude of phenotypic and genotypic coefficients of variation, heritability and genetic advance are to be determined.

Krishnamoorthy et al (1964) reported that in sesamum the number of branches per plant and number of seeds per capsule were least affected by environmental influence. Osman and Khidir (1974) studied fifteen characters of sesamum and had reported that the phenotypic variance in almost all the characters was higher than the genotypic variance. But the

major portion of variance was contributed by the genotypic component. All the characters had higher genotypic coefficient of variation (g.c.v). High phenotypic and genotypic coefficients of variability were obtained for height up to first pod and number of primary branches per plant whereas they were low for oil, moisture and protein percentages. Sanjeevieh and Joshi (1974) studied the morphological characters associated with yield in thirty one varieties of sesamum, collected from all over India and had reported that number of capsules on main branch, number of nodes on main branch and number of branches were little influenced by environment. Coefficient of genetic variation was higher for number of capsules on main branch, number of branches and yield per plant. Solanki and Paliwal (1981) from their studies on genetic variability in sesamum reported that the genotypic and phenotypic variances were high for capsules per plant and seeds per capsule. Rai et al. (1981) studied the genetic variability of sesamum and pointed out that number of branches per plant had high genetic coefficient of variation and was less influenced by environment. Characters like capsule length and plant height exhibited low estimates of g.c.v.

b) Heritability and genetic advance

Johnson et al. (1955) suggested that the estimates of heritability indicates only the effectiveness with which selection of genotype can be made based on the phenotypic

performance but fails to indicate its genetic progress that can be achieved. Swarup and Chaugale (1962) had cautioned that high heritability per se was no index of high genetic gain but should be accompanied by high genetic advance. Heritability and genetic advance of different morphological characters have been analysed by various workers in sesamum as detailed below:

Osman and Khidir (1974) reported that in sesamum except for yield, protein and moisture content all the other characters such as days to flowering and maturity, plant height, height up to first pod, number of primary branches, pod length, number of pods per plant, number of seeds per pod, weight of seeds per pod, number of seeds per plant, 1000-seed weight and oil content gave heritability estimates exceeding eighty per cent in one season or the other. Five characters viz., height up to first pod, number of primary branches, number of seeds per plant, days to flowering and number of pods per plant exhibited a very high magnitude of genetic advance whereas oil, protein and moisture content gave very low values. Sanjeevaiah and Joshi (1974) studied the phenotypic characters associated with yield in thirty one varieties of sesamum and reported that heritability estimates were very high for plant height, number of capsules on main branch and number of branches per plant. Heritability was low for seed yield and other characters.

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Rai et al. (1981), from their studies on genetic

variability in Sesamum indicum, concluded that among the different characters studied, only number of branches possessed high values for heritability and genetic advance. Plant height recorded high heritability in conjunction with low genetic advance. Heritability studies on sesamum conducted by Solanki and Paliwal (1981) indicated that heritability was high for 1000-seed weight, capsule length, seeds per capsule, days to maturity and capsule girth. Medium heritability was recorded for yield per plant and capsules per plant. High heritability combined with high genetic advance was recorded for seeds per capsule, days to maturity and number of capsules per plant. Chavan et al. (1982) studied the M_2 progenies of three varieties of sesamum for twelve yield components and reported that high heritability estimates accompanied by high expected genetic advance were found for number of capsules per plant, number of primary branches, height up to the first capsule and number of capsules on the main shoot.

II. Correlation studies

a) Simple, partial and multiple correlations

An understanding of correlation, especially the genotypic and phenotypic correlation, is of great importance since it is a preliminary requirement in a breeding programme designed to manipulate plant architecture. Grafius (1959) suggested that there may not be genes for yield per se, but rather various components, the multiplicative interaction of

which results in the artifact of yield. The association between two characters is a part of the complicated pathway in which other traits are also interwoven. Greater the number of variables included in a correlation study, more complex will be their indirect associations.

Knowledge of the relation of yield and its components is invaluable to the plant breeder in selecting desirable strains. Since a change in one character is accompanied by changes in several others, conclusion of practical application cannot be drawn from simple correlation and regression coefficients. Phenotypic association between variables may be genetically controlled or may be brought about by environmental influences. They may be brought about by the direct influence of one variable on another by correlated common causes. The information on the type of variation available in the genetic stock and on the role played by the environment on expression of plant characters is a pre-requisite for any crop-breeding programme.

Khidir and Osman (1970) conducted correlation studies on some agronomic characters in ninty local types of sesame and made the following conclusions. Yield per plant was positively and significantly correlated with stem height, branches per plant, seeds per pod, seeds per plant and 1000-seed weight. Number of days to first flowering proved to be positively and significantly correlated with days to first maturity and significantly and negatively correlated with

stem height. Number of seeds per plant was positively correlated with the number of pods per plant, stem height, number of branches per plant and with pod length. Number of seeds per plant was negatively and significantly correlated with the 1000-seed weight. Stem height was positively correlated with the number of branches per plant, pod length and the number of pods per plant but negatively correlated with 1000-seed weight. Number of branches per plant was positively correlated with the number of pods per plant and negatively with the number of seeds per pod. Number of pods per plant, branches and seeds per pod showed no correlations with pod length.

Ramachandran et al. (1972) worked out the correlation coefficients taking yield, dry weight of seeds per plant and four characters viz., height of plant, number of branches, capsule size and girth of stem using the variety of Sesamum indicum, TMV-3. The studies revealed high degree of association of yield with height of plant and number of branches. Sanjeeviah and Joshi (1974) reported positive genetic correlation between height and number of nodes on main branch. Genetic correlation was high for plant height and number of branches also. Yield was found to be strongly correlated with number of capsules on the branches and number of branches per plant. Strong negative correlation was recorded for number of capsules and number of branches. Shukla and Verma (1974) from their studies on twenty eight

sesamum cultivars reported that number of secondary branches, capsules on main branch and capsules per plant contributed maximum to seed yield. Negative relationship was found between number of days to flowering and seed yield.

Chaudhary et al. (1977) from the trials conducted with fifteen sesamum cultivars reported that seed yield per plant was positively correlated with days to first flowering and fifty per cent flowering and number of capsules and branches per plant. Plant height was negatively correlated to capsule length. The yield was found higher in tall cultivars than in dwarf ones. Murugesan et al. (1979) studied the genotypic and phenotypic correlations of five quantitative characters in Sesamum indicum and reported that significant positive genotypic and phenotypic correlation existed between grain yield and total number of pods per plant, number of primary as well as secondary branches per plant in summer and monsoon seasons. Yadava et al. (1980) reported association of yield and its component characters in sesamum using correlation and path analysis. The results clearly showed that the genotypic correlations were higher than phenotypic correlation. Seed yield was found to be positively and significantly correlated with the number of primary branches, total number of capsules and weight of 1000 seeds. Total number of capsules showed a significant positive association with the primary branches. The number of days taken to first flowering was found to be positively and significantly correlated with the time taken

for fifty per cent flowering.

The degree of association between yield and other auxiliary characters in sesamum was analysed by Rai et al. (1981) and reported that yield was significantly and positively correlated with number of capsules on main stem, number of capsules on branches and total capsules per plant. Chavan and Chopde (1981) studied correlation in eighty two M_2 progenies and reported that phenotypic and genotypic associations were strong for seed yield per plant, number of primary branches, number of days to fifty per cent flowering and length of capsule. Genotypic correlations were higher than phenotypic correlations. Seed yield per plant was highly correlated with the number of branches and capsules per plant. The number of seeds per capsule was negatively correlated with seed yield per plant. The number of primary branches, days to fifty per cent flowering, plant height and length of capsule were correlated positively with the number of capsules per plant but negatively with the number of seeds per capsule except length of capsule and plant height. The number of seeds per capsule had a positive association with the length of capsule and plant height. Zhan (1983) based on the studies on quantitative characters in sesamum reported that height, number of seeds per capsule and 1000-seed weight were positively correlated with yield per plot.

Simple, partial and multiple correlations of height of plant, number of branches and number of capsules against yield in three varieties of sesamum was worked out by Sikka and Gupta (1949b) and the results showed that from amongst the three characters studied, the greatest contribution to yield was made by the number of capsules, followed in order, by number of branches and height. Muhammed and Durairaj (1964) analysed the association between yield and three yield components viz., 1000-seed weight, capsule number and capsule size in one hundred varieties of Sesamum indicum that were classified into three seed colour groups. Total, partial and multiple correlations were calculated for the characters. Capsule number, capsule size and 1000-seed weight were found to have significant positive association to yield. Among the three attributes, 1000-seed weight did not seem to be a decisive character in determining the yield. Inter-componental correlation showed absence of any association between capsule number and 1000-seed weight. Positive significant association was observed between capsule size and capsule number. Between capsule size and 1000-seed weight also there was significant positive correlation.

Osman and Khidir (1974) studied in detail the relation of yield components in sesame. Simple and partial correlation and regression coefficients, multiple correlation coefficients and coefficients of determination were worked out. The studies showed that apart from protein, yield per plant was

positively correlated with all the characters studied. Days to flowering and maturity, plant height, height to first pod, pods per plant and number of seeds per plant gave positive and highly significant correlation coefficients with yield and with one another in the two seasons tried. Number of pods per plant gave significant coefficients with plant height and with number of primary branches when either or both of the other two attributes were kept constant. Yield was significantly and positively correlated with late flowering, late maturity, height to first pod, number of pods per plant and total number of seeds per plant. The above characters; besides being correlated with yield were highly correlated with each other.

b) Path analysis

Correlation coefficients could be helpful in measuring the association between two characters but they do not provide the causal basis of such an association. Phenotypic associations between variables may be brought about by environmental influences. A positive genotypic correlation between two variables can be counteracted by a negative environmental correlation, thus making it impossible to select for any two variables at the same time because of the cancelling out effects of environment. The reverse may also be true. Further more selection for a trait in one direction may cause an undesired diminution of another trait by direct

or indirect effect through a third variable. Therefore it becomes necessary for a plant breeder to look more closely at the nature of the association among traits in which he is trying to make progress.

The path-coefficient analysis devised by Wright (1921 a) is an effective means of examining the direct and indirect relationships permitting a critical examination of the specific factors that produce a given correlation. Dewey and Lu (1959) stated that the path-coefficient is simply a standardised partial regression coefficient and as such measures the direct influence of one variable upon another and permits the separation of the correlation coefficient into components of direct and indirect effects. The use of the method requires a cause and effect situation among the variables and the experimenter must assign direction in the causal system based upon experimental evidence. After the pioneering work of Dewey and Lu (1959) on crested wheat, the technique of path-coefficient analysis was extensively used by different workers in a large number of crop plants for mems.

Kaushal et al. (1974) reported that capsule number per plant and plant height had a positive direct effect on yield in erect types of sesamum.

Dixit (1975) conducted studies on six parents, six F_2's and twelve back cross progeny of Sesamum indicum and

the results showed good genotypic correlation between yield and number of capsules per plant, length of main fruiting branch and number of capsules on main fruiting branch. Number of branches showed a direct positive effect on grain yield. The maximum direct effect was shown by number of capsules on main fruiting branch. Plant height and days for flowering showed negative direct effects on grain yield and number of days to flowering was negatively correlated with yield.

Murugesan et al. (1979), from their studies on some quantitative characters in sesamum during the summer and monsoon seasons of 1976, reported that number of primary branches per plant had the highest direct effect on seed yield followed by number of secondary branches. The plant height had minimum direct effect on seed yield during summer 1976. Path analysis of monsoon 1976 data revealed that the character: plant height at which first capsule was formed had the highest direct effect on seed yield followed by plant height. The characters, total number of capsules per plant and number of secondary branches per plant had very low direct effects on seed yield.

Yadava et al. (1980) carried out path analysis in sesamumto measure the direct and indirect effects of characters influencing yield. The number of capsules had the maximum direct effect on seed yield followed by 1000-seed weight, days to 50 per cent flowering and number of

primary branches. The number of days for first flowering exerted a high, direct but negative effect on seed yield. The number of capsules had indirect positive effects via plant height, 1000-seed weight and days to first flowering, but had negligible indirect effects via the remaining characters. Besides high direct effects, primary branches also affected the seed yield indirectly via days to maturity and 50 per cent flowering.

Gupta and Gupta (1977) studied the variability, inter-relationship and path-coefficients of some quantitative characters in sesamum and reported that the number of capsules had a direct effect on seed yield. Path-coefficients were worked out in 28 genotypes of sesame by Shukla (1983) for six agronomical characters including yield. The study revealed that number of capsules per plant and number of primary branches per plant were the major component characters showing highest direct effects on seed yield. Days to 50 per cent flowering and plant height showed negative direct effects on seed yield but both the characters produced positive effects on yield via number of primary branches. Number of primary branches showed negative effects via days to 50 per cent flowering and plant height. It was indicated that early flowering reduced plant height and more primary branches contributed to seed yield. Plant height had a positive effect on yield via number of capsules per plant, which exerted negative effect on yield via plant

height. Hence it would be desirable to select a dwarf plant type. The positive indirect effects of secondary branches per plant as well as via plant height were high which resulted in significant correlation between secondary branches and seed yield. In addition, secondary branches showed positive correlations with the number of capsules per plant. Hence secondary branches could be important component of a desired plant model in sesame.

III. Heterosis

The manifestation of increased vigour, greater size, higher productivity and similar intensifying effects have long been observed by biologists in many plant and animal hybrids. Exploitation of heterosis in cultivated plants and animals is to date by far the most important application of the science of genetics in agriculture.

This phenomenon resulting from hybridization has been designated as 'stimulating effects of hybridity', 'heterozygosis', 'stimulus of heterozygosis', 'heterozygotic stimulation', 'hybrid vigour', or more comprehensively 'heterosis' as first proposed by Shull (1914). One of the many explanation of heterosis is that it is the expression of the joint action of favourable combination of genes at different loci. The that interaction such as complementary action between non-allelic genes brought together from the parents, surpasses the simple summation of the effect of those genes in the parents. Subsequently Powers (1944),

Hull (1945, 1949) recognised partial dominance, complete dominance and over dominance in different cases of heterosis. Comstock and Robinson (1948) pointed out that non-allelic interaction or epistasis could inflate measures of inter-allelic interaction and later they suggested that epistasis might be partly responsible for heterotic effects. Jinks (1955) suggested that apparent over-dominance may be partly due to epistasis. Mather (1949) concluded that non-allelic interaction was a more likely and more frequent cause of heterosis rather than any special relation between the alleles of the same locus. Bowman (1959) reported that a combination of the three types of gene interaction (dominance, over-dominance and epistasis) might be operative in heterotic crosses. Wallace (1963) supported that a pair of alleles may show over-dominance in one genetic background, but not necessarily in another. It was also pointed out that the apparent over-dominance detected under visual observation is not always a case of true over-dominance. Many workers supported the role of epistasis in heterosis such as Sharma (1965) in bhindi, Swarup and Sharma (1965) in cabbage and Swarup and Pal (1966) in cauliflower etc.

Shakhbazov (1978) advanced the hypothesis that heterosis is associated with electron interaction between homologous chromosomes in the heterozygote. It was suggested that a reduction in complementary interaction between homologous chromosomes increases their active

surface and the total electrical change of the cell nucleus and that this increases the resistance of the cells to external influences and also their mitotic activity. Heterotic hybrids are characterized by a high mitotic index and a rapid mitotic cycle.

The importance of a proper understanding of hybrid vigour is now universally admitted. In recent years the search for the causes of hybrid vigour and its practical utilization has passed the experimental stage and reached that of large-scale commercial application in a few crops particularly in maize, sorghum etc.

Pal (1945) studied hybrid vigour in gram, sesamum, maize and chillies. The characters mainly studied were height of plant, number of leaves per plant and number of branches per plant. Number and weight of fruits were also studied. He concluded that among the four crop plants, maize is the most suitable one for conducting experiments on hybrid vigour. In sesamum manifestation of hybrid vigour was estimated for characters such as height of plant, number of leaves per plant, number of branches per plant, number of days from sowing to maturity, number of capsules per plant and yield per plant. The results showed that there was no hybrid vigour in respect of height in most of the hybrids from different crosses. There was no evidence of hybrid vigour for the number of leaves per plant, number of branches per plant, number of days from sowing to first

flowering and to maturity. For number of capsules per plant, the hybrids approached the better parent. Six out of eight hybrids showed striking increase in yield over the better parent.

Sarathe and Darbal (1969) estimated heterosis in Sesamum orientale for characters like cotyledon area, days for flowering, leaf area, flowering node number, number of branches, height, number of flowers per plant, days for harvesting, capsules per plant, seeds per capsule, 1000-seed weight, yield per plant and oil content. Hybrid vigour was recorded for leaf area, number of flowers and capsules per plant and yield. For seeds per capsule and 1000-seed weight slight increase was noticed over the mid parental value. But for oil content there was no increase.

Murty (1974) reported from his studies on heterosis in sesamum that heterosis over mid parent was conspicuous for all characters studied. Yield and component characters viz., number of primary and secondary branches and number of capsules per plant exhibited heterosis over the best parent. The developmental traits showed heterosis over the better parent only.

Joseph (1979) had estimated heterosis for tuber yield in sweet potato hybrids and reported that seven out of sixteen hybrids showed significant increase over the higher parental value and the percentage increase ranged from 31.26 to 84.63. Heterosis was estimated for three characters

viz., number of pods per plant, height of plant at maturity and number of branches per plant in Sesamum indicum by Sverup John (1980).

Heterosis was observed in nine out of twelve characters in the intervarietal hybrids derived from diallel crosses, involving five parents, in green gram by Wilson (1982). Components of heterosis and inbreeding depression were studied by Chavan et al. (1982) in sesamum and they reported that significant positive heterosis was manifested for characters such as capsules per plant, number of days to maturity and yield per plant. Paramasivan et al. (1982) also studied heterosis in hybrids of sesamum. The quantitative traits viz., height of plant, number of capsules per plant and seed yield per plant were recorded in the intervarietal hybrids as well as their parents. Number of seeds per capsule and weight of 1000 seeds also were observed in each cross combination. Heterosis was calculated as the percentage increase/decrease over superior parent. All the hybrids expressed heterosis for number of capsules per plant except one. Heterosis for yield and yield components in a number of crosses was due to favourable action and interaction of genes for the traits. The differences in heterosis might be due to several reasons such as (i) genetic diversity of the parents used (ii) agronomic conditions in the experiment, particularly soil type and

plant spacing and (iii) non-allelic interaction which can either increase or decrease the expression of heterosis. Results of the study also indicated the involvement of a few modifier genes which are negative in effect in the expression of seeds per capsule. For weight of 1000 seeds the values were lower than the low value parent.

Heterosis for yield and its component characters in relation to F_1 hybrid of sesame was studied by Tyagi and Singh (1981). Pronounced heterosis was recorded for the number of branches, plant height, number of capsules and yield. The vigour was less marked for oil content, test weight, length of capsule and number of seeds per capsule.

IV. Combining ability

The development of a plant breeding strategy hinges mainly on the support provided by genetic information on the inheritance and behaviour of major characters associated with yield and quality. To derive such genetic information it is necessary to conceive a genetic model in relation to the material that is proposed to be utilized. This process involve in most cases, the designing of a suitable mating system to fit into the chosen genetic model. Diallel crossing is one such important mating system enjoying universal application in plant breeding. The diallel analysis provides a considerable amount of genetic information. It provides information on the (i) nature and

amount of genetic parameters and (ii) general and specific combining ability of the parents and their crosses respectively. The term "general combining ability" (g.c.a) was used by Sprague and Tatum (1942) to designate the average performance of a line in a number of hybrid combinations. They used "specific combining ability" (s.c.a) to designate those cases in which certain hybrid combinations did relatively better or worse than would be expected on the basis of the average performance of the lines involved. The two main approaches being followed for diallel analysis are: (i) Hayman's approach (ii) Griffing's approach.

Hayman (1954 b) defines a diallel system as "the set of all possible matings between several genotypes". This gives rise to p^2 combinations including the selfs, crosses and reciprocals among the 'p' parental lines. Griffing (1956 b) demonstrated the method of estimating g.c.a and s.c.a effects along with their variances. He pointed out that twice the g.c.a variance contains not only the additive genetic variance but also a portion of the epistatic variance (additive x additive) and that the s.c.a variance includes all the dominance and remaining portion of epistatic variance. When interpreted in terms of the classical method of covariance between relatives (Fisher, 1918, 1930), the g.c.a variance is equal to the covariance between parent and offspring in a random mating population at equilibrium.

Griffing (1956) has given a mathematical treatment of the problem of estimating general and specific combining abilities from diallel crosses involving four methods depending upon whether or not the parental inbreds or the reciprocal F_1's or both are included. Again, depending upon whether the experimental material can be assumed to be a random sample from some population about which inferences are to be made or whether the experimental material constitutes the entire population about which valid inferences are to be made, two models also have been suggested by him.

Hayman (1957) pointed out that in the absence of epistasis, g.c.a is composed of both additive and dominance portions, while s.c.a consists of mainly dominance portion. When epistasis is present both these combining abilities contain epistatic portion. In g.c.a this portion is an average of epistatic effects in the corresponding array, while in s.c.a it relates more directly to the epistasis in a particular cross.

Analyses of combining ability were carried out in sesamum by Murty (1974) according to the procedure outlined by Griffing (1956) for Method I Model 1. The results showed that g.c.a variances were larger than s.c.a variances for days to flowering, plant height, number of primary and secondary branches and number of capsules per plant indicating the predominance of additive gene action. However, the

magnitude of s.c.a variances were double of g.c.a variances for percentage of oil and were in moderate proportions for plot yield and percentage of protein. In the presence of s.c.a variances the g.c.a variances reflect not only additive variances but also non-additive variances (Griffing, 1956). Hence, Murty (1974) concluded that additive as well as non-additive gene action might be controlling the inheritance of the various characters.

Dixit (1978) conducted combining ability analysis using five strains of sesamum along with their 10 hybrids. The parents and hybrids were evaluated for protein content and test weight. Both additive and non-additive type of gene action were responsible for the inheritance of protein content. Additive type of gene action was predominant for test weight. The variety 'Kanpur local' was the best general combiner for both the traits, the other good combiner being 'Jhansi local' and 'TC-62'. 'Kanpur local' x 'T4' and 'TC-62' x 'Kayamkulam local' were the best specific combinations for protein content and 'Jhansi local' x 'Kanpur local' for test weight.

Rathinaswamy (1980) conducted genetic analysis in Sesamum indicum. Nine parents belonging to India, Israel, Japan, Uganda, U.S.A. and U.S.S.R. having a broad morphological and yield dissimilarities were selected and 36 hybrids obtained from 9 x 9 diallel cross without reciprocals formed the breeding material for study in six environmental

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conditions. A perusal of analysis of variance in individual environments and in pooled analysis indicated that hybrids and parents differed among themselves for all the characters. The g.c.a and s.c.a variances were significant for plant height in all but one environment establishing the presence of both additive and non-additive variances but the predominant one is additive variance. In respect to branches per plant both g.c.a and s.c.a variances were significant in all environments but the additive gene effect was more predominant. Capsules per plant showed high g.c.a variance indicating additive gene action. For capsule length even-though additive and non-additive variances were there, the additive variance was predominant. Seed yield per plant was under additive gene action which was well established by the g.c.a, s.c.a ratios. Gupta (1981) studied combining ability of yield components in sesamum and reported that g.c.a had higher magnitude for plant height, number of branches, capsules per plant and grain yield.

Combining ability studies were conducted by Fatteh et al. (1982) using six parents and thirty F_1's of Sesamum indicum according to Method I and Model-2 of Griffing (1956). Yield, seven yield-related traits and oil content were subjected for estimation. The s.c.a and g.c.a effects were highly significant for all the characters. The ratio g.c.a: s.c.a revealed that the variances due to g.c.a were higher for all the characters except oil percentage and

number of effective branches suggesting thereby that the additive type of gene action might be governing the former traits and the non-additive type of gene action appears to have been involved for the latter two traits.

Singh et al. (1983) from their investigation on combining ability in a set of twelve strains and F_1's and F_2's of thirty crosses of sesamum could bring about some important conclusions. Analysis of variance showed that the genotypes exhibited significant variances for all the characters except days to reproductive phase, harvest index, oil content and protein content. The F_1's differed significantly for all the characters except days to reproductive phase, days to maturity, number of seeds per capsule, harvest index, oil content and protein contents. Similarly the F_2's differed significantly for days to flowering, number of primary branches, number of secondary branches, number of seeds per capsule, plant height and protein content. In both F_1 and F_2, g.c.a variances were significant for days to flowering, number of primary branches, plant height and yield per plant. In F_1, harvest index and 1000-seed weight showed significant g.c.a variance. In F_2, g.c.a variances were significant for number of secondary branches, number of capsules per plant, number of seeds per capsule and oil content.

Variances for s.c.a were significant for number of primary branches in the F_1 and for days to flowering,

number of primary and secondary branches, days to maturity and oil content in F_2. Additive variance was responsible for the expression of days to flowering, days to maturity, number of secondary branches, days to reproductive phase and harvest index. Over dominance was expressed for days to flowering, days to maturity, number of secondary branches and harvest index in F_2. Partial dominance was expressed for number of secondary branches and harvest index in the F_1. Thus the results indicated that yield and its important components showed preponderance of both non-additive and additive genetic variance.

V. Components of genetic variation

Since genes are generally inferable only from the effects of their differences in changing the expression of the characters observable in an organism, all genetical study requires some consideration of the relation between genes and characters. Oligogenes are mostly responsible for the qualitative characters while polygenes are responsible for the quantitative characters which show continuous variation. Polygenes except in special circumstances cannot be counted as individual units. They lack specificity. Their expression, due to their presence or absence, may be insignificant.

Most of the economic characters are polygenically inherited and hence it is of prime importance to study their

inheritance in terms of the components of genetic variance. The estimation of the magnitude of the component has been made possible by methods that partition the genetic variance. The basic concept of partitioning the total variance into heritable (fixable) and non-heritable (non-fixable) components was developed by Fisher (1918). He further partitioned the heritable variance into three components viz., (i) additive component resulting from the average effect of genes; (ii) dominance component arising from intra-allelic interaction and (iii) an epistatic component associated with non-allelic interactions. Taking the mid-parental value as the origin, Mather (1949) denoted the effects of the recessive homozygote, the heterozygote and the dominant homozygote as -d, h and +d respectively. Thus the contribution of that locus to the fixable genetic variance was proportional to d, while h represented the dominance deviation contributing to the non-fixable component of the genetic variance. Summed over all the loci the genetic variance has been taken to be due to additive component (D) and dominance deviation (H).

Based on Mather's components of variation, D and H, Jinks and Hayman (1953) developed an approach to the analysis of data from diallel crosses of homozygous lines. Determination of the genetic parameters D, H_1, H_2 and F provides the estimates of over all dominance, distribution of dominant and recessive alleles in the parents, etc.

To test the accuracy of the estimates, standard errors were derived from the variance of Wr-Vr. Hayman (1954 b) presented in detail the theory and algebraic basis of the analysis of diallel crosses giving new notations and adding two more statistics, h^2 and Fr, in addition to those given by Jinks and Hayman (1953). He further stated that classification of the experiment into one of the four categories exhibiting, no dominance, partial dominance, complete dominance or over dominance is possible by testing the deviation of $D-H_1$ from zero combined with the test of significance of H_2.

Later, Jinks (1956) extended the applicability of diallel analysis to F_2 and back cross generation derived from a set of diallel crosses. He concluded that the expected statistics for the F_2 generation were of the same general form as those of the F_1 except that the contribution of h was halved by one generation of inbreeding. Thus the coefficients of H_1 and H_2 are the same as those of the F_1 statistics but the coefficient of h is reduced to half.

The relative importance of additive and dominance variation was analysed by Zuberi et al (1972) in Brassica campestris and reported that epistasis had inflated additive variation in the segregating progenies. Inheritance of kernel weight in wheat was studied by Sandhu and Anand (1972). T studies revealed that both additive and dominance effects

were responsible for the character. Dominance and epistatic effects were greater in magnitude than additive effects. Of the epistatic effects, additive x additive and additive x dominance types were important whereas dominance x dominance effect was also important in late sowings.

Gill et al. (1972) studied the inheritance of different characters in wheat and reported that additive and dominance genetic variances were important for 100-grain weight, tiller number and ear length. Predominance of additive genetic variance was observed for grain per ear, 100-seed weight and tiller number. Over dominance was operative for 100-grain weight, tiller number and ear length, whereas partial dominance was observed for grain per ear and plant height. Murty (1974) from the studies on combining ability of different characters in sesame reported that additive gene action was predominant for days to flowering, plant height, number of primary and secondary branches and number of capsules per plant. Murty and Hashim (1973) reported that oil and protein content in sesame were controlled by additive as well as dominant gene effects.

Inheritance of eight agronomic characters in winter wheat was studied in detail by Ketata et al. (1976). The F_1 deviated significantly from the mid-parental values for heading date, plant height and kernels per spikelet indicating non-additive gene action for those traits.

Additive effects were the main source of genetic variation for kernel weight. Batade et al. (1977) reported that number of pods per plant in soybean was controlled both by additive and non-additive gene action. The F value was positive for the character suggesting preponderance of dominant alleles. Chaudhary et al. (1977) reported that number of days to initial flowering and fifty per cent flowering, number of branches per plant, yield per plant and plant height were controlled by additive gene action in sesame. A preponderance of non-additive gene action in the expression of grain yield was reported by Srivastava et al. (1978) in soybean. Singh et al. (1978) suggested the importance of additive gene action for this character in gram. Ramakrishna et al. (1979) reported that number of branches per plant was controlled by non-additive gene action in bengal gram. Katiyar and Singh (1979) observed in chickpea that days to flowering showed additive action in F_1 and non-additive in F_2. Mak and Yap (1980) reported partial dominance for days to flowering in long bean (Vigna sesquipedalis). Sengupta (1980) from his studies on the combining ability of sesame reported that except for single plant yield for no other characters, the g.c.a/s.c.a ratio exceeded unity indicating that yield is totally under the influence of additive gene action.

Gupta (1981) conducted studies on the yield components of sesamum and reported that non-additive gene

effects were more important in the inheritance of number of branches, capsules per plant and grain yield. Singh et al. (1983) studied gene action in sesame and had recorded over dominance for days to flowering, days to maturity, number of secondary branches and harvest index in the F_2 and partial dominance for number of secondary branches and harvest index in the F_1. For number of seeds per capsule, 1000-seed weight, oil content and protein content, non-additive gene action was predominant in both the F_1 and F_2. The average degree of dominance also suggested over dominance for number of seeds per capsule and oil content in the F_2 and 1000-seed weight in both F_1 and F_2.

VI. Inheritance studies in sesamum

Inheritance studies had been conducted by many workers in sesamum and they are reviewed hereunder.

Ali Mohammed and Gupta (1941) studied the inheritance of alternate and opposite arrangement of leaves in Sesamum indicum. The F_1 showed dominance for alternate leaves. In F_2 the segregation observed for the two phenotypes agreed well with the 3:1 ratio indicating that there is only a monogenic difference between alternate and opposite leaved characters in sesamum.

Culp (1960) conducted investigations on the inheritance of plant height and capsule length in sesame. Data from three out of four crosses studied indicated

complete dominance of genes for tall plants. The character was highly influenced by environment as indicated by the wide ranges in height of the parents and F_1 generation. From the F_2 data the number of effective factors conditioning the inheritance of plant height was estimated. It was found that a minimum of 3 to 8 pairs of genes conditioned the inheritance of plant height in crosses which showed complete dominance for tall plants. Number of effective factors conditioning inheritance of capsule length was also analysed and it was found that a minimum of two to five pairs of genes are involved in the expression of the character. In one cross, complete dominance of long capsules was found. In the other crosses partial dominance of long capsules was formed.

Inheritance of paper shell capsules, capsule number and plant colour were studied by Culp (1960) in sesame. F_1, F_2 and back cross progenies were studied. In one cross, the paper shell character was inherited as a simple recessive and the F_2 showed 3:1 segregation. But in the other crosses a duplicate recessive epistasis was indicated. The observed segregation of capsule number per leaf axil in the F_2 and the back crosses indicated that one capsule per leaf axil was dominant over three capsules per leaf axil and controlled by one pair of Mendelian factors. Plant colour also was found to be controlled by a single pair of genes, green colour being dominant to purple.

There was no indication of linkage between any of the three characters under study.

Prabhakara Reddy et al (1971) investigating the inheritance pattern of six contrasting characters including non-shattering in sesame, reported that all the characters studied were recessive and segregated monogenically. No recombination of characters were found in the F_2 and hence a pleiotropic effect was attributed to the non-shattering gene which controlled the other characters also. Sverup John (1980) from the genetic studies on pod characters in sesamum reported that two independent recessive genes were responsible for the expression of multipod and multiloculed conditions.

MATERIALS AND METHODS

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The present investigations were carried out at the Department of Agricultural Botany, College of Agriculture, Vellayani, Kerala Agricultural University during the period from 1980-81 to 1982-83.

Materials

Forty four varieties of Sesamum indicum L. including both exotic and indigenous types collected from different states of India were used for biometrical analysis. These varieties showed much variability in their morphological characters, duration and yield. The name, origin and source of the varieties are given in table 1 and the salient features in table 4.

Six varieties with varying phenotypic expression for the plant type characters were selected and used as parents for hybridization programme. The performance of these selected varieties are given in table 2. A diallel set (without reciprocals) was analysed in detail in F_1 and F_2 generations. Double cross hybrids obtained by intercrossing F_1's were also used for variability analysis.

Method

The field experiments were laid out in the garden land attached to the Department of Agricultural Botany, as an irrigated crop adopting uniform management practices as

Table 1. Details of varieties tested.

Sl. No.	Name of variety	Source	Treatment No.
1.	Kayamkulam-1	Rice Research Station, Kayamkulam	V_1
2.	Manacavu	-do-	V_2
3.	TMV-3	-do-	V_3
4.	PT 58-35	-do-	V_4
5.	B-14	-do-	V_5
6.	Selection-4	-do-	V_6
7.	K.R.R -1	-do-	V_7
8.	Vayalellu	-do-	V_8
9.	Multipoded mutant	-do-	V_{10}
10.	Gouri	-do-	V_{12}
11.	No.42	-do-	V_{29}
12.	E.S.2	Department of Agricultural Botany, College of Agriculture, Vellayani	V_{13}
13.	T.12	-do-	V_{14}
14.	Assam Local	-do-	V_{15}
15.	E.C.36-345	-do-	V_{16}
16.	E.S.400	-do-	V_{17}
17.	Patan-64	-do-	V_{18}
18.	G-85	-do-	V_{19}
19.	TMV-2	-do-	V_{20}
20.	E.S.183	-do-	V_{21}
21.	E.S.104	-do-	V_{22}
22.	E.S.112	-do-	V_{23}

(continued)

Table 1. (Continued)

Sl. No.	Name of variety	Source	Treatment No.
23.	N.P. 66-173	Department of Agricultural Botany, College of Agriculture, Vellayani	V_{24}
24.	SI 11-14	-do-	V_{26}
25.	SI-914	-do-	V_{25}
26.	58-2	-do-	V_{27}
27.	No.128	-do-	V_{28}
28.	Punjab til No.1	-do-	V_{30}
29.	M3-2	-do-	V_{31}
30.	N66-135	-do-	V_{32}
31.	N62-32	-do-	V_{33}
32.	NP-6	-do-	V_{34}
33.	T.C.30	-do-	V_{35}
34.	S1 15-51	-do-	V_{36}
35.	RT-1 (37)	-do-	V_{37}
36.	SP 111-2	-do-	V_{38}
37.	P31	-do-	V_{39}
38.	P10	-do-	V_{9}
39.	P5	-do-	V_{11}
40.	P32	-do-	V_{40}
41.	P35	-do-	V_{41}
42.	P23	-do-	V_{42}
43.	P28	-do-	V_{43}
44.	P19	-do-	V_{44}

Table 2. Performance of the selected parents for diallel analysis.

Treatment No.	Plant height at maturity (cm)	No. of primary productive branches/ plant	No. of productive nodes on main axis	No.of pods on main axis	Total pods/ plant	No.of seeds/ pod	1000-seed weight (g)	Duration for first flowering	Percentage of multipoded nodes/ plant	Percentage of multipoded pods/ plant	Oil content (percentage)	Seed yield/ plant (g)
V_2	71.80	6.40	20.30	18.20	77.80	53.06	2.65	34.33	2.26	0	37.33	12.56
V_{13}	79.83	4.26	14.73	15.46	37.66	55.73	3.06	34.33	0	0	38.33	6.05
V_{25}	112.00	5.46	26.60	41.33	133.53	56.53	3.21	40.33	36.70	0	37.33	21.05
V_{29}	84.60	4.33	16.60	19.46	54.20	68.00	3.30	55.00	0	0	59.33	8.53
V_{37}	69.40	1.53	22.60	33.86	45.26	66.66	2.81	39.33	40.60	0	47.33	6.63
V_{41}	68.73	1.66	12.00	11.93	29.00	69.20	4.00	40.66	0	100	45.33	5.28

recommended in the package of practices for the crop by the Kerala Agricultural University (1978). The crops were raised during the first crop season of April-May to July-August and during the second crop season extending from August-September to October-November.

Seeds were sown in lines with a spacing of 30 cm between rows and 15 cm between plants. Thinning was done fifteen days after sowing retaining 15 single plants in each row. Cattle manure at the rate of 5 tonnes/ha was incorporated to the soil along with the last ploughing and NPK was applied at the rate of 30:15:30 kg/ha. Urea was used to supply nitrogen and it was given in split doses; 50% as basal and the balance, 25 days after sowing. As far as possible uniform conditions were provided for the crop.

I. Varietal evaluation

The first part of the study consists of varietal evaluation. The forty four varieties selected were planted in Randomized Block Design with 3 replications. Ten plants were selected from each row representing a treatment in each replication and the following observations were recorded.

1. Number of days for first flowering

The number of days taken from the date of sowing to the opening of the first flower was recorded for each plant and the average was calculated.

2. Plant height at maturity

Height of the plant from the ground level to the tip

of the main stem was measured and recorded in centimetre.

3. Number of primary productive branches per plant

The number of primary branches bearing pods was observed and reoorded at crop maturity for each plant.

4. Number of productive nodes on main axis

The number of nodes which develop pods on the leaf axils on the main axis was observed and recorded at crop maturity.

5. Number of pods on main axis

The total number of pods produced on the main axis was counted and recorded at crop maturity.

6. Total pods per plant

The number of total pods produced per plant including those produced on the main axis and branches was recorded at harvesting.

7. Seed yield per plant

Total seed yield per plant was observed and recorded in grams.

8. 1000-seed weight

Random samples of 1000 seeds were taken from each variety and their weight were recorded in gram. Five samples were observed from each variety under each replication.

9. Number of seeds per pod

The number of fully developed seeds in each pod was counted. Five pods from the middle part of the main stem from each plant were selected for recording the seed number per pod.

10. Oil content

The percentage of oil present in 0.3 g of seeds was estimated from all the entries. Five samples were analysed from each treatment under each replication. Extraction of oil from the seeds was done following cold percolation method as described by Kartha and Sethi (1957).

Estimation of oil content

Samples of 0.3 g of seeds were used for oil estimation. The seeds, along with 2 g of anhydrous $K_2(SO_4)3$ were powdered in a glass mortar. A small quantity of glass powder was also added to the mixture for easy crushing of the seeds. The powdered mixture was transferred to 2 cm x 1.5 cm glass percolator which was packed over a layer of coarsely powdered anhydrous potassium sulphate (about 0.8 cm thick) supported over a thin pad of cotton. The mortar and pestle used for crushing were washed twice with 0.5 g of anhydrous potassium sulphate and the washings were also poured over the seed powder. The mortar and pestle were then washed with 3.5 cc carbon tetrachloride and poured it over the packed powder. This was allowed to remain as such for five minutes to make

the mixture wet. Then 15 cc of carbon tetrachloride was poured from the upper portion of the column slowly. The percolate was collected in an already weighed petridish. The solvent, carbon tetrachloride was allowed to evaporate completely by placing the petridish in an oven. The oil portion remained in the petridish as the residue. The petridish was again weighed. The difference in the weight of the petridish at the two weighings was the weight of oil. The percentage oil content was calculated as

$$\frac{\text{Weight of oil}}{\text{Weight of the sample}} \times 100.$$

Statistical Techniques

a. Variance - Covariance analysis

The total observed value of a character (X) can be made additively by genotypic and environmental effects, i.e.

$$X = G + E$$

where G is determined genetically and E, environmentally. The extent of variation in X is due to genetic forces and environmental forces and shall be determined following the method given by Kempthorne (1957).

$$V(X) = V(G) + V(E) + 2\ Cov\ (G,E)$$

where V(X) = variance of x

V(G) = variance due to genotype

V(E) = variance due to environment and

Cov (G,E) = Covariance between genotype and environment.

If the genotypes and environment are associated at random, Cov (G,E) is equal to zero so that

$$V(X) = V(G) + V(E), \text{ or}$$

$$\sigma^2 p(x) = \sigma^2 g(x) + \sigma^2 e(x)$$

where $\sigma^2 p(x)$ is the phenotypic variance of x, $\sigma^2 g(x)$ is the genotypic variance of x and $\sigma^2 e(x)$ is the variance due to environment.

If we have two observations x and y on each individual, the extent of covariation between x and y due to genetic and environmental forces shall be determined by the same method given by Kempthorne (1957) so,

$$\text{Cov}(x,y) = \text{Cov}(G(x,y)) + \text{Cov}(E(x,y))$$

$$\text{or } \sigma p(x,y) = \sigma g(x,y) + \sigma e(x,y)$$

where $\sigma g(x,y)$ is the covariance between x and y attributable to genotypes and $\sigma e(x,y)$ is the covariance between x and y attributable to environment.

If the experiment is designed in a Randomised Complete Block Design with v treatments and r replications, the estimates of $\sigma^2 p(x)$, $\sigma^2 p(y)$, $\sigma^2 g(x)$, $\sigma^2 g(y)$, $\sigma^2 e(x)$, $\sigma^2 e(y)$, $\sigma p(x,y)$, $\sigma g(x,y)$ and $\sigma e(x,y)$ are derived from the analysis of covariance table (Table 3).

The phenotypic correlation coefficient is then estimated as

$$\hat{r}_{p(x,y)} = \frac{\hat{\sigma} p(x,y)}{\sigma p(x) \cdot \sigma p(y)}$$

where $\sigma p(x)$ and $\sigma p(y)$ are the standard deviations of x and y.

Table 3. Analysis of covariance

Source	df	MS(x)	Expectation of MS(x)
Block	r-1	B_x	
Treatment (Varieties)	v-1	V_x	$\sigma^2_{e(x)} + r\sigma^2_{g(x)}$
Error	(r-1)(v-1)	E_x	$\sigma^2_{e(x)}$
Total	rv-1	T_x	$\sigma^2_{p(x)}$

Hence we have the following estimates:

$$\hat{\sigma}^2_{g(x)} = \frac{1}{r}(V_x - E_x), \quad \hat{\sigma}^2_{e(y)} =$$

$$\hat{\sigma}^2_{g(y)} = \frac{1}{r}(V_y - E_y), \quad \sigma^2_{e(y)} =$$

$$\hat{\sigma}_{g(x,y)} = \frac{1}{r}(V_{xy} - E_{xy}), \quad \hat{\sigma}_{e(x,y)} =$$

MSP(x,y)	Expectation of MSP(x,y)	MS(y)	Expectation of MS(y)
B_{xy}		B_y	
V_{xy}	$\sigma_{e(x,y)}^2 + r\sigma_{g(x,y)}^2$	V_y	$\sigma_{e(y)}^2 + r\sigma_{g(y)}^2$
E_{xy}	$\sigma_{e(x,y)}^2$	E_y	$\sigma_{e(y)}^2$
T_{xy}	$\sigma_{p(x,y)}^2$	T_y	$\sigma_{p(y)}^2$

E_x

E_y

E_{xy}

Table 4. Varietal variation on different yield

Variety	Height of plant at maturity (cm)	No. of primary productive branches/ plant	No. of productive nodes on main axis	No. of pods on main axis
1	2	3	4	5
1.	83.46	4.60	21.40	20.26
2.	71.80	6.40	20.30	18.20
3.	84.46	4.60	21.20	22.46
4.	78.80	3.80	19.13	17.86
5.	81.53	5.26	16.53	18.93
6.	95.00	5.53	25.00	25.80
7.	85.00	4.26	22.33	22.26
8.	88.93	6.80	23.60	23.13
9.	77.86	3.20	18.86	37.53
10.	62.73	3.26	16.93	17.86
11.	77.13	2.00	17.86	15.33
12.	68.73	2.13	15.20	15.20
13.	79.83	4.26	14.73	15.46
14.	70.66	4.06	19.13	20.33
15.	86.80	4.20	21.40	23.60
16.	85.46	6.26	15.40	14.93

attributing characters in sesamum.

Total number of pods/ plant	No. of seeds/ pod	Seed yield/ plant (g)	1000-seed weight (g)	Oil content (%)	No. of days to first flower-ing
6	7	8	9	10	11
43.33	47.73	6.89	2.60	48.60	39.33
77.80	53.06	12.56	2.65	37.33	34.33
65.26	52.53	10.43	2.78	46.00	37.66
52.00	53.53	8.32	2.70	58.66	43.66
50.06	52.26	7.74	2.72	43.33	39.66
51.20	57.60	8.07	2.58	36.66	39.33
56.26	51.20	8.99	3.56	37.00	40.66
69.80	56.80	11.16	2.61	65.33	42.00
57.33	55.46	9.10	3.20	60.00	40.33
32.40	50.93	5.18	2.70	50.10	40.66
33.13	64.80	5.10	2.93	44.60	45.66
21.93	52.00	3.85	3.10	54.00	53.66
37.66	55.73	6.05	3.06	38.33	34.33
43.00	58.40	6.88	2.65	51.33	49.00
37.66	58.13	5.97	3.57	44.00	44.00
53.53	61.20	8.47	3.76	39.33	46.33

(continued)

Table 4. (Continued)

Variety	Height of plant at maturity (cm)	No. of primary productive branches/ plant	No. of productive nodes on main axis	No. of pods on main axis
1	2	3	4	5
17.	71.40	4.26	19.66	16.80
18.	79.53	2.00	17.33	17.06
19.	79.33	4.00	22.66	17.80
20.	74.86	5.33	18.40	18.73
21.	82.13	4.40	16.73	20.00
22.	70.00	2.86	14.80	11.86
23.	90.20	3.33	30.00	25.33
24.	66.86	4.66	19.26	16.40
25.	112.00	5.46	26.60	41.33
26.	91.53	1.66	24.60	25.46
27.	69.13	3.00	15.26	14.33
28.	104.13	4.46	25.06	24.60
29.	84.60	4.33	16.60	19.46
30.	83.86	3.73	18.53	22.20
31.	76.86	1.26	20.23	24.20
32.	92.86	2.40	20.13	26.30
33.	82.53	2.60	19.53	22.26

Total number of pods/ plant	No. of seeds/ pod	Seed yield/ plant (g)	1000-seed weight (g)	Oil content (%)	No. of days to first flower-ing
6	7	8	9	10	11
21.86	55.86	3.60	3.79	45.33	48.00
27.46	68.26	4.39	3.75	47.33	46.00
52.13	64.80	11.59	4.00	50.66	41.00
37.06	56.53	5.99	2.77	34.66	49.66
50.46	60.80	7.74	2.66	47.33	40.00
30.73	57.06	4.94	3.53	49.33	37.00
55.60	64.53	8.89	3.45	50.00	40.00
27.33	52.00	4.23	3.53	48.66	51.00
133.53	56.53	21.05	3.21	37.33	40.33
35.46	58.40	5.27	3.35	58.66	39.00
27.80	54.13	4.94	2.72	45.33	36.33
55.46	61.06	8.88	3.48	54.66	48.66
54.20	68.00	8.53	3.30	59.33	55.00
49.60	57.86	6.61	2.92	41.33	50.00
37.06	66.93	6.85	3.17	44.66	42.66
42.20	65.73	6.99	3.60	39.33	50.33
41.66	66.40	7.74	2.88	51.33	44.33

(continued)

Table 4 (Continued) -3-

Variety	Height of plant at maturity (cm)	No. of primary productive branches/ plant	No. of productive nodes on main axis	No. of pods on main axis	Total number of pods/ plant
34.	77.60	2.53	19.40	27.53	49.13
35.	79.13	4.00	15.66	18.26	42.60
36.	95.13	3.40	21.60	23.13	53.40
37.	69.40	1.53	22.60	33.86	45.26
38.	80.33	2.86	20.93	24.86	41.20
39.	59.60	3.00	10.00	15.33	20.80
40.	74.53	4.13	13.46	12.46	36.13
41.	68.73	1.66	12.00	11.93	29.00
42.	83.93	3.13	16.80	16.53	27.26
43.	80.46	1.93	20.46	20.13	32.73
44.	99.33	2.73	17.53	20.06	27.40
G.M.	80.87	3.67	19.20	20.85	44.68
M.S.S.	339.66**	6.08**	46.31**	115.42**	1080.26**
C.D.	19.61	2.10	7.99	8.57	27.03

**Significant at 1

No. of seeds/ pod	Seed yield/ plant (g)	1000-seed weight (g)	Oil content (%)	No. of days to first flower-ing
63.20	8.21	3.15	41.33	41.33
58.60	7.04	3.25	48.00	48.66
64.80	9.28	3.03	40.00	43.00
66.66	6.63	2.81	47.33	39.33
54.13	6.66	2.64	50.66	52.00
61.86	5.52	3.16	46.66	39.00
67.46	4.47	2.58	48.00	48.33
69.20	5.28	4.00	45.33	40.66
56.53	4.73	2.55	52.00	55.33
67.60	5.25	3.52	44.66	47.66
52.53	10.18	3.40	47.33	49.00
59.07	7.41	3.13	46.93	43.96
102.19**	27.33**	0.55**	152.29**	90.85**
8.12	5.11	7.72	5.64	7.72

per cent level

b. Coefficients of variation

Coefficient of variation, being a unitless measurement is a good basis for comparing the extent of variation between different characters with different scales.

Phenotypic coefficient of variation (PCV) for character X $= \frac{\sigma p(x)}{\bar{X}} \times 100$

where $\bar{X}$ is the mean of X

Genotypic coefficient of variation (GCV) for character X $= \frac{\sigma g(x)}{\bar{X}} \times 100$

c. Estimation of genetic parameters

(i) Heritability (H^2)

Heritability is the fraction of the total variation which is heritable and is estimated in the broad sence as $H^2 = \frac{\sigma^2 g}{\sigma^2 p}$ following Crow and Kimura (1970). H^2 is called the heritability coefficient and can take values in the range 0 to 1. Heritability (H^2) provides a measure of genetic variation, i.e. the variation upon which all the possibilities of changing the genetic composition of the population through selection depend.

(ii) Genotypic correlation

An estimate of genotypic correlation gives an idea of the extent to which two characters have the same physiological basis for their expression. The genotypic correlation between x and y is estimated as

$$r_{g(xy)} = \frac{\sigma g(x,y)}{\sigma g(x) \cdot \sigma g(y)}$$ where

$\sigma g(x)$ and $\sigma g(y)$ are the standard deviation of X and Y. The significance of genotypic correlation is tested by students' t-test given by Singh and Chaudhary (1979)

$$t = r_{g(x,y)} \; SE(r_{g(x,y)})$$

where $SE(r_{g(x,y)}) = \frac{1}{f+1}\left[\frac{1}{2}(1-r^2_{g(x,y)})^2 + 1\left(1-r^2_{g(x,y)}\right)\left(\frac{1}{D} - \frac{r_{p(x,y)}\, r_{g(x,y)}}{C}\right) + 4\left(\frac{ry_{(x,y)}}{D} - \frac{r_{p(x,y)}}{C}\right)^2 - \frac{2(1-r_{g(x,y)})^2\,(1-r^2_{p\,(x,y)})}{C^2}\right]$

where $\frac{1}{D} = \frac{1}{2}\left(\frac{1}{H_x^2} + \frac{1}{H_y^2}\right)$

H_x^2 = heritability of x

H_y^2 = heritability of y,

$C = (H_x^2\, H_y^2)^{\frac{1}{2}}$, and

f = error degrees of freedom

(iii) Genetic gain or genetic advance

Genetic advance is a measure of the change in the mean genotype level of the population produced by selection and depends upon heritability of the character and selection differential. It is estimated as percentage of mean as :-

$G_s = \frac{KH\,\sigma_A}{\bar{X}} \times 100$ where $\bar{X}$ is the mean of character

Expectation of genetic advance under selection)

H is the heritability coefficient

σA Phenotypic standard deviation of the mean of original lines

x and k is the selection differential which is taken as 1.76 at 1% selection (Allard, 1960).

d. Path analysis

The method of path analysis was developed by Wright (1921, 1934, 1954, 1960 a, b) to study the cause and effect relationship among a system of variables. Given a linear system which is fully determined apart from pure random variation and given a path diagram which gives the qualitative nature of the causality, path coefficients shall be obtained. This method depends on the combination of knowledge of degree of correlation among the variables in a system with such knowledge as may be possessed of the causal relations; and helps to measure the direct influence along each separate path in such a system and to find the degree to which the variation of a given effect is determined by each particular cause.

The following points are noted to interpret the path coefficient.

1. If the correlation coefficient between a causal factor and the effect is almost equal to its direct effect, then correlation explains the true relationship and a directed selection through this trait will be effective.

2. If the correlation coefficient is positive, but the direct effect is negative or negligible, the indirect effects seem to be cause of correlation.

3. Correlation coefficient may be negative but the direct effect is positive and high restrictions are to be imposed to nullify the undesirable indirect effects in order to make use of the direct effect (Singh and Kakar, 1977).

The simultaneous equations which give solutions for path coefficients are

$r_{iy} = r_{i1}p_{1y} + r_{i2}p_{2y} + \cdots + r_{ij}p_{iy} + \cdots + r_{ik}p_{ky}$, where

r_{iy}, i = 1,2, ----K are the correlation coefficients between the dependent variable (y) and K independent variables r_1, r_2---r_k. x_1, x_2---- x_k, r_{ik} i= 1,2, ---K are the inter-correlations between independent variables, p_{iy} is the direct effect of factor x_i and $r_{ik}\ p_{ky}$ is the indirect effect of i^{th} (x_i) factor via k^{th} factor (r_k) on y.

II. Cytogenetic analysis

The six selected varieties (Table 2) were crossed in all possible combinations (excluding reciprocals) and the seeds of each cross combination were collected separately.

Technique of crossing

As the flowers are bisexual and naturally self-pollinated, emasculation was done so that the flower becomes functionally female. The time of normal anthesis is between 6 a.m. and 7 a.m. Emasculation was done in the previous evening. Emasculation in the case of sesame is easy since the stamens are epipetalous. The mature flower buds which would open on the next day were selected and the

corolla tube was carefully pulled out without damaging the pistil using a pair of finely pointed forceps. The androecium will be completely removed along with the corolla tube. The emasculated bud was then covered with a paper cover to prevent contamination. Similarly flower buds of the pollen parent were bagged to prevent contamination. On the next day, by about 7 a.m., newly opened flowers from the male parent plant were taken and the dehised anthers were rubbed on the pistil of the emasculated flower using the fine camel hair brush. After pollination the paper cover was replaced and properly labelled. The paper cover was retained for one week. The pods were collected in labelled bags on maturity.

Planting and layout of F_1

Seeds from the 15 cross combinations and the 6 parents were sown in the field in R.B.D. with 2 replications. Twenty five plants were retained in each treatment under each replication. Observations were recorded from 15 plants in each treatment under each replication. Five plants in each treatment under each replication were used for cytological studies and the remaining five plants were used for selfing in each treatment. The F_1 crosses were repeated using the parental varieties at the same time to get fresh F_1 s. The crop was raised following the package of practice recommendations made for the crop by Kerala Agricultural University. As far as possible, uniform management practices

were provided for the crop. Observations recorded from F_1 population include:

1. Plant height at maturity
2. Number of primary productive branches/plant
3. Number of productive nodes on main axis
4. Number of pods on main axis
5. Total pods per plant
6. Seed yield per plant
7. 1000-seed weight
8. Oil content (Percentage) and
9. Number of days for first flowering

Technique of selfing

The technique of selfing is easy as the plant is naturally self pollinated. Mature flower buds which would open on the next day were selected and covered with small paper covers on the previous evening of anthesis. A label bearing date of selfing was tied at the node of the stem. The paper cover was retained for one week. The selfed pods were collected at maturity and dried properly.

Pollen sterility estimation and cytological techniques

Pollen sterility was estimated from five plants under each treatment. The pollen grains from one flower each from each plant were stained in acetocarmine-glycerine medium on a slide and sterility counts were taken. Ten fields from each slide was scored. The percentage of sterility was estimated for each treatment.

For cytological observations, flower buds of appropriate size from each treatment were fixed separately in a 3:4:1 mixture of absolute alcohol, chloroform and propionic acid fixative which has been previously saturated with ferric chloride. The fixation was done between 11 a.m. and 12 noon. The maximum division was noticed between 11.15 a.m. and 11.45 a.m. The fixed buds after 24 hrs were transferred to 70% ethyl alcohol. Anthers were tapped in a drop of 1% propiono-carmine stain. Gentle tapping and judicious warming favoured excellent spreading and differential staining of the chromosome and cytoplasm in the pollen mother cell.

Planting of F_2 with F_1 s

The selfed seeds of F_1 were used for raising the F_2. The 15 F_2 progeny along with the six parents and the 15 fresh F_1s were evaluated in a field trial laid out in an R.B.D. with 3 replications. Part of the F_1 seeds were kept for double crossing programme. Observations were recorded in the F_1 and F_2 from 40 plants in each treatment under each replication. For studying the segregation pattern of different characters a total of 120 plants were observed in the F_2 of different crosses.

Planting and layout of double cross hybrids

Part of the seeds from the different crosses kept were sown in the field and intercrossing of hybrids were

carried out. The seeds of these double crosses were collected separately at maturity. The 27 double cross hybrids obtained were planted in the field along with the six parents and 15 F_1s in an R.B.D. with 3 replications and observations on the nine characters listed for F_1 were recorded.

Statistical techniques

Genetic analysis of quantitative characters was done using the following statistical techniques both in F_1 and F_2 generations.

i) Analysis of variance

Analysis of variance was carried out in F_1 and F_2 and double cross hybrids for every character following Panse and Sukhatme (1957).

ii) Combining ability analysis

The combining ability analysis was carried out both in F_1 and F_2 generations following the method 2 under Model I as suggested by Griffing (1956 b). The Model I was selected because the varieties were a chosen fixed set. It follows that variety and block effects are fixed. In this approach using the suitable statistical model the component variances due to general and specific combining ability estimated which in turn may be translated into genetical components such as σ^2_A and σ^2_D under certain assumptions.

Before proceeding for combining ability analysis the null hypothesis that there was no significant difference

among the crosses was tested as suggested by Premarajan et al. (1979). The statistical model for the purpose was

$$X_{ijk} = \mu + g_{ij} + bk + e_{ijk}$$

where

X_{ijk} was the mean of the observation on $(i \times j)^{th}$ cross in the k^{th} block

μ was the general mean

g_{ij} was the effect of $(i \times j)^{th}$ cross

bk was the effect of k^{th} block

e_{ijk} was the error effect with $E(e_{ijk}) = 0$

and $V(e_{ijk}) = \sigma_e^2$

From the analysis of variance as given below, the mean sum of squares of the crosses were tested against the mean sum of squares of error for significance using F values.

Estimation of sum of squares.

Sum of squares due to g.c.a $= \frac{1}{(n+2)} \left[(Y_{i.} + Y_{ii})^2 - \frac{4}{n} Y^2_{..} \right]$

Sum of squares due to s.c.a =

$$\sum \left(\sum Y_{ij}^2 - \frac{1}{n+2} \quad Y_{i.} + Y_{ii} \right)^2 + \frac{2}{(n+1)(n+2)} \quad Y^2$$

Sum of squares due to error:

The sum of squares obtained from the earlier analysis of variance was further divided by number of replications.

Analysis of variance for combining ability analysis

Source	df	SS	M.S	E(M.S)
g.c.a	(p-1)	Mg.	$\sigma^2_e + \sigma^2_s + (n+2)\sigma^2_g$	
s.c.a	p(p-1)/2	Ms	$\sigma^2_e + \sigma^2_s$	
Error		Me'	σ^2_e	

Estimation of component variances and their genetic interpretations — Singh and Chaudhary (1979)

$$\sigma^2_g = \frac{1}{n+2}(Mg-Ms)$$

$$\sigma^2_s = Ms-M'e$$

$$\sigma^2_e = M'e$$

Where σ^2_g, σ^2_s and σ^2_e are the estimates

$$\sigma^2_G = \frac{1}{4}\sigma^2_A$$

$$\sigma^2_s = \sigma^2_D$$

Accordingly $\sigma^2_A = 2\sigma^2_g$

$$\sigma^2_D = \sigma^2_s$$

Estimation of g.c.a effects

$$g_i = \frac{1}{n+2}\left[(Y_{i.} + Y_{ii}) - \frac{2}{n}Y_{..}\right]$$

g.c.a. effects for all parents were calculated.

Estimation of s.c.a effects

$$s_{ij} = Y_{ij} - \frac{1}{n+2}(Y_{i.} + Y_{ii} + Y_{.j} + Y_{jj}) + \frac{2}{(n+1)(n+2)}$$

s.c.a effects for all the crosses were estimated.

Standard errors.

$$\text{S.E.}(g_i) = \left((n-1)\sigma_e^2/n\ (n+2)\right)^{\frac{1}{2}}$$

$$\text{S.E.}(S_{ii}) = \left((n^2+n+2)\ \sigma_e^2/(n+1)(n+2)\right)^{\frac{1}{2}}$$

$$\text{S.E.}(g_i - g_j) = \left(2\sigma_e^2/n+2\right)^{\frac{1}{2}}$$

$$\text{S.S.}(S_{ij}) = \left((n(n-1)\sigma_e^2/(n+1)(n+2)\right)^{\frac{1}{2}}$$

$$\text{S.E.}(S_{ii} - S_{jj}) = \left((2(n-2)\sigma_e^2/(n+2)\right)^{\frac{1}{2}}$$

$$\text{S.E.}(S_{ij} - S_{ik}) = \left((2(n+1)\sigma_e^2/(n+2)\right)^{\frac{1}{2}}$$

$$\text{S.E.}(S_{ij} - S_{kl}) = \left(2n\sigma_e^2/(n+2)\right)^{\frac{1}{2}}$$

Each g.c.a and s.c.a estimate was subjected to 't' test to know the significance.

$$t = \frac{\hat{g}_i - 0}{SE(\hat{g}_i)} \quad \text{and} \quad t = \frac{(\hat{S}_{ij} - 0)}{SE(\hat{S}_{ij})}$$

The 't' value obtained was tested against table 't' value at 5% and 1% probability level for 'n' degrees of freedom.

For testing the significance of difference between two effects, the critical difference was calculated by multiplying the respective standard error of difference with

't' value at 'm' degrees of freedom.

iii) Heterosis

The magnitude of heterosis was calculated in comparison to the mean value of the better parent as well as mid-parental value. Heterosis expressed in percentage increase or decrease of F_1's over mid-parent and better parent were calculated following the technique suggested by Hayes et al. (1955) and Briggle (1963).

$$\text{Mid-parent heterosis} = \frac{(\bar{F}_1 - \overline{M.P})}{\overline{M.P}} \times 100$$

$$\text{Better parent heterosis} = \frac{(\bar{F}_1 - \overline{B.P})}{\overline{B.P}} \times 100$$

In the estimation of heterosis for days to first flowering, the parents of early flowering were considered as the better parents.

To test the significance of difference of F_1 mean over mid-parent and better parent, critical difference was calculated from their standard errors of differences as mentioned below

To test the significance over mid-parent

$$C.D.\ (0.05) = te_{(0.05)} \sqrt{\frac{3 \times MS_e}{2r}}$$

To test the significance over better parent

$$C.D.\ (0.05) = te(0.05)\sqrt{\frac{2 \times MS_e}{r}}$$

Where

e = degrees of freedom for error

MS_e = mean sum of squares for error

r = number replications

Using the same method heterosis in double cross hybrids over mid-parent and better parent was also calculated taking the single cross hybrids as parents.

iv) <u>Estimation of genetic components of variation and related genetic parameters</u>

The components of genetic variation and related genetic parameters were calculated from F_1 and F_2 generations following Hayman (1954 b) and Jinks (1954, 1956). The assumptions on which the biometrical analysis based are:-

Diploid segregation,

Only environmental differences between reciprocal crosses

Independent action of non-allelic gene,

No multiple allelism,

Homozygosity of parents and

Genes independently distributed among the parents.

The expected values of the components of genetic variance were estimated by solving the following equations separately for F_1 and F_2 generations.

The expected values of the components of variation in F_1 derived by Hayman (1954) are:-

$\hat{E}$ = Expected environmental component of variation

$\hat{D}$ = $V_oL_o - E$ = Variance due to additive effects

$\hat{F}$ = $2\,V_oL_o - 4\,W_oL_{o1} - \frac{2(n-2)}{n}\,\hat{E}$ = Mean of arrays

$\hat{H}_1$ = $V_oL_o - 4\,W_oL_{o1} + 4V_1L_1 - \frac{(3n-2)}{n}\,\hat{E}$ = Variance due to dominance effect of the genes

$\hat{H}_2$ = $4\,V_1L_1 - 4\,V_oL_1 - 2\hat{E}$

$\hat{h}^2$ = $4(ML_1 - ML_o)^2 - \frac{4(n-1)}{n^2}\,\hat{E}$ = dominance effect

In F_2 generation, the components of variation were estimated by the formula given by Jinks (1956). The expected statistics for F_2 generation are of the same form as those of F_1 except that contribution of 'h' is halved by one generation of inbreeding. For this reason the coefficients of H_1 and H_2 are ¼ of those of the F_1 statistics, while the coefficients of F is halved, being second and first degree statistics in 'h' respectively (Jinks, 1956; Hayman, 1958 and Mather and Jinks, 1971). Thus the composition of F_2 variances and co-variances according to Jinks (1956) were as follows:-

$\bar{V}_z = V_1L_1 = \frac{1}{2}D+1/16\ H_1-1/8\ F+E_2$ = Mean variance of arrays

$\bar{W}_r = W_oL_{o2} = \frac{1}{2}D+1/8\ F+(1/n)\ E_2$ = Mean covariance between the parents and the arrays

$V_m = V_oL_2 = \frac{1}{4}D+1/16\ H_1-(1/16)\ H_2-1/8\ F+\frac{1}{n}\ E_2$

$V_p = V_oL_o = D+.E$ = Variance of parent

where,

n = number of parents and the components of variation in F_2 are:-

$\hat{E}_2$ = Expected error component of variation

$\hat{D} = V_oL_o-E$

$\hat{F} = 4\ V_oL_o-8\ W_oL_{o1}-4\frac{(n-2)}{n}\ \hat{E}_2$

$\hat{H}_1 = 16\ V_1L_1-16\ W_oL_{o1}+4\ V_oL_o-\frac{4(5n-4)}{n}\ \hat{E}_2$

$\hat{H}_2 = 16\ V_1L_1-16\ V_oL_1-\frac{16(n-1)}{n}\ \hat{E}_2$

$\hat{h}^2 = (4\ ML_1-4\ ML_o)^2-16\ \frac{(n-1)}{n}\hat{E}_2$

Where,

D = Component of genetic variance due to additive effect of genes,

F = relative frequency of dominant to recessive alleles in the parental population and variation in the dominance level over loci;

H_1 = Component of genetic variance due to the dominance effect of the genes;

H_2 = $H_1(1-(U-V)^2)$ where,

U = proportion of positive genes in the parents

V = proportion of negative genes in the parents

h^2 = dominance effect (as the algebraic sum over all loci in heterozygous phase in all the crosses);

V_oL_o = variance of the parents;

V_1L_1 = mean variance of the arrays;

V_oL_1 = variance of the mean of the arrays;

W_oL_{o1} = mean covariance between parents and the arrays

(ML_1-ML_o) = the difference between the mean of 'p' parents and the mean of $\frac{P(p-1)}{2}$ progenies and

E = the expected component of variation due to environment.

To test the validity of the assumptions of diallel cross 't' test was used.

$$t^2 = \frac{n-2}{4}\left[\frac{(Var.Vr-Var.Wr)^2}{(Var.VrxVar.Wr)-Cov^2(Vr,Wr)}\right]$$

Which is an F with 4 and (n-2) degrees of freedom (Singh and Chaudhary, 1979).

The standard errors, to test the significance of the components of genetic variance, were calculated using the following formula.

Standard error (S.E)(D) = $(S^2 \times CD)^{\frac{1}{2}}$

(S.E)(F) = $(S^2 \times CF)^{\frac{1}{2}}$

(S.E)(H_1) = $(S^2 \times CH_1)^{\frac{1}{2}}$

(S.E)(H_2) = $(S^2 \times CH_2)^{\frac{1}{2}}$

(S.E)(h^2) = $(S^2 \times Ch^2)^{\frac{1}{2}}$

(S.E)(E) = $(S^2 \times CE)^{\frac{1}{2}}$

Where, S^2 = ½ Var (Wr-Vr) and CD, CF, CH_1, CH_2, Ch^2 and CE are the multipliers, the terms of the main diagonal of the covariance matrix given by Hayman (1954).

The significance of the various statistics was tested by 't' test at n-2 degrees of freedom as

$$t = \frac{\text{Estimate}}{\text{S.E. of estimate}}$$

The allied genetic parameters like degree of dominance, proportion of the genes with positive and negative effects in the parents, proportion of dominant and recessive genes in the parents were also estimated.

Mean degree of dominance was given by $(\hat{H}_1/\hat{D})^{\frac{1}{2}}$. When the ratio was more than one, over dominance was indicated, when equal to one, complete dominance and when less than one, it was a case of partial dominance.

The ratio $\hat{H}_2/4\ \hat{H}_1 = \frac{16\sigma u^2 v^2 h^2}{4(4\ uvh^2)} = uv$;

gives the product of gene frequencies.

If u = v = ½, then $\hat{H}_2/4\ \hat{H}_1 = 0.25$. Any discrepancy in gene frequency gives a value less than 0.25.

The proportion of dominant to recessive genes in the parents $= \dfrac{(4DH_1)^{\frac{1}{2}}+F}{(4DH_1)^{\frac{1}{2}}-F}$

v) Estimation of heritability in narrow sense

Heritability in narrow sense is defined as the ratio of additive and/or additive x additive genetic variance to the total phenotypic variance. Narrow sense heritability was estimated as percentage both in F_1 and F_2 according to Mather and Jinks (1971) and as suggested by Verhalen and Murray (Singh and Chaudhary, 1979) respectively, using the formula.

$$\text{Heritability } (F_1) \text{ (narrow sense)} = \frac{\frac{1}{2}D+\frac{1}{2}H_1-\frac{1}{2}H_2-\frac{1}{2}F}{\frac{1}{2}D+\frac{1}{2}H_1-\frac{1}{2}H_2-\frac{1}{2}F+E}$$

$$\text{Heritability } (F_2) \text{ (narrow sense)} = \frac{\frac{1}{4}D}{\frac{1}{4}D+\frac{1}{16}H_1-\frac{1}{8}F+E}$$

vi) Analysis on created variability

a) Means and variances

Detailed observations on quantitative traits like:-

1) Plant height at maturity
2) Number of primary productive branches per plant
3) Number of productive nodes on main axis
4) Number of pods on main axis

5) Total number of pods per plant

6) Seed yield per plant

7) 1000-seed weight

8) Oil content and

9) Number of days taken for first flowering were carried out from the F_2 generation. The mean values were calculated for the parents and F_2 progeny. The variance and coefficient of variation were calculated for individual F_2 families and parents. Using 'F' test the variances of different F_2 families were compared.

b) Frequency and spectrum of F_2 distribution

Detailed observations on individual plants of each cross for the various quantitative characters were made in the F_2 generation and the phenotypes were grouped under different classes to analyse the frequency and spectrum of created variability. The different class categories selected for each characters were as follows:-

(1) Plant height

Category	Class interval
1	Below 63 cm
2	63 to 108 cm
3	Above 108 cm

(2) Number of primary productive branches per plant

Category	Class interval
1	Below 0.5

2	0.5 to 3.0
3	3.1 to 5.6
4	Above 5.6

(3) Number of productive nodes on main axis

Category	Class interval
1.	Below 15
2	15 to 30
3	31 to 46
4	Above 46

(4) Number of pods on main axis

Category	Class interval
1	Below 21
2	21 to 30
3	31 to 40
4	Above 40

(5) Total number of pods per plant

Category	Class interval
1	Below 20
2	20 to 40
3	41 to 60
4	61 to 80
5	Above 80

(6) Seed yield per plant

Category	Class interval
1	Below 3.0 g
2	3.0 to 6.5 g
3	Above 6.5 g

(7) 1000-seed weight

Category	Class interval
1	Below 2.5 g
2	2.5 to 3.5 g
3	Above 3.5 g

(8) Oil content

Category	Class interval
1	Below 40%
2	40 to 50%
3	Above 50%

(9) Number of days taken for first flowering

Category	Class interval
1	Below 35 days
2	35 to 41 days
3	Above 41 days

RESULTS

EXPERIMENTAL RESULTS

I. Variability analysis

A. Varietal evaluation

Data collected from forty four varieties of sesamum are presented in table 4. Statistical analysis of the data exhibited significant variation in respect of all the ten characters studied. Multipoded and multiloculed characters were excluded from statistical analysis and hence only there were ten characters for variability analysis.

The height of plants varied very much with a range in value from 89.69 cm in V_{39} to 112 cm in V_{25}. For number of primary productive branches the lowest value of 1.26 was recorded by V_{31} and the highest value, 6.8 by V_{8}. The number of productive nodes on main axis ranged from the minimum value of 10 in V_{39} to the maximum value of 30, as recorded by V_{23}. For number of pods on main axis also the variation was very much. It ranged from the minimum value of 11.86 in V_{22} to the maximum value of 41.33 in V_{25}. Total number of pods per plant varied very widely from the minimum value of 20.80 in V_{39} to the maximum value of 133.53 in V_{25}. For seed yield per plant the highest value (21.05) was recorded by V_{25} and the lowest (3.60) by V_{17}. Number of seeds per pod varied from 47.73 in V_{1} to 69.20 in V_{41}. The highest value of 4.00 g for 1000-seed weight was recorded in V_{41} and V_{19}. The lowest value of 2.55 was recorded in V_{42}.

For oil content the maximum percentage was recorded by V_8 (65.33) and the minimum by V_{20} (34.66). For first flowering V_2 and V_{13} took the minimum days of 34.33 while V_{42} took the maximum of 55.33 days.

B. Genetic parameters

Analysis on components of variance, coefficient of variation, heritability and genetic advance for the different characters are presented in table 5.

The phenotypic variance for the different characters ranged from the minimum of 0.28 for number of seeds per pod to the maximum of 542.79 for total number of pods per plant. The values of phenotypic variance were 209.42, 3.13, 31.42, 56.86, 15.64, 45.18, 58.74 and 50.58 for height of plant, number of primary productive branches, number of productive nodes and pods on main axis, seed yield per plant, 1000-seed weight, oil content and number of days for first flowering respectively.

Genotypic variance for the different characters ranged from the minimum of 0.12 for number of seeds per pod to the maximum of 268.73 for total pods per plant. The values of genotypic variance recorded were 65.12, 1.47, 7.44, 29.28, 5.84, 28.83, 46.77 and 25.80 for height of plant, number of primary and productive branches per plant, number of productive nodes on main axis, number of pods on main axis, seed yield per plant, 1000-seed weight, oil content and number of days for first flowering respectively.

Table 5. Components of variance, coefficient of variation, heritability and genetic advance in sesamum.

Sl. No.	Characters	Variance			Coefficient of variation			
		Environmental	Genotypic	Phenotypic	Phenotypic	Genotypic	Heritability	Genetic advance (as percentage over mean)
1.	Height of plant maturity	144.30	65.12	209.42	17.89	9.98	0.31	9.44
2.	Number of primary and productive branches/plant	1.65	1.47	3.13	48.50	33.27	0.47	39.94
3.	Number of productive nodes on main axis	23.98	7.44	31.42	29.30	14.26	0.23	12.17
4.	Number of pods on main axis	27.58	29.28	56.86	36.28	26.03	0.51	32.78
5.	Total pods per plant	274.06	268.73	542.79	52.14	36.69	0.49	45.42
6.	Seed yield per plant	9.79	5.84	15.64	53.50	32.70	0.37	35.09
7.	Number of seeds per pod	0.15	0.12	0.28	17.14	11.47	0.45	10.80
8.	1000-seed weight	22.35	28.83	45.18	15.29	10.87	0.50	13.53
9.	Oil content (%)	11.96	46.77	58.74	16.35	14.59	0.79	22.87
10.	Number of days for first flowering	24.77	25.80	50.58	12.04	8.60	0.51	13.59

Environmental variance ranged from 0.15 for number of seeds per pod to 274.06 for total pods per plant. The values of environmental variance recorded for other characters were 144.30 for height of plant, 1.65 for number of primary productive branches, 23.98 for productive nodes on main axis, 27.58 for number of pods on main axis, 9.79 for seed yield per plant, 22.35 for 1000-seed weight, 11.96 for oil content and 24.77 for number of days for first flowering.

The phenotypic coefficient of variation was minimum for number of days for first flowering (12.04) and was maximum for seed yield per plant (53.50). It was closely followed by the character total pods per plant having a value 52.14. The values recorded for the other characters were 17.89, 48.50, 29.30, 36.28, 17.14, 15.29 and 16.35 for plant height, number of primary productive branches, number of productive nodes on main axis, number of pods on main axis, number of seeds per pod, 1000-seed weight and oil content respectively.

Genotypic coefficient of variation was minimum for number of days for first flowering (8.60) and maximum for total pods per plant (36.69). The values for the characters, number of primary productive branches and seed yield per plant (33.27 and 32.70 respectively) were also close to the maximum value. The values recorded for the remaining characters like, plant height, number of productive nodes on main axis, number of pods on main axis, number of seeds per

Environmental variance ranged from 0.15 for number of seeds per pod to 274.06 for total pods per plant. The values of environmental variance recorded for other characters were 144.30 for height of plant, 1.65 for number of primary productive branches, 23.98 for productive nodes on main axis, 27.58 for number of pods on main axis, 9.79 for seed yield per plant, 22.35 for 1000-seed weight, 11.96 for oil content and 24.77 for number of days for first flowering.

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Genotypic coefficient of variation was minimum for number of days for first flowering (8.60) and maximum for total pods per plant (36.69). The values for the characters, number of primary productive branches and seed yield per plant (33.27 and 32.70 respectively) were also close to the maximum value. The values recorded for the remaining characters like, plant height, number of productive nodes on main axis, number of pods on main axis, number of seeds per

pod, 1000-seed weight and oil content were 9.98, 14.26, 26.03, 11.47, 10.87 and 14.59 respectively.

The heritability values for the different characters ranged from the minimum of 0.23, recorded for number of productive nodes on main axis to the maximum of 0.79 recorded for oil content. The heritability values did not show much difference for number of pods on main axis (0.51), number of days for first flowering (0.51), 1000-seed weight (0.50) and total pods per plant (0.49). Heritability values for the other characters were 0.31 for plant height, 0.47 for number of primary and productive brmches per plant, 0.37 for seed yield per plant and 0.45 for number of seeds per pod.

Maximum genetic advance (45.42) was recorded for total pods per plant and was minimum (9.44) for plant height at maturity. The values of genetic advance recorded in the other characters were, 39.94 in number of primary productive branches per plant, 12.17 in number of productive nodes on main axis, 32.78 in number of pods on main axis, 35.09 in seed yield per plant, 10.80 in number of seeds per pod, 13.53 in 1000-seed weight, 22.87 in oil content and 13.59 in number of days for first flowering.

C. <u>Covariance and correlations</u>

Analysis of covariance was done in all the possible combinations for different pairs of characters. The genotypic, phenotypic and environmental covariance components

were computed and are presented in table 6. From the variances and covariances the genotypic and phenotypic correlation coefficients were also estimated and are presented in table 7. The different pairs of characters showed different degrees of correlations. Among the 45 character pair combinations, 14 were significant; 10 at 1 per cent level and 4 at 5 per cent level in the genotypic correlation coefficients. In the phenotypic correlation coefficients 14 were significant at 1 per cent level and 4 were significant at 5 per cent level. In the environmental correlation coefficients, 14 out of 16 were significant at 1 par cent level and the rest at 5 per cent level.

Plant height showed a positively significant correlation with number of productive nodes on main axis, number of pods on main axis, total pods per plant and weight of seeds per plant both at phenotypic and genotypic levels. But it was correlated with number of primary productive branches per plant only at phenotypic level. Environmental correlation coefficients were also positively significant in all the above character pairs.

Number of primary productive branches per plant showed positively significant genotypic correlation with total pods per plant, seed yield per plant and number of days for first flowering. But the correlation was negative in the case of number of days for first flowering. At phenotypic level number of primary productive branches

Table 6. Genotypic (G), environmental (E) and phenotypic (P)

		Height of plant at maturity (cm)	No. of primary productive branches	No. of productive nodes on main axis	No. of pods on main axis
Height of plant at maturity (cm)	G		3.1647	12.5868	23.8962
	E		5.6086	40.3723	34.6719
	P		8.7734	52.9591	48.5682
No. of primary productive branches	G			0.7679	-0.1095
	E			1.3268	0.3984
	P			2.0948	0.1988
No. of productive nodes on main axis	G				11.3110
	E				15.6663
	P				26.9773
No. of pods on main axis	G				
	E				
	P				
Total pods/ plant	G				
	E				
	P				
Seed yield/ plant (g)	G				
	E				
	P				
No. of seeds/ pod	G				
	E				
	P				
1000-seed weight (g)	G				
	E				
	P				
Oil Content (%)	G				
	E				
	P				
No. of days to first flowering	G				
	E				
	P				

covariance between different characters.

Total pods/ plant	Seed yield/ plant (g)	No. of seeds/ pod	1000-seed weight (g)	Oil content (%)	No. of days to first flowering
91.7384	15.7384	0.3810	2.7358	-5.7689	-4.7508
78.5212	11.4498	0.1099	5.0899	-0.1947	21.0989
170.3874	27.1883	0.4909	7.8257	-5.9637	16.3481
11.9970	1.8294	-0.1604	-1.4259	-0.7167	-4.0774
7.7385	0.7328	-0.0031	0.3628	-0.0834	1.1487
19.7356	2.5622	-0.1635	-1.0632	-0.8002	-2.9287
29.2292	4.6455	0.1055	2.5427	1.3876	-4.5769
35.4209	4.3022	-0.2117	-0.7542	0.5576	9.8439
64.6501	8.9477	-0.1062	-3.2969	1.9453	5.2670
64.2102	9.3238	-0.0956	4.9812	2.1874	-0.7984
32.5960	5.1662	-0.2021	0.1881	-0.1591	5.2117
96.8062	14.4889	-0.2978	5.1693	2.0283	4.4133
	41.9847	-0.7195	-29.2280	-16.4616	-15.9143
	33.8775	-1.1652	-0.8343	0.4789	17.3857
	75.8622	-1.8847	-30.0626	-15.9826	1.4714
		0.0049	-5.2529	-1.8652	-2.7046
		-0.1738	1.4385	-0.4896	2.4137
		-0.1689	-3.8144	-2.4548	-0.2908
			0.1804	-0.2329	0.9716
			0.1118	0.1186	-0.2577
			0.2922	-0.1143	0.7139
				8.2396	3.5193
				-0.7252	3.1429
				7.5144	6.6623
					1.3196
					-1.5162
					-0.1967

Table 7. Genotypic (G), environmental (E) and phenotypic (P)

		Height of plant at maturity (cm)	No. of primary productive branches	No. of productive nodes on main axis	No. of pods on main axis
Height of plant at maturity (cm)	G		0.3230	0.5717*	0.5472*
	E		0.3626**	0.6862**	0.5496**
	P		0.3426**	0.6528**	0.5367**
No. of primary productive branches	G			0.2319	-0.0167
	E			0.2104*	0.0456
	P			0.2113*	0.0148
No. of productive nodes on main axis	G				0.7663**
	E				0.6091**
	P				0.6381**
No. of pods on main axis	G				
	E				
	P				
Total pods/ plant	G				
	E				
	P				
Seed yield/ plant (g)	G				
	E				
	P				
No. of seeds/ pod	G				
	E				
	P				
1000-seed weight (g)	G				
	E				
	P				
Oil content (%)	G				
	E				
	P				
No. of days to first flowering	G				
	E				
	P				

correlation between different characters.

Total pods/ plant	Seed yield/ plant (g)	No. of seeds/ pod	1000-seed weight (g)	Oil content (%)	No. of days to first flowering
0.6944**	0.8067**	0.1313	0.0709	-0.1045	-0.1159*
0.3948*	0.3045**	0.0230	0.0896	-0.0047	0.3529**
0.5054**	0.4750**	0.0633	0.0804	-0.0537	0.1588
0.6028**	0.6233**	-0.3676	-0.2458	-0.0863	-0.6611**
0.3630**	0.1818	-0.0061	0.0596	-0.0187	0.1792
0.4786**	0.3660**	-0.1725	-0.0893	-0.0589	-0.2326**
0.6536**	0.7044*	0.1077	-0.1951	0.0743	-0.3303
0.4369**	0.2806**	-0.1088	-0.0326	0.0329	0.4038**
0.4949**	0.4035**	-0.0353	-0.0874	-0.0452	0.1320
0.7238**	0.7127**	-0.0492	-0.1926	0.0591	-0.0290
0.3749**	0.3143**	-0.0969	-0.0076	-0.0088	0.1994
0.5510**	0.4858**	-0.0737	-0.1019	0.0350	0.0822
	1.0005*	-0.1222	-0.3731	-0.1468	-0.1911
	0.6538**	-0.1722	-0.0106	0.0084	0.2109*
	0.8233**	-0.1510	-0.1919	-0.0895	0.0088
		0.0556	-0.4547	-0.1188	-0.2202
		-0.1399	0.0972	-0.0452	0.1549
		-0.0797	-0.1434	-0.0809	-0.0103
			0.1050	-0.0948	0.5323*
			0.0596	0.0864	-0.1304
			0.0811	-0.0279	0.1874*
				0.2521	0.1449
				-0.0413	0.1336
				0.1458	0.1393
					0.0379
					-0.0881
					-0.0036

showed positively significant correlation with number of productive nodes on main axis, total pods per plant and seed yield per plant. But it showed significant negative correlation with number of seeds per pod and number of days for first flowering.

Number of productive nodes on main axis showed positively significant correlation with number of pods on main axis, total pods per plant and seed yield per plant at genotypic level. At phenotypic and environmental levels also the correlation coefficients were positively significant for the above character combinations. Number of productive nodes on main axis showed positively significant correlation with number of days for first flowering only at environmental level. Number of pods on main axis recorded positively significant correlation with total pods per plant and seed yield per plant at genotypic, phenotypic and environmental levels.

The correlation coefficients were positively significant at genotypic, phenotypic and environmental levels between total pods per plant and seed yield per plant. Total pods per plant showed a negatively significant correlation with 1000-seed weight at phenotypic level. But it showed positive significance with number of days for first flowering.

Number of seeds per pod showed significant genotypic and phenotypic correlation with number of days for first flowering.

D. Path-coefficient analysis

In order to obtain a clear picture of the cause and effect relationship of various plant characters and seed yield, a path-coefficient analysis was undertaken. The observed genotypic correlation coefficients were partitioned into direct and indirect effects. The direct and indirect effects of the components are presented in table 8. The cause effect relationship brought out by the path-coefficient analysis is represented diagramatically in Fig.1.

Among the five components of seed yield, the direct effect was highest for total pods per plant (0.7930) followed by height of plant (0.2123); number of productive nodes on main axis (0.0809) and number of primary productive branches per plant (0.0572). Number of pods on main axis had negative effect (-0.0386). The effect of all other attributes were not considered in the model, i.e. the residual effect works out to only -0.0295604.

The indirect effects of the above characters are also considered. Height of plant had a strong positive correlation with seed yield (0.8067) and showed a direct positive effect of 0.2123. Its indirect effect via number of primary productive branches per plant, number of productive nodes on main axis and total pods per plant were 0.0185, 0.0463 and 0.5508 respectively, the maximum being through total pods per plant. Indirect effect through number of pods on main axis was negative, the value being 0.0211.

FIG: 1. PATH DIAGRAM AND ASSOCIATION OF COMPONENTS OF SEED YIELD IN SESAMUM

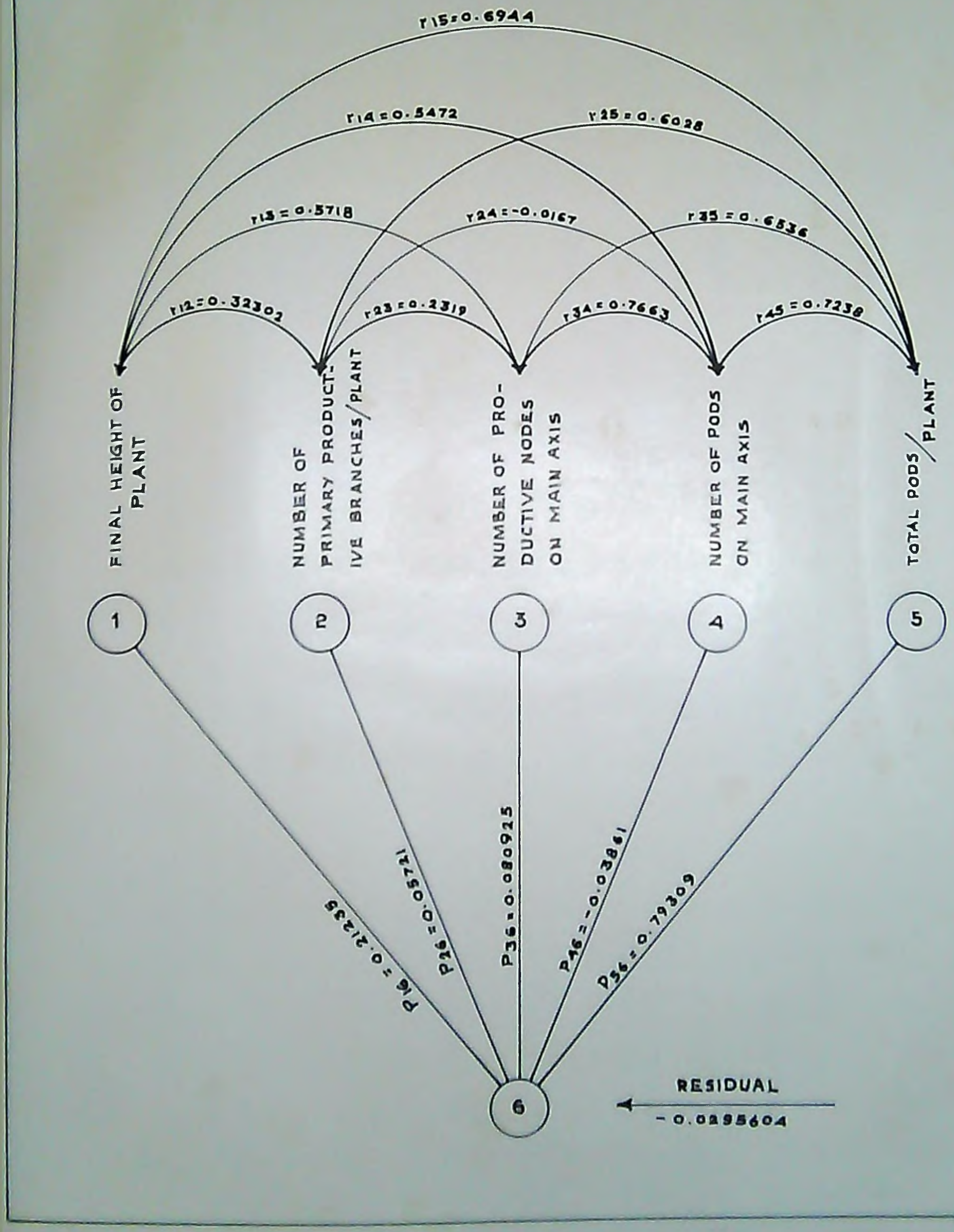


Table 8. Path-coefficient analysis at the genotypic levels of components of seed yield.

Variables	Direct effect on seed yield	Indirect effects on seed yield via					Total correlations
		Height of plant at maturity	Number of primary productive branches/ plant	Number of productive nodes on main axis	Number of pods on main axis	Total pods/ plant	
Height of plant at maturity	0.2123	-	0.0185	0.0463	-0.0211	0.5508	0.8067
Number of primary productive branches/ plant	0.0572	0.0686	-	0.0188	0.0006	0.4781	0.6232
Number of productive nodes on main axis	0.0809	0.1214	0.0133	-	-0.0296	0.5184	0.7044
Number of pods on main axis	-0.0386	0.1162	-0.0009	0.0620	-	0.5741	0.7127
Total pods/plant	0.7930	0.1475	0.0345	0.0529	-0.0279	-	0.9999

Residual factor = -0.0295604

Number of primary productive branches per plant also had significant positive correlation with seed yield, the correlation coefficient being 0.6232. Its direct effect on seed yield was 0.0572. Indirect effects via plant height, number of productive nodes on main axis, number of pods on main axis and total pods per plant were 0.0686, 0.0188, 0.0006 and 0.4781 respectively. Here also the above character influences the yield, maximum through total pods per plant indirectly.

Number of productive nodes on main axis was strongly and positively correlated with seed yield, the correlation coefficient being 0.7044. It exerted a direct effect of 0.0809. The indirect effects via plant height, number of primary productive branches per plant and total pods per plant were positive, the values being 0.1214, 0.0133 and 0.5184. The indirect effect was maximum via total pods per plant. Indirect effect through number of pods on main axis was negative, the value being 0.0296.

Number of pods on main axis showed significant positive correlation with seed yield, the correlation coefficient being 0.7127 but the direct effect on seed yield was negative, the value being 0.0386. The indirect effect via plant height and number of productive nodes on main axis and total pods per plant were positive, the values being 0.1162, 0.0620 and 0.5741 respectively. Maximum indirect effect was via total pods per plant. Indirect effect via

number of primary productive branches per plant was negative, the value being 0.0009.

Total pods per plant had the highest significant correlation with seed yield (0.9999). Its direct effect on seed yield was high the value being 0.7930. Its indirect effects via plant height, number of primary productive branches per plant and number of productive nodes on main axis were positive, the values being 0.1475, 0.0345 and 0.0529 respectively. The maximum indirect effect was through plant height. Indirect effect via number of pods on main axis was negative, the value being 0.0279.

Among the different yield components studied, total pods per plant had the highest correlation (0.9999) and the maximum direct effect on seed yield (0.7930). The second important yield component was plant height. The correlation coefficient was high (0.8067) and the direct effect (0.2123) was more than its indirect effect via other characters.

The third important yield component was number of productive nodes on main axis. The correlation coefficient was high (0.7044). Eventhough its direct effect on seed yield is low it had higher positive indirect effect via total pods per plant (0.5184) and plant height (0.1214).

The fourth important yield attribute was number of primary productive branches per plant. It had significant positive correlation coefficient of 0.6232. Eventhough its direct effect on seed yield was only 0.0572 its indirect

effects via total pods per plant (0.4781) and plant height (0.0686) were higher and positive.

The fifth yield component viz., number of pods on main axis showed high correlation (0.7127) with seed yield but exerted a negative direct effect on seed yield (-0.0386). Its indirect effects via total pods per plant (0.5741), plant height (0.1162) and number of productive nodes on main axis (0.0620) were positive and the maximum being through total pods per plant. Indirect effect through number of primary productive branches was negative but was very much low.

II. Cytogenetic analysis

A. Performance analysis in single cross hybrids

The mean values and the analysis of variance in the single cross hybrids (F_1) and parents with respect to the nine characters are presented in table 9.

Significant differences were exhibited by the hybrids over their parents for all the characters except oil content. The results are summarised below.

Plant height at maturity:

The mean height recorded by the parents ranged from 64.90 to 107.25 cm in V_{13} and V_{29} respectively whereas it ranged from 78.35 to 121.40 cm in the hybrids, $V_2 \times V_{13}$ and $V_2 \times V_{41}$ respectively. Among the hybrids, the height was intermediate to those of parents in most of the crosses. The variation in plant height of single cross hybrids and

Table 9. Phenotypic expression in various yield attributing characters in the single cross hybrids (F_1's) and parents.

Sl. No.	Treatments	Number of days for first flowering	Plant height at maturity (in cm)	Number of primary productive branches/ plant	Number of productive nodes on main axis	Number of pods on main axis	Total number of pods/ plant	Seed yield/ plant (in g)	1000-seed weight (in g)	Oil content (Percentage)
1.	2	48.00	96.40	3.10	19.75	19.75	58.15	7.21	2.68	44.50
2.	2 x 25	48.00	106.75	4.90	20.95	20.60	56.85	8.04	2.69	61.33
3.	2 x 13	39.50	78.35	3.40	16.20	14.70	79.70	10.82	3.06	50.13
4.	2 x 29	45.50	92.65	3.85	17.85	16.30	69.85	7.87	2.50	55.53
5.	2 x 37	44.00	95.40	3.60	23.30	20.45	76.30	7.66	2.98	39.29
6.	2 x 41	47.50	121.40	2.75	22.80	23.15	62.90	6.73	3.06	44.83
7.	25	48.00	106.65	4.55	25.70	25.60	72.15	9.30	3.18	41.91
8.	25 x 13	40.50	99.30	4.70	21.05	21.05	54.55	5.08	2.42	58.17
9.	25 x 29	43.50	104.95	3.85	25.70	27.20	60.45	8.29	2.94	52.42
10.	25 x 37	47.50	97.70	1.70	24.05	35.95	44.95	6.63	2.62	46.74
11.	25 x 41	50.50	110.75	2.80	20.50	19.70	70.45	10.58	3.06	52.04
12.	13	39.50	64.90	3.25	12.10	12.10	24.45	6.46	2.97	42.25
13.	13 x 29	43.00	82.40	3.50	14.65	16.30	73.70	12.08	2.59	48.08
14.	13 x 37	40.50	83.15	2.75	19.10	19.10	58.90	9.29	2.36	65.25
15.	13 x 41	47.00	104.20	3.65	19.60	19.65	74.45	11.61	2.89	61.25

(continued)

Table 9. (Continued)

Sl. No.	Treatments	Number of days for first flowering	Plant height at maturity (in cm)	Number of primary productive branches/ plant	Number of productive nodes on main axis	Number of pods on main axis	Total number of pods/ plant	Seed yield/ plant (in g)	1000-seed weight (in g)	Oil content (Percentage)
16.	29	45.50	107.25	3.50	24.45	25.05	95.60	13.21	3.30	53.91
17.	29 x 37	42.50	94.40	2.70	21.15	23.95	57.95	11.20	3.14	51.17
18.	29 x 41	47.00	116.55	3.20	25.05	24.20	106.70	14.99	3.04	59.08
19.	37	40.50	81.00	0.75	21.20	22.05	36.40	6.39	2.78	46.99
20.	37 x 41	45.50	95.90	1.70	18.40	18.05	44.10	7.33	3.02	53.50
21.	41	56.00	79.60	1.85	11.30	10.05	23.60	3.79	4.19	43.49
M.S.S.		33.32**	393.81**	2.14*	33.86*	62.32*	844.98**	15.69*	0.30**	90.95
C.D.		6.10	21.09	2.06	7.00	9.81	23.79	5.27	0.57	-

* Significant at 5 per cent level

** Significant at 1 per cent level

parents is represented in Fig.2.

Number of primary productive branches per plant:

Mean number of primary productive branches in the parents ranged from 0.75 to 4.55. The minimum was recorded by V_{37} and the maximum by V_{25}. Among the hybrids, the minimum number of primary productive branches (1.70) was recorded in the crosses $V_{25} \times V_{37}$ and $V_{37} \times V_{41}$. Maximum number of primary productive branches (4.90) was observed in the cross $V_2 \times V_{25}$. In most of the crosses the number of branches was intermediate to those of the parents. The variation in the number of primary productive branches per plant in the single cross hybrids and parents is represented in Fig.3.

Number of productive nodes on main axis:

Number of productive nodes on main axis showed a wide range of variation in the parents. It ranged from the minimum of 11.30 as recorded by V_{41} to the maximum of 25.70 in V_{25}. Among the hybrids, the minimum value of 14.65 was recorded by the cross $V_{13} \times V_{29}$ while the maximum value 25.70, was recorded by $V_{25} \times V_{29}$. In all the crosses number of productive nodes on main axis was intermediate to those of the parents. The variation for number of productive nodes on main axis in the single cross hybrids and parents is represented in Fig. 4.

Fig. 2 Mean height of plants at maturity in the parents and single and double cross hybrids

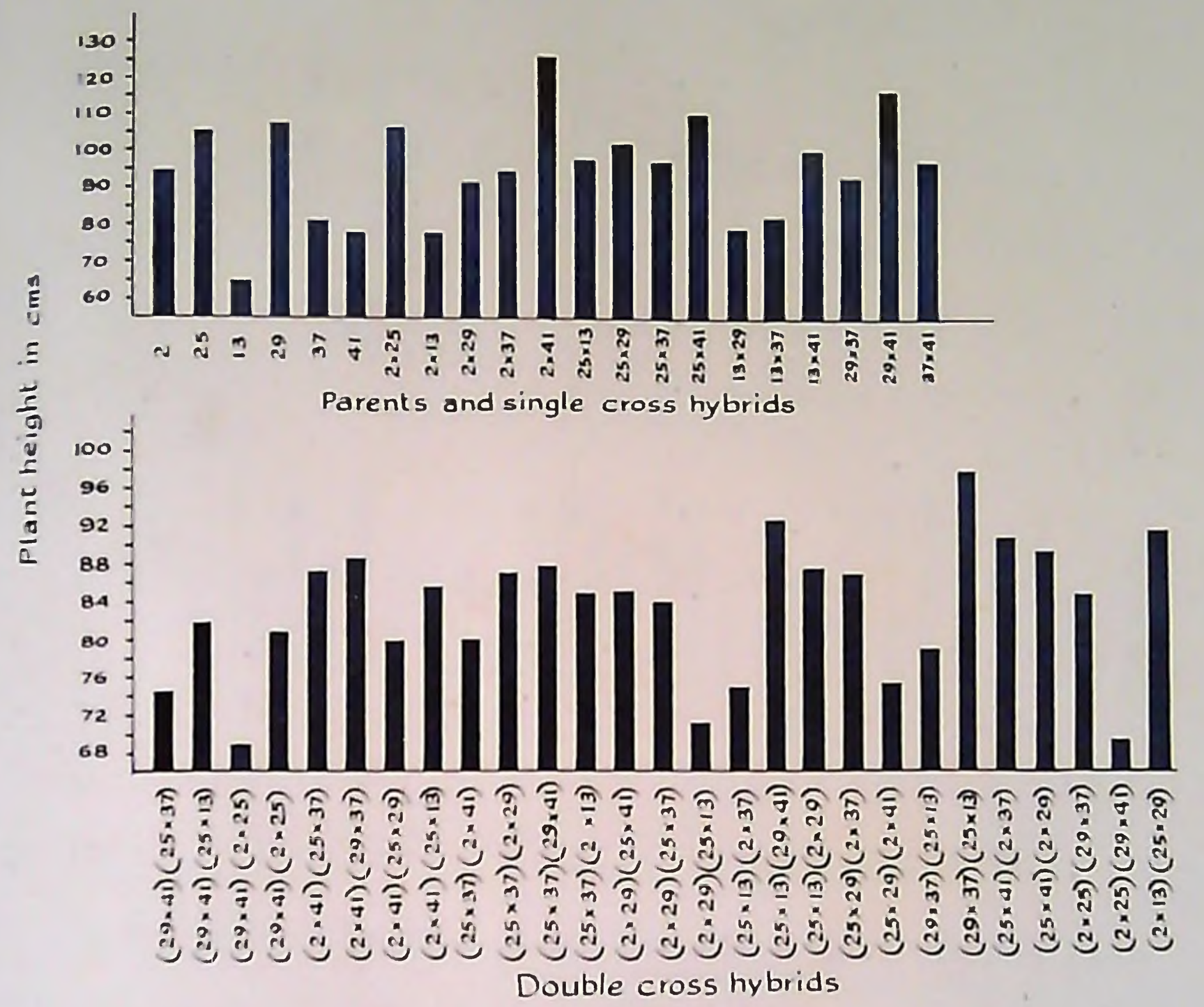


Fig. 3 Mean number of primary productive branches in the parents and single and double cross hybrids

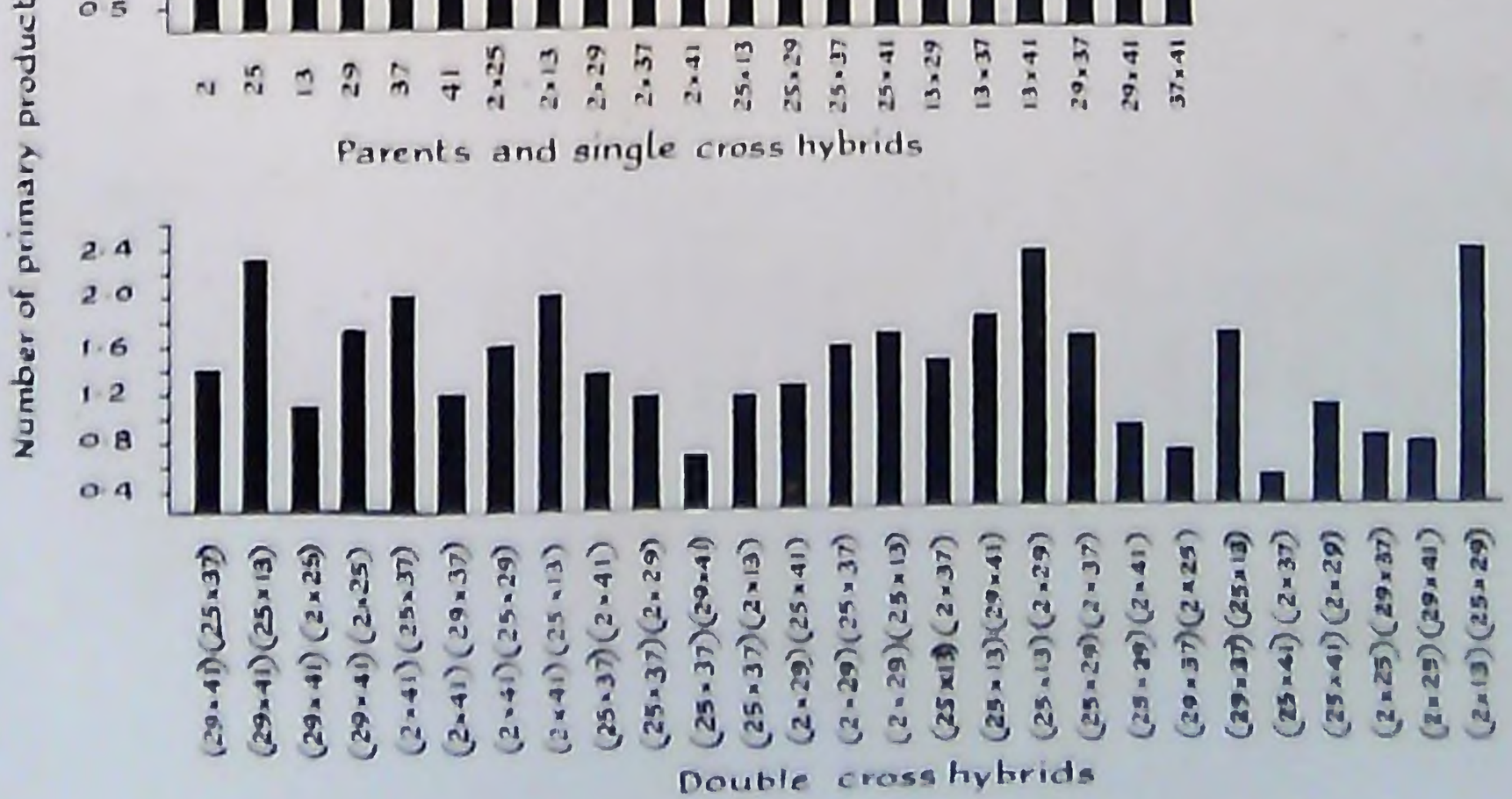


Fig. 4 Mean number of productive nodes on main axis in the parents and single and double cross hybrids

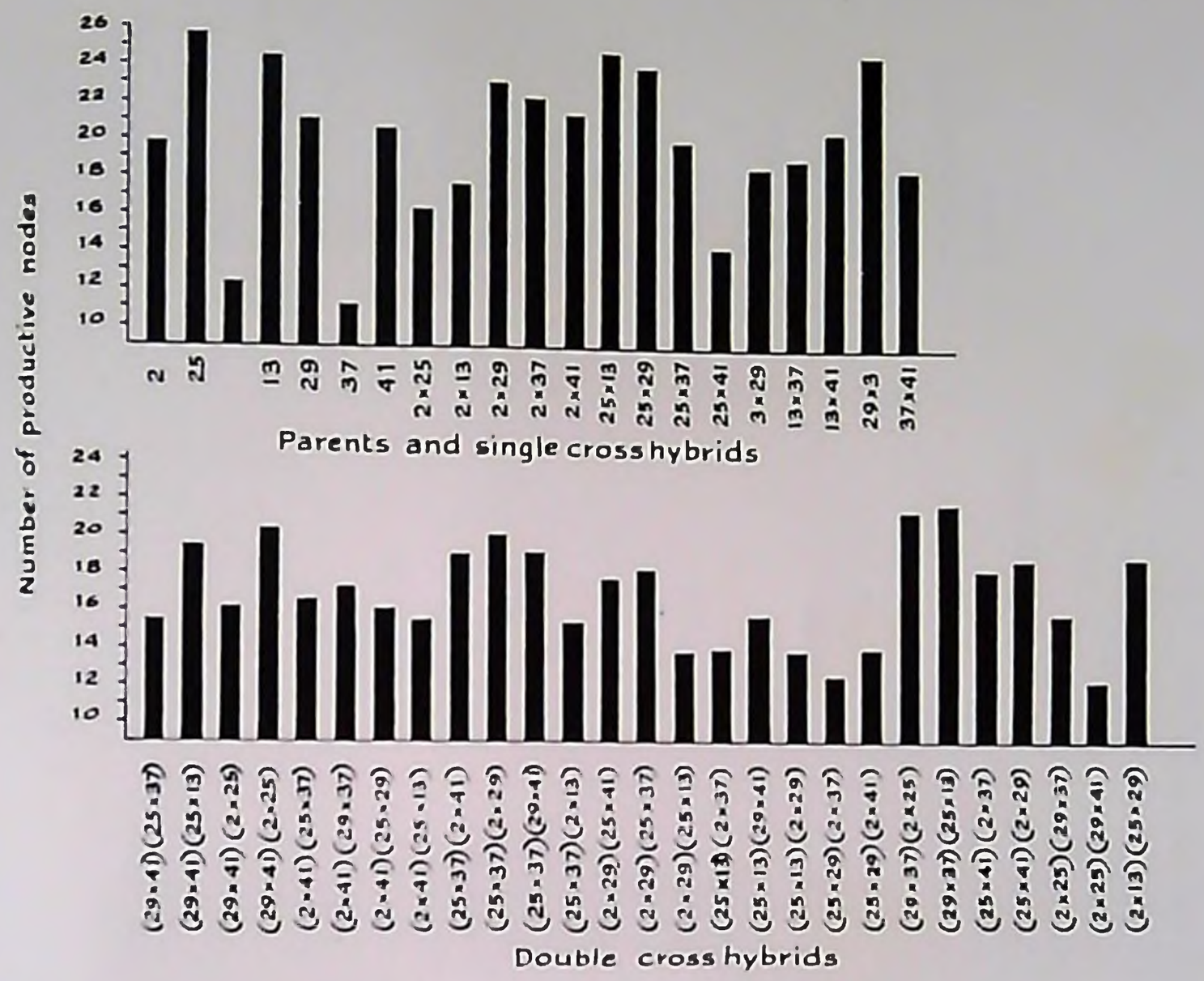


Fig 5 Mean number of pods on main axis in the parents and single and double cross hybrids

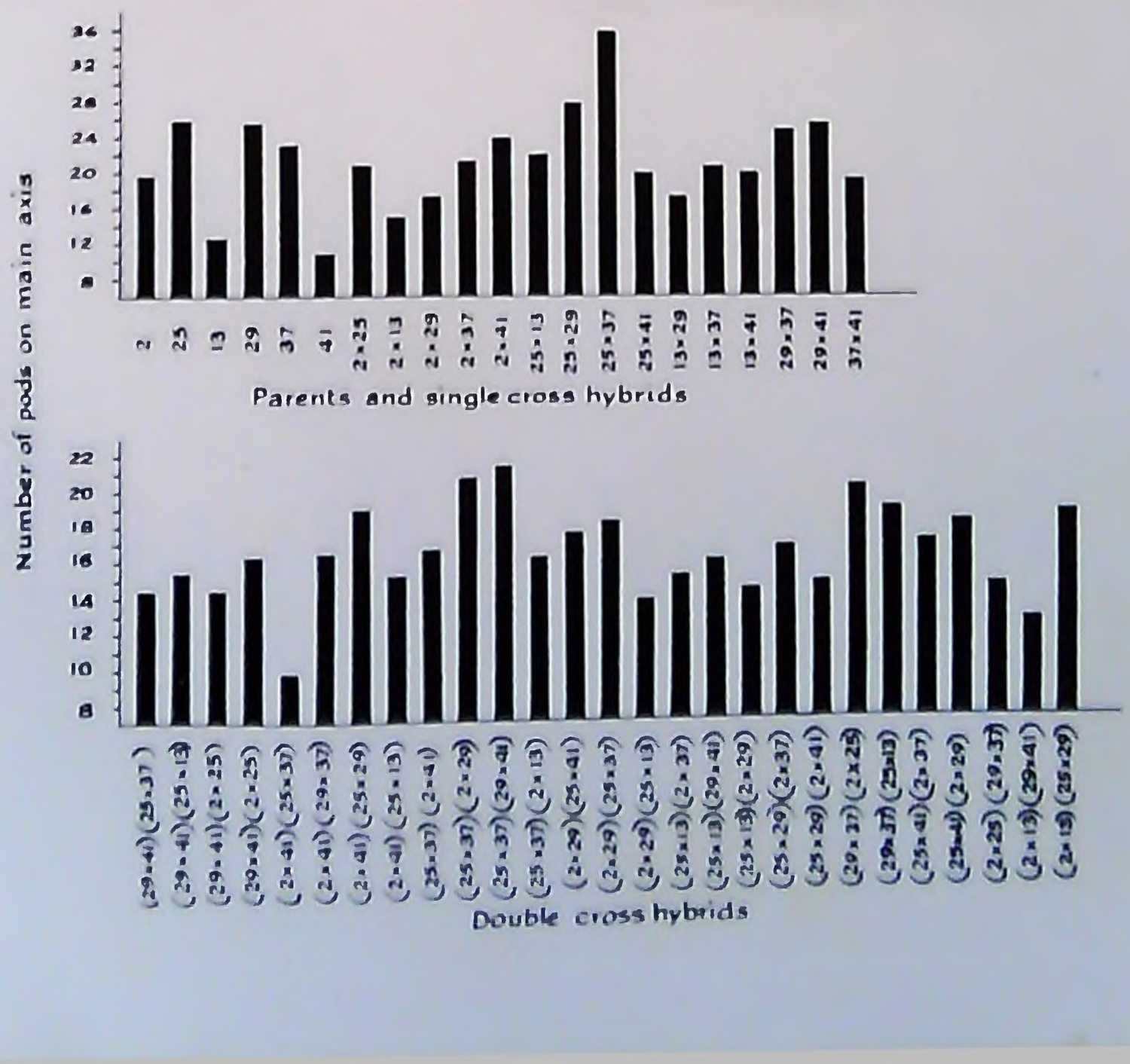


Fig 6 Mean number of pods per plant in the parents and single and double cross hybrids

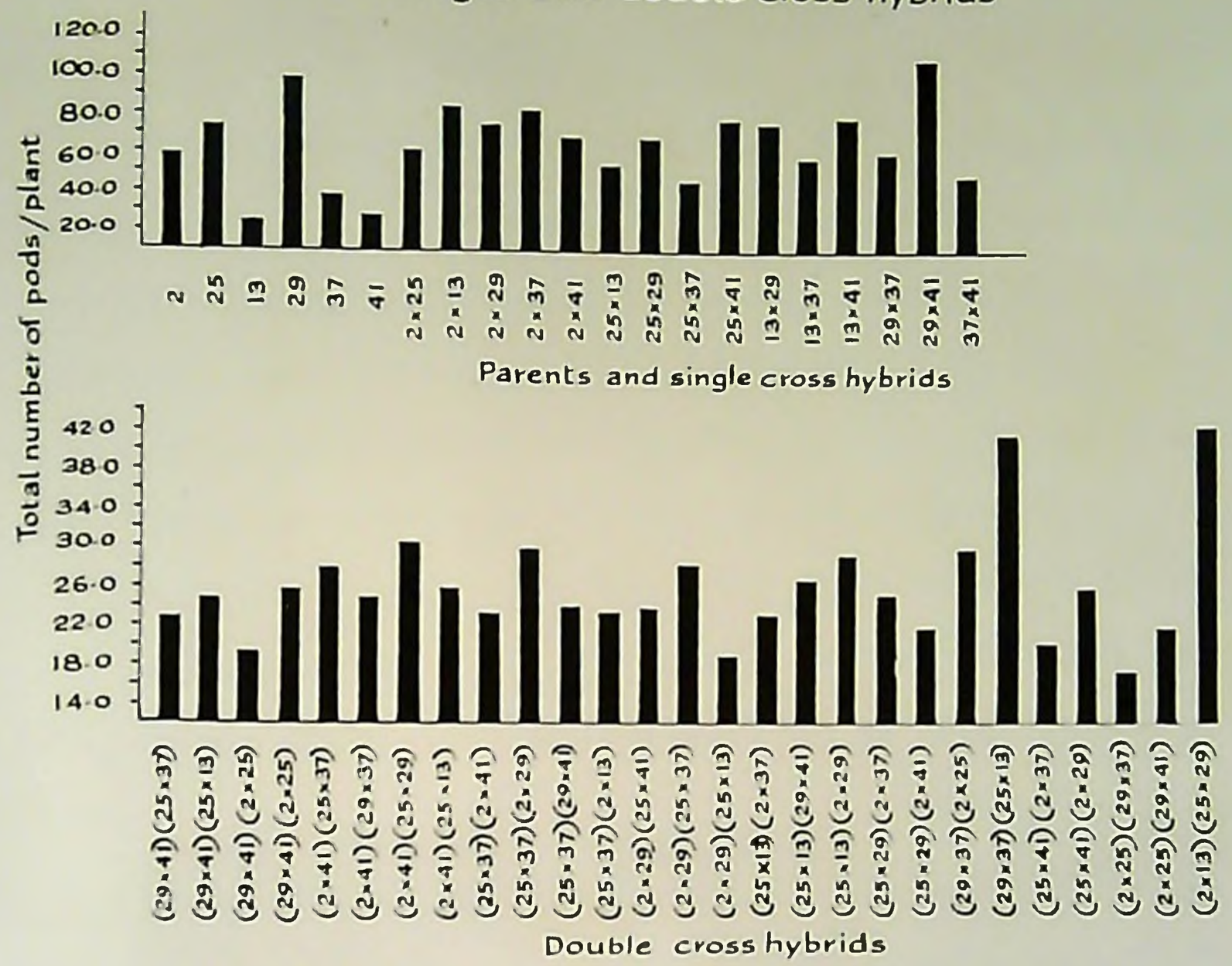
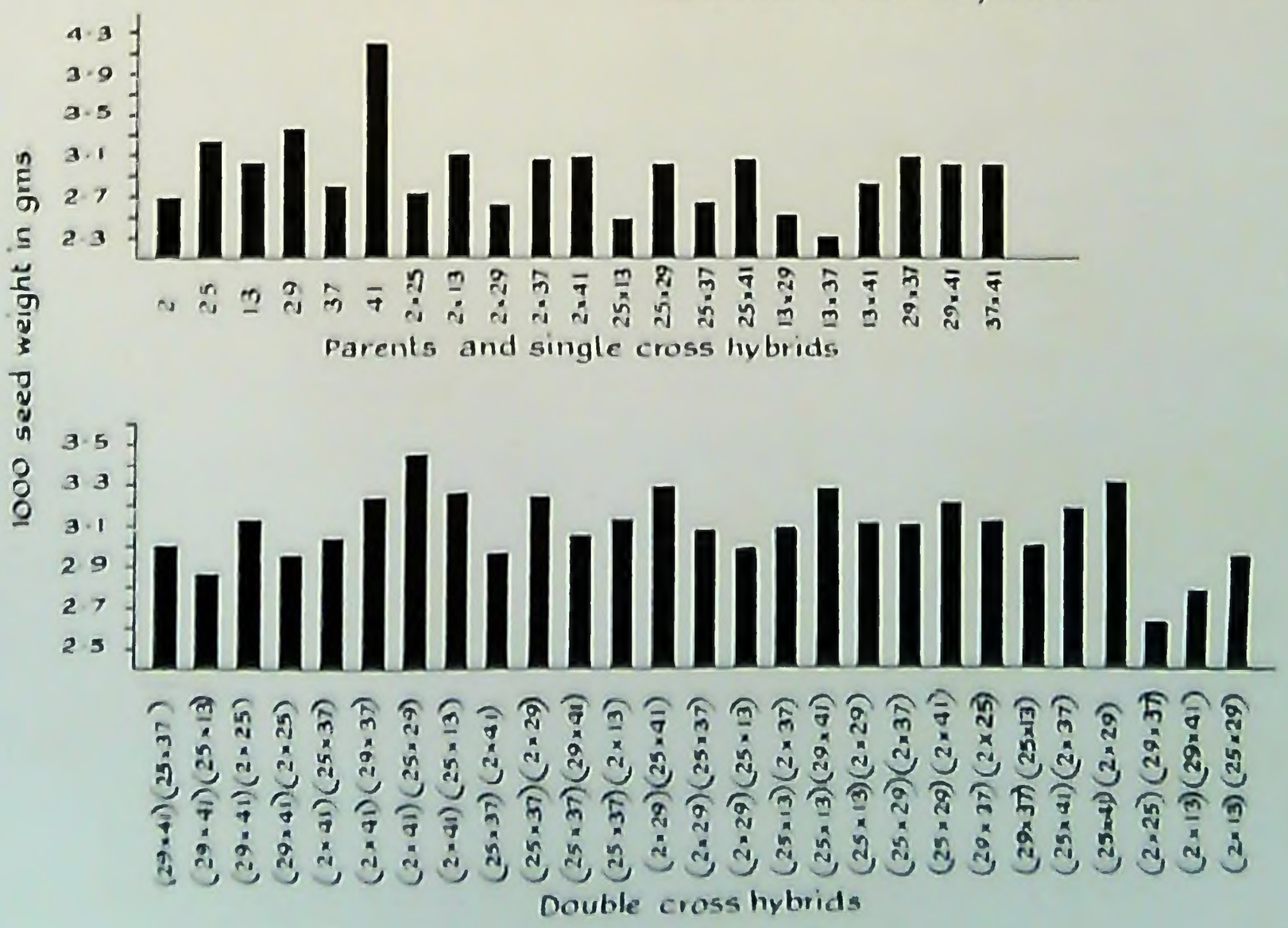


Fig 7 Thousand seed weight of parents and single and double cross hybrids



Number of pods on main axis:

The number of pods on main axis in the parental varieties ranged from the minimum of 10.05 recorded by V_{41} to the maximum of 25.60 recorded by V_{25} whereas the value ranged from the minimum of 14.70 recoorded by $V_2 \times V_{13}$ to the maximum of 35.95 recoorded by $V_{25} \times V_{37}$. The hybrids showed a wide range of variation compared to their parents. In all the hybrids the values were found to be intermediate to those of the parents. Variation for number of pods on main axis in the single cross hybrids and parents is represented in Fig.5.

Total number of pods per plant:

Total number of pods per plant in parents ranged from the minimum of 23.60 recorded by V_{41} to the maximum of 95.60 recorded by V_{29}. Among the hybrids, the range was from the minimum of 44.10 recorded by $V_{37} \times V_{41}$ to the maximum of 106.70 recorded by $V_{29} \times V_{41}$. The values recorded by hybrids were intermediate or higher than the parental values. Variation for total number of pods per plant in the single cross hybrids and parents is represented in Fig.6.

Seed yield per plant:

Among the parents seed yield per plant was minimum in V_{41} (3.79 g). Maximum seed yield per plant was recorded by V_{29} (13.21 g). Among the hybrids it ranged from the minimum of 5.08 g recorded by $V_{25} \times V_{13}$ to the maximum of

Fig. 8 Seed weight per plant in the parents and single and double cross hybrids

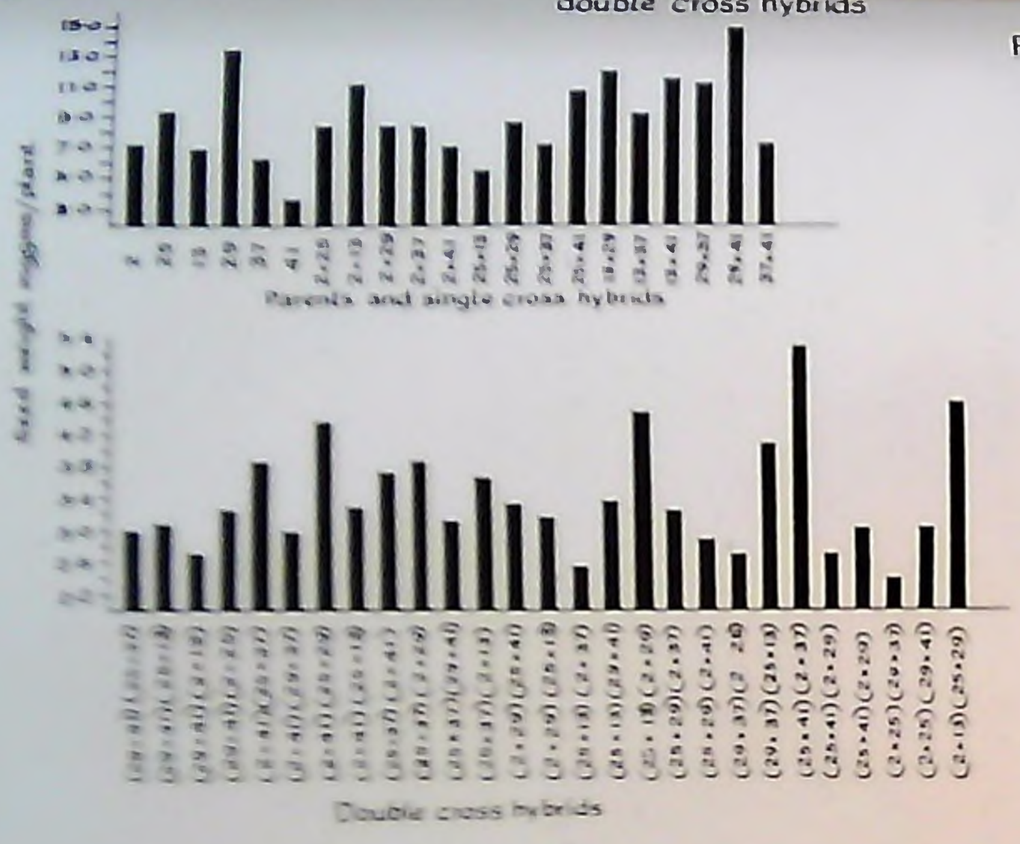


Fig 9 Percentage oil content in the parents and single and double cross hybrids

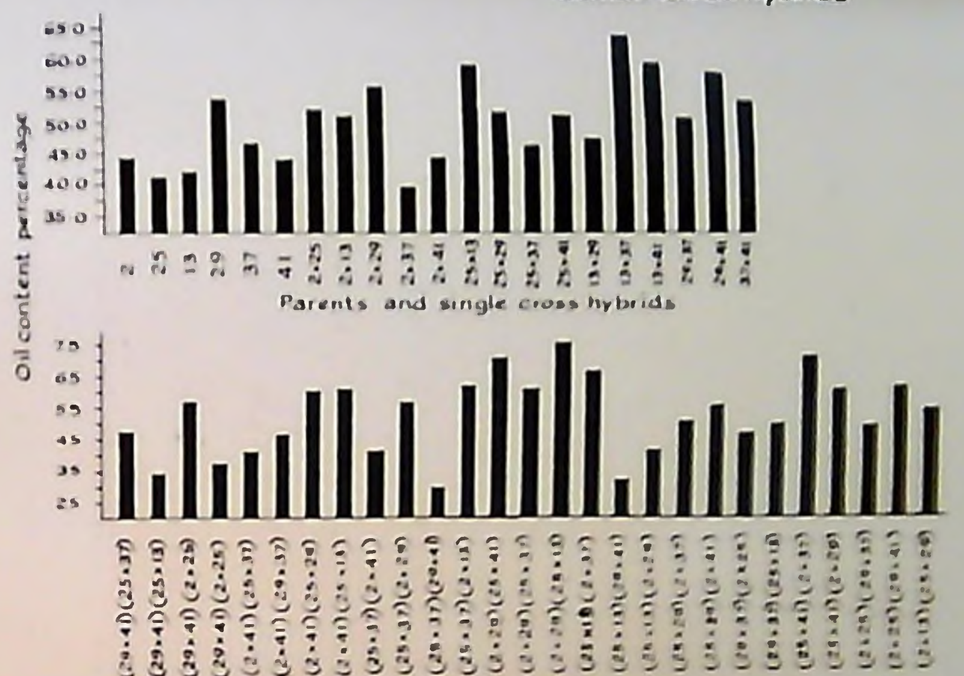
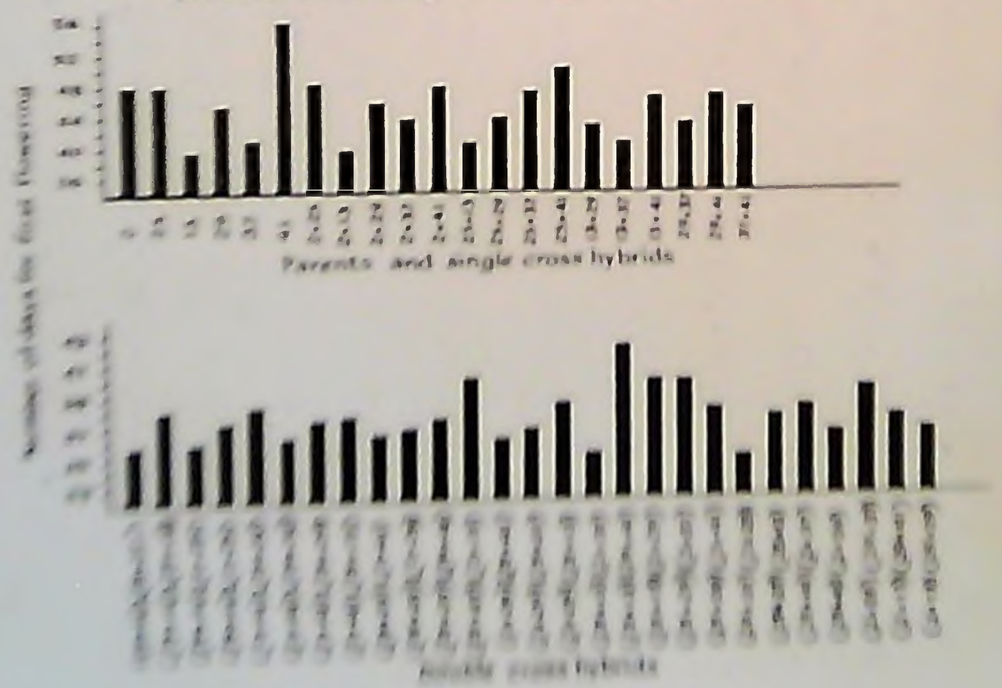


Fig 10 Mean number of days taken for first flowering by the parents and single and double cross hybrids



14.99 g recorded by V_{29} x V_{41}. The hybrids were intermediate or better than both the parents in their yielding ability. The variation for seed yield per plant in the single cross hybrids and parents is represented in Fig.7.

1000-seed weight:

Weight of 1000 seeds ranged from the minimum of 2.68 g in V_2 to the maximum of 4.19 g in V_{41}. The range for this character among the hybrids was from the minimum of 2.36 g recorded by V_{13} x V_{37} to the maximum of 3.14 recorded in V_{29} x V_{37}. The hybrids showed a very narrow range of variation. They were intermediate or inferior to their parents. The variation for 1000-seed weight in the single cross hybrids and parents is represented in Fig.8.

Oil content:

The percentage oil content among the parents showed a range from the minimum of 41.91 in V_{25} to the maximum of 53.91 in V_{29}. Among the hybrids it ranged from the minimum of 39.29 recorded by V_2 x V_{37} to a maximum of 65.25 recorded by V_{13} x V_{37}. The hybrids recorded a wide range of variation. The hybrids in general were intermediate or better than their parents in their oil yield. The variation for oil content in the single cross hybrids and parents is represented in Fig. 9.

Number of days for first flowering:

The range of variation for number of days for first

flowering ranged from 39.50 recorded by V_{13} to the maximum of 56.00 recorded by V_{41}. Among the hybrids, the range was from the minimum of 39.50 recorded by $V_2 \times V_{13}$ to a maximum of 50.50 recorded by $V_{25} \times V_{41}$. The hybrids showed a narrow range of variation. The hybrids were intermediate or early flowering types when compared to their parents. The variation in duration for first flowering in the single cross hybrids and parents is represented in Fig. 10.

A-1. Heterosis in single cross hybrids

Data collected from diallel analysis involving six varieties and one set of hybrids were analysed statistically and the results are presented below.

The analysis of variance was conducted with respect to all the characters to test the significance of crosses and parents and are presented in table 9. The hybrids and parents showed significant differences for all the characters studied.

The extent of heterosis was calculated in comparison with the mean value of the better parent as well as with the mid-parental values. In the estimation of heterosis for earliness, the early flowering parents were considered as better parents. The F_1 data and the percentage of heterosis over mid-parent and better parent with respect to various characters are presented in tables 10-1 to 10-3.

Plant height at maturity:

Table 10-1 shows the percentage of heterosis manifested

Table 10-1. Analysis on heterosis in single cross hybrids.

Sl. No.	Parents and hybrids	Mean plant height	Percentage of heterosis over Mid parent	Percentage of heterosis over Better parent	Mean number of primary productive branches/ plant	Percentage of heterosis over Mid parent	Percentage of heterosis over Better parent	Mean number of productive nodes on main axis	Percentage of heterosis over Mid parent	Percentage of heterosis over Better parent
1.	2	96.40	-	-	3.10	-	-	19.75	-	-
2.	2 x 25	106.75	5.14	0.09	4.90	27.93	7.69	20.95	-7.83	-18.48
3.	2 x 13	78.35	-2.85	-18.72	3.40	6.92	4.62	16.20	1.89	-17.97
4.	2 x 29	92.65	-8.11	-13.61	3.85	16.66	10.00	17.85	-19.23	-26.99
5.	2 x 37	95.40	75.54	-1.04	3.66	86.53	16.13	23.30	13.77	9.91
6.	2 x 41	121.40	37.95*	25.93	2.75	10.89	-11.29	22.80	46.81*	15.44
7.	25	106.65	-	-	4.55	-	-	25.70	-	-
8.	25 x 13	99.30	15.77	-6.89	4.70	20.51	3.29	21.05	11.38	-18.09
9.	25 x 29	104.95	-1.87	-2.14	3.85	-4.47	-15.38	25.70	4.47	0
10.	25 x 37	97.70	4.07	-8.39	1.70	-35.85	-62.64*	24.05	2.56	-16.20
11.	25 x 41	110.75	18.92	3.84	2.80	-12.50	-38.46	20.50	10.81	-20.23
12.	13	64.90	-	-	3.25	-	-	12.10	-	-
13.	13 x 29	82.40	-4.28	-23.17*	3.50	3.55	0	14.65	-19.86	-40.08*
14.	13 x 37	83.15	13.98	2.65	2.75	37.50	-15.38	19.10	14.72	-9.91
15.	13 x 41	104.20	44.22*	30.90*	3.65	43.14	12.31	19.60	67.52*	61.98*
16.	29	107.25	-	-	3.50	-	-	24.45	-	-
17.	29 x 37	94.40	0.29	-11.98	2.70	26.76	-22.86	21.15	-7.36	-13.49
18.	29 x 41	116.55	24.75*	8.67	3.20	19.40	-8.57	25.05	40.10*	2.45
19.	37	81.00	-	-	0.75	-	-	21.20	-	-
20.	37 x 41	95.90	19.43	18.39	1.70	30.77	-8.11	18.40	13.23	-13.21
21.	41	79.60	-	-	1.85	-	-	11.30	-	-
C.D.(0.05)			18.27	21.09		1.78	2.06		6.07	7.01

*Significant at 5 per cent level

by the fifteen hybrids over their mid-parents and better parents. Compared to the mid-parental value, the percentage of heterosis in the fifteen hybrids ranged from -8.11 to 75.54. Positive heterosis was found in eleven hybrids viz., $V_2 \times V_{37}$ (75.54), $V_{13} \times V_{41}$ (44.22), $V_2 \times V_{41}$ (37.95), $V_{29} \times V_{41}$ (24.75), $V_{37} \times V_{41}$ (19.43), $V_{25} \times V_{41}$ (18.92). $V_{25} \times V_{13}$ (15.77), $V_{13} \times V_{37}$ (13.98), $V_2 \times V_{25}$ (5.14), $V_{25} \times V_{37}$ (4.07) and $V_{29} \times V_{37}$ (0.29). Four hybrids recorded negative heterosis. They were $V_2 \times V_{13}$(-2.85), $V_2 \times V_{29}$ (-8.11), $V_{25} \times V_{29}$ (-1.87) and $V_{13} \times V_{29}$ (-4.28). The positive heterosis recorded by $V_{13} \times V_{41}$, $V_2 \times V_{41}$ and $V_{29} \times V_{41}$ were statistically significant.

Compared to better parent the percentage of heterosis ranged from -23.17 to 30.90. The seven hybrids which recorded positive heterosis were $V_{13} \times V_{41}$ (30.90), $V_2 \times V_{41}$ (25.93), $V_{37} \times V_{41}$ (18.39), $V_{29} \times V_{41}$ (8.67), $V_{25} \times V_{41}$ (3.84), $V_{13} \times V_{37}$ (2.65) and $V_2 \times V_{25}$ (0.09). The positive heterosis recorded by $V_2 \times V_{41}$ and $V_{13} \times V_{41}$ were statistically significant. The cross $V_{13} \times V_{29}$ showed a significant negative heterosis.

Number of primary productive branches per plant:

The percentage of heterosis manifested by the fifteen hybrids over their mid-parents and better parents are presented in table 10-1. The percentage of heterosis ranged from -35.85 to 86.53 in the hybrids when compared to the mid-parental values. Heterosis was negative in the hybrids -

V_{25} x V_{29} (-4.47), V_{25} x V_{37} (-35.85) and V_{25} x V_{41} (-12.50). All the other hybrids expressed positive heterosis. Maximum percentage of positive heterosis was recorded in V_2 x V_{37} (86.53) followed by the hybrids V_{13} x V_{41} (43.14), V_{13} x V_{37} (37.50), V_{37} x V_{41} (30.77), V_2 x V_{25} (27.93), V_{29} x V_{37} (26.76) V_{25} x V_{13} (20.51), V_{29} x V_{41} (19.40), V_2 x V_{29} (16.66), V_2 x V_{41} (10.89), V_2 x V_{13} (6.92) and V_{13} x V_{29} (3.55). But none of the hybrids showed statistical significance. Compared to the better parent, the percentage of heterosis ranged from -62.64 in V_{25} x V_{37} to 16.13 in V_2 x V_{37}. Out of the fifteen hybrids, positive heterosis was recorded in six hybrids viz., V_2 x V_{37} (16.13), V_{13} x V_{41} (12.31), V_2 x V_{29} (10.00), V_2 x V_{25} (7.69), V_2 x V_{13} (4.62) and V_{25} x V_{13} (3.29). All the other hybrids recorded negative heterosis. The negative heterosis recorded in V_{25} x V_{37} was statistically significant.

Number of productive nodes on main axis:

Table 10-1 gives the percentage of heterosis manifested by the fifteen hybrids over their mid parents and better parents.

The percentage of heterosis ranged from -19.86 in V_{13} x V_{29} to 67.52 in V_{13} x V_{41} when compared to the mid-parental values. Out of the fifteen hybrids, positive heterosis was recorded by the hybrids, V_{13} x V_{41} (67.52), V_2 x V_{41} (46.81), V_{29} x V_{41} (40.10), V_{13} x V_{37} (14.72), V_2 x V_{37} (13.77), V_{37} x V_{41} (13.23), V_{25} x V_{13} (11.38),

V_{25} x V_{41} (10.81), V_{25} x V_{37} (2.56), V_{25} x V_{29} (4.47) and V_2 x V_{13} (1.69). Four hybrids recorded negative heterosis viz., V_2 x V_{29} (-19.23), V_{13} x V_{29} (-19.86), V_2 x V_{25} (-7.83) and V_{29} x V_{37} (-7.36). The positive heterosis manifested by the hybrids - V_2 x V_{41}, V_{13} x V_{41} and V_{29} x V_{41} were statistically significant. The percentage of heterosis over better parent ranged from -40.08 to 61.98. Except V_{13} x V_{41} (61.98), V_2 x V_{41} (15.44), V_2 x V_{37} (9.91) and V_{29} x V_{41} (2.45), all others showed negative heterosis over better parents. The positive heterosis recorded in V_{13} x V_{41} and negative heterosis recorded in V_{13} x V_{29} were statistically significant.

Number of pods on main axis:

The percentage of heterosis manifested by the fifteen hybrids over their mid-parents and better parents are given in table 18-2.

Compared to the mid-parental values, the percentage of heterosis in the fifteen hybrids ranged from -27.23 in V_2 x V_{29} to 77.35 in V_{13} x V_{41}. Heterosis was positive in eleven hybrids viz., V_{13} x V_{41} (77.35), V_2 x V_{41} (55.37), V_{25} x V_{37} (50.86), V_{29} x V_{41} (37.89), V_{25} x V_{13} (26.99), V_{37} x V_{41} (12.46), V_{13} x V_{37} (11.83), V_{25} x V_{41} (10.49), V_{25} x V_{29} (7.39), V_2 x V_{13} (4.26) and V_{29} x V_{37} (1.69). In the remaining four hybrids heterosis was negative. Maximum positive heterosis recorded in V_{13} x V_{41} and the positive heterosis recorded in V_{25} x V_{37} were statistically significant.

Table 16-2. Analysis on heterosis in single cross hybrids.

Sl. No.	Parents and hybrids	Mean number of pods/ plant	Percentage of heterosis over Mid parent	Percentage of heterosis over Better parent	Mean seed yield/ plant	Percentage of heterosis over Mid parent	Percentage of heterosis over Better parent	Mean number of pods on main axis	Percentage of heterosis over Mid parent	Percentage of heterosis over Better parent
1.	2	58.15	-	-	7.20	-	-	19.75	-	-
2.	2x25	56.85	-12.74	-21.21	8.03	-2.61	-13.55	20.60	-9.17	-19.53
3.	2x13	79.70	92.97*	37.06	10.82	58.33	50.11	14.70	4.26	-25.57
4.	2x29	69.85	-9.14	-26.94*	7.86	-22.95	-40.42	16.30	-27.23	-34.93
5.	2x37	76.30	61.39*	31.21	7.65	12.66	6.27	20.45	-2.15	-7.26
6.	2x41	62.90*	53.86*	8.17	6.73	21.26	-6.63	23.15	55.37	17.22
7.	25	72.15	-	-	9.30	-	-	25.60	-	-
8.	25x13	54.55	12.94	-24.39	5.07	-35.59	-45.38	21.05	26.99	-17.77
9.	25x29	60.45	-27.93*	-36.77*	8.28	-26.42	-37.24	27.20	7.39	6.25
10.	25x37	44.95	-17.19	-37.69*	6.62	-15.49	-28.71	35.95	50.86*	40.43*
11.	25x41	70.45	47.14*	-2.36	10.57	61.13	13.76	19.70	10.49	-23.05
12.	13	24.45	-	-	6.46	-	-	12.10	-	-
13.	13x29	73.70	-12.94	-22.91	12.08	22.86	25.51	16.30	-12.27	-34.93
14.	13x37	58.90	93.56*	61.81	9.29	44.74	-0.62	19.10	11.83	-13.38
15.	13x41	74.45	209.82*	204.49*	11.60	126.46*	-20.74	19.65	77.35*	62.39
16.	29	95.60	-	-	13.21	-	-	25.05	-	-
17.	29x37	57.95	-12.19	-39.38*	11.20	14.35	-25.89	23.95	1.69	-4.39
18.	29x41	106.70	79.03*	11.61	14.99	76.41*	-35.73	24.20	37.89	-3.39
19.	37	36.40	-	-	6.38	-	-	22.05	-	-
20.	37x41	44.10	47.00	21.15	7.33	44.19	-20.28	18.05	12.46	-18.14
21.	41	23.60	-	-	3.78	-	-	10.05	-	-
C.D.(0.05)			20.61	23.79		4.56	5.27		8.49	9.81

* Significant at 5 per cent level

The percentage of heterosis over better parent ranged from -34.93 to 62.39. Compared to the better parent four hybrids showed positive heterosis, viz., $V_{13} \times V_{41}$ (62.39), $V_{25} \times V_{37}$ (40.43), $V_2 \times V_{41}$ (17.22) and $V_{25} \times V_{29}$ (6.25). All other hybrids expressed negative heterosis. The positive heterosis manifested by $V_{25} \times V_{37}$ was statistically significant.

Total number of pods per plant:

Table 19-2 shows the percentage of heterosis manifested by the fifteen hybrids over their mid-parents and better parents in respect to total number of pods per plant. Compared to the mid-parental values the percentage of heterosis in the hybrids ranged from -27.93 in $V_{25} \times V_{29}$ to 209.82 in $V_{13} \times V_{41}$. Heterosis was positive in $V_{13} \times V_{41}$ (209.82), $V_{13} \times V_{37}$ (93.56), $V_2 \times V_{13}$ (92.97), $V_{29} \times V_{41}$ (79.03), $V_2 \times V_{37}$ (61.39), $V_2 \times V_{41}$ (53.86), $V_{25} \times V_{41}$ (47.14), $V_{37} \times V_{41}$ (47.00), and $V_{25} \times V_{13}$ (12.94). In the remaining hybrids heterosis was negative. The positive heterosis recorded by $V_2 \times V_{13}$, $V_2 \times V_{37}$, $V_2 \times V_{41}$, $V_{25} \times V_{41}$, $V_{13} \times V_{37}$, $V_{13} \times V_{41}$ and $V_{29} \times V_{41}$ and negative heterosis recorded by $V_{25} \times V_{29}$ were statistically significant.

Compared to better parent the percentage of heterosis ranged from -39.38 to 204.49. The seven hybrids with positive heterosis include ($V_{13} \times V_{41}$ (204.49), $V_{13} \times V_{37}$ (61.81), $V_2 \times V_{13}$ (37.06), $V_2 \times V_{37}$ (31.21), $V_{37} \times V_{41}$ (21.15),

V_{29} x V_{41} (11.61) and V_2 x V_{41} (8.17).

Seed yield per plant:

The percentage of heterosis manifested by the different hybrids over mid-parent and better parent are presented in table 18-2. Compared to mid-parental value the percentage of heterosis ranged from -35.59 to 126.46. The ten hybrids with positive heterosis include V_{13} x V_{41} (126.46), V_{29} x V_{41} (76.41), V_{25} x V_{41} (61.63), V_2 x V_{13} (58.33), V_{13} x V_{37} (44.74), V_{37} x V_{41} (44.19), V_{13} x V_{29} (22.86), V_2 x V_{41} (21.26), V_{29} x V_{37} (14.35) and V_2 x V_{37} (12.66). The remaining five hybrids showed negative heterosis. The positive heterosis recorded in V_{13} x V_{41} and V_{29} x V_{41} were statistically significant.

Compared to better parent, positive heterosis was noted in four hybrids. The percentage of heterosis ranged from -45.38 to 50.11. The hybrids which showed positive heterosis were V_2 x V_{13} (50.11), V_{13} x V_{29} (25.51), V_{25} x V_{41} (13.76) and V_2 x V_{37} (6.27). The negative heterosis recorded by V_2 x V_{29} (-40.42) was statistically significant.

1000-seed weight:

Table 18-3 shows the percentage of heterosis manifested by the fifteen hybrids over their mid-parents and better parents. The percentage of heterosis ranged from -21.43 to 9.16 in the hybrids when compared to the mid-parental values. Except in V_2 x V_{37} (9.16), V_2 x V_{13} (8.30) and V_{29} x V_{37}(3.29), the heterosis was negative in all other hybrids. The negative

heterosis manifested by the hybrids $V_{25} \times V_{13}$ (-21.43), $V_{13} \times V_{37}$ (-18.06), $V_{13} \times V_{41}$ (19.27), $V_{29} \times V_{41}$ (-18.93), $V_{13} \times V_{29}$ (-17.52), $V_{25} \times V_{41}$ (17.07), $V_2 \times V_{29}$ (-16.39) and $V_{37} \times V_{41}$ (-13.47) were statistically significant.

Compared to better parent, the percentage heterosis ranged from -38.37 to 7.19. Positive heterosis was recorded only by the two hybrids $V_2 \times V_{37}$ (7.19) and $V_2 \times V_{13}$ (3.03). All the other hybrids showed negative heterosis, of which those manifested by the hybrids $V_2 \times V_{29}$, $V_2 \times V_{41}$, $V_{25} \times V_{13}$, $V_{25} \times V_{41}$, $V_{13} \times V_{29}$, $V_{13} \times V_{37}$, $V_{13} \times V_{41}$, $V_{29} \times V_{41}$ and $V_{37} \times V_{41}$ were statistically significant.

Oil content (Percentage):

The percentage of heterosis manifested by the fifteen hybrids over their mid-parents and better parents in respect of oil content are presented in table 10-3. The percentage of heterosis ranged from -14.12 to 46.23. Compared to mid parental values. Heterosis was negative only in the hybrid $V_2 \times V_{37}$. In thirteen hybrids heterosis was positive. The positive heterosis recorded for the different hybrids were 46.23 ($V_{13} \times V_{37}$), 42.87 ($V_{13} \times V_{41}$), 38.24 ($V_{25} \times V_{13}$), 24.57 ($V_{25} \times V_{29}$), 21.87 ($V_{25} \times V_{41}$), 21.31 ($V_{29} \times V_{41}$), 18.79 ($V_2 \times V_{25}$), 18.26 ($V_{37} \times V_{41}$), 15.56 ($V_2 \times V_{13}$), 12.84 ($V_2 \times V_{29}$), 5.15 ($V_{25} \times V_{37}$), 1.91 ($V_2 \times V_{41}$) and 1.43 ($V_{29} \times V_{37}$). In the hybrid $V_{13} \times V_{29}$ heterotic effect was nil. The positive heterosis recorded in $V_{13} \times V_{37}$ and

$V_{13} \times V_{41}$ were statistically significant.

Compared to better parent, the percentage of heterosis in the different hybrids ranged from -16.39 to 40.84. Heterosis was positive in $V_{13} \times V_{41}$ (40.84), $V_{13} \times V_{37}$ (38.86), $V_{25} \times V_{13}$ (37.68), $V_{25} \times V_{41}$ (19.66), $V_2 \times V_{25}$ (15.35), $V_{37} \times V_{41}$ (13.85), $V_2 \times V_{13}$ (12.65), $V_{29} \times V_{41}$ (9.59), $V_2 \times V_{29}$ (3.01) and $V_2 \times V_{41}$ (0.74). The remaining five hybrids recorded negative heterosis. None of the hybrids showed statistical significance.

Number of days for first flowering:

Table 10-3 shows the percentage of heterosis manifested by the fifteen hybrids over their mid-parents and better parents in respect of number of days for first flowering. Compared to the mid parental values, the percentage of heterosis ranged from -9.71 to 7.34. Positive heterosis was found only in five hybrids, $V_{25} \times V_{37}$ (7.34), $V_{37} \times V_{41}$ (5.69), $V_{13} \times V_{41}$ (1.57), $V_{13} \times V_{37}$ (1.25) and $V_{13} \times V_{29}$ (1.18). Nine hybrids showed negative heterosis and one cross showed no heterosis. None of the hybrids showed statistical significance for the heterotic effects. Maximum negative heterosis was expressed in the cross $V_2 \times V_{13}$ (-9.71).

Compared to the better parent (early flowering parent), the percentage of heterosis ranged from -4.39 to 18.99. The hybrids - $V_2 \times V_{25}$, $V_2 \times V_{13}$ and $V_2 \times V_{29}$ showed no heterotic effect. Ten hybrids showed positive heterosis. They were $V_{13} \times V_{41}$ (18.99), $V_{25} \times V_{37}$ (17.20), $V_{37} \times V_{41}$ (12.35),

Table 10-3. Analysis on heterosis in single cross hybrids.

Sl. No.	Parents and hybrids	Mean 1000-seed weight	Percentage of heterosis over		Mean oil content (%)
			Mid parent	Better parent	
1.	2	2.68	-	-	44.50
2.	2 x 25	2.69	-8.19	-15.41	51.33
3.	2 x 13	3.06	8.30	3.03	50.13
4.	2 x 29	2.50	-16.39*	-24.24*	55.53
5.	2 x 37	2.98	9.16	7.19	39.29
6.	2 x 41	3.06	-11.65	-26.97**	44.83
7.	25	3.18	-	-	41.91
8.	25 x 13	2.42	-21.43*	-23.89*	58.17
9.	25 x 29	2.94	-9.26	-10.91	52.42
10.	25 x 37	2.62	-12.08	-17.61	46.74
11.	25 x 41	3.06	-17.07*	-26.97*	52.04
12.	13	2.97	-	-	42.25
13.	13 x 29	2.59	-17.52*	-21.52*	48.05
14.	13 x 37	2.36	-18.06*	-20.54*	65.25
15.	13 x 41	2.89	-19.27*	-31.03*	61.25
16.	29	3.30	-	-	53.91
17.	29 x 37	3.14	3.29	-4.85	51.17
18.	29 x 41	3.04	-18.93*	-27.45*	59.08
19.	37	2.78	-	-	46.99
20.	37 x 41	3.02	-13.47*	-38.37*	53.50
21.	41	4.19	-	-	43.49
C.D.(0.05)			0.49	0.58	

* Significant at 5

Percentage of heterosis over		Mean No. of days for first flowering	Percentage of heterosis over	
Mid parent	Better parent		Mid parent	Better parent
-	-	48.00	-	-
18.79	15.35	48.00	0	0
15.56	12.65	39.50	-9.71	0
12.84	3.01	45.50	-2.67	0
-14.12	-16.39	44.00	-0.56	8.64
1.91	0.74	47.50	-8.65	-1.04
-	-	48.00	-	-
38.24	37.68	40.50	-7.43	2.53
24.57	-2.76	43.50	-6.95	-4.39
5.15	-0.53	47.50	7.34	17.28
21.87	19.66	50.50	-2.88	5.21
-	-	39.50	-	-
-	-10.81	43.00	1.18	8.86
46.23*	38.86	40.50	1.25	2.53
42.87*	40.84	47.00	1.57	18.99
-	-	45.50	-	-
1.43	-5.08	42.50	-1.16	4.94
21.31	9.59	47.00	-7.39	3.29
-	-	40.50	-	-
18.26	13.85	45.50	5.69	12.35
-	-	56.00	-	-
16.91	19.52		5.28	6.10

5 per cent level

V_{13} x V_{29} (8.86), V_2 x V_{37} (8.64), V_{25} x V_{41} (5.21), V_{29} x V_{37} (4.94), V_{29} x V_{41} (3.29), V_{13} x V_{37} (2.53) and V_{25} x V_{13} (2.53). Two hybrids viz., V_2 x V_{41} (-1.04) and V_{25} x V_{29} (-4.39) recorded negative heterosis. The positive heterosis exhibited by the two hybrids V_{13} x V_{41} and V_{25} x V_{37} were statistically significant.

A.2. Combining ability analysis in F_1

Analysis of variance of the various characters in F_1 generation is presented in table 9. The data clearly show a highly significant difference for all the attributes except oil content.

The analysis of variance for general and specific combining ability is presented in table 11. The mean squares due to general combining ability (g.c.a) were significant for all the characters except oil content whereas the mean squares due to specific combining ability (s.c.a) were significant for characters like plant height, total number of pods per plant, seed yield per plant and 1000-seed weight.

The estimates of the g.c.a effects of the six parental populations and s.c.a effects of the fifteen F_1 populations and tests of significance are presented in tables 12 and 13 respectively.

Plant height at maturity:

Analysis of variance due to g.c.a and s.c.a were highly significant. This indicates that both additive and

Table 11. Analysis of variance for combining ability in single cross F_1 generation.

Source	D.F.	Mean sum of squares								
		Days for first flowering	Plant height at maturity	No. of primary productive branches/ plant	No. of productive nodes on main axis	No. of pods on main axis	Total number of pods/ plant	Seed yield/ plant	1000-seed weight	Oil content (Percentage)
G.C.A.	5	54.510**	430.179**	3.147**	38.714**	70.012**	639.433**	11.994**	0.302**	29.108
S.C.A.	15	4.050	119.150*	0.383	9.674	18.214	350.181**	6.467*	0.102**	50.936
Error	42	4.280	51.131	0.487	5.645	11.063	65.059	3.188	0.038	43.785

* Significant at 5 per cent level

** Significant at 1 per cent level

Table 12. Estimates of general combining ability (g.c.a).

Parents	Days for first flowering	Plant height at maturity	No. of primary productive branches/ plant	No. of productive nodes on main axis	No. of pods on main axis	Total number of pods/ plant	1000-seed weight	Oil content (Percentage)	Seed yield/ plant
2	0.500	1.767	0.335	-0.127	-1.285	3.481	-0.105	-2.729	0.748
25	1.187	7.442**	0.629**	2.754**	3.389**	-0.313	-0.051	-1.304	0.539
13	-0.337	-12.000**	0.310	-3.352**	-3.748**	-5.481*	-0.154*	1.551	0.035
29	-0.499	4.029	0.260	1.460	1.633	15.725**	0.040	2.393	2.417**
37	1.937**	-5.583*	-1.008**	0.848	2.077	-9.881*	-0.103	-0.627	-8.283**
41	4.125**	4.348	-0.527*	-1.580*	-2.517*	-3.531	0.373**	0.718	-0.337
S.E. (gi)	±0.667	±2.307	±0.225	±0.767	±1.073	±2.603	±0.063	±2.136	±0.576
S.E. (gi-gj)	±1.034	±3.575	±0.349	±1.187	±1.663	±4.032	±0.097	±3.308	±0.893
C.D.(0.05) gi-gj	2.068	7.150	0.698	2.374	3.326	8.064	0.194	6.620	1.786

* Significant at 5 per cent level
**Significant at 1 per cent level

Table 13. Estimates of specific combining ability (s.c.

Crosses	Days for first flower-ing	Plant height at maturity	No. of primary productive branches/ plant	No. of produc-tive nodes on main axis
2 x 25	1.098	1.367	0.790	-1.908
2 x 13	-2.839	-7.588	-0.391	-0.552
2 x 29	0.285	-9.319	0.109	-3.714
2 x 37	0.223	3.042	1.128	2.348
2 x 41	-2.339	19.112**	-0.204	4.279*
25 x 13	-2.526	7.686	0.615	1.416
25 x 29	-2.402	-2.695	-0.185	1.254
25 x 37	3.036	-3.321	-1.066	0.217
25 x 41	-0.027	2.786	-0.447	-0.902
13 x 29	1.661	-5.801	-0.216	-3.690
13 x 37	0.598	4.561	0.303	1.373
13 x 41	1.035	15.680*	0.721	4.304*
29 x 37	-0.276	-0.219	0.303	-1.389
29 x 41	-1.839	11.999	0.321	4.942*
37 x 41	1.901	0.962	0.090	-1.095
S.E.(S_{ij})	1.833	6.338	0.618	2.106
S.E.($S_{ij}-S_{ik}$)	2.736	9.459	0.923	3.143
S.E.($S_{ij}-S_{kl}$)	2.533	8.758	0.855	2.909
C.D.(0.05)				
($S_{ij}-S_{ik}$)	5.472	18.920	1.846	6.286
" ($S_{ij}-S_{kl}$)	5.066	17.520	1.710	5.820

* Significant
** Significant

a) in F_1 generation.

No. of pods on main axis	Total number of pods/ plant	1000 seed weight	Oil content (Percentage)	Seed yield/ plant
-2.666	-0.833	-0.080	4.656	0.535
-0.979	19.593**	0.392*	0.601	2.745
-4.759	-11.363	-0.357*	5.159	-2.589
-1.054	20.690**	0.262	-8.055	0.446
6.240*	0.943	-0.134	-0.865	-0.972
0.246	-1.663	-0.300	7.212	-3.209*
1.015	-16.969*	0.024	0.619	-2.381
9.321**	-6.863	-0.155	-2.036	-7.794
-2.334	12.287	-0.189	1.922	2.666
-2.297	1.449	-0.225	-6.574	0.842
0.059	12.255	-0.313	13.614*	1.300
5.203	21.455**	-0.247	8.271	3.120*
-0.472	-9.900	0.272	-1.308	0.828
4.371	32.499**	-0.301	5.264	4.124**
-2.222	-4.495	-0.175	2.702	-0.288
2.948	7.149	0.173	5.865	1.583
4.399	10.670	0.258	8.754	2.360
4.073	9.878	0.239	8.104	2.187
8.798	21.340	0.516	17.510	4.720
8.146	19.760	0.478	16.210	4.370

at 5 per cent level
at 1 per cent level

non-additive gene actions govern the expression of this character. The magnitude of variance due to g.c.a was about three and a half times of that due to s.c.a depicting preponderance of additive gene action.

The parents V_{25}, V_{13} and V_{37} showed significant g.c.a effects. Among these only V_{25} had the positive g.c.a effect (7.442) while the others, V_{13} and V_{37} showed negative g.c.a effects of -12.00 and -5.583 respectively. Thus V_{25} is a good general combiner for incorporating higher plant height and V_{13} and V_{37} for dwarfness. Among the F_1s, the s.c.a effects were significant and positive in $V_2 \times V_{41}$ and $V_{13} \times V_{41}$, the s.c.a effects being 19.112 and 15.680 respectively. The maximum value was noted in $V_2 \times V_{41}$.

Number of primary productive branches per plant:

Variance due to g.c.a was highly significant and was eight times higher than that due to s.c.a An insignificant s.c.a effect supports the fact that this particular character is influenced by preponderance of additive gene action.

The parent V_{25} had significant positive g.c.a effect (0.629) while V_{37} and V_{41} recorded significant negative effects, -1.008 and -0.527 respectively. So V_{25} is a good general combiner for incorporating higher branching ability, while V_{37} and V_{41} are good general combiners for non-branching-ness. None of the F_1s showed significant s.c.a effect.

Number of productive nodes on main axis:

Variance due to g.c.a was highly significant and was about four and a half times higher than that due to s.c.a. The s.c.a effect was not significant which indicated that the character is governed mostly by additive genes. The parental varieties V_{25}, V_{13} and V_{41} recorded significant g.c.a effects. Variety 25 showed significant positive effect (2.754) while the other two varieties V_{13} and V_{41} showed significant negative effects of -1.008 and -0.527 respectively. Variety 25 is screened out as a general combiner for higher number of productive nodes on main axis.

Among the different F_1s, V_2 x V_{41}, V_{13} x V_{41} and V_{29} x V_{41} recorded significant positive s.c.a effects of 4.279, 4.304 and 4.942 respectively.

Number of pods on main axis:

In the case of number of pods on main axis also variance due to g.c.a was highly significant and was about three times higher than that of s.c.a. The s.c.a effect was not significant indicating that the character is governed mostly by additive genes. The variety 25 showed high positive g.c.a effect of 3.389 while V_{13} and V_{41} showed significant negative g.c.a effects of -3.748 and -2.517 respectively. Variety 25 is the best general combiner for maximum number of pods on main axis. Among the different cross combinations V_2 x V_{41} and V_{25} x V_{37} showed significant positive s.c.a

effects of 6.240 and 9.321 respectively. It indicates that these are specific combinations which can yield maximum pods on main axis.

Total number of pods per plant:

The highly significant g.c.a and s.c.a varianees recorded for this character showed that both additive and non-additive gene actions were involved in the expression of this particular character. The magnitude of g.c.a variance was almost double to that of s.c.a. Variety 13 and V_{37} recorded significant negative g.c.a effects while V_{29} showed significant positive g.c.a effect of 15.725. The g.c.a effects of V_{13} and V_{37} were -5.481 and -9.881 respectively. The variety 29 is the best general combiner for maximum pods per plant. Among the different crosses, $V_2 \times V_{13}$, $V_2 \times V_{37}$, $V_{25} \times V_{29}$, $V_{13} \times V_{41}$ and $V_{29} \times V_{41}$ recorded significant s.c.a effects, the values being 19.593, 20.690. 16.969, 21.455 and 32.499 respectively. The s.c.a effects were positive in all the above crosses except in the cross $V_{25} \times V_{29}$. The maximum positive s.c.a effect was recorded by the cross $V_{29} \times V_{41}$ followed by $V_{13} \times V_{41}$, $V_2 \times V_{37}$ and $V_2 \times V_{13}$ respectively. These are good specific combinations which yield maximum pods per plant.

Seed yield per plant:

As regards grain yield per plant, analysis of variance showed significant g.c.a and s.c.a varianees. Statistical

analysis indicates the influence of both additive and non-additive genes in the expression of this character. The g.c.a variance was almost double to that of s.c.a depicting preponderance of additive gene action. Two varieties (V_{29} and V_{37}) showed significant g.c.a effects. The g.c.a effect of V_{29} was significant and positive (2.417) while the g.c.a effect of V_{37} was significant and negative. The crosses, $V_{25} \times V_{13}$, $V_{13} \times V_{41}$ and $V_{29} \times V_{41}$ showed significant s.c.a effects of which $V_{25} \times V_{13}$ showed negative effect (-3.209). The s.c.a effects of the other two crosses were 3.120 and 4.124 respectively.

1000-seed weight:

Both g.c.a and s.c.a variances were highly significant. Here also both additive and non-additive genes contribute equally for the expression of this trait. Among the different parental varieties significant g.c.a effects were observed in V_{13} and V_{41}. The best general combiner was V_{41} with the highly significant positive effect of 0.373 while V_{13} recorded significant negative effect (0.154). The s.c.a effects were significant only in two crosses. The cross $V_2 \times V_{13}$ showed significant positive s.c.a effect and it was the best specific combination for maximum 1000-seed weight. The s.c.a effect of $V_2 \times V_{29}$ was significant and negative.

Oil content:

The variances due to g.c.a and s.c.a were not significant.

As regards g.c.a effects, none of the varieties showed significant effect. Among the different crosses, $V_{13} \times V_{37}$ only recorded significant positive s.c.a effect of 13.614.

Number of days for first flowering:

The g.c.a variance was highly significant for this particular character. The magnitude of g.c.a variance was thirteen and a half times greater than that due to s.c.a It indicated that the character is completely under the control of additive gene action. Among the g.c.a effects of parental varieties V_{37} and V_{41} showed significant positive effects of 1.937 and 4.125 respectively. None of the crosses recorded significant s.c.a effect.

A-3. Components of variation and allied parameters

The components of variation and genetic ratios were made from F_1. The analysis of variance for F_1 is presented in table 9. The results on components of variation, genetic ratios and heritability per cent (narrow sense) are presented in tables 14 and 15. The validity of the assumptions of diallel cross was tested using t^2 test as suggested by Hayman (1954). The results revealed that the assumptions underlying diallel analysis were valid for all the traits.

Plant height at maturity:

The estimates of $\hat{D}$, $\hat{H}_1$ and $\hat{F}$ were significant in F_1. The value of $\hat{h}^2$ was not significant in F_1. The mean degree

of dominance in F_1 (1.31) indicated over dominance. The distribution of genes with positive and negative effects were not symmetrical in F_1 (0.14) as the value was less than 0.25. The proportion of dominant to recessive alleles indicated that dominant alleles were in excess in F_1. Heritability estimate was 60 per cent in F_1.

Number of primary productive branches per plant:

The estimates of $\hat{D}$, $\hat{H}_1$, $\hat{H}_2$ and $\hat{h}^2$ were significant in F_1. $\hat{F}$ was not significant in F_1. The non-significant values of $\hat{F}$ in F_1 indicated that the expression of this character was not affected by the dominant genes. The mean degree of dominance in F_1 (0.84) indicated partial dominance. The distribution of genes with positive and negative effects was not symmetrical in F_1 as the value was only 0.22. The proportion of dominance to recessive alleles in F_1 (1.18) indicated the predominance of dominant alleles. The heritability estimate was 66.0 per cent in F_1.

Number of productive nodes on main axis:

In F_1 the values for $\hat{D}$, $\hat{F}$, $\hat{H}_1$ and $\hat{H}_2$ were significant indicating the importance of both additive and non-additive components. $\hat{h}^2$ was not significant in F_1. The value for mean degree of dominance in F_1 (1.04) indicated over-dominance. The distribution of genes with positive and negative effects was not symmetrical in F_1 (0.19). Dominant alleles were found more in F_1. Heritability estimate was 46.00 per cent in F_1.

Number of pods on main axis:

The estimates for $\hat{D}$, $\hat{H}_2$, $\hat{F}$ and $\hat{h}^2$ were not significant in F_1. The value for mean degree of dominance in F_1 (1.30) indicated over dominance. The distribution of genes with positive and negative effects showed asymmetry as indicated by the value, 0.20 in F_1. The dominant alleles were in excess in F_1 as indicated by the value 1.39 in F_1. Heritability estimate for F_1 was 25.00 per cent.

Total number of pods per plant:

The estimated values for $\hat{D}$, $\hat{H}_1$, $\hat{H}_2$, $\hat{h}^2$ and $\hat{F}$ in F_1 were significant, indicating the influence of additive and non-additive components. The value for mean degree of dominance indicated partial dominance in F_1 (0.13). In this case also the distribution of genes with positive and negative effects showed asymmetry as indicated by the value 0.17 in F_1. The proportion of dominant to recessive genes in the parents showed excess of dominant alleles in F_1. The heritability estimate for F_1 was 32.0 per cent.

1000-seed weight:

The estimates for $\hat{D}$, $\hat{H}_1$, $\hat{H}_2$, $\hat{h}^2$ and $\hat{F}$ were significant in F_1 indicating the influence of both additive and non-additive components. The mean degree of dominance was 1.12 in F_1 indicating over dominance for the expression of the character. The distribution of genes with positive and negative effects showed asymmetry as it was in the other

characters. The proportion of dominant to recessive genes in the parents showed excess of dominant alleles in F_1. The heritability estimate was 25.00 per cent for F_1.

Seed yield per plant:

The estimates of $\hat{D}$, $\hat{H}_1$, $\hat{H}_2$ and $\hat{F}$ were significant in F_1 indicating the importance of both additive and non-additive components. The mean degree of dominance was 2.76 in F_1 indicating over dominance for the expression of the character. In this case also the distribution of genes with positive and negative effects showed asymmetry. The proportion of dominant to recessive genes in the parents showed excess of dominant alleles in F_1. Heritability estimate was 27.00 per cent.

Oil content (Percentage):

The estimates of $\hat{D}$, $\hat{H}_1$, $\hat{H}_2$, $\hat{F}$ and $\hat{h}^2$ were not significant in F_1. Mean degree of dominance for the character indicated over dominance in F_1. Distribution of genes with positive and negative effects showed asymmetry. The proportion of dominant and recessive genes in the parents showed excess of dominant alleles in F_1. Heritability estimate was 16.00 per cent for F_1.

Number of days for first flowering:

The estimates of $\hat{D}$, $\hat{H}_1$, $\hat{H}_2$, $\hat{h}^2$ and $\hat{F}$ were significant in F_1 indicating the influence of additive and non-additive components. Estimate for mean degree of dominance in F_1 was

Table 14. Estimates of components of variation in F_1 generation.

Parameters	Days for first flowering	Plant height at maturity	No. of primary productive branches/ plant	No. of productive nodes on main axis	No. of pods on main axis	Total No. of pods/ plant	1000-seed weight	Seed yield/ plant	Oil content (Percentage)
$\hat{D}$	140.20**	1096.83**	6.67**	144.10**	163.36	3258.79**	1.15*	37.08**	31.85
	±3.38	±303.36	±0.53	±20.28	±174.91	±366.18	±0.01	±11.04	±282.18
$\hat{F}$	48.80**	860.64*	0.91	120.29**	70.77	4058.84**	0.98**	39.80**	61.86
	±4.13	±370.54	±0.64	±24.77	±260.97	±447.28	±0.01	±13.48	±344.60
$\hat{H}_1$	52.99**	1900.66*	4.74**	156.30**	279.54**	5975.41**	1.46**	102.57**	671.40
	±8.59	±770.08	±0.32	±51.49	±1127.21	±929.58	±0.05	±28.02	±716.31
$\hat{H}_2$	48.96**	1135.68	4.33**	119.88**	233.96	4126.88**	1.18**	75.66**	565.88
	±7.67	±687.93	±0.29	±45.99	±899.55	±830.41	±0.04	±25.03	±639.92
$\hat{h}^2$	21.03**	245.55	1.85*	24.63	50.59	2226.83**	1.39**	22.17	529.11
	±5.16	±463.03	±0.81	±30.96	±407.51	±558.92	±0.02	±16.85	±430.71
$\hat{E}$	4.20	48.75	0.47*	5.37	10.77	69.13	0.36**	4.29	49.42
	±1.28	±114.67	±0.20	±7.66	±24.99	±138.41	±0.01	±4.17	±106.66
t^2 value	0.38	4.03	1.55	0.12	0.17	0.01	0.03	2.21	0.76

* Significant at 5 per cent level
** Significant at 1 per cent level

0.61 indicating partial dominance. The distribution of genes with positive and negative effects showed asymmetry as it was in the case of other characters. The proportion of dominant and recessive genes in the parents showed excess of dominant alleles in F_1. Heritability estimate was 74.00 per cent for F_1.

B. Performance analysis in double cross hybrids

The mean values and the analysis of variance for various characters in the single and double cross hybrids and parents are presented in table 16. In general the treatments showed significant differences for all the nine characters studied.

Plant height at maturity:

The variation in plant height in the double cross hybrids is represented in Fig.2.

The mean height recorded by the parental varieties ranged from 65.86 to 112.0 cm in V_{37} and V_{25} respectively whereas the range in double cross hybrids were from 69.06 in $(V_{29} \times V_{41})(V_2 \times V_{13})$ to 98.46 in $(V_{29} \times V_{37})(V_{25} \times V_{13})$. The values recorded by the hybrids $(V_{25} \times V_{13})(V_{29} \times V_{41})$, $(V_2 \times V_{13})$ $(V_{25} \times V_{29})$ and $(V_{25} \times V_{41})(V_2 \times V_{37})$ were 92.86, 91.93 and 90.73 respectively which were very close to the highest value. In general the double cross hybrids showed a higher value in plant height compared to dwarf varieties used as parents. The dwarf varieties in combination with tall, medium or dwarf varieties gave medium plant height in double cross hybrids.

Number of primary productive branches per plant:

The variation in the number of primary productive branches per plant in the double cross hybrids is represented in Fig.3.

Mean number of primary productive branches recorded for the parental varieties V_2, V_{25}, V_{29}, V_{37}, V_{41} and V_{13} were 6.40, 5.30, 4.33, 0.33, 1.76 and 4.16 respectively. Minimum

number of primary productive branches was recorded by the parent V_{37} and maximum number of primary productive branches was recorded by the parent V_2. Among the double cross hybrids the number of primary productive branches ranged from 0.46 in $(V_{25} \times V_{41})(V_2 \times V_{37})$ to 2.40 in two hybrids namely $(V_{25} \times V_{13})$ $(V_2 \times V_{29})$ and $(V_2 \times V_{13})(V_{25} \times V_{29})$. The hybrids $(V_{25} \times V_{37})$ $(V_{29} \times V_{41})$, $(V_{25} \times V_{29})(V_2 \times V_{41})$, $(V_{29} \times V_{37})$ $(V_2 \times V_{25})$, $(V_2 \times V_{25})(V_{29} \times V_{37})$ and $(V_2 \times V_{23})(V_{29} \times V_{41})$ also recorded lower values being 0.73, 0.86, 0.73, 0.86 and 0.80 respectively. In almost all the combinations the mean number of productive branches per plant showed a significant positive shift in mean values.

Number of productive nodes on main axis:

The variation in the number of productive nodes on main axis in the double cross hybrids is represented in Fig.4.

Mean number of productive nodes on main axis recorded for the parental varieties were 20.33, 14.73, 26.60, 16.60, 22.60 and 12.36 in V_2, V_{13}, V_{25}, V_{29}, V_{37} and V_{41} respectively. The lowest value was recorded by the parent V_{41} and the highest value was recorded by V_{25}. The parents V_{37} and V_2 also recorded higher values. Among the double cross hybrids, the values ranged from 22.20 in $(V_{29} \times V_{37})(V_{25} \times V_{13})$ to 12.26 recorded by $(V_2 \times V_{25})(V_{29} \times V_{41})$. The hybrid $(V_{25} \times V_{29})$ $(V_2 \times V_{37})$ recorded a value of 12.46 which was very close to the lowest value recorded for the hybrid $(V_2 \times V_{25})(V_{29} \times V_{41})$.

The values recorded for the hybrids (V_{25} x V_{37})(V_2 x V_{41}), (V_{29} x V_{37}) (V_2 x V_{25}) and (V_{29} x V_{41})(V_2 x V_{25}) were 20.00, 21.93 and 20.20 respectively which were very close to the highest value recorded for the hybrid (V_{29} x V_{37})(V_{25} x V_{13}).

Number of pods on main axis:

The variation in the number of pods on main axis in the double cross hybrids is represented in Fig.5.

Mean number of pods on main axis recorded by the parental varieties - V_2, V_{13}, V_{25}, V_{29}, V_{37} and V_{41} were 18.27, 14.36, 39.96, 19.82, 23.82 and 12.00 respectively. The highest value was recorded by the parent V_{25} and the lowest by V_{41}. The mean number of 23.82 recorded for the parent V_{37} was also higher. The other parents V_2, V_{29} and V_{13} recorded lower values of 18.27, 19.82 and 14.36 respectively. Among the double cross hybrids the values ranged from 9.66 recorded by (V_{29} x V_{41})(V_{25} x V_{37}) to 20.40 recorded by (V_{25} x V_{37}) (V_{29} x V_{41}). The value recorded for (V_2 x V_{25})(V_{29} x V_{41}) was 12.74 and was close to the lowest value recorded by the parent V_{41}. The values recorded by (V_{25} x V_{37})(V_2 x V_{29}) and (V_{29} x V_{37})(V_2 x V_{25}) were 20.06 and 20.27 respectively which were close to the highest value recorded by (V_{29} x V_{41}) (V_{25} x V_{37}).

Total pods per plant:

The variation in total pods per plant in the double cross hybrids is represented in Fig.6.

Among the parental varieties the mean number of pods per plant varied from 32.33 in V_{37} to 87.66 in V_{25}. The parents V_2 and V_{29} recorded intermediate values of 51.26 and 50.00 respectively. The values recorded by the double cross hybrids ranged from 16.53 recorded for the hybrid $(V_2 \times V_{25})$ $(V_{29} \times V_{37})$ to 41.80 recorded for $(V_{29} \times V_{37})(V_{25} \times V_{13})$. The hybrid $(V_2 \times V_{13})(V_{25} \times V_{29})$ recorded a value of 41.13 which was very close to the highest value. The values recorded for the hybrids $(V_{29} \times V_{41})(V_2 \times V_{13})$ and $(V_2 \times V_{29})(V_{25} \times V_{13})$ were 18.07 and 18.80 which were close to the lowest value.

Seed yield per plant:

The variation in the seed yield per plant in the double cross hybrids is represented in Fig. 8.

Mean values for seed yield per plant in the parental varieties ranged from 5.07 recorded for V_{13} to 16.72 recorded for V_{25}. Among the hybrids, the values ranged from 2.45 recorded for $(V_2 \times V_{25})(V_{29} \times V_{37})$ to 5.37 recorded for $(V_{29} \times V_{37})(V_{25} \times V_{13})$. The hybrids $(V_{29} \times V_{41})(V_2 \times V_{13})$, $(V_2 \times V_{41})(V_{29} \times V_{37})$, $(V_2 \times V_{29})(V_{25} \times V_{13})$, $(V_{25} \times V_{29})$ $(V_2 \times V_{37})$, $(V_{25} \times V_{29})(V_2 \times V_{41})$ and $(V_{25} \times V_{41})(V_2 \times V_{37})$ recorded very low values compared to parents. But the values recorded by the hybrids $(V_2 \times V_{13})(V_{25} \times V_{29})$, $(V_{25} \times V_{13})$ $(V_{29} \times V_{41})$, $(V_{29} \times V_{37})(V_2 \times V_{25})$ and $(V_2 \times V_{41})(V_{25} \times V_{29})$ were very close to the highest value.

1000-seed weight:

The variation in thousand seed weight in the double cross hybrids is represented in Fig. 7.

Among the parental varieties, the mean values ranged from 2.65 recorded for V_{29} to 2.88 recorded for V_{37}. The value recorded for V_{13} (2.85) was very close to the highest value. The other parental varieties recorded close values. Among the double cross hybrids, $(V_2 \times V_{41})(V_{25} \times V_{29})$ recorded maximum weight of 3.44. The hybrids $(V_{25} \times V_{41})(V_2 \times V_{29})$ recorded a closer value of 3.33. The minimum value of 2.62 was recorded for the hybrid $(V_2 \times V_{25})(V_{29} \times V_{37})$.

Oil content:

Variation in oil content in the double cross hybrids is represented in Fig.9.

In the parental varieties, the percentage of oil content ranged from 53.20 recorded for V_{37} to 43.26 recorded for V_{41}. The parent V_{29} also recorded a higher value of 51.26. Among the double cross hybrids, 75.33 per cent was recorded for $(V_2 \times V_{29})(V_{25} \times V_{13})$. Oil percentage recorded for $(V_{25} \times V_{41})$ $(V_2 \times V_{37})$, $(V_2 \times V_{29})(V_{25} \times V_{41})$ and $(V_{25} \times V_{13})(V_2 \times V_{37})$ were 72.00, 70.50 and 66.00 respectively which were comparatively higher values. The minimum value of 26.33 was recorded for $(V_{25} \times V_{37})(V_{29} \times V_{41})$. The values recorded for the hybrids $(V_{29} \times V_{41})(V_{25} \times V_{13})$, $(V_{25} \times V_{13})(V_{29} \times V_{41})$ were 29.17 and 32.16 which were very low compared to those of other hybrids and also with the parental varieties.

Table 15. Estimates of components of variation (proportional values)

Parameters		No. of days for first flower-ing	Plant height at maturity	No. of primary produc-tive branches/ plant	No. of produc-tive nodes on main axis	No. of pods on main axis	Total number of pods/ plant	1000-seed weight	Seed yield/ plant	Oil con-tent (Percen-tage)
$(\hat{H}_1/\hat{D})^{\frac{1}{2}}$	F_1	0.61	1.31	0.84	1.04	1.30	0.13	1.12	2.76	4.59
$(\hat{H}_2/4\hat{H}_1)$	F_1	0.23	0.14	0.22	0.19	0.20	0.17	0.20	0.18	0.21
$\frac{(4\hat{D}\hat{H}_1)^{\frac{1}{2}} + \hat{F}}{(4\hat{D}\hat{H}_1)^{\frac{1}{2}} - \hat{F}}$	F_1	1.79	1.85	1.18	2.34	1.39	2.70	2.21	1.95	1.53
Heritability (Narrow sense)	F_1	0.74	0.60	0.66	0.46	0.25	0.32	0.25	0.27	0.16

Table 16. Phenotypic expressions on various characters in cross hybrids.

Sl. No.	Treatments	Number of days for first flowering	Plant height at maturity (in cm)	Number of primary productive branches/ plant	Number of productive nodes on main axis
1.	2	34.33	71.80	6.40	20.33
2.	25	40.33	112.01	5.30	26.60
3.	29	53.33	84.60	4.33	16.60
4.	37	39.00	65.86	0.33	22.60
5.	41	40.66	68.76	1.76	12.36
6.	13	35.00	67.23	4.16	14.73
7.	2 x 25	48.00	100.50	4.20	18.50
8.	2 x 13	38.50	78.35	3.40	16.10
9.	2 x 29	45.50	90.65	3.85	17.85
10.	2 x 37	44.00	95.40	3.60	23.30
11.	2 x 41	47.50	121.40	2.75	22.80
12.	25 x 13	40.50	99.30	4.70	21.05
13.	25 x 29	43.50	104.95	3.85	25.70
14.	25 x 37	47.50	97.70	1.70	24.05
15.	25 x 41	50.50	110.75	2.80	20.50
16.	13 x 29	43.00	82.40	3.50	14.65

in the parents and single and double

Number of pods on main axis	Total number of pods/ plant	Seed yield/ plant (in g)	1000-seed weight (in g)	Oil Content percentage)
18.27	51.26	12.54	2.76	45.00
39.96	87.66	16.72	2.67	45.86
19.82	50.00	8.53	2.65	51.26
23.82	32.33	6.63	2.88	53.20
12.00	33.06	5.25	2.66	43.26
14.36	37.66	5.07	2.85	46.53
17.80	55.50	8.02	2.69	51.00
12.70	79.70	10.80	3.06	50.13
16.30	69.85	7.87	2.50	55.53
20.45	76.30	7.66	2.98	39.29
23.15	62.90	6.73	3.06	44.83
21.05	54.55	5.08	2.42	58.17
27.20	60.45	8.29	2.94	52.42
35.95	44.95	6.63	2.62	46.74
19.70	70.45	10.58	3.06	52.04
16.30	73.70	12.08	2.59	48.08

(continued)

Table 16. (Continued)

Sl. No. Treatments	Number of days for first flowering	Plant height at maturity (in cm)	Number of primary productive branches/ plant
17. 13 x 37	40.50	83.15	2.75
18. 13 x 41	47.00	104.20	3.65
19. 29 x 37	42.50	94.40	2.70
20. 29 x 41	47.00	116.55	3.20
21. 37 x 41	45.50	95.90	1.70
22. (29x41)(25x37)	35.66	74.86	1.40
23. (29x41)(25x13)	38.00	81.46	2.33
24. (29x41)(2x13)	35.66	69.06	1.13
25. (29x41)(2x25)	37.33	80.86	1.73
26. (29x41)(25x37)	38.00	87.20	2.00
27. (2x41)(29x37)	36.33	89.13	1.20
28. (2x41)(25x29)	37.67	80.33	1.60
29. (2x41)(25x13)	37.67	85.66	2.00
30. (25x37)(2x41)	36.33	80.33	1.33
31. (25x37)(2x29)	36.66	87.20	1.20
32. (25x37)(29x41)	37.33	87.66	0.73
33. (25x37)(2x13)	40.33	84.73	1.20

Number of productive nodes on main axis	Number of pods on main axis	Total number of pods/ plant	Seed yield/ plant (in g)	1000-seed weight (in g)	Oil content (Percentage)
19.10	19.10	58.90	9.29	2.36	65.25
19.60	19.65	74.45	11.61	2.89	61.25
21.15	23.95	57.95	11.20	3.14	51.17
25.05	24.20	106.70	14.99	3.04	59.08
18.40	18.05	44.10	7.33	3.02	53.50
15.20	14.53	22.13	3.00	3.07	48.66
19.40	15.13	24.00	3.07	2.84	29.17
16.40	14.40	18.07	2.64	3.10	56.66
20.20	16.60	24.60	3.19	2.92	36.66
16.66	9.66	26.86	3.80	3.05	38.66
16.93	16.53	23.93	2.92	3.22	44.00
16.26	18.13	29.20	4.36	3.44	58.00
15.20	15.13	24.86	3.24	3.23	58.66
18.73	16.80	22.73	3.69	2.90	39.66
20.00	20.06	29.53	3.78	3.17	54.33
19.00	20.40	23.53	3.08	2.97	26.33
15.26	15.87	23.20	3.82	3.00	62.66

(continued)

Table 16. (Continued)

Sl. Treatments No.	Number of days for first flowering	Plant height at maturity (in cm)	Number of primary productive branches/ plant	Number of productive nodes on main axis	Number of pods on main axis	Total number of pods/ plant	Seed yield/ plant (in g)	1000-seed weight (in g)	Oil content (Percentage)
34. (2x29)(25x41)	36.00	85.60	1.26	17.66	17.40	23.60	3.24	3.29	70.50
35. (2x29)(25x37)	36.66	84.00	1.60	18.26	18.06	27.93	3.34	3.09	59.33
36. (2x29)(25x13)	38.33	71.40	1.66	14.00	13.67	18.80	2.51	2.92	75.33
37. (25x13)(2x37)	35.00	74.66	1.48	14.20	14.33	23.80	3.43	2.96	66.00
38. (25x13)(29x41)	42.00	92.86	1.80	16.07	15.86	27.20	4.59	3.24	32.16
39. (25x13)(2x29)	40.00	87.80	2.40	14.00	14.13	28.93	3.29	2.99	40.66
40. (25x29)(2x37)	39.66	87.53	1.66	12.46	16.53	24.73	2.92	3.07	50.66
41. (25x29)(2x41)	38.00	76.66	0.86	14.33	14.93	21.13	2.76	3.24	56.33
42. (29x37)(2x25)	34.66	79.73	0.73	21.93	20.27	30.60	4.18	3.10	48.00
43. (29x37)(25x13)	37.33	98.46	1.73	22.20	19.20	41.80	5.37	3.07	49.16
44. (25x41)(2x37)	38.00	90.73	0.46	18.20	17.40	19.80	2.73	3.23	72.00
45. (25x41)(2x29)	36.33	89.00	1.12	18.80	18.33	25.20	3.29	3.33	60.66
46. (2x25)(29x37)	39.33	84.33	0.86	16.00	14.13	16.53	2.45	2.62	48.33
47. (2x25)(29x41)	37.67	69.86	0.80	12.26	12.74	20.06	3.02	2.80	59.33
48. (2x13)(25x29)	36.66	91.93	2.40	19.20	18.60	41.13	4.64	2.91	54.33
M.S.S.	11.90**	187.10**	5.45**	31.96**	74.23*	536.68**	26.26**	0.13**	417.28**
C.D.	2.72	10.14	0.83	3.86	4.54	14.50	2.24	0.28	14.68

* Significant at 5 per cent level
** Significant at 1 per cent level

Number of days for first flowering:

Variation for number of days for first flowering in the double cross hybrids is represented in Fig. 10.

The minimum number of days (34.33) was taken by the parental variety V_2. The variety V_{13} also recorded earliness for flowering taking 35 days. Maximum number of days for flowering was taken by V_{29} (53.33). In the double cross hybrids, the duration varied from 34.66 in (V_{29} x V_{37}) (V_2 x V_{25}) to 42 days in (V_{25} x V_{13})(V_{29} x V_{41}). The hybrids (V_{25} x V_{37})(V_2 x V_{13}) and (V_{25} x V_{13})(V_2 x V_{29}) were late flowering types taking 40.33 and 40.00 days respectively. All the other hybrids took below 40 days for first flowering.

B-1. <u>Heterosis in double cross hybrids</u>

Plant height at maturity:

The percentage of heterosis manifested by the double cross hybrids over the mid-parent and better parents for plant height at maturity is represented in table 17-1.

In parental single cross hybrids the mean plant height ranged from 78.35 cm in the cross V_2 x V_{13} to 121.40 cm in V_2 x V_{41}. In the double cross hybrids the minimum values for plant height 69.06 and 69.86 cm were recorded by (V_{29} x V_{41}) (V_2 x V_{13}) and (V_2 x V_{25})(V_{29} x V_{41}) respectively. The maximum value of 98.46 cm was recorded by (V_{29} x V_{37})(V_{25} x V_{13}). Percentage of heterosis over mid-parent was negative in all the double cross hybrids except in one. The positive

heterosis recorded by the double cross hybrid (V_{29} x V_{37}) (V_{25} x V_{13}) was not significant. The negative heterosis of twenty two out of twenty six double cross hybrids were significant. The percentage of heterosis in the double cross hybrids ranged from -37.43 to 1.66. As regards heterosis over better parent, the percentage of heterosis was negative in all the double cross hybrids. Except in (V_{29} x V_{37}) (V_{25} x V_{13}), heterosis was significant in all other crosses. The percentage of heterosis ranged from -40.75 in (V_{29} x V_{41}) (V_2 x V_{13}) to -0.85 recorded in (V_{29} x V_{37})(V_{25} x V_{13}).

Number of primary productive branches per plant:

The percentage of heterosis manifested by the double cross hybrids over the mid-parent and better parent for number of primary productive branches per plant is represented in table 17-1. In the parental single cross hybrids the number of primary productive branches per plant ranged from 1.7 in V_{25} x V_{37} to 4.9 in V_2 x V_{25}. In the double cross hybrids, mean number of branches varied from 0.46 in the cross (V_{25} x V_{41})(V_2 x V_{37}) to 2.40 in (V_2 x V_{13})(V_{25} x V_{29}) and (V_{25} x V_{13})(V_2 x V_{29}). The percentage of heterosis over mid-parent and better parent was negative in all the double cross hybrids. Twenty six out of twenty seven double cross hybrids showed statistical significance in both cases. Over mid-parent, negative heterosis ranged from -10.31 in (V_2 x V_{41})(V_{25} x V_{37}) to -85.63 in (V_{25} x V_{41})(V_2 x V_{37}).

Over better parent the values ranged from -27.27 to -87.22 in the crosses $(V_2 \times V_{41})(V_{25} \times V_{37})$ and $(V_{25} \times V_{41})(V_2 \times V_{37})$ respectively.

Number of productive nodes on main axis:

Table 17-1 shows the percentage of heterosis for number of productive nodes on main axis manifested by the double cross hybrids over their mid-parent and better parent values in single crosses. In the single cross parents, the mean number of productive nodes on main axis ranged from 16.20 in the cross $V_2 \times V_{13}$ to the maximum of 25.7 in $V_{25} \times V_{29}$. In the double cross hybrids it ranged from the minimum of 12.26 in $(V_2 \times V_{25})(V_{29} \times V_{41})$ to 22.70 in $(V_{29} \times V_{37})$ $(V_{25} \times V_{13})$. Percentage of heterosis of double cross hybrids over the mid-parent ranged from -48.98 in $(V_{25} \times V_{29})(V_2 \times V_{37})$ to 5.21 in $(V_{29} \times V_{37})(V_{25} \times V_{13})$. Out of the twenty seven double cross hybrids only two showed positive heterosis over mid-parent as well as better parent eventhough they were not statistically significant. Over mid-parent nineteen and over better parent twenty three double cross hybrids showed significant negative heterosis. The two double cross hybrids which showed positive heterosis were $(V_{29} \times V_{37})(V_2 \times V_{25})$ and $(V_{29} \times V_{37})(V_{25} \times V_{13})$. Heterosis over better parent ranged from -51.36 in $(V_{25} \times V_{29})(V_2 \times V_{37})$ to 4.96 in $(V_{29} \times V_{37})(V_{25} \times V_{13})$.

Number of pods on main axis:

Table 17-2 shows the percentage of heterosis manifested by the double cross hybrids over their mid-parent and better parent single cross hybrids in the case of number of pods on main axis. In the single cross parents the mean number of pods on main axis ranged from 14.70 in the cross $V_2 \times V_{13}$ to the maximum of 35.95 in the cross $V_{25} \times V_{37}$. In the double cross hybrids the mean varied from the minimum of 9.66 in $(V_2 \times V_{41})(V_{25} \times V_{37})$ to the maximum of 20.40 in the cross $(V_{25} \times V_{37})(V_{29} \times V_{41})$. Hybrids such as $(V_{25} \times V_{37})(V_2 \times V_{29})$ and $(V_{29} \times V_{37})(V_2 \times V_{25})$ also recorded values close to the maximum value. Percentage of heterosis over mid-parent was negative in all the double cross hybrids except in $(V_{25} \times V_{41})(V_2 \times V_{29})$ with 1.83 per cent and $(V_2 \times V_{25})(V_{29} \times V_{37})$ with 36.58 per cent. The percentage of heterosis over mid-parent ranged from -67.31 to 36.58. The positive heterosis exhibited by $(V_2 \times V_{25})(V_{29} \times V_{37})$ was significant. The negative heterosis of twenty double cross hybrids over mid-parent were significant. Over the better parent all the double cross hybrids exhibited negative heterosis ranging from -73.13 per cent in $(V_2 \times V_{41})$ $(V_{25} \times V_{37})$ to -6.95 per cent in $(V_{25} \times V_{41})(V_2 \times V_{29})$. Twenty three double cross hybrids showed significant negative heterosis over better parent. The best hybrid with maximum positive heterosis was $(V_2 \times V_{25})(V_{29} \times V_{37})$.

Total number of pods per plant:

Percentage of heterosis for total number of pods per plant manifested by the double cross hybrids over their single cross mid-parents and better parents are presented in table 17-2.

In the parents the mean value ranged from 44.95 in $V_{25} \times V_{37}$ to 106.70 in $V_{29} \times V_{41}$. In the double cross hybrids, it ranged from the minimum of 16.53 in $(V_2 \times V_{25})(V_{29} \times V_{37})$ to 41.80 in $(V_{29} \times V_{37})(V_{25} \times V_{13})$. All the double cross hybrids recorded significant negative heterosis over mid-parent as well as better parent where it ranged from -25.62% to 80.61% over mid-parent and from -27.76% to -83.06% over better parent.

1000-seed weight:

Table 17-3 represents the percentage of heterosis manifested by the double cross hybrids over their mid-parent and better parent with respect to thousand seed weight.

In the single cross parents, the mean ranged from 2.42 in $V_{25} \times V_{13}$ to 3.14 in $V_{29} \times V_{37}$. In the double cross hybrids, it ranged from the minimum of 2.62 in $(V_2 \times V_{25})$ $(V_{29} \times V_{37})$ to the maximum of 3.33 in $(V_{25} \times V_{41})(V_2 \times V_{29})$. Percentage of heterosis over mid-parent ranged from -10.27 in $(V_2 \times V_{25})(V_{29} \times V_{37})$ to 23.83 in $(V_{25} \times V_{37})(V_2 \times V_{29})$. Positive significant heterosis was recorded in twelve hybrids and negative significant heterosis was recorded in $(V_2 \times V_{25})$ $(V_{29} \times V_{37})$. Heterosis over better parent ranged from

-16.56% in (V_2 x V_{25})(V_{29} x V_{37}) to 25.50% in (V_2 x V_{41}) (V_{29} x V_{37}). The positive heterosis of five double cross hybrids were significant. The negative heterosis of (V_2 x V_{25}) (V_{29} x V_{37}) over better parent was also statistically significant.

Seed yield per plant:

Table 17-3 represents the percentage of heterosis manifested by the double cross hybrids over their single cross mid-parent and better parent with respect to the seed yield per plant.

In the single cross parents, the mean weight of seeds per plant ranged from 5.08 in the cross V_{25} x V_{13} to 14.99 in V_{29} x V_{41}. In the double cross hybrids, it ranged from 2.45 in (V_2 x V_{25})(V_{29} x V_{37}) to 4.64 in (V_2 x V_{13})(V_{25} x V_{29}). The percentage of heterosis over mid-parent ranged from -79.55 in (V_{29} x V_{41})(V_2 x V_{13}) to -34.03 in (V_{29} x V_{37}) (V_{25} x V_{13}). Heterosis over mid-parent as well as better parent were all significantly negative. Over better parent, the percentage of heterosis ranged from -82.39 to -43.54.

Oil content (Percentage):

Table 17-2 depicts the percentage of heterosis manifested by the double cross hybrids over their single cross mid-parent and better parent with respect to percentage of oil content.

In the parents the mean percentage of oil content ranged from 39.29 in V_2 x V_{37} to 59.08 in V_{29} x V_{41}. In

the double cross hybrids, it ranged from 26.33 in (V_{25} x V_{37}) (V_{29} x V_{41}) to 75.33 in (V_2 x V_{29})(V_{25} x V_{13}). Percentage of heterosis over mid-parent ranged from -50.25 in (V_{29} x V_{41}) (V_{25} x V_{13}) to 57.65 in (V_{25} x V_{41})(V_2 x V_{37}). Out of the twenty seven double cross hybrids, fifteen hybrids recorded positive heterosis and twelve hybrids recorded negative heterosis. Positive heterosis of five hybrids were significant. Over better parent, percentage of heterosis ranged from -55.43 in (V_{25} x V_{37})(V_{29} x V_{41}) to 38.36 (V_{25} x V_{41}) (V_2 x V_{37}). Twelve hybrids recorded positive heterosis, of which, three were statistically significant. Negative heterosis was recorded in fourteen hybrids and six hybrids recorded statistical significance.

Number of days for first flowering:

Table 17-3 represents the data on the percentage of heterosis exhibited by the double cross hybrids over their mid-parent and better parent with respect to the duration for first flowering.

In the single cross parents, mean values ranged from 39.50 in V_2 x V_{13} to 50.50 in V_{25} x V_{41}. In the double cross hybrids it ranged from 34.66 in (V_{29} x V_{37})(V_2 x V_{25}) to 42.00 in (V_{25} x V_{13})(V_{29} x V_{41}). Over mid-parent, all the double cross hybrids showed negative heterosis. The percentage of heterosis ranged from -4.0 in (V_{25} x V_{13}) (V_{29} x V_{41}) to 24.53 in (V_{29} x V_{41})(V_{25} x V_{37}). Except one, (V_{25} x V_{13})(V_{29} x V_{41}) all the other double cross hybrids

Table 17-1. Analysis on heterosis in double cross hybrids.

Sl. No.	Parents (Single cross hybrids) and double cross hybrids	Mean number of productive branches/ plant	Percentage of heterosis over Mid parent	Percentage of heterosis over Better parent	Mean number of productive nodes on main axis	Percentage of heterosis over Mid parent	Percentage of heterosis over Better parent	Mean plant height at maturity	Percentage of heterosis over Mid parent	Percentage of heterosis over Better parent
1.	29 x 41	3.20	-	-	25.05	-	-	116.55	-	-
2.	25 x 37	1.70	-	-	24.05	-	-	97.70	-	-
3.	25 x 13	4.70	-	-	21.05	-	-	99.30	-	-
4.	2 x 13	3.40	-	-	16.20	-	-	78.35	-	-
5.	2 x 25	4.90	-	-	20.95	-	-	106.75	-	-
6.	2 x 41	2.75	-	-	22.80	-	-	121.40	-	-
7.	29 x 37	2.70	-	-	21.15	-	-	94.40	-	-
8.	25 x 29	3.85	-	-	25.70	-	-	104.95	-	-
9.	2 x 29	3.85	-	-	17.85	-	-	92.65	-	-
10.	25 x 41	2.80	-	-	20.50	-	-	110.75	-	-
11.	2 x 37	3.60	-	-	23.30	-	-	95.40	-	-
12.	(29x41)(25x37)	1.40	-42.86**	-56.25**	15.20	-38.09**	-39.32**	74.86	-30.12**	-35.77**
13.	(29x41)(25x13)	2.33	-41.01**	-50.43**	19.40	-15.84**	-22.55**	81.46	-24.53**	-30.11**
14.	(29x41)(2x13)	1.13	-65.76**	-66.76**	16.40	-20.50**	-34.53**	69.06	-29.13**	-40.75**
15.	(29x41)(2x25)	1.73	-57.28**	-64.69**	20.20	-12.17	-19.36**	80.86	-27.58**	-30.72**
16.	(2x41)(25x37)	2.00	-10.31	-27.27	16.66	-28.72	-30.56	87.20	-20.40**	-28.17**
17.	(2x41)(29x37)	1.20	-56.04**	-56.36**	16.93	-23.11**	-25.88**	89.13	-17.39**	-26.58**
18.	(2x41)(25x29)	1.60	-51.52**	-58.44**	16.26	-32.78**	-36.58**	80.33	-29.53**	-33.83**
19.	(2x41)(25x13)	2.00	-46.38**	-57.45**	-15.20	-30.69**	-33.33**	85.66	-22.37**	-29.44**

(continued)

Table 17-1. (Continued)

Sl. No.	Parents (Single cross hybrids and double cross hybrids)	Mean number of productive branches/ plant	Percentage of heterosis over Mid parent	Percentage of heterosis over Better parent	Mean number of productive nodes on main axis	Percentage of heterosis over Mid parent	Percentage of heterosis over Better parent	Mean plant height at maturity	Percentage of heterosis over Mid parent	Percentage of heterosis over Better parent
20.	(25x37)(2x41)	1.33	-40.36*	-51.64*	18.73	-20.19*	-22.25*	80.33	-26.67*	-33.83*
21.	(25x37)(2x29)	1.20	-56.83*	-68.83*	20.00	-4.53*	-16.84*	87.20	-7.89*	-10.75*
22.	(25x37)(29x41)	0.73	-70.20*	-77.19*	19.00	-22.61*	-24.15*	87.66	-18.17*	-24.76*
23.	(25x37)(2x13)	1.20	-34.43*	-74.70*	15.26	-23.29*	-36.38*	84.73	-3.75*	-13.28*
24.	(2x29)(25x41)	1.26	-62.16*	-67.27*	17.66	-7.72*	-13.66*	85.60	-15.83*	-22.71*
25.	(2x29)(25x37)	1.60	-42.45*	-58.44*	18.26	-12.65*	-31.42*	84.00	-11.75*	-14.02*
26.	(2x29)(25x13)	1.66	-61.21*	-64.68*	14.00	-28.02*	-33.49*	71.40	-25.61*	-28.10*
27.	(25x13)(2x37)	1.48	-64.34*	-68.51*	14.20	-35.98*	-39.06*	74.66	-23.31*	-24.81*
28.	(25x13)(29x41)	1.80	-54.43*	-61.70*	16.07	-30.15*	-35.73*	92.86	-13.96*	-20.33*
29.	(25x13)(2x29)	2.40	-43.93*	-48.94*	14.00	-28.02*	-33.49*	87.80	-8.52*	-11.58*
30.	(25x29)(2x37)	1.66	-55.49*	-56.88*	12.46	-48.98*	-51.36*	87.53	-12.63*	-16.59*
31.	(25x29)(2x41)	0.86	-73.94*	-77.66*	14.33	-41.03*	-44.36*	76.66	-32.27*	-36.85*
32.	(29x37)(2x25)	0.73	-80.79*	-85,10*	21.93	4.04	3.55	79.73	-20.73*	-25.28*
33.	(29x37)(25x13)	1.73	-53.24*	-63.19*	22.20	5.21	4.96	98.46	1.66	-0.85
34.	(25x41)(2x37)	0.46	-85.63*	-87.22*	18.20	-16.89	-21.89*	90.73	-11.98*	-18.08*
35.	(25x41)(2x29)	1.12	-66.37*	-70.91*	18.80	-1.98	-8.29	89.00	-12.49*	-19.64*
36.	(2x25)(29x37)	0.86	-77.37*	-82.45*	16.00	-23.99*	-24.35*	84.33	-16.16*	-21.00*
37.	(2x25)(29x41)	0.80	-80.25*	-83.67*	12.26	-46.52*	-50.89*	69.86	-37.43*	-40.06*
38.	(2x13)(25x29)	2.40	-33.88*	-37.66*	19.20	-8.35	-25.29*	91.93	-0.31	-12.41*
	C.D.		0.36	0.82		3.28	3.78		8.61	9.94

* Significant at 5 per cent level

Table 17-2. Analysis on heterosis in double cross

Sl. No.	Parents (Single cross hybrids) and double cross hybrids	Mean number of pods on main axis	Percentage of heterosis over Mid parent	Percentage of heterosis over Better parent
1.	29 x 41	24.20	-	-
2.	25 x 37	35.95	-	-
3.	25 x 13	21.05	-	-
4.	2 x 13	14.70	-	-
5.	2 x 25	20.60	-	-
6.	2 x 41	23.15	-	-
7.	29 x 37	23.95	-	-
8.	25 x 29	27.20	-	-
9.	2 x 29	16.30	-	-
10.	25 x 41	19.70	-	-
11.	2 x 37	20.45	-	-
12.	(29x41)(25x37)	14.53	-51.69**	-59.58**
13.	(29x41)(25x13)	15.13	-33.14**	-37.48**
14.	(29x41)(2x13)	14.40	-25.96**	-40.49**
15.	(29x41)(2x25)	16.60	-25.89**	-31.40**
16.	(2x41)(25x37)	9.66	-67.31**	-73.13**
17.	(2x41)(29x37)	16.53	-29.81**	-31.11**
18.	(2x41)(25x29)	18.13	-27.99**	-33.35**
19.	(2x41)(25x13)	15.13	-31.54**	-34.64**
20.	(25x37)(2x41)	16.80	-43.15**	-53.27**

ybrids.

ean mber of ods per Lant	Percentage of heterosis over Mid parent	Percentage of heterosis over Better parent	Mean oil content (Percentage)	Percentage of heterosis over Mid parent	Percentage of heterosis over Better parent
106.70	-	-	59.09	-	-
44.95	-	-	46.74	-	-
54.55	-	-	58.17	-	-
79.70	-	-	50.13	-	-
56.85	-	-	51.33	-	-
62.90	-	-	44.83	-	-
57.95	-	-	51.17	-	-
60.45	-	-	52.42	-	-
69.85	-	-	55.53	-	-
70.45	-	-	52.04	-	-
76.30	-	-	39.29	-	-
22.13	-70.82**	-79.26**	48.66	-8.03	-17.64
24.00	-70.23**	-77.51**	29.17	-50.25**	-50.63**
18.07	-80.61**	-83.06**	56.66	3.75	-4.10
24.60	-69.92**	-76.94**	36.66	-33.59**	-37.95**
26.86	-50.19**	-57.29**	38.66	-15.57	-17.29
23.93	-60.40**	-61.96**	44.00	-8.85	-14.89
29.20	-52.66**	-53.58**	58.00	19.27	10.64
24.86	-57.67**	-60.48**	58.66	13.90	0.84
22.73	-57.85**	-63.86**	39.66	-13.39	-15.15

(continued)

Table 17-2. (Continued)

Sl. No.	Parents (Single cross hybrids) and double cross hybrids	Mean number of pods on main axis	Percentage of heterosis over Mid parent	Better parent	Mean number pods pe plant
21.	(25x37)(2x29)	20.06	-23.23*	-44.20*	29.53
22.	(25x37)(29x41)	20.40	-32.18*	-43.25*	23.53
23.	(25x37)(2x13)	15.87	-37.34*	-55.86*	23.20
24.	(2x29)(25x41)	17.40	-3.33	-11.68*	23.60
25.	(2x29)(25x37)	18.06	-30.88*	-49.76*	27.93
26.	(2x29)(25x13)	13.67	-26.82*	-35.06*	18.80
27.	(25x13)(2x37)	14.33	-30.94*	-31.92*	23.80
28.	(25x13)(29x41)	15.86	-29.92*	-34.46*	27.20
29.	(25x13)(2x29)	14.13	-32.20*	-32.87*	28.93
30.	(25x29)(2x37)	16.53	-30.63*	-39.22*	24.73
31.	(25x29)(2x41)	14.93	-40.71*	-45.11*	21.13
32.	(29x37)(2x25)	20.27	-9.02	-7.01	30.60
33.	(29x37)(25x13)	19.20	-14.67	-13.78*	41.80
34.	(25x41)(2x37)	17.40	-13.35	-14.91	19.80
35.	(25x41)(2x29)	18.33	1.83	-6.95	25.20
36.	(2x25)(29x37)	14.13	36.58*	-41.00*	16.53
37.	(2x25)(29x41)	12.74	-43.13*	-47.36*	20.06
38.	(2x13)(25x29)	18.60	-11.22	-31.62*	41.13
	C.D.		3.85	4.44	

* Significant at 5

Percentage of heterosis over Mid parent	Percentage of heterosis over Better parent	Mean oil content (Percentage)	Percentage of heterosis over Mid parent	Percentage of heterosis over Better parent
-48.55**	-57.72**	54.33	6.24	-7.91
-68.97**	-77.67**	26.33	-50.24**	-55.43**
-62.81**	-70.89**	62.66	29.36*	24.99
-68.50**	-66.36**	70.50	31.07**	26.96**
-60.01**	-51.34**	59.33	16.01	6.84
-69.77**	-73.09**	75.33	32.51**	29.49**
-63.63**	-68.81**	66.00	35.44**	13.46
-66.27**	-74.50**	32.16	-45.15**	-45.56**
-53.49**	-58.58**	40.66	-28.48**	-30.10**
-63.83**	-67.59**	50.66	10.47	-3.36
-65.74**	-66.41**	56.33	15.83	7.46
-46.69**	-47.19**	48.00	-6.34	-6.49
-25.62**	-27.76**	49.16	-10.08	-15.49
-73.02**	-74.05**	72.00	57.65**	38.36**
-64.08**	-64.23**	60.66	12.77	9.24
-71.25**	-71.53**	48.33	-5.69	5.80
-75.47**	-81.19**	59.33	7.46	0.42
-41.31**	-48.39**	54.33	5.95	3.64
12.31	14.21		12.46	14.39

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Table 17-3. Analysis on heterosis in double cross

Sl. No.	Parents (Single cross hybrids) and double cross hybrids	Mean 1000 seed weight	Percentage of heterosis over	
			Mid parent	Better parent
1.	29 x 41	3.04	-	-
2.	25 x 37	2.62	-	-
3.	25 x 13	2.42	-	-
4.	2 x 13	3.06	-	-
5.	2 x 25	2.69	-	-
6.	2 x 41	3.06	-	-
7.	29 x 37	3.14	-	-
8.	25 x 29	2.94	-	-
9.	2 x 29	2.50	-	-
10.	25 x 41	3.06	-	-
11.	2 x 37	2.98	-	-
12.	(29x41)(25x37)	3.01	6.36	-0.99
13.	(29x41)(25x13)	2.84	4.03	-6.58
14.	(29x41)(2x13)	3.10	1.64	1.31
15.	(29x41)(2x25)	2.92	1.74	-3.95
16.	(2x41)(25x37)	3.05	7.39	-0.33
17.	(2x41)(29x37)	3.22	3.87	25.50
18.	(2x41)(25x29)	3.44	14.67*	12.42*
19.	(2x41)(25x13)	3.23	17.88*	5.56
20.	(25x37)(2x41)	2.90	1.96	-5.23

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Mean seed yield per plant	Percentage of heterosis over Mid parent	Percentage of heterosis over Better parent	Mean No. of days taken for first flowering	Percentage of heterosis over Mid parent	Percentage of heterosis over Better parent
14.99	-	-	47.00	-	-
6.63	-	-	47.50	-	-
5.08	-	-	40.50	-	-
10.82	-	-	39.50	-	-
8.04	-	-	48.00	-	-
6.73	-	-	47.50	-	-
11.20	-	-	42.50	-	-
8.29	-	-	43.50	-	-
7.87	-	-	45.50	-	-
10.58	-	-	50.50	-	-
7.66	-	-	44.00	-	-
3.01	-72.16**	-79.92**	35.66	-24.53**	-24.13**
3.07	-69.42**	-79.52**	38.00	-13.14**	-6.17
2.64	-79.55**	-82.39**	35.66	-17.55**	-9.72**
3.19	-72.31**	-78.72**	37.33	-21.41**	-20.57**
3.80	-43.11**	-43.54**	38.00	-20.00**	-20.00**
2.93	-67.33**	-73.84**	36.33	-19.27**	-14.52**
4.36	-41.94**	-47.41**	37.67	-17.21**	-13.40**
3.24	-45.18**	-51.86**	37.67	-14.39**	-6.99**
3.70	-44.61**	-45.02**	36.33	-23.52**	-23.52**

(continued)

Table 17-3. (Continued) -2-

Sl. No.	Parents (Single cross hybrids) and double cross hybrids	Mean 1000 seed weight	Percentage of heterosis over Mid parent	Percentage of heterosis over Better parent	Mean seed yield per plant
21.	(25x37)(2x29)	3.17	23.83**	20.99**	3.76
22.	(25x37)(29x41)	2.97	4.95	-3.62	3.08
23.	(25x37)(2x13)	3.00	5.63	-1.96	3.82
24.	(2x29)(25x41)	3.29	18.35**	7.52	3.24
25.	(2x29)(25x37)	3.09	20.70**	17.94**	3.34
26.	(2x29)(25x13)	2.92	18.69**	16.80**	2.51
27.	(25x13)(2x37)	2.96	9.63**	-0.67	3.43
28.	(25x13)(29x41)	3.24	18.25**	5.88	4.59
29.	(25x13)(2x29)	2.99	21.54**	19.60**	3.29
30.	(25x29)(2x37)	3.07	3.72	3.02	2.92
31.	(25x29)(2x41)	3.24	8.00**	5.88	2.76
32.	(29x37)(2x25)	3.10	6.16	-0.01	4.18
33.	(29x37)(25x13)	3.07	10.43**	-2.23	5.37
34.	(25x41)(2x37)	3.23	6.95	5.56	2.73
35.	(25x41)(2x29)	3.33	19.78**	8.82	3.29
36.	(2x25)(29x37)	2.62	-10.27**	-16.56**	2.45
37.	(2x25)(29x41)	2.[illegible]	-2.44	-7.89	3.02
38.	(2x13)(25x29)	2.91	-3.00	-4.90	4.64
	C.D.		0.24	0.28	

* Significant at 5

Percentage of heterosis over		Mean No. of days taken for first flowering	Percentage of heterosis over	
Mid parent	Better parent		Mid parent	Better parent
-48.14**	-52.22**	36.66	-21.16**	-19.43**
-71.51**	-79.45**	37.33	-20.99**	-20.57**
-56.24**	-64.10**	40.33	-7.29**	2.10
-64.89**	-69.38**	36.00	-19.79**	-20.88**
-53.93**	-57.56**	36.66	-21.16**	-19.43**
-61.27**	-68.11**	38.33	-10.86**	-5.36
-46.15**	-55.22**	35.00	-17.16**	-13.58**
-54.28**	-69.38**	42.00	-4.00	3.70
-49.19**	-58.19**	40.00	-6.98**	-1.20
-63.41**	-61.04**	39.66	-9.35**	-8.80**
-63.25**	-66.71**	38.00	-16.48**	-12.64**
-56.55**	-62.68**	34.66	-23.40**	-18.45**
-34.03**	-52.05**	37.33	-10.05**	-7.83*
-70.07**	-74.19**	38.00	-19.58**	-13.64**
-64.30**	-68.86**	36.33	-24.31**	-20.15**
-74.53**	-78.13**	39.33	-13.08**	-7.46**
-73.78**	-79.85**	37.67	-20.69**	-19.85**
-51.46**	-57.12**	36.66	-11.66**	-7.19**
1.90	2.19		2.31	2.66

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recorded significantly negative heterosis. Compared to better parent (early flowering parent) only two hybrids viz., (V_{25} x V_{37})(V_2 x V_{13}) and (V_{25} x V_{13})(V_{29} x V_{41}) showed positive heterosis but they were not statistically significant. The negative heterosis of twenty two double cross hybrids were statistically significant. Percentage of heterosis over better parent ranged from -24.13 in (V_{29} x V_{41})(V_2 x V_{25}) to 3.70 in (V_{25} x V_{13})(V_{29} x V_{41}).

C. Cytological studies

Meiotic analysis was done in the pollen mother cells of single cross hybrids and double cross hybrids. Normal meiotic stages were observed in all cases. No cytological abnormalities were noted in any of the hybrids.

Pollen sterility

Percentage of pollen sterility calculated in the parents, single cross and double cross hybrids are presented in table 18. In the parents the percentage of pollen sterility ranged from 0.21 in V_2 to the maximum of 4.49 in V_{13}. In the single cross hybrids percentage of pollen sterility varied from the minimum of 2.76 found in the cross $V_2 \times V_{37}$ to the maximum of 9.6 found in the cross $V_2 \times V_{29}$. In the double cross hybrids, percentage of pollen sterility ranged from the minimum of 1.25 found in the cross $(V_{25} \times V_{41})(V_2 \times V_{37})$ to the maximum of 9.22 found in the cross $(V_{25} \times V_{29})(V_2 \times V_{37})$.

ble 18. Pollen sterility analysis.

.	Single cross hybrids	Percentage of pollen sterility
.	2 x 25	8.12
.	2 x 37	2.76
.	2 x 29	9.60
.	2 x 41	6.06
.	2 x 13	8.03
.	13 x 29	5.25
.	13 x 37	3.81
.	13 x 41	6.02
.	25 x 29	6.28
.	25 x 13	4.41
.	25 x 37	4.92
.	25 x 41	3.48
.	29 x 37	6.13
.	29 x41	6.66
.	37 x 41	8.92

Double cross hybrids	Percentage of pollen sterilit
(29x41) (25x37)	5.79
(29x41) (2x13)	6.89
(29x41) (2x13)	8.30
(29x41) (2x25)	6.02
(2x41) (25x37)	7.14
(2x41) (29x37)	5.56
(2x41) (25x29)	4.29
(2x41) (25 x13)	5.78
(25x37) (2x41)	4.86
(25x37) (2x29)	5.20
(25x37) (29x41)	6.89
(25x37) (2x13)	1.60
(2x29) (25x41)	4.40
(2x29) (25x37)	6.28
(2x29) (25x13)	6.73
(25x13) (2x37)	4.65

(continued)

Table 13. (Continued) -2-

Sl. No.	Double cross hybrids	Percentage of pollen sterility
17.	(25x13) (29x41)	5.88
18.	(25x13) (2x29)	7.60
19.	(25x29) (2x37)	9.22
20.	(25x29) (2x41)	5.18
21.	(29x37) (2x25)	2.81
22.	(29x37) (25x13)	2.20
23.	(25x41) (2x37)	1.25
24.	(25x41) (2x29)	5.77
25.	(2x25) (29x37)	1.43
26.	(2x25) (29x41)	6.46
27.	(2x13) (25x29)	4.90

Parents	Percentage of pollen sterility
2	0.21
25	0.88
13	4.49
29	2.56
37	2.86
41	0.72

D. Performence analysis in F_2 progeny

The mean values and the analysis of variance in the F_2 progeny and parents with respect to the nine characters are presented in table 19.

Significant differences were exhibited by the F_2 compared to the original parents for all the nine characters studied.

Plant height at maturity:

Plant height at maturity in the parents ranged from 68.90 cm observed in V_{13} to the highest value of 105.17 observed in V_{25}. In the F_2, the character showed a wide range from the minimum of 65.73 cm observed in the cross $V_2 \times V_{13}$ to a maximum of 124.58 cm observed in the cross $V_{29} \times V_{37}$. The F_2 mean values of the crosses $V_{13} \times V_{41}$, $V_2 \times V_{41}$ and $V_{29} \times V_{37}$ were significantly different from their parental mean values. In the crosses $V_2 \times V_{25}$ and $V_2 \times V_{13}$ the F_2 mean values were significantly different from that of V_2. The F_2 mean of the cross $V_{25} \times V_{13}$ showed significant difference with that of the parent V_{13}. In the cross $V_{25} \times V_{29}$ the mean was significantly different from that of V_{25}. In the crossee $V_{25} \times V_{41}$ and $V_{29} \times V_{41}$ the F_2 mean values showed significant difference from that of the parent V_{41}. In the other crosses, $V_{25} \times V_{37}$, $V_2 \times V_{37}$, $V_{13} \times V_{29}$, $V_{13} \times V_{37}$ and $V_{37} \times V_{41}$ the F_2 mean values did not show significant difference from their parental mean values.

Number of primary productive branches per plant:

Mean number of primary productive branches in the parents ranged from 0.7 recorded by V_{37} to the maximum value of 2.96 recorded by V_2. In the F_2 the number of branches ranged from the minimum of 1.26 recorded by the cross V_{13} x V_{37} to the maximum of 4.43 recorded by the cross V_2 x V_{25}.

Comparing the mean values of F_2 with the mean values of parents, the following results were obtained. In the three crosses viz., V_2 x V_{25}, V_{13} x V_{29} and V_{29} x V_{37} the F_2 mean values were significantly different from their parental mean values. In the cross V_2 x V_{13} the F_2 mean was significantly different from that of V_2 and in the cross V_2 x V_{41} the F_2 mean was significantly different from that of V_{41}. In the crosses V_2 x V_{29} and V_{25} x V_{29} the F_2 mean values were significantly different from that of V_{29}. Similarly in the crosses V_2 x V_{37} and V_{25} x V_{37} the F_2 mean values were significantly different from that of V_{37}. The F_2 mean in the cross V_{13} x V_{37} showed significant difference with that of V_{13}. In the other crosses V_{25} x V_{13}, V_{25} x V_{41}, V_{13} x V_{41}, V_{29} x V_{41} and V_{37} x V_{41} the F_2 mean values did not deviated significantly from their parental mean values.

Number of productive nodes on main axis:

In the parents, the number of productive nodes on main axis ranged from the minimum value of 14.53 recorded by V_{13} to the maximum value of 22.93 recorded by V_{37}. In the F_2 progeny the character showed a very wide range from the

minimum of 14.37 recorded in the cross $V_{13} \times V_{29}$ to the maximum of 32.90 recorded in the cross $V_2 \times V_{25}$.

Comparing the mean values the F_2 showed significant difference from both the parents in the crosses $V_2 \times V_{25}$, $V_2 \times V_{37}$, $V_2 \times V_{41}$, $V_{25} \times V_{37}$, $V_{25} \times V_{41}$, $V_{29} \times V_{37}$ and $V_{37} \times V_{41}$. In the crosses $V_{25} \times V_{13}$ and $V_{13} \times V_{41}$ the mean values of F_2 were significantly different from that of V_{13}. In the cross $V_{25} \times V_{29}$ the F_2 mean was significantly different from that of the cross V_{29}. The F_2 mean values were not significantly different from those of the parents in the remaining crosses viz., $V_2 \times V_{13}$, $V_2 \times V_{29}$, $V_{13} \times V_{29}$, $V_{13} \times V_{37}$ and $V_{29} \times V_{41}$.

Number of pods on main axis:

Number of pods on main axis ranged from the minimum of 16.23 recorded by V_{29} to the maximum of 30.20 recorded by V_{37} among the parents. In the F_2 progeny, it ranged widely from the minimum of 14.00 recorded by the cross $V_2 \times V_{13}$ to the maximum of 42.77 recorded by $V_{25} \times V_{37}$. The variation was very wide in the F_2 progeny.

The mean value of F_2 showed significant difference from the mean value of both the parents in the crosses $V_2 \times V_{25}$, $V_2 \times V_{41}$ and $V_{25} \times V_{37}$. In the crosses $V_{25} \times V_{29}$, $V_{29} \times V_{37}$ and $V_{29} \times V_{41}$ the F_2 mean values were significantly different from that of V_{29}. In the cross $V_2 \times V_{37}$, the F_2 mean was significantly different from that of V_2. In the

cross V_{25} x V_{41} F_2 mean was significantly different from that of V_{41} and in the cross V_{13} x V_{37} F_2 mean was significantly different from that of the parent V_{37}. In the remaining crosses viz., V_2 x V_{13}, V_{25} x V_{13}, V_{13} x V_{29}, V_{13} x V_{41} and V_{37} x V_{41} the F_2 mean values were not significantly different from those of their parents.

Total number of pods per plant:

In the parents the total number of pods per plant ranged from the minimum of 21.80 recorded by V_{13} to the maximum of 49.77 recorded by V_2. A very high amount of variation was observed in the F_2 progeny. The range of variation was very wide. It extended from the minimum of 28.28 recorded by the cross V_2 x V_{13} to a maximum of 119.03 recorded by the cross V_2 x V_{25}.

The F_2 mean values showed significant difference from both the parents in the crosses V_2 x V_{25}, V_2 x V_{37}, V_2 x V_{41}, V_{25} x V_{13}, V_{25} x V_{37}, V_{25} x V_{41}, V_{13} x V_{29}, V_{29} x V_{37} and V_{37} x V_{41}. In the crosses V_2 x V_{13} and V_2 x V_{29} the F_2 mean values showed significant difference with that of V_2. In the cross V_{25} x V_{29} the F_2 mean was significantly different from that of V_{29} and in the crosses V_{13} x V_{37} and V_{13} x V_{41} the F_2 mean values were significantly different from that of V_{13}. The F_2 mean value of V_{29} x V_{41} showed no significant difference with those of its parents.

Seed yield per plant:

Seed yield per plant in the parents ranged from the minimum of 3.35 g recorded by V_{13} to a maximum of 6.58 g recorded by V_{25}. Among the hybrids the variation showed a wide range. It extended from a minimum of 3.69 recorded by the cross $V_{29} \times V_{41}$ to a maximum of 17.26 recorded by the cross $V_2 \times V_{25}$.

The F_2 mean value showed significant difference with those of parents in the crosses $V_2 \times V_{25}$, $V_2 \times V_{37}$, $V_2 \times V_{41}$, $V_{25} \times V_{37}$ and $V_{25} \times V_{41}$. In the cross $V_{25} \times V_{13}$, the F_2 mean showed significant difference from that of V_{13}. In the cross $V_{29} \times V_{37}$ the F_2 mean showed significant difference from V_{29} and the F_2 mean of the cross $V_{37} \times V_{41}$ showed significant difference from that of V_{41}. In the other crosses $V_2 \times V_{13}$, $V_2 \times V_{29}$, $V_{25} \times V_{29}$, $V_{13} \times V_{29}$, $V_{13} \times V_{37}$, $V_{13} \times V_{41}$ and $V_{29} \times V_{41}$, the F_2 mean values were not significantly different from those of their parents.

1000-seed weight:

Thousand seed weight in the parents ranged from 2.65 g (V_{29}) to 3.35 (V_{13}). Among the F_2 hybrids it ranged from the lowest value of 2.03 recorded by the cross $V_2 \times V_{25}$ to the highest value of 3.49 recorded by the cross $V_{29} \times V_{41}$. Range of variation in F_2 was wider than the parental range.

The F_2 mean values showed significant difference from those of their parents in the crosses $V_2 \times V_{25}$, $V_2 \times V_{41}$,

Seed yield per plant:

Seed yield per plant in the parents ranged from the minimum of 3.35 g recorded by V_{13} to a maximum of 6.58 g recorded by V_{25}. Among the hybrids the variation showed a wide range. It extended from a minimum of 3.69 recorded by the cross $V_{29} \times V_{41}$ to a maximum of 17.26 recorded by the cross $V_2 \times V_{25}$.

The F_2 mean value showed significant difference with those of parents in the crosses $V_2 \times V_{25}$, $V_2 \times V_{37}$, $V_2 \times V_{41}$, $V_{25} \times V_{37}$ and $V_{25} \times V_{41}$. In the cross $V_{25} \times V_{13}$, the F_2 mean showed significant difference from that of V_{13}. In the cross $V_{29} \times V_{37}$ the F_2 mean showed significant difference from V_{29} and the F_2 mean of the cross $V_{37} \times V_{41}$ showed significant difference from that of V_{41}. In the other crosses $V_2 \times V_{13}$, $V_2 \times V_{29}$, $V_{25} \times V_{29}$, $V_{13} \times V_{29}$, $V_{13} \times V_{37}$, $V_{13} \times V_{41}$ and $V_{29} \times V_{41}$, the F_2 mean values were not significantly different from those of their parents.

1000-seed weight:

Thousand seed weight in the parents ranged from 2.65 g (V_{29}) to 3.35 (V_{13}). Among the F_2 hybrids it ranged from the lowest value of 2.03 recorded by the cross $V_2 \times V_{25}$ to the highest value of 3.49 recorded by the cross $V_{29} \times V_{41}$. Range of variation in F_2 was wider than the parental range.

The F_2 mean values showed significant difference from those of their parents in the crosses $V_2 \times V_{25}$, $V_2 \times V_{41}$,

Table 19. Performance analysis in F_2 generation.

Sl. No.	Treatments	Number of days for first flowering	Plant height at maturity (cm)	Number of primary productive branches/ plant
1.	2	38.87	83.83	2.96
2.	2 x 25	39.13	98.87	4.43
3.	2 x 13	39.28	65.73	2.00
4.	2 x 29	38.73	79.03	2.80
5.	2 x 37	38.73	85.13	2.35
6.	2 x 41	41.33	105.43	3.63
7.	25	39.67	105.17	2.70
8.	25 x 13	39.00	102.25	2.10
9.	25 x 29	40.13	84.27	3.26
10.	25 x 37	38.87	95.95	2.26
11.	25 x 41	38.93	116.95	1.93
12.	13	38.40	68.90	2.43
13.	13 x 29	37.80	79.85	3.86
14.	13 x 37	35.53	79.57	1.26

Number of productive nodes on main axis	Number of pods on main axis	Total number of pods per plant	Seed yield/ plant (g)	1000-seed weight (g)	Oil content (Percentage)
18.57	19.03	49.77	4.26	2.76	51.13
32.90	39.33	119.03	17.26	2.03	58.67
18.78	14.00	28.28	4.45	3.18	44.00
15.97	15.96	30.30	5.53	2.78	45.87
31.35	32.40	69.80	9.27	2.92	56.20
29.00	26.67	86.80	12.08	3.43	42.47
20.43	23.37	46.77	6.58	2.67	45.87
24.40	23.35	67.27	8.43	2.88	45.73
24.92	26.28	59.20	6.46	2.24	50.67
29.57	42.77	78.15	14.02	2.83	38.67
29.88	29.08	79.50	7.63	2.76	44.80
14.53	18.73	21.80	3.35	3.08	50.80
14.37	16.15	46.58	6.22	3.24	39.27
18.42	20.35	40.60	5.68	2.99	54.00

(continued)

Table 19. (Continued)

Sl. No.	Treatments	Number of days for first flowering	Plant height at maturity (in cm)	Number of primary productive branches/ plant	Number of productive nodes on main axis	Number of pods on main axis	Total number of pods per plant	Seed yield/ plant (in g)	1000-seed weight (in g)	Oil content (Percentage)
15.	13 x 41	39.47	99.37	1.66	21.78	22.00	41.73	5.99	2.53	46.93
16.	29	39.50	87.20	0.80	15.97	16.23	24.37	3.67	2.65	49.87
17.	29 x 37	40.13	124.58	2.28	32.70	35.27	65.28	7.97	2.55	49.47
18.	29 x 41	38.47	94.52	1.66	18.05	24.50	31.37	3.69	3.49	51.33
19.	37	40.67	86.67	0.70	22.93	30.20	33.97	5.45	2.88	53.20
20.	37 x 41	38.93	94.10	1.55	32.00	25.08	57.80	8.02	2.83	48.53
21.	41	42.40	82.50	1.90	16.27	19.60	34.20	4.03	2.67	47.13
M.S.S.		5.47**	640.96**	2.73**	128.46**	183.96**	1801.52**	38.41**	0.36**	78.02**
C.D.		1.79	12.81	0.92	6.13	7.19	16.82	3.29	0.33	10.42

* Significant at 5 per cent level

** Significant at 1 per cent level

V_{25} x V_{29} and V_{29} x V_{41}. In the cross V_2 x V_{13}, the F_2 mean showed significant difference from that of V_2 and in the crosses V_{25} x V_{13} and V_{13} x V_{41} the F_2 mean values showed significant difference from that of the parent V_{13}. In the cross V_{13} x V_{29} the F_2 showed significant difference from that of V_{29} and in the cross V_{29} x V_{37} the mean of F_2 showed significant difference from that of V_{37}. In all the other crosses viz., V_2 x V_{29}, V_2 x V_{37}, V_{25} x V_{37}, V_{25} x V_{41}, V_{13} x V_{37} and V_{37} x V_{41} the F_2 mean values showed no significant difference with those of parents.

Oil content (Percentage):

Among the parents, oil content ranged from the minimum of 45.87 recorded by V_{25} to the maximum of 53.20 recorded by V_{37}. In the F_2 progeny of different crosses it ranged from 38.67 recorded by the cross V_{25} x V_{37} to a maximum of 58.67 recorded by the cross V_2 x V_{25}. The range of variation was wide in the F_2.

The F_2 mean was significantly different from those of the parents only in the cross V_{13} x V_{29}. In the cross V_2 x V_{25} the F_2 mean was significantly different from that of the parent V_{25}. Similarly in the cross V_{25} x V_{37} the F_2 mean showed significant difference from that of V_{37}. In all the other crosses F_2 mean values did not deviated significantly from those of their parents.

Number of days for first flowering:

In the parents the duration taken for flowering ranged from 38.40 days recorded by V_{13} to a maximum of 42.40 recorded by V_{41}. Among the F_2 hybrids it ranged from 35.53 recorded by the cross $V_{13} \times V_{37}$ to the maximum of 41.33 recorded by the cross $V_2 \times V_{41}$.

Only in the cross $V_{13} \times V_{37}$ the F_2 mean showed significant difference from those of the parents. The F_2 mean of the cross $V_2 \times V_{41}$ showed significant difference with that of the parent V_2 and the F_2 mean of the cross $V_{25} \times V_{37}$ showed significant difference from that of the parent V_{37}. In the other crosses $V_{25} \times V_{41}$, $V_{13} \times V_{41}$, $V_{29} \times V_{41}$ and $V_{37} \times V_{41}$ the F_2 mean values were significantly different from that of the parent V_{41}.

D-1. Combining ability analysis in F_2

Analysis of variance for the various characters in F_2 generation is presented in table 19. Highly significant differences were shown by the different crosses for all the characters. Except for oil yield the differences were significant both at 5 and 1 per cent levels.

The analysis of variance for general and specific combining ability is given in table 20. The mean squares due to general combining ability were significant for all the characters except for oil yield. The mean squares due to specific combining ability were also significant for all the characters. For number of primary productive branches, productive nodes on main axis and oil content the effects were significant at 5 per cent level only.

The estimates of the s.c.a effects for different characters among different crosses are presented in table 21.

Plant height:

Variance due to g.c.a and s.c.a were significant at 1 per cent level. The g.c.a variance was about double to that of s.c.a. Among the F_2 progenies significant s.c.a effects were recorded in the crosses $V_2 \times V_{13}$, $V_2 \times V_{41}$, $V_{25} \times V_{13}$, $V_{25} \times V_{29}$, $V_{25} \times V_{41}$, $V_{13} \times V_{41}$ and $V_{29} \times V_{37}$. But the effects were negative in the case of two crosses $V_2 \times V_{13}$ and $V_{25} \times V_{29}$: Maximum positive s.c.a effect was shown by $V_{29} \times V_{37}$ (31.985). The cross $V_{25} \times V_{29}$ recorded the maximum negative value of -15.325.

Number of primary productive branches per plant:

The variance due to g.c.a as well as s.c.a were significant at 5 per cent level. The g.c.a variance was about three times to that of s.c.a. The s.c.a effects were significant in six crosses viz., $V_2 \times V_{25}$, $V_2 \times V_{13}$, $V_2 \times V_{41}$, $V_{25} \times V_{29}$, $V_{13} \times V_{29}$ and $V_{29} \times V_{37}$ of which the s.c.a effects in crosses $V_{25} \times V_{29}$ and $V_{29} \times V_{37}$ were significant at 5 per cent level only. The s.c.a effect was negative in the cross $V_2 \times V_{13}$. Maximum positive s.c.a effect was recorded in the cross $V_{13} \times V_{29}$ (1.695).

Number of productive nodes on main axis:

The analysis of variance for g.c.a and s.c.a showed significant variation. The g.c.a variance was about two and a half times higher than that of s.c.a. Significant s.c.a effects were observed in eight out of the fifteen crosses viz., $V_2 \times V_{25}$, $V_2 \times V_{29}$, $V_2 \times V_{37}$, $V_2 \times V_{41}$, $V_{25} \times V_{41}$, $V_{13} \times V_{37}$, $V_{29} \times V_{37}$ and $V_{37} \times V_{41}$. The s.c.a effects of $V_2 \times V_{29}$, $V_2 \times V_{37}$, $V_{25} \times V_{41}$ and $V_{13} \times V_{37}$ were significant at 5 per cent level only. The s.c.a effects of crosses $V_2 \times V_{29}$ and $V_{13} \times V_{37}$ were negative. Maximum positive s.c.a effect was recorded by the cross $V_{29} \times V_{37}$ (8.963) followed by the cross $V_2 \times V_{25}$(6.684).

Number of pods on main axis:

Variance due to g.c.a and s.c.a were highly significant for this character. The magnitude of g.c.a variance was

about three and a half times to that of s.c.a. The s.c.a effects were significant in six crosses viz., $V_2 \times V_{25}$, $V_2 \times V_{13}$, $V_2 \times V_{29}$, $V_{25} \times V_{37}$, $V_{13} \times V_{37}$ and $V_{29} \times V_{37}$. The s.c.a effects in $V_2 \times V_{13}$, $V_2 \times V_{29}$ and $V_{13} \times V_{37}$ were negative and significant at 5 per cent level only. Maximum positive s.c.a effect of 11.169 was shown by the cross $V_2 \times V_{25}$ followed by the cross $V_{25} \times V_{37}$ with 8.374.

Total number of pods per plant:

Analysis of variance showed that g.c.a and s.c.a variances were highly significant. The g.c.a variance was double to that of s.c.a variance. Eight crosses recorded significant s.c.a effects. The crosses include, $V_2 \times V_{25}$, $V_2 \times V_{13}$, $V_2 \times V_{29}$, $V_2 \times V_{41}$, $V_{25} \times V_{13}$, $V_{25} \times V_{41}$, $V_{13} \times V_{29}$ and $V_{29} \times V_{37}$. Among these the two crosses $V_{25} \times V_{13}$ and $V_{25} \times V_{41}$ showed significance only at 5 per cent level. The s.c.a effects of the two crosses $V_2 \times V_{13}$ and $V_2 \times V_{29}$ were negative. Maximum positive s.c.a effect was recorded by the cross $V_2 \times V_{25}$ (42.464) followed by the crosses $V_2 \times V_{41}$ (26.616) and $V_{29} \times V_{37}$ (22.388).

1000-seed weight:

Analysis of variance showed that both g.c.a and s.c.a variances were significant at 1 per cent level. The magnitude of g.c.a variance was almost equal to that of s.c.a. The s.c.a effects of seven crosses were significant at 1 per cent level and that of one cross at 5 per cent level. The crosses

showing significant variation include $V_2 \times V_{25}$, $V_2 \times V_{41}$, $V_{25} \times V_{29}$, $V_{13} \times V_{29}$, $V_{13} \times V_{41}$, $V_{29} \times V_{37}$, $V_{29} \times V_{41}$ and $V_{25} \times V_{37}$. Among these the s.c.a effects of three crosses viz., $V_2 \times V_{25}$, $V_{25} \times V_{29}$ and $V_{29} \times V_{37}$ were negative. The s.c.a effect was positive and maximum in the cross $V_{29} \times V_{41}$ (0.611) which was closely followed by the crosses $V_2 \times V_{41}$ (0.522) and $V_{13} \times V_{41}$ (0.518).

Oil content:

Analysis of variance showed that only s.c.a variance was significant at 5 per cent level. The g.c.a variance was only half to that of s.c.a variance. The s.c.a effects were significant in the three crosses viz., $V_2 \times V_{25}$, $V_{25} \times V_{37}$ and $V_{13} \times V_{29}$, of which $V_{13} \times V_{29}$ was significant at 5 per cent only. The s.c.a effects of the two crosses $V_{25} \times V_{37}$ and $V_{13} \times V_{29}$ were negative. Maximum positive s.c.a effect was recorded by the cross $V_2 \times V_{25}$ (9.936).

Seed yield per plant:

The g.c.a and s.c.a variances were highly significant and t he g.c.a variance was one and half times higher than that of s.c.a. The s.c.a effects of four crosses viz., $V_2 \times V_{25}$, $V_2 \times V_{41}$, $V_{25} \times V_{37}$ and $V_{13} \times V_{29}$ were significant and positive. Only the cross $V_{13} \times V_{29}$ showed significance at 5 per cent level. Maximum positive s.c.a effect was recorded by the cross $V_2 \times V_{25}$ (7.110) followed by the crosses $V_2 \times V_{41}$ (4.614) and $V_{25} \times V_{37}$ (4.023).

Table 21. Estimates of specific combining ability (s.c

Crosses	Days for first flower-ing	Plant height at maturity	No. of primary productive branches/ plant	No. of produc-tive nodes on main axis
2 x 25	-0.231	3.623	1.099**	6.684**
2 x 13	0.858	-11.504**	-0.879**	-0.468
2 x 29	-0.498	-7.215	-0.044	-4.674*
2 x 37	-0.398	-3.117	0.052	4.213*
2 x 41	1.152*	14.346**	0.943**	5.194**
25 x 13	0.519	11.669**	-0.561*	2.974
25 x 29	0.846	-15.325**	0.641*	2.100
25 x 37	-0.321	-5.644	0.187	0.255
25 x 41	-1.304*	12.519**	-0.538	3.903*
13 x 29	-0.548	-1.735	1.695**	-1.485
13 x 37	-2.715**	-4.021	-0.358	-3.931*
13 x 41	0.169	12.942**	-0.350	2.767
29 x 37	1.079	31.985**	0.693*	8.963**
29 x 41	-1.637*	-0.919	-0.315	-2.356
37 x 41	-1.071	-3.337	0.174	5.098**
S.E.(S_{ij})	0.574	4.096	0.296	1.960
S.E.(S_{ij}-S_{ik})	0.877	6.113	0.443	2.925
S.E.(S_{ij}-S_{kl})	0.794	5.659	0.410	2.708
C.D.(0.05) (S_{ij}-S_{ik})	1.714	3.056	0.886	5.850
,, (S_{ij}-S_{kl})	1.588	1.318	0.820	5.416

* Significant
** Significant

.a) in F_2 generation.

No. of pods on main axis	Total number of pods/ plant	1000 seed weight	Oil content (Percen-tage)	Seed yield/ plant
11.169**	42.464**	-0.596**	9.936**	7.110**
-4.884*	-19.709**	0.198	-4.889	-2.014
-5.082*	-19.367**	-0.028	-3.623	-0.900
3.147	7.869	0.071	4.594	0.506
3.630	26.616**	0.522**	-6.023	4.614**
-0.673	11.407*	0.120	-0.756	0.730
0.095	1.666	-0.350**	3.577	-1.201
8.374**	8.353	0.208*	-10.539**	4.023**
0.907	11.449*	0.072	-1 .289	-1.065
-0.759	17.626**	0.288**	-7.981*	2.244*
-4.763*	-0.619	0.006	4.636	-0.629
3.103	2.259	0.518**	0.686	0.983
7.988**	22.388**	-0.269**	-0.497	1.694
3.438	-0.782	0.511**	4.486	-1.286
-4.182	4.388	-0.076	-0.431	0.714
2.299	5.380	0.105	3.331	1.052
3.431	9.029	0.157	4.971	1.569
3.176	7.434	0.145	4.602	1.453
6.860	16.058	0.314	9.942	3.138
6.352	14.868	0.290	9.204	2.906

at 5 per cent level
at 1 per cent level

Table 20. Analysis of variance for combining ability in F_2 generation.

Source	D.F.	Mean sum of squares								
		Days for first flowering	Plant height at maturity	No. of primary productive branches/ plant	No. of productive nodes on main axis	No. of pods on main axis	Total number of pods/ plant	Seed yield/ plant	1000-seed weight	Oil content (Percentage)
G.C.A.	5	2.521**	331.876**	1.627*	75.539*	130.610**	961.190**	17.856**	0.119*	14.054
S.C.A.	15	1.592**	174.247**	0.674*	31.918*	38.226**	480.280**	11.120**	0.124**	29.992*
Error	63	0.419	21.353	0.112	4.889	6.725	36.840	1.407	0.014	14.122

* Significant at 5 per cent level

** Significant at 1 per cent level

Number of days for first flowering:

Variance due to g.c.a and s.c.a were highly significant. Significent s.c.a effects were recorded by the crosses $V_2 \times V_{41}$, $V_{25} \times V_{41}$, $V_{13} \times V_{37}$ and $V_{29} \times V_{41}$. Except the cross $V_2 \times V_{41}$ the other three crosses recorded negative s.c.a effects. Maximum positive s.c.a effect was recorded by the cross $V_2 \times V_{41}$(1.152). Maximum negative s.c.a effect was recorded by the cross $V_{13} \times V_{37}$ (-2.715) followed by the two crosses $V_{29} \times V_{41}$ (-1.637) and $V_{25} \times V_{41}$ (-1.304).

D-2. Components of variation in F_2 generation

The components of variation and genetic ratios made from F_2 data are presented in tables 22 and 23.

Plant height:

The estimates of D, H_1 and H_2 were significant. F was not significant. The value of h^2 was also not significant in F_2. The mean degree of dominance in F_2 (2.24) indicated over dominance. The distribution of genes with positive and negative effects were not symmetrical in F_2 (0.22) as the value was less than 0.25. The proportion of dominant to recessive alleles indicated that dominant alleles were in excess. Heritability estimate was 3.00 per cent.

Number of primary productive branches per plant:

In F_2 estimates of D, H_1 and H_2 were significant but h^2 was not significant. F was not significant in F_2. The non-significant values of F in F_2 indicated that the expression of this character was not affected by the dominant genes. The mean degree of dominance in F_2 (1.69) indicated over dominance. The distribution of genes with positive and negative effects was not symmetrical in F_2 as the value was 0.20. The proportion of dominance to recessive alleles in F_2 (2.0) indicated the predominance of dominant alleles. The heritability estimate was 28.00% in F_2.

Number of productive nodes on main axis:

In F_2, estimate of $\hat{H}_1$ was only statistically significant. Estimates of $\hat{D}$, $\hat{F}$, $\hat{h}^2$ and $\hat{H}_2$ were not significant. The value for mean degree of dominance in F_2 (2.86) indicated over dominance. The distribution of genes with positive and negative effects were not symmetrical in F_2 (0.17). Dominant alleles were found more in F_2. Heritability estimate was 7.00% in F_2.

Number of pods on main axis:

The estimates of $\hat{H}_1$ and $\hat{H}_2$ were highly significant in F_2. The estimates of $\hat{D}$, $\hat{F}$ and $\hat{h}^2$ were not significant. The value for mean degree of dominance in F_2 (2.57) indicated over dominance. The distribution of genes with positive and negative effects showed asymmetry as indicated by the value 0.19 in F_2. The dominant alleles were in excess in F_2 as indicated by the value 0.31. Heritability estimate was 9.00% in F_2.

Total number of pods per plant:

In F_2 the estimates of H_1 and H_2 were significant. The estimates of $\hat{D}$, $\hat{F}$ and $\hat{h}^2$ were not significant. The value of mean degree of dominance indicated over dominance in F_2 (3.80). In this case also the distribution of genes with positive and negative effects showed asymmetry as indicated by the value 0.21. The proportion of dominant to recessive genes showed excess of dominant alleles. Heritability

estimate for F_2 was 5.00%.

1000-seed weight:

In F_2, the estimates for $\hat{D}$, $\hat{H}_1$, $\hat{H}_2$, $\hat{h}^2$ and $\hat{F}$ were not significant. The mean degree of dominance was 2.46 indicating over dominance for the expression of the character. The distribution of genes with positive and negative effects showed asymmetry and the proportion of dominant to recessive genes in the parents showed excess of dominant alleles. The heritability estimate was 3.00% for the character in F_2.

Seed yield per plant:

In F_2, only the estimates of $\hat{H}_1$ and $\hat{H}_2$ were significant. The mean degree of dominance in F_2 was 6.19 indicating over dominance for the expression of the character. The distribution of genes with positive and negative effects showed asymmetry and the proportion of dominant to recessive genes in the parents showed excess of dominant alleles. The heritability estimate was 2.00% in F_2.

Oil content (Percentage):

The estimates of $\hat{D}$, $\hat{H}_1$, $\hat{H}_2$, $\hat{h}^2$ and $\hat{F}$ were not significant. Mean degree of dominance for the character indicated over dominance in F_2. Distribution of genes with positive and negative effects showed asymmetry and the proportion of dominant and recessive genes in the parents showed excess of dominant alleles. Heritability estimate was 2.00%.

Table 22. Estimates of components of variation in F_2 generation.

Parameteres	Days for first flowering	Plant height at maturity	No. of primary productive branches/ plant	No. of productive nodes on main axis	No. of pods on main axis	Total No. of pods/ plant	1000-seed weight	Seed yield/ plant	Oil content (Percentage)
$\hat{D}$	17.35**	1156.52*	8.36**	74.62	202.60	1051.19	0.30	9.29	23.90
	±6.15	±505.26	±2.14	±118.99	±175.90	±2129.68	±1.56	±60.91	±211.89
$\hat{F}$	30.72	175.15	9.52	-419.75	-541.09	-5405.34	-0.51	-98.33	-40.28
	±29.94	±2456.74	±10.43	±578.57	±855.29	±10361.40	±7.59	±309.84	±1030.30
$\hat{H}_1$	292.03**	23293.43**	95.78**	2457.26*	5386.60**	60959.86**	7.46	1427.91*	3609.46
	±62.53	±5130.56	±21.79	±1208.26	±1786.15	±21632.00	±15.85	±618.56	±2151.63
$\hat{H}_2$	268.24**	20683.87**	77.43**	1750.24	4151.93**	52537.09**	15.96	1201.05*	3606.46
	±55.86	±4583.26	±19.46	±1079.37	±1595.61	±19321.00	±14.16	±552.58	±1922.11
$\hat{h}^2$	6.09	744.13	3.22	968.15	360.86	14109.40	0.43	272.40	-475.22
	±37.59	±3084.49	±13.10	±726.41	±1073.83	±13007.90	±9.53	±371.92	±1293.56
$\hat{E}$	1.25	64.00	0.33	14.66	20.17	110.52	0.04	4.22	42.36
	±2.32	±190.98	±0.81	±44.97	±66.49	±805.97	±0.59	±23.02	±80.09

* Significant at 5 per cent level
** Significant at 1 per cent level

Table 23. Estimates of components of variation in

Parameters	No. of days for first flowering	Plant height at maturity	No. of primary productive branches/ plant
$(\hat{H}_1/\hat{D})^{\frac{1}{2}}$	2.05	2.24	1.69
$\hat{H}_2/4\,\hat{H}_1$	0.22	0.22	0.20
$\frac{(4\hat{D}\hat{H}_1)^{\frac{1}{2}} + \hat{F}}{(4\hat{D}\hat{H}_1)^{\frac{1}{2}} - \hat{F}}$	2.51	1.00	2.01
Heritability (narrow sense)	0.21	0.03	0.28

F_2 generation (Proportional values)

No. of productive nodes on main axis	No. of pods on main axis	Total number of pods/ plant	Seed yield/ plant	1000-seed weight	Oil content (Percentage)
2.86	2.57	3.80	6.19	2.46	6.14
0.17	0.19	0.21	0.21	0.53	0.24
0.01	0.31	-0.91	0.07	0.49	0.87
0.07	0.09	0.05	0.02	0.03	0.02

Number of days for first flowering:

In F_2, the estimates for $\hat{D}$, $\hat{H}_1$ and $\hat{H}_2$ were significant. $\hat{F}$ and $\hat{h}^2$ were not significant. Estimate of mean degrees of dominance in F_2 was 2.05 indicating over dominance. The distribution of genes with positive and negative effects showed asymmetry and the proportion of dominant and recessive genes in the parents showed excess dominant alleles in F_2. Heritability estimate was 21.00%.

D-3. Segregation pattern in F_2 generation

The frequency and spectrum of phenotypic variants created in the F_2 generation in the fifteen diallel set of crosses were studied and the results are given below. The phenotypic distribution in F_2 on plant height, number of primary productive branches, number of productive nodes on main axis, number of pods on main axis, total number of pods per plant, seed yield per plant, 1000 seed weight, oil content and duration for first flowering are presented in tables 25-1 to 25-9.

Plant height at maturity:

The frequency distribution in percentage is represented in table 24-1, Fig. 14. Compared to the parental range (63-108 cm) the frequency of positive types ranged from 1.66% in $V_{13} \times V_{37}$ to 49.80% in $V_{29} \times V_{37}$. The crosses $V_2 \times V_{13}$, $V_{25} \times V_{29}$, $V_{25} \times V_{13}$, $V_{25} \times V_{37}$ and $V_{25} \times V_{41}$ showed no positive types. The percentage of negative types compared to parental values ranged from 4.88 in $V_{29} \times V_{37}$ to 66.40 in $V_2 \times V_{13}$. The cross $V_{25} \times V_{41}$ recorded no negative type. The spectrum of variants in each cross is represented in table 25-1 along with variance and coefficient of variation. Maximum number of positive variants were recorded in $V_{29} \times V_{37}$ falling in the class categories from 109 to 148. Maximum number of negative variants were recorded in the cross $V_2 \times V_{13}$ falling in the class categories from 45 to 62. The

variance in the different crosses ranged from 163.81 in $V_2 \times V_{13}$ to 769.75 in $V_{13} \times V_{41}$. Coefficient of variation in the different crosses for the character ranged from 14.7% in $V_{25} \times V_{41}$ to 30.60% in $V_{13} \times V_{29}$. The 'F' test analysis on variance showed that there was significant difference in the distribution of individuals in different crosses. The different cross combinations and their statistical significance in the F_2 distribution are represented in table 26-1. The F_2 distribution in $V_2 \times V_{13}$ showed the maximum difference from those of other crosses and minimum difference was shown by $V_{37} \times V_{41}$ and $V_{13} \times V_{37}$.

Number of primary productive branches per plant:

The frequency distribution in percentage for the character is represented in table 24-1, Fig. 13 . Compared to the parental range (0.5 to 3.0) the frequency of positive types ranged from 8.30% in $V_{13} \times V_{37}$ to 54.78% in $V_2 \times V_{29}$ which was closely followed by the cross $V_{13} \times V_{29}$ (54.12%). The frequency of negative types ranged from 1.66% in $V_2 \times V_{25}$ to 20.75% in $V_{29} \times V_{41}$ which was closely followed by the crosses $V_{13} \times V_{37}$ and $V_{25} \times V_{37}$ (19.92%).

The spectrum of variants in each cross is represented in table along with their variances and coefficient of variation. Maximum number of positive variants were recorded in the crosses $V_2 \times V_{29}$, $V_{13} \times V_{29}$ and $V_{25} \times V_{29}$ falling in the class categories from 3.1 to 11.5. Maximum number of

negative variants were recorded in the cross V_{13} x V_{37} and V_{25} x V_{37} falling in the class category from 0.1 to 0.4. The coefficient of variation in the different F_2 families ranged from 41.9% in the cross V_2 x V_{29} to 134.8% in the cross V_{13} x V_{37}. The variance for the character ranged from 0.83 in the cross V_{37} x V_{41} to 12.28 in the cross V_2 x V_{41}. The variance of F_2 of different crosses were tested for difference and the results are presented in table 26-2. There was significant difference in the distribution of individuals in different crosses. The F_2 distribution in V_2 x V_{41} showed the maximum difference from those of other crosses and minimum difference was shown by V_{25} x V_{13}.

Number of productive nodes on main axis:

The frequency distribution is represented in table 24-2, Fig. 15. Compared to the parental range (15-30) the percentage of positive types ranged from 1.66 to 44.82 in crosses V_{29} x V_{41} and V_{29} x V_{37} respectively. In the cross V_2 x V_{37} also percentage of positive types was high being 41.50. The three crosses V_2 x V_{29}, V_2 x V_{13} and V_{25} x V_{13} showed no positive type. The percentage of negative types ranged from 6.64 in the crosses V_{25} x V_{41} and V_{29} x V_{37} to 71.38 in V_{13} x V_{29}.

The spectrum of variants in each cross is represented in table 25-2 along with variance and coefficient of variation. Maximum number of positive variants were recorded in V_{29} x V_{37} falling in the class categories from 31 to 65. Maximum

number of negative variants were recorded in the cross $V_{13} \times V_{29}$ falling in the class category from 5 to 15. The variance in the different crosses ranged from 34.74 in $V_2 \times V_{13}$ to 238.04 in $V_2 \times V_{25}$. Coefficient of variation in the different crosses ranged from 31.23% in $V_2 \times V_{37}$ to 63.36% in $V_{13} \times V_{29}$. The 'F' test analysis on variance showed that there was significant difference in the distribution of individuals in different crosses. The different cross combinationsand their statistical significance in the F_2 distribution are recorded in table 26-3. The F_2 distribution in $V_{25} \times V_{37}$ and $V_2 \times V_{13}$ were the most significantly different ones and the minimum difference was recorded in $V_{13} \times V_{37}$.

Number of pods on main axis:

The frequency distribution is represented in table 24-2, Fig. 16 . Compared to the parental range (21-30) the percentage of positive types ranged from 3.32 in $V_{37} \times V_{41}$ to 78.04 in $V_{25} \times V_{37}$ followed by the crosses $V_2 \times V_{37}$ (73.02) and $V_{29} \times V_{37}$ (67.23). The cross $V_2 \times V_{13}$ showed no positive type. The percentage of negative types ranged from 9.13 in $V_{29} \times V_{37}$ to 69.72 in $V_2 \times V_{13}$.

The spectrum of variants in each cross is represented in table 25-4 along with variance and coefficient of variation. Maximum number of positive variants were recorded in $V_2 \times V_{37}$ falling in the class categories from 31 to 69. Maximum number of negative variants were recorded in $V_2 \times V_{13}$ falling

in the class categories from 1 to 19. The variance in the different crosses ranged from 23.61 in $V_2 \times V_{13}$ to 442.35 in $V_{25} \times V_{37}$. Coefficient of variation ranged from 26.1% in $V_{29} \times V_{41}$ to 47.4% in $V_{25} \times V_{29}$. The 'F' test analysis on variance showed that there was significant difference in the distribution of individuals in different crosses. The different cross combinations and their statistical significance in the F_2 distribution are represented in table 26-4. The F_2 distribution in $V_2 \times V_{25}$, $V_2 \times V_{13}$ and $V_{25} \times V_{37}$ showed the maximum difference from those of other crosses and minimum difference was recorded in $V_{13} \times V_{37}$.

Total number of pods per plant:

The frequency distribution is represented in table 24-3, Fig. 17 . Compared to the parental range (21-40) the percentage of positive types ranged from 19.92 in $V_{29} \times V_{41}$ to 86.32 in $V_2 \times V_{25}$ followed by $V_{25} \times V_{37}$ (78.02). The percentage of negative types ranged from 6.64 in $V_{25} \times V_{41}$ to 41.50 in $V_2 \times V_{13}$. The cross $V_2 \times V_{25}$ showed no negative type.

The spectrum of variants in each cross is represented in table 25-5 along with variance and coefficient of variation. Maximum number of positive variants were recorded in $V_2 \times V_{25}$ falling in the class categories from 41 to 300. Maximum number of negative variants were recorded in $V_2 \times V_{13}$ falling in the class category from 1 to 19. The variance in the different crosses ranged from 259.49 in $V_2 \times V_{13}$ to 4403.59 in $V_2 \times V_{25}$. Coefficient of variation ranged from

54.9% in $V_{25} \times V_{41}$ to 122.05% in $V_{13} \times V_{37}$.

The 'F' test analysis showed that there was significant difference in the distribution of individuals in different crosses. The different cross combinations and their statistical significance in the F_2 distribution are presented in table 26-5. The F_2 distribution in $V_2 \times V_{13}$ and $V_{13} \times V_{41}$ showed the maximum difference from those of other crosses and minimum difference was shown by $V_{25} \times V_{13}$ and $V_{29} \times V_{37}$.

Seed yield per plant:

The frequency distribution is represented in table 24-3, Fig. 19. Compared to the parental range (3.0 to 6.5 g) the percentage of positive types ranged from 24.9 in $V_{13} \times V_{29}$ to 81.34 in $V_2 \times V_{25}$ followed by $V_2 \times V_{41}$ (79.68). The percentage of negative types ranged from 4.15 in $V_{37} \times V_{41}$ to 37.35 in $V_2 \times V_{13}$.

The spectrum of variants in each cross is represented in table 25-6 along with variance and coefficient of variation. Maximum number of positive variants were recorded in $V_2 \times V_{25}$ falling in the class categories from 6.6 to 36.5. Maximum number of negative variants were recorded in $V_2 \times V_{13}$ falling in the class categories from 0.1 to 3.8. Variance in the different crosses ranged from 3.26 in $V_2 \times V_{13}$ to 92.16 in $V_2 \times V_{25}$. Coefficient of variation ranged from 41.6% in $V_{29} \times V_{41}$ to 95.7% in $V_{13} \times V_{29}$.

The 'F' test analysis on variance showed that there was significant difference in the distribution of individuals in different crosses. The different cross combinations and their statistical significance in the F_2 distribution are represented in table 26-6. The F_2 distribution in $V_2 \times V_{13}$, $V_2 \times V_{25}$ and $V_{29} \times V_{41}$ showed the maximum difference from those of other crosses and minimum difference was recorded in $V_{25} \times V_{29}$.

1000-seed weight:

The frequency distribution is represented in table 24-4, Fig. 18 . Compared to the parental range (2.5 to 3.5 g) the percentage of positive types ranged from 10 to 95 in $V_2 \times V_{25}$ and $V_{29} \times V_{41}$ respectively. In $V_2 \times V_{13}$ also percentage of positive variants were very high being 90. The percentage of negative types ranged from 20 in crosses $V_{29} \times V_{37}$, $V_{25} \times V_{37}$, $V_{25} \times V_{29}$, $V_{13} \times V_{37}$ and $V_2 \times V_{29}$ to 40 in the crosses $V_2 \times V_{25}$ and $V_{13} \times V_{41}$. In $V_2 \times V_{37}$, $V_2 \times V_{41}$, $V_2 \times V_{13}$, $V_{13} \times V_{29}$, $V_{25} \times V_{41}$, $V_{29} \times V_{41}$ and $V_{37} \times V_{41}$ negative types were absent.

The spectrum of variants in each cross is represented in table 25-7. along with variance and coefficient of variation. Coefficient of variation in the different crosses ranged from 4.86% in the cross $V_{37} \times V_{41}$ to 14.84% in the cross $V_2 \times V_{29}$. Variance in the different crosses ranged from 0.02 in $V_{37} \times V_{41}$ to 0.14 in $V_2 \times V_{29}$. The 'F' test analysis on variance showed that there was significant

difference in the distribution of individuals in different crosses. The different cross combinations and their statistical significance in the F_2 distribution are recorded in table 26-7. The F_2 distribution in $V_{37} \times V_{41}$ showed the maximum difference from those of other crosses while the crosses $V_{13} \times V_{29}$ and $V_{13} \times V_{37}$ showed minimum difference.

Oil content:

The frequency distribution of F_2 segregants of different crosses is represented in table 24-4, Fig. 12 . Compared to the parental range (40 to 50) the percentage of positive types ranged from 6.66 in $V_{13} \times V_{29}$ to 69.93 in $V_{13} \times V_{37}$ followed by 63.27 in $V_2 \times V_{37}$. The percentage of negative types ranged from 16.65 in $V_{13} \times V_{37}$, $V_{29} \times V_{37}$ and $V_{37} \times V_{41}$ to 73.26 in $V_{13} \times V_{29}$.

The spectrum of variants in each cross is represented in table 25-8 along with variance and coefficient of variation. Coefficient of variation ranged from 18.38% in $V_{37} \times V_{41}$ to 35.92% in $V_2 \times V_{25}$. Maximum number of positive variants were recorded in $V_{13} \times V_{37}$ and maximum number of negative variants were recorded in $V_{13} \times V_{29}$ falling in the class categories from 51 to 80 and from 20 to 39 respectively. Varimnce in the different crosses ranged from 74.39 in $V_{13} \times V_{29}$ to 313.97 in $V_2 \times V_{25}$. The 'F' test analysis on variance showed that there was significant difference in the

distribution of individuals in different crosses. The different cross combinations and their statistical significance in the F_2 distribution are represented in table 26-8. The F_2 distribution in $V_{13} \times V_{29}$ showed the maximum difference from those of other crosses and the crosses $V_{25} \times V_{37}$ and $V_{25} \times V_{41}$ recorded minimum difference.

Number of days for first flowering:

Table 24-4, Fig.11 represents the frequency distribution of the F_2 segregants. Compared to the parental range (35 to 41) the percentage of positive types ranged from 6.66 in $V_{13} \times V_{41}$ and $V_{37} \times V_{41}$ to 53.28 in $V_2 \times V_{41}$ and $V_{29} \times V_{37}$. The crosses $V_2 \times V_{25}$, $V_2 \times V_{29}$, $V_{13} \times V_{29}$, $V_{13} \times V_{37}$, $V_{25} \times V_{13}$, $V_{25} \times V_{37}$ and $V_{29} \times V_{41}$ showed no positive variant. The percentage of negative types ranged from 6.66 in $V_{29} \times V_{37}$ to 49.95 in $V_{13} \times V_{37}$. The two other crosses which showed negative variants were $V_2 \times V_{13}$ and $V_{13} \times V_{29}$. The remaining crosses did not record any negative type.

The spectrum of variants of each cross is represented in table 25-9 along with variance and coefficient of variation. Maximum number of positive variants were recorded in $V_{29} \times V_{37}$ and $V_2 \times V_{41}$ falling in the class categories from 42 to 49. Maximum negative variants were recorded in $V_{13} \times V_{37}$ falling in the class categories from 30 to 34. The coefficient of variation ranged from 2.1% in $V_2 \times V_{25}$ to 5.7% in $V_{29} \times V_{37}$. The variance in the F_2 families of different crosses ranged

Table 24-1. Frequency distribution (percentage) of F_2 primary productive branches.

Characters	Plant height at maturity		
Crosses / Class categories	<63 cm	63-108 cm (Parental range)	>108 cm
2 x 25	16.60	68.06	14.94
2 x 37	33.20	56.44	9.96
2 x 29	18.26	78.02	3.32
2 x 41	21.58	63.08	14.94
2 x 13	66.40	33.20	-
13 x 29	48.14	44.82	6.64
13 x 37	29.88	68.06	1.66
13 x 41	18.26	56.44	24.07
25 x 29	26.56	73.04	-
25 x 13	21.58	78.02	-
25 x 37	6.98	92.13	-
25 x 41	-	100.00	-
29 x 37	4.88	45.28	49.80
29 x 41	9.96	83.00	6.64
37 x 41	8.30	71.38	19.92

segregants for plant height and number of

Number of primary productive branches/plant			
<0.5	0.5-3.0 (Parental range)	3.1-5.6	>5.6
1.66	24.90	31.54	4.15
6.64	59.76	23.24	9.96
4.15	40.67	44.82	9.96
13.28	48.14	23.24	13.28
9.96	59.76	29.88	-
7.47	37.35	22.58	31.54
19.92	71.38	6.64	1.66
17.43	60.59	16.60	4.98
11.62	36.52	46.48	4.98
8.30	73.04	13.28	4.98
19.92	49.80	23.24	6.64
12.45	62.25	23.24	1.66
6.64	44.82	34.86	11.62
20.75	65.57	11.62	1.66
16.60	69.72	13.28	-

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Table 24-2. Frequency distribution (Percentag
and pods on main axis.

Characters / Crosses	Class categories	Number of productive no main axis		
		<15	15-30 (Parental range)	31
2 x 25		8.30	58.10	1
2 x 37		11.62	46.48	2
2 x 29		51.46	48.14	
2 x 41		16.60	43.16	3
2 x 13		59.76	39.84	
13 x 29		71.38	19.92	
13 x 37		44.82	46.48	
13 x 41		28.22	63.08	
25 x 29		18.26	68.06	1
25 x 13		23.24	76.36	
25 x 37		19.92	48.14	1
25 x 41		6.64	54.78	2
29 x 37		6.64	48.14	2
29 x 41		28.22	69.72	1
37 x 41		10.60	48.14	1

Table 24-3. Frequency distribution (Percentag
seed yield per plant.

Characters		Total number of	
Class categories / Crosses	<20	21-40 (Parental range)	41-
2 x 25	-	13.28	11
2 x 37	11.62	26.56	8
2 x 29	38.18	29.88	23
2 x 41	11.62	16.60	13
2 x 13	41.50	36.52	19
13 x 29	31.54	36.52	16
13 x 37	29.88	43.16	14
13 x 41	24.90	33.20	19
25 x 29	21.58	16.60	18
25 x 13	18.26	21.58	6
25 x 37	8.30	13.28	24
25 x 41	6.64	19.92	23
29 x 37	9.96	29.88	16
29 x 41	23.24	56.44	9
37 x 41	8.30	24.90	26

F_2 segregants for total number of pods and

per plant		Seed yield per plant		
61-80	>80	<3.00g	3.00-6.5g (Parental range)	>6.5 g
9.96	64.74	4.98	13.28	81.34
6.64	46.48	18.26	28.22	53.12
8.30	-	31.54	36.52	31.54
16.60	42.33	9.96	9.96	79.68
1.66	-	37.35	35.69	26.56
3.32	11.62	33.20	41.50	24.90
1.66	9.96	5.81	40.67	53.12
11.62	9.96	30.71	32.37	36.52
19.92	23.24	9.96	34.86	54.78
14.94	38.18	13.28	23.24	61.42
19.92	33.20	17.43	9.13	73.04
16.60	33.20	13.28	53.12	33.20
19.92	23.24	5.81	22.41	71.38
4.98	4.98	13.28	53.12	33.20
18.26	21.58	4.15	29.05	66.40

Table 24-4. Frequency distribution (Percentage) flowering, 1000-seed weight and oil

Characters / Crosses	Number of days for first flowering		
	Class categories	< 35	35-41 (Parental range)	>41
2 x 25		-	100.00	-
2 x 37		-	79.92	19.98
2 x 29		-	100.00	-
2 x 41		-	46.62	53.28
2 x 13		13.32	66.60	19.98
13 x 29		19.98	79.92	-
13 x 37		49.95	49.95	-
13 x 41		-	93.24	6.66
25 x 29		-	66.60	33.30
25 x 13		-	100.00	-
25 x 37		-	100.00	-
25 x 41		-	79.92	19.98
29 x 37		6.66	39.96	53.28
29 x 41		-	100.00	-
37 x 41		-	93.24	6.66

F_2 segregants for number of days for first
tant.

1000-seed weight			Oil content		
2.5g	2.5-3.5g (Parental range)	>3.5g	<40	40-50 (Parental range)	>50
40	50	10	33.30	13.32	53.28
-	40	60	19.98	16.65	63.27
20	50	30	29.97	23.31	46.62
-	30	70	43.29	6.66	49.95
-	10	90	53.28	23.31	23.31
-	20	80	73.26	19.98	6.66
20	30	50	16.65	13.32	69.93
40	25	35	33.30	39.96	26.64
20	35	45	33.30	33.30	33.30
30	35	35	36.63	49.95	13.32
20	55	25	46.62	29.97	23.31
-	30	70	46.62	13.32	39.96
20	35	45	16.65	39.96	43.29
-	5	95	19.98	23.31	56.61
-	30	70	16.65	33.30	49.95

Table 25-1. Spectrum of segregants in F_2 for pl

Treatment \ Class range	41-49	50-58	59-67	68-76	7[illegible]-85	86-94	95-103	104-112	1
2 x 25	0	8	12	10	10	16	28	18	
2 x 37	0	6	34	24	18	10	10	6	
2 x 29	4	4	14	22	32	18	18	4	
2 x 41	0	16	10	12	18	24	2	20	1
2 x 13	10	34	36	36	26	10	4	0	
13 x 29	8	26	24	8	14	18	14	0	
13 x 37	0	8	28	44	18	14	2	4	
13 x 41	2	6	14	6	20	14	12	16	1
25 x 29	12	6	14	28	29	16	12	8	
25 x 13	2	6	18	24	18	18	18	16	
25 x 37	0	2	4	20	26	30	12	14	
25x41	0	0	0	2	12	14	18	28	3
29 x 37	0	0	6	2	0	12	14	28	
29 x 41	0	2	10	16	20	34	24	6	
37 x 41	0	2	8	12	12	22	24	16	
2	0	6	12	14	8	10	4	4	
25	0	2	6	6	4	4	13	6	1
29	0	2	6	10	22	16	2	2	
37	2	6	10	8	12	8	4	6	
41	0	6	12	10	6	20	6	0	
13	10	16	10	6	14	2	0	0	

140-148	149-157	158-166	167-175	$\bar{x}$	σ^2	C.V.
2	0	0	0	112.00	553.19	21.0
0	0	0	0	84.5	49.13	26.2
0	0	0	0	86.7	251.73	18.3
0	4	0	0	93.5	715.08	28.6
0	0	0	0	65.3	163.81	19.4
0	0	0	0	78.3	574.07	30.6
0	0	0	0	78.2	252.00	20.3
4	0	2	0	99.8	769.75	27.8
0	0	0	0	81.5	428.53	25.4
0	0	0	0	86.3	344.27	21.5
0	0	0	0	93.5	276.80	17.6
0	0	0	0	113.2	276.90	14.7
10	0	0	2	122.7	638.89	20.6
0	0	0	0	92.7	277.80	17.9
6	0	0	0	103.2	583.16	23.4
0	0	0	0	82.0	340.40	22.5
4	0	0	0	104.7	701.67	25.3
0	0	0	0	84.7	157.14	14.8
0	0	0	0	84.7	488.71	26.1
0	0	0	0	81.7	248.63	19.3
0	0	0	0	67.7	341.59	27.3

Table 25-2. Spectrum of segregants in F_2 for pri

Treatments \ Class range	0.1-0.9	1.0-1.8	1.9-2.7	2.8-3.6	3.7-4.5	4.6-5.4	5.5-6.3
2 x 25	0	80	24	16	22	16	14
2 x 37	0	24	56	16	12	10	2
2 x 29	0	16	38	36	18	12	0
2 x 41	4	46	24	26	4	0	4
2 x 13	8	28	48	28	8	0	0
13 x 29	12	16	26	10	16	2	22
13 x 37	48	24	38	6	2	0	0
13 x 41	18	46	30	20	0	0	2
25 x 29	6	36	16	44	12	6	0
25 x 13	0	42	56	0	16	2	2
25 x 37	30	4	48	2	28	0	4
25 x 41	12	28	50	18	10	2	0
29 x 37	8	16	38	26	18	6	4
29 x 41	10	54	40	0	14	2	0
37 x 41	12	48	44	14	2	0	0
2	0	14	6	20	14	6	0
25	0	20	10	18	6	2	0
29	34	8	14	4	0	0	0
37	28	24	4	4	0	0	0
41	20	14	6	10	10	0	0
13	14	0	24	2	14	0	6

Table 25-3. Spectrum of segregants in F_2 fo

Treatments \ Class range	5-13	14-22	23-31	32-4
2 x 25	10	32	38	16
2 x 37	14	20	36	36
2 x 29	62	44	14	0
2 x 41	20	32	20	44
2 x 13	72	42	6	0
13 x 29	86	22	2	8
13 x 37	54	46	10	6
13 x 41	34	56	20	10
25 x 29	22	28	54	16
25 x 13	28	48	44	0
25 x 37	24	30	28	20
25 x 41	8	48	18	34
29 x 37	8	24	34	36
29 x 41	34	70	14	2
37 x 41	20	32	26	20
2	20	32	4	4
25	18	12	24	2
29	30	26	4	0
37	22	12	12	8
41	22	34	4	0
13	36	22	2	0

Table 25-4. Spectrum of segregants for pod

Treatments \ Class mark	1-9	10-18	19-27	28-36	37-
2 x 25	0	14	26	29	28
2 x 37	0	14	18	38	32
2 x 29	0	60	46	14	0
2 x 41	0	24	34	36	24
2 x 13	2	82	36	0	0
13 x 29	0	72	32	4	10
13 x 37	2	40	48	18	6
13 x 41	0	30	56	22	12
25 x 29	0	26	32	42	12
25 x 13	0	28	44	40	0
25 x 37	0	12	14	26	14
25 x 41	0	12	46	18	34
29 x 37	3	8	30	31	30
29 x 41	2	30	78	10	0
37 x 41	0	24	44	30	20
2	0	20	36	2	2
25	0	19	14	21	2
29	0	34	16	6	4
37	0	30	26	4	0
41	0	26	28	4	2
13	2	30	12	8	6

on main axis.

46–54	55–63	64–72	73–81	$\bar{X}$	σ^2	C.V.
14	6	2	10	41.5	375.6	46.7
16	2	0	0	37.0	116.7	29.2
0	0	0	0	21.2	47.1	32.4
2	0	0	0	39.5	114.5	27.1
0	0	0	0	17.8	23.6	27.3
2	0	0	0	21.3	99.7	46.9
4	2	0	0	25.5	131.3	44.9
0	0	0	0	26.3	81.3	34.3
0	0	2	4	31.5	222.9	47.4
8	0	0	0	28.0	107.9	37.1
16	18	8	12	47.8	442.3	44.0
10	0	0	0	33.7	138.3	34.9
18	2	0	0	36.4	171.7	36.0
0	0	0	0	23.0	36.0	26.1
2	0	0	0	29.3	107.5	35.4
0	0	0	0	22.7	45.1	29.6
4	0	0	0	28.2	134.3	41.1
0	0	0	0	21.6	81.5	41.8
0	0	0	0	20.7	38.0	29.8
0	0	0	0	22.0	43.3	33.5
2	0	0	0	23.7	138.7	49.7

Table 25-5. Spectrum of segregants in F_2 for t

Treatments \ Class range	1-19	20-38	39-57	58-76	77-95	96-114	115-133	134-152
2 x 25	0	16	14	12	20	16	10	8
2 x 37	14	32	10	8	26	18	8	0
2 x 29	46	36	28	6	4	0	0	0
2 x 41	14	20	16	20	21	8	2	2
2 x 13	50	44	24	2	0	0	0	0
13 x 29	38	44	20	4	0	0	4	2
13 x 37	36	52	18	2	4	0	2	0
13 x 41	30	40	24	14	4	6	2	0
25 x 29	26	20	22	24	6	12	10	0
25 x 13	22	26	8	18	28	8	0	4
25 x 37	10	16	30	24	16	6	6	2
25 x 41	8	24	28	20	14	12	10	4
29 x 37	12	36	29	24	12	8	0	0
29 x 41	28	68	12	6	6	0	0	0
37 x 41	10	30	32	22	16	2	2	2
2	20	12	18	0	4	4	0	0
25	20	16	12	6	2	2	2	0
29	34	16	6	4	0	0	0	0
37	22	16	14	4	4	0	0	0
41	30	26	4	0	0	0	0	0
13	22	28	6	2	2	0	0	0

pods per plant.

172-190	191-209	210-228	229-247	248-266	267-285	$\bar{x}$	σ^2	C.V
4	4	4	4	2	2	116.6	4403.5	59.
0	4	0	0	0	0	69.6	2100.3	65.
0	0	0	0	0	0	31.0	474.2	70.
4	2	2	2	4	0	84.0	4325.9	78.
0	0	0	0	0	0	26.3	259.4	61.
4	0	2	2	0	0	46.0	2862.0	116.
0	0	2	4	0	0	42.0	2627.6	122.
0	0	0	0	0	0	41.3	842.9	70.3
0	0	0	0	0	0	56.6	1423.9	66.6
0	0	0	0	0	0	64.0	1910.7	68.3
0	0	0	0	0	4	76.0	2907.5	70.9
0	0	0	0	0	0	67.3	1365.1	54.9
2	2	0	0	2	0	62.6	2390.2	78.1
0	0	0	0	0	0	32.3	385.6	60.80
2	0	0	0	0	0	59.0	1346.7	62.2
0	0	0	0	0	0	38.0	867.3	77.5
0	0	0	0	0	0	39.3	951.7	78.5
0	0	0	0	0	0	23.3	327.7	77.7
0	0	0	0	0	0	34.0	568.1	70.1
0	0	0	0	0	0	21.3	157.5	57.8
0	0	0	0	0	0	28.0	356.1	67.4

Table 25-6. Spectrum of segregants in F_2 for seed yield per plant.

Treatments \ Class range	0.1-1.9	2.0-3.8	3.9-5.7	5.8-7.6	7.7-9.5	9.6-11.4	11.5-13.3	13.4-15.2	15.3-17.1	17.2-19.0	19.1-20.9	21.0-22.8	22.9-24.7	24.8-26.6	26.7-28.5	28.6-30.4	30.5-32.3	32.4-34.2	M1	σ^2_1	C.V.
2 x 25	2	8	12	6	12	4	14	6	6	8	12	2	8	2	4	8	4	2	16.0	92.1	60.0
2 x 37	6	32	18	8	8	10	14	6	10	6	0	2	0	0	0	0	0	0	8.6	32.8	66.6
2 x 29	22	32	28	14	16	4	2	0	0	2	0	0	0	0	0	0	0	0	5.0	12.1	68.8
2 x 41	10	4	10	12	12	20	18	14	4	2	0	2	2	6	2	2	0	0	11.7	50.2	60.2
2 x 13	18	54	16	20	10	0	2	0	0	0	0	0	0	0	0	0	0	0	4.3	3.2	42.0
13 x 29	14	52	24	12	6	0	0	2	0	0	2	4	0	0	0	4	0	0	5.9	32.5	95.7
13 x 37	2	10	44	30	18	8	0	0	4	0	0	2	0	2	0	0	0	0	7.3	19.2	59.8
13 x 41	20	34	22	18	10	12	4	0	0	0	0	0	0	0	0	0	0	0	5.2	10.7	62.2
25 x 29	2	20	32	20	12	12	6	4	4	4	2	0	2	0	0	0	0	0	8.1	25.6	62.5
25 x 13	4	24	16	14	8	12	20	8	0	4	4	0	2	2	0	0	0	0	9.7	59.6	79.6
25 x 37	14	14	4	16	16	18	10	4	4	6	6	0	0	4	0	4	0	0	10.5	54.9	70.6
25 x 41	4	24	52	32	4	2	0	2	0	0	0	0	0	0	0	0	0	0	12.5	55.8	59.8
29 x 37	4	6	24	32	10	20	8	0	2	2	4	8	0	0	0	0	0	0	9.3	30.2	59.1
29 x 41	4	24	52	32	4	2	0	2	0	0	0	0	0	0	0	0	0	0	5.4	5.0	41.6
37 x 41	2	6	32	22	22	18	6	8	0	0	2	2	0	0	0	0	0	0	8.5	17.2	48.8
2	10	26	18	4	0	2	0	0	0	0	0	0	0	0	0	0	0	0	3.8	4.4	55.3
25	4	4	26	14	0	4	0	2	0	2	2	0	2	0	0	0	0	0	6.2	26.9	83.7
29	10	32	16	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.3	2.0	43.8
37	2	18	10	14	6	6	2	2	0	0	0	0	0	0	0	0	0	0	6.3	11.1	55.1
41	4	14	18	16	4	2	0	0	0	0	0	0	0	0	0	0	0	0	5.3	5.3	43.5
13	4	20	18	14	4	0	0	0	0	0	0	0	0	0	0	0	0	0	4.8	4.3	43.5

Table 25-7. Spectrum of segregants in F_2 for 1000-seed

Treatments \ Class range	1.6-1.8	1.9-2.1	2.2-2.4	2.5-2.7	2.8-3.0	3.1-3.3	3.4-3.6
2 x 25	2	4	2	6	4	2	0
2 x 37	0	0	0	2	6	8	2
2 x 29	2	2	0	4	6	4	2
2 x 41	0	0	0	0	6	6	4
2 x 13	0	0	0	0	2	6	4
13 x 29	0	0	0	2	2	8	4
13 x 37	0	0	4	0	6	4	4
13 x 41	0	4	4	0	5	4	3
25 x 29	0	4	0	0	7	3	6
25 x 13	0	2	4	3	4	7	0
25 x 37	0	0	4	5	6	5	0
25 x 41	0	0	0	1	5	4	6
29 x 37	0	2	2	2	5	1	6
29 x 41	0	0	0	0	1	6	5
37 x 41	0	0	0	0	6	10	4
2	0	0	0	2	3	4	1
25	0	0	1	2	4	1	2
29	0	0	1	0	4	0	2
37	0	0	00	1	1	4	2
41	0	0	0	2	2	1	0
13	0	0	0	0	0	3	4

weight.

3.7-3.9	4.0-4.2	4.3-4.5	4.6-4.8	$\bar{x}$	σ^2	C.V.
0	0	0	0	2.4	0.1	12.0
2	0	0	0	2.9	0.1	7.3
0	0	0	0	2.5	0.2	14.8
4	0	0	0	2.9	0.1	6.7
4	4	0	0	3.1	0.1	8.3
4	0	0	0	2.9	0.1	8.0
2	0	0	0	2.8	0.1	8.9
0	0	0	0	2.8	0.2	12.6
0	0	0	0	2.5	0.2	13.9
0	0	0	0	2.6	0.1	10.7
0	0	0	0	2.6	0.1	8.1
2	2	0	0	3.0	0.1	6.9
2	0	0	0	2.8	0.1	13.1
4	1	3	0	3.1	0.1	9.2
0	0	0	0	2.8	0.1	4.8
0	0	0	0	2.7	0.1	6.5
0	0	0	0	2.7	0.2	8.9
3	0	0	0	2.9	0.1	11.3
2	0	0	0	2.9	0.1	8.0
0	3	0	2	3.3	0.3	18.3
2	1	0	0	3.1	0.1	3.4

Table 25-8. Spectrum of segregants in F_2 for oil

Treatments \ Class range	15-19	20-24	25-29	30-34	35-39	40-44	45-49
2 x 25	2	2	1	2	3	1	3
2 x 37	3	1	1	0	1	0	5
2 x 29	2	3	0	3	1	2	6
2 x 41	0	2	2	6	3	0	2
2 x 13	2	1	1	5	7	4	3
13 x 29	0	4	4	3	11	2	4
13 x 37	0	1	2	1	1	2	2
13 x 41	0	0	0	0	10	8	4
25 x 29	0	0	0	0	10	6	4
25 x 13	1	0	0	2	8	6	9
25 x 37	1	1	2	2	8	4	5
25 x 41	2	1	0	4	7	3	1
29 x 37	1	0	1	0	3	3	9
29 x 41	1	0	0	1	4	2	5
37 x 41	0	0	0	1	4	3	7
2	0	0	0	2	4	1	8
25	1	1	0	3	7	4	5
29	0	1	0	2	4	3	7
37	0	1	0	3	3	2	5
41	0	2	2	0	8	4	10
13	2	0	0	4	7	3	2

. content.

50-54	55-59	60-64	65-69	70-74	75-79	$\bar{x}$	σ^2	C.V
3	5	3	1	1	3	49.33	313.97	35.
3	5	6	0	2	3	52.33	294.97	32.
3	3	2	3	1	2	48.33	296.86	35.
3	3	2	4	0	3	48.67	293.00	35.
3	2	2	0	0	0	40.67	135.77	28.
2	0	0	0	0	0	36.33	74.39	23.
4	5	6	4	0	2	54.17	195.78	25.
4	2	0	0	0	2	46.17	108.20	22.5
4	0	4	0	2	0	47.50	113.21	22.4
1	2	0	1	0	0	43.50	82.26	20.8
2	4	0	0	0	1	42.67	144.00	28.1
4	4	0	0	1	3	45.67	260.64	35.3
5	3	1	2	0	2	50.00	158.00	25.1
2	7	3	3	1	1	52.50	176.70	25.32
8	4	0	2	1	0	50.00	84.46	18.38
2	6	4	3	0	0	51.33	106.02	20.06
2	4	2	0	0	1	44.83	152.98	27.59
4	2	1	2	2	2	50.83	197.24	27.63
4	5	1	1	2	3	51.16	254.78	31.20
2	2	0	0	0	0	42.17	28.27	20.98
5	3	0	1	1	2	46.17	233.27	33.08

Table 25-8. Spectrum of segregants in F_2 for oil

Treatments \ Class range	15-19	20-24	25-29	30-34	35-39	40-44	45-49
2 x 25	2	2	1	2	3	1	3
2 x 37	3	1	1	0	1	0	5
2 x 29	2	3	0	3	1	2	6
2 x 41	0	2	2	6	3	0	2
2 x 13	2	1	1	5	7	4	3
13 x 29	0	4	4	3	11	2	4
13 x 37	0	1	2	1	1	2	2
13 x 41	0	0	0	0	10	8	4
25 x 29	0	0	0	0	10	6	4
25 x 13	1	0	0	2	8	6	9
25 x 37	1	1	2	2	8	4	5
25 x 41	2	1	0	4	7	3	1
29 x 37	1	0	1	0	3	3	9
29 x 41	1	0	0	1	4	2	5
37 x 41	0	0	0	1	4	3	7
2	0	0	0	2	4	1	8
25	1	1	0	3	7	4	5
29	0	1	0	2	4	3	7
37	0	1	0	3	3	2	5
41	0	2	2	0	8	4	10
13	2	0	0	4	7	3	2

. content.

50-54	55-59	60-64	65-69	70-74	75-79	$\bar{x}$	σ^2	C.V
3	5	3	1	1	3	49.33	313.97	35.
3	5	6	0	2	3	52.33	294.97	32.
3	3	2	3	1	2	48.33	296.86	35.
3	3	2	4	0	3	48.67	293.00	35.
3	2	2	0	0	0	40.67	135.77	28.
2	0	0	0	0	0	36.33	74.39	23.
4	5	6	4	0	2	54.17	195.78	25.
4	2	0	0	0	2	46.17	108.20	22.5
4	0	4	0	2	0	47.50	113.21	22.4
1	2	0	1	0	0	43.50	82.26	20.8
2	4	0	0	0	1	42.67	144.00	28.1
4	4	0	0	1	3	45.67	260.64	35.3
5	3	1	2	0	2	50.00	158.00	25.1
2	7	3	3	1	1	52.50	176.70	25.32
8	4	0	2	1	0	50.00	84.46	18.38
2	6	4	3	0	0	51.33	106.02	20.06
2	4	2	0	0	1	44.83	152.98	27.59
4	2	1	2	2	2	50.83	197.24	27.63
4	5	1	1	2	3	51.16	254.78	31.20
2	2	0	0	0	0	42.17	28.27	20.98
5	3	0	1	1	2	46.17	233.27	33.08

25 x 13	0	0	10	20
25 x 37	0	0	14	16
25 x 41	0	0	16	8
29 x 37	0	2	6	6
29 x 41	0	0	16	14
37 x 41	0	0	12	16
2	0	0	12	16
25	0	0	6	20
29	0	0	6	20
37	0	0	0	14
41	0	2	4	6
13	0	0	18	12

Table 25-9. Spectrum of segregants in

Treatments \ Class range	30-32	33-35	36-38	39-41
2 x 25	0	0	6	24
2 x 37	0	0	18	6
2 x 29	0	0	10	20
2 x 41	0	0	0	14
2 x 13	0	4	2	18
13 x 29	0	6	14	10
13 x 37	11	4	13	2
13 x 41	0	0	4	24
25 x 29	0	0	2	18

F_2 for duration for first flowering.

42–44	45–47	48–50	51–53	54–56	$\bar{x}$	σ^2	C.V.
0	0	0	0	0	38.6	0.6	2.1
6	0	0	0	0	38.2	0.0	4.2
0	0	0	0	0	38.9	0.0	2.4
12	0	4	0	0	39.6	3.7	4.9
6	0	0	0	0	38.7	3.1	4.6
0	0	0	0	0	37.3	2.0	3.8
0	0	0	0	0	38.6	4.3	5.4
2	0	0	0	0	38.9	0.1	2.3
10	0	0	0	0	38.5	0.1	3.4
0	0	0	0	0	38.6	0.8	2.4
0	0	0	0	0	38.1	0.9	2.6
2	4	0	0	0	37.9	0.1	5.5
12	4	0	0	0	39.7	5.1	5.7
0	0	0	0	0	37.9	0.9	2.6
2	0	0	0	0	38.4	2.8	4.4
2	0	0	0	0	38.9	1.4	3.1
4	0	0	0	0	38.9	0.3	1.5
4	0	0	0	0	38.9	0.3	1.5
14	2	0	0	0	40.2	0.1	3.0
7	6	0	2	3	41.3	16.0	9.7
0	0	0	0	0	37.8	0.9	2.6

Table 26-1. Test of significance for plant height variants in F_2 generation.

	2x25	2x37	2x29	2x41	2x13	13x29	13x37	13x41	25x29	25x13	25x37	25x41	29x37	29x41	37x41
2 x 25															
2 x 37	-														
2 x 29	*	*													
2 x 41	*	*	*												
2 x 13	*	*	*	*											
13 x 29	-	-	*	-	*										
13 x 37	*	*	-	*	*	*									
13 x 41	*	*	*	-	*	-	*								
25x 29	-	-	*	*	*	-	*	*							
25 x 13	*	*	-	*	*	*	-	*	-						
25 x 37	*	*	-	*	*	*	-	*	*	-					
25 x 41	*	*	-	*	*	*	-	*	*	-	-				
29 x 37	-	-	*	-	*	-	*	-	*	*	*	*			
29 x 41	*	*	-	*	*	*	-	*	*	-	-	-	*		
37 x 41	-	-	*	-	*	-	*	-	-	*	*	*	-	*	

* = Significant - = Not significant

Table 26-2. Test of significance of variants in F_2 generation for primary productive branches.

	2x25	2x37	2x29	2x41	2x13	13x29	13x37	13x41	25x29	25x13	25x37	25x41	29x37	29x41	37x41
2 x 25															
2 x 37	*														
2 x 29	*	-													
2 x 41	*	*	*												
2 x 13	*	*	-	*											
13 x 29	-	*	*	*	*										
13 x 37	*	*	*	*	*	*									
13 x 41	*	*	*	*	*	*	*								
25 x 29	*	-	-	*	*	*	*	*							
25 x 13	*	-	-	*	*	*	*	-	-						
25 x 37	*	*	*	*	*	*	-	*	*	*					
25 x 41	*	-	-	*	-	*	*	*	-	-	*				
29 x 37	*	*	*	*	*	*	*	*	*	-	-	*			
29 x 41	*	-	-	*	-	*	*	*	-	-	*	-	*		
37 x 41	*	*	*	*	-	*	*	*	*	-	*	*	*	*	

* = Significant - = Not significant

Table 26-3. Test of significance of variants in F_2 generation for productive nodes on main axis.

	2x25	2x37	2x29	2x41	2x13	13x29	13x37	13x41	25x29	25x13	25x37	25x41	29x37	29x41	37x41
2 x 25															
2 x 37	*														
2 x 29	*	*													
2 x 41	*	*	*												
2 x 13	*	*	*	*											
13 x 29	*	-	*	*	*										
13 x 37	*	*	*	-	*	-									
13 x 41	*	-	-	*	*	*	*								
25 x 29	*	-	*	*	*	-	-	*							
25 x 13	*	-	-	*	*	*	*	-	*						
25 x 37	-	*	*	*	*	*	*	*	*	*					
25 x 41	*	*	*	-	*	*	-	*	*	*	*				
29 x 37	*	*	*	-	*	*	-	*	*	*	*	*			
29 x 41	*	*	-	*	-	*	*	-	*	-	*	*	*		
37 x 41	-	*	*	*	*	*	*	*	*	*	*	*	*	*	

* = Significant - = Not significant

Table 26-4. Test of significance of variants in F_2 generation for pods on main axis.

	2x25	2x37	2x29	2x41	2x13	13x29	13x37	13x41	25x29	25x13	25x37	25x41	29x37	29x41	37x41
2 x 25															
2 x 37	*														
2 x 29	*	*													
2 x 41	*	-	*												
2 x 13	*	*	*	*											
13 x 29	*	-	*	-	*										
13 x 37	*	-	*	-	*	-									
13 x 41	*	*	*	*	*	-	*								
25 x 29	*	*	*	*	*	*	*	*							
25 x 13	*	-	*	-	*	-	-	*	*						
25 x 37	*	*	*	*	*	*	*	*	*	*					
25 x 41	*	-	*	-	*	*	-	*	*	-	*				
29 x 37	*	*	*	*	*	*	-	*	-	*	*	-			
29 x 41	*	*	-	*	*	*	*	*	*	*	*	*	*		
37 x 41	*	-	*	-	*	-	-	*	*	-	*	-	*	*	

* = Significant - = Not significant

Table 26-5. Test of significance of variants in F_2 generation for total number of pods/plant.

	2x25	2x37	2x29	2x41	2x13	13x29	13x37	13x41	25x29	25x13	25x37	25x41	29x37	29x41	37x41
2 x 25															
2 x 37	*														
2 x 29	-	*													
2 x 41	*	*	*												
2 x 13	*	*	*	*											
13 x 29	*	*	*	*	*										
13 x 37	*	-	*	*	*	-									
13 x 41	*	*	*	*	*	*	*								
25 x 29	*	*	*	*	*	*	*	*							
25 x 13	*	-	*	*	*	*	-	*	-						
25 x 37	*	*	*	*	*	-	*	*	*	*					
25 x 41	*	*	*	*	*	*	*	*	-	*	*				
29 x 37	*	-	*	*	*	-	-	*	*	-	*	*			
29 x 41	*	*	-	*	*	*	*	*	*	*	*	*	*		
37 x 41	*	*	*	*	*	*	*	*	-	*	*	-	*	*	

* = Significant - = Not significant

Table 26-6. Test of significance of variants in F_2 generation for seed yield/plant.

	2x25	2x37	2x29	2x41	2x13	13x29	13x37	13x41	25x29	25x13	25x37	25x41	29x37	29x41	37 x 41
2 x 25															
2 x 37	*														
2 x 29	*	*													
2 x 41	*	*	*												
2 x 13	*	*	*	*											
13 x 29	*	-	*	*	*										
13 x 37	*	*	*	*	*	*									
13 x 41	*	*	-	*	*	*	*								
25 x 29	*	-	*	*	*	-	-	*							
25 x 13	*	*	*	-	*	*	*	*	*						
25 x 37	*	*	*	-	*	*	*	*	*	-					
25 x 41	*	*	*	-	*	*	*	*	*	-	-				
29 x 37	*	-	*	*	*	-	*	*	-	*	*	*			
29 x 41	*	*	*	*	*	*	*	*	*	*	*	*	*		
37 x 41	*	*	*	*	*	*	-	*	-	*	*	*	*	*	

* = Significant - = Not significant

Table 26-7. Test of significence of variants in F_2 generation for thousand seed weight.

	2x25	2x37	2x29	2x41	2x13	13x29	13x37	13x41	25x29	25x13	25x37	25x41	29x37	29x41	37x41
2 x 25															
2 x 37	*														
2 x 29	*	*													
2 x 41	*	-	*												
2 x 13	-	*	*	*											
13 x 29	*	-	*	*	-										
13 x 37	-	*	*	*	-	-									
13 x 41	*	*	*	*	*	*	*								
25 x 29	*	*	*	*	*	*	*	-							
25 x 13	-	*	*	*	-	*	-	*	*						
25 x 37	*	-	*	-	*	-	*	*	*	*					
25 x 41	*	-	*	-	*	-	*	*	*	*	-				
29 x 37	*	*	*	*	*	*	*	-	-	*	*	*			
29 x 41	-	*	*	*	-	*	-	*	*	-	*	*	*		
37 x 41	*	*	*	*	*	*	*	*	*	*	*	*	*	*	

* = Significant - = Not significant

Table 26-8. Test of significance of variants in F_2 generation for oil content (Percentage).

	2x25	2x37	2x29	2x41	2x13	13x29	13x37	13x41	25x29	25x13	25x37	25x41	29x37	29x41	37x41
2 x 25															
2 x 37	-														
2 x 29	-	-													
2 x 41	-	-	-												
2 x 13	*	*	*	*											
13 x 29	*	*	*	*	*										
13 x 37	*	*	*	*	*	*									
13 x 41	*	*	*	*	-	*	*								
25 x 29	*	*	*	*	-	*	*	-							
25 x 13	*	*	*	*	*	-	*	-	-						
25 x 37	*	*	*	*	-	*	-	-	-	*					
25 x 41	-	-	-	-	*	*	-	*	*	*	*				
29 x 37	*	*	*	*	-	*	-	*	*	*	-	*			
29 x 41	*	*	*	*	*	*	-	*	*	*	-	-	-		
37 x 41	*	*	*	*	*	-	*	-	-	-	*	*	*	*	

* = Significant - = Not significant

Table 26-9. Test of significance of variants in F_2 generation for duration for first flowering.

	2x25	2x37	2x29	2x41	2x13	13x29	13x37	13x41	25x29	25x13	25x37	25x41	29x37	29x41	37x41
2 x 25															
2 x 37	*														
2 x 29	*	*													
2 x 41	*	*	*												
2 x 13	*	*	*	-											
13 x 29	*	*	*	*	*										
13 x 37	*	*	*	-	-	*									
13 x 41	*	*	-	*	*	*	*								
25 x 29	*	-	*	*	*	*	*	*							
25 x 13	-	*	*	*	*	*	*	*	*						
25 x 37	*	*	*	*	*	*	*	*	*	-					
25 x 41	*	*	*	*	*	*	*	*	*	*	*				
29 x 37	*	*	*	-	*	*	-	*	*	*	*	*			
29 x 41	*	*	*	*	*	*	*	*	*	-	-	*	*		
37 x 41	*	*	*	-	-	-	*	*	*	*	*	*	*	*	

* = Significant - = Not significant

FIG: 11. FREQUENCY DISTRIBUTION FOR FLOWERING IN F_2 (FIRST FLOWER OPENING)

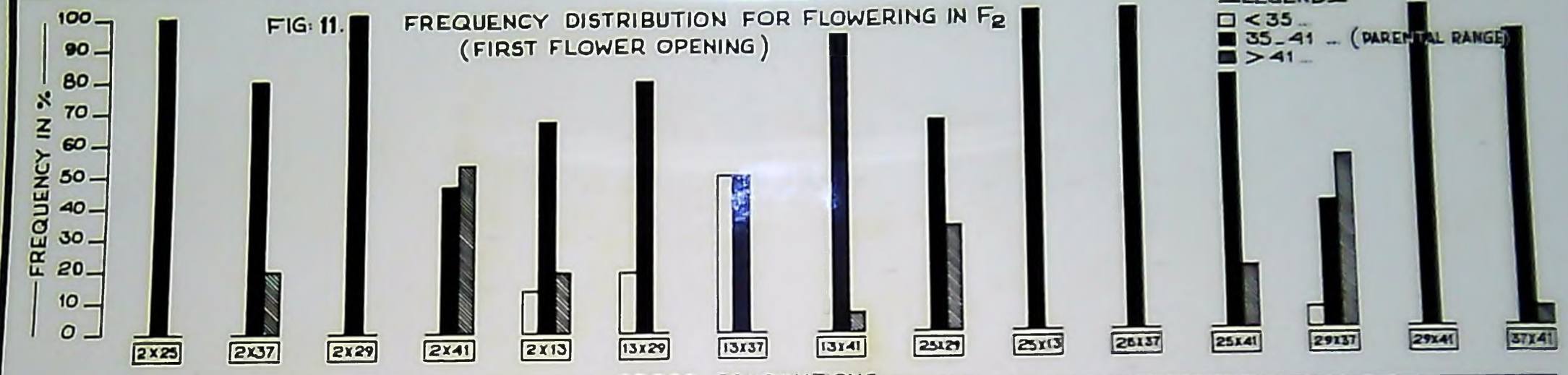


FIG: 12. FREQUENCY DISTRIBUTION FOR OIL YIELD IN F_2 (PERCENTAGE)

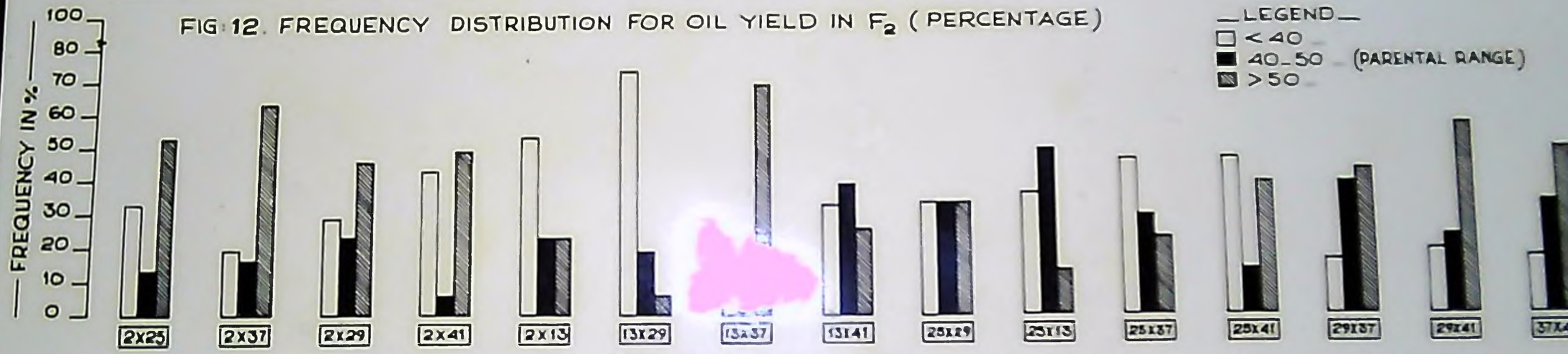


FIG 13. FREQUENCY DISTRIBUTION FOR PRIMARY PRODUCTIVE BRANCHES IN F_2

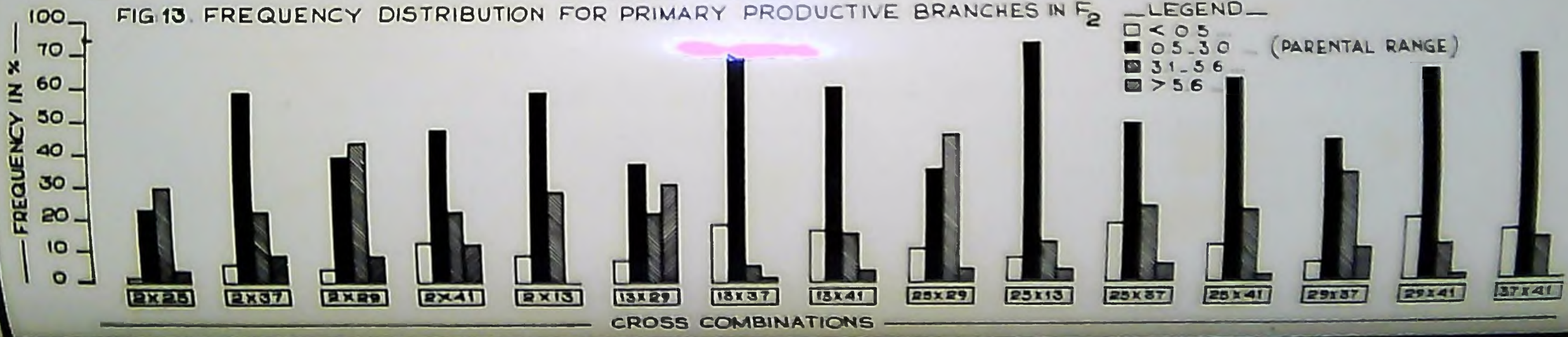


FIG. 14. FREQUENCY DISTRIBUTION OF HEIGHT VARIANTS IN F_2

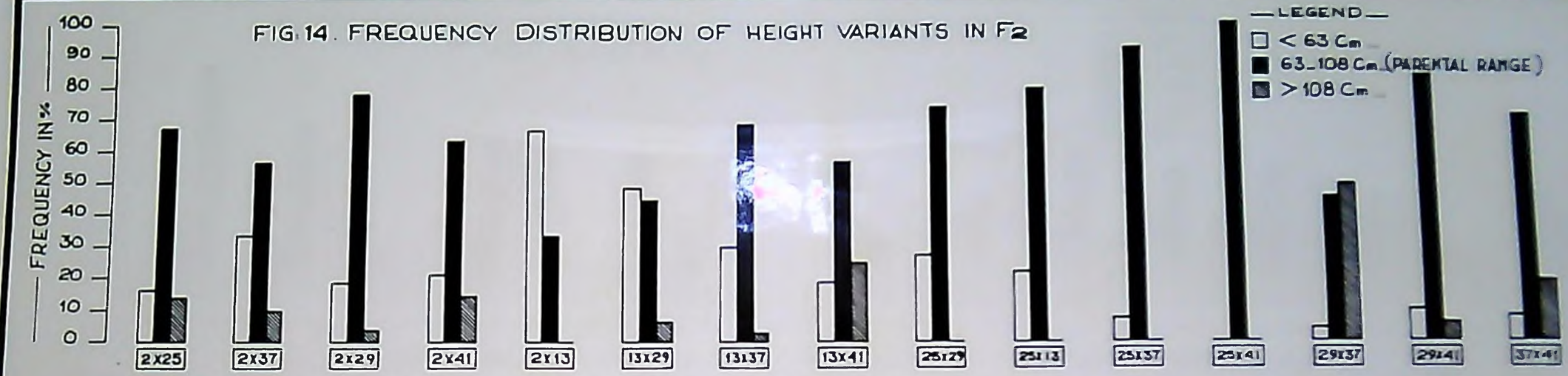


FIG 15. FREQUENCY DISTRIBUTION OF PRODUCTIVE NODES ON MAIN AXIS IN F_2

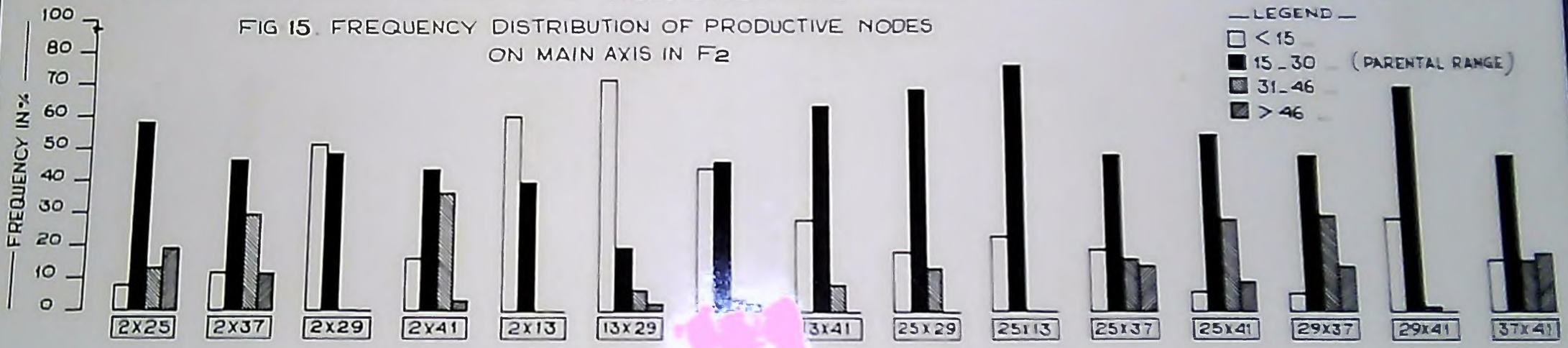
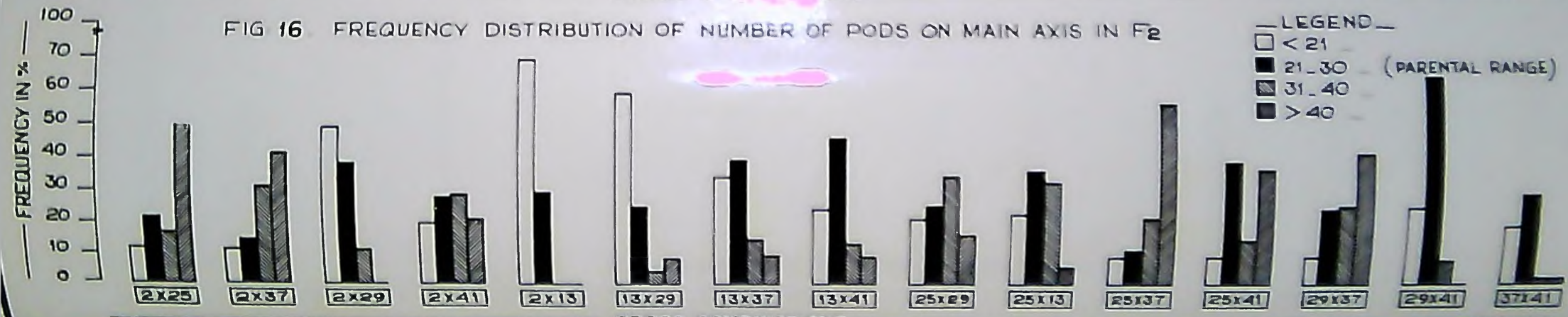


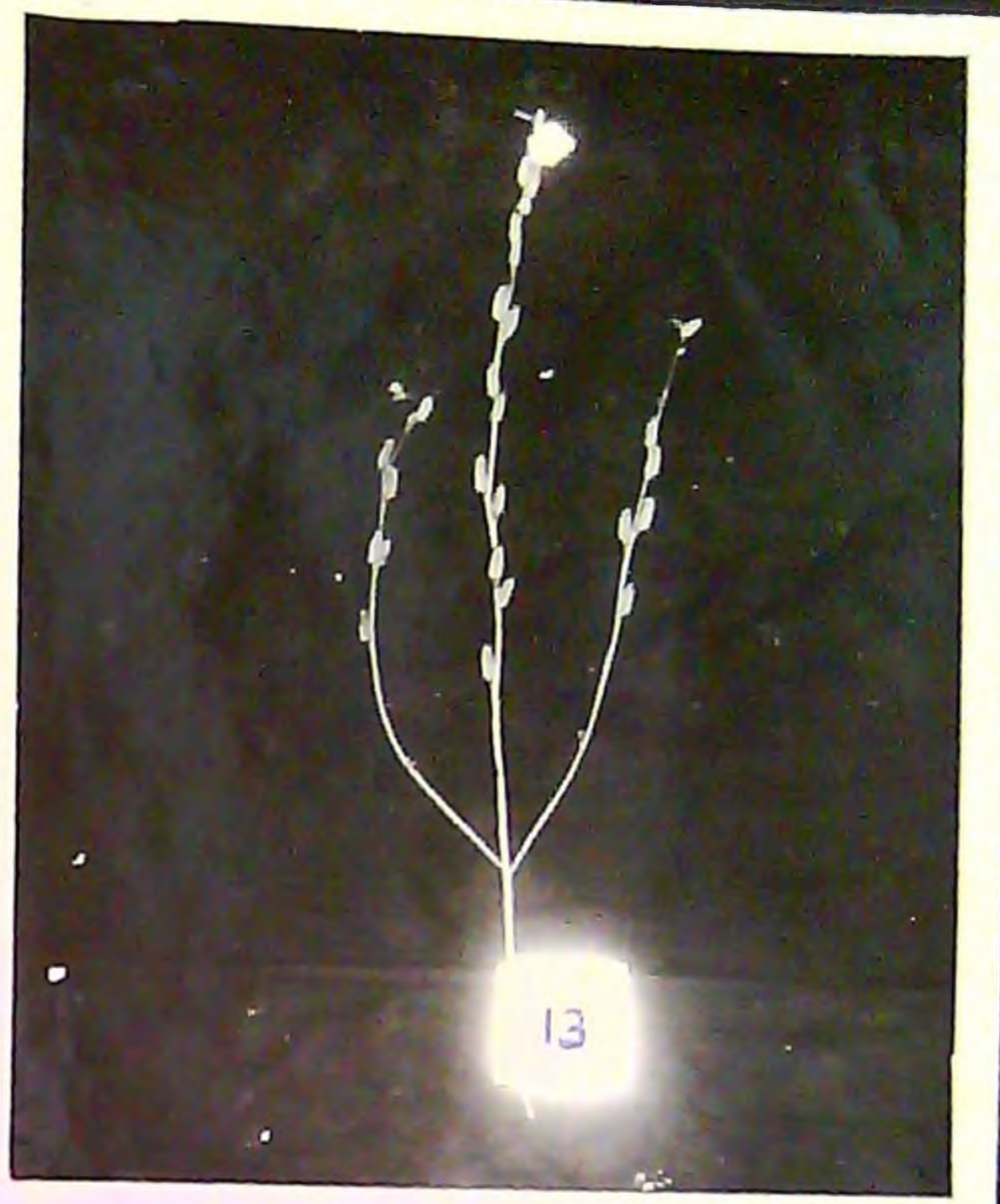
FIG 16. FREQUENCY DISTRIBUTION OF NUMBER OF PODS ON MAIN AXIS IN F_2



from 0.01 in $V_2 \times V_{37}$, $V_2 \times V_{29}$, $V_{13} \times V_{41}$ and $V_{25} \times V_{29}$ to 5.12 in $V_{29} \times V_{37}$. The 'F' test analysis on variance showed that there was significant difference in the distribution of individuals in different crosses. The different cross combinations and their statistical significance in the F_2 distribution are presented in table 26-9. The F_2 distribution in $V_2 \times V_{25}$, $V_2 \times V_{29}$, $V_{13} \times V_{29}$, $V_{13} \times V_{41}$, $V_{25} \times V_{29}$ and $V_{25} \times V_{41}$ showed maximum difference from those of other crosses and minimum difference was recorded by $V_2 \times V_{41}$.

Plate-1. Varieties used as parents


2


13

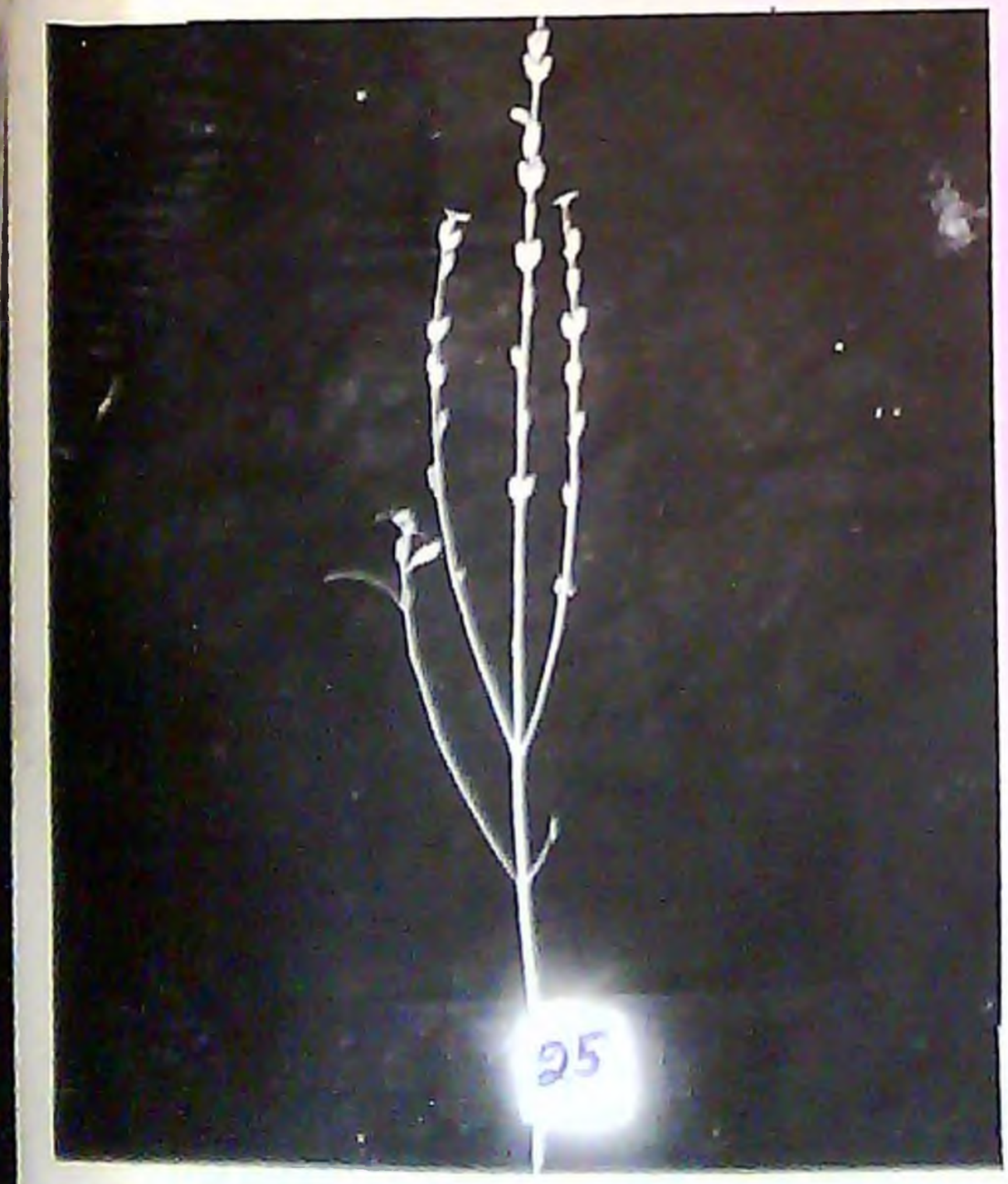
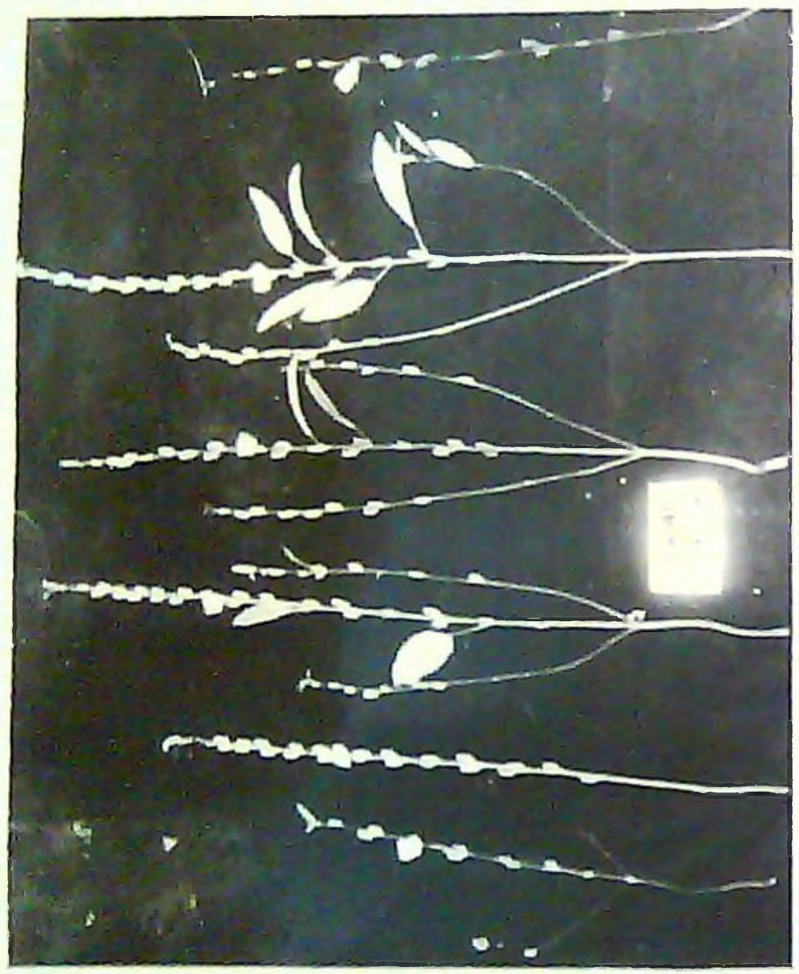

25

Plate-2. Varieties used as parents

Plate-3. Single cross hybrids

Plate-4. Double cross hybrids showing variation



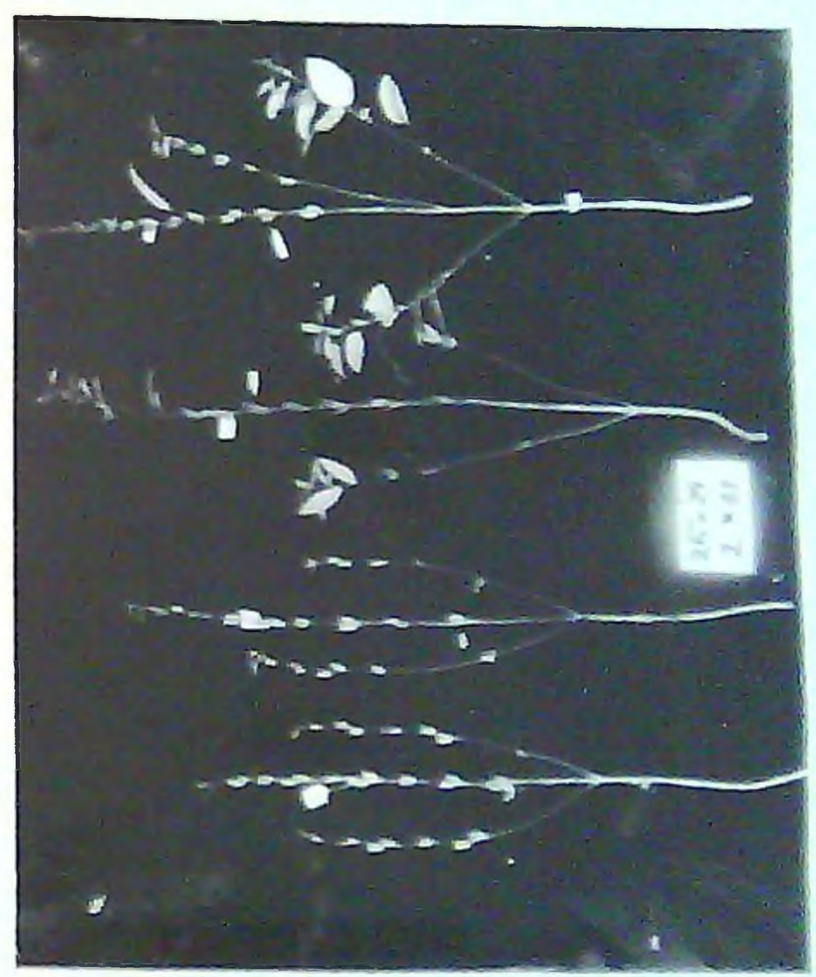


Plate-5. Double cross hybrids showing variation

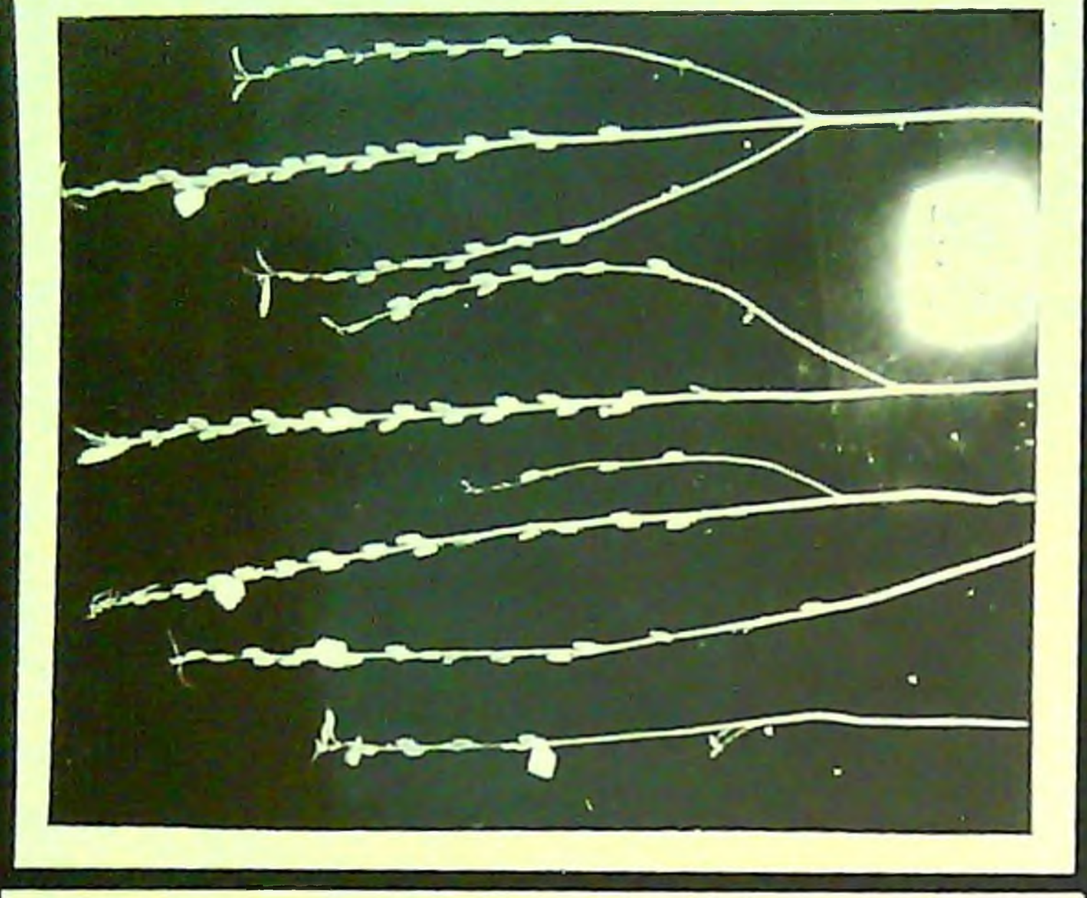
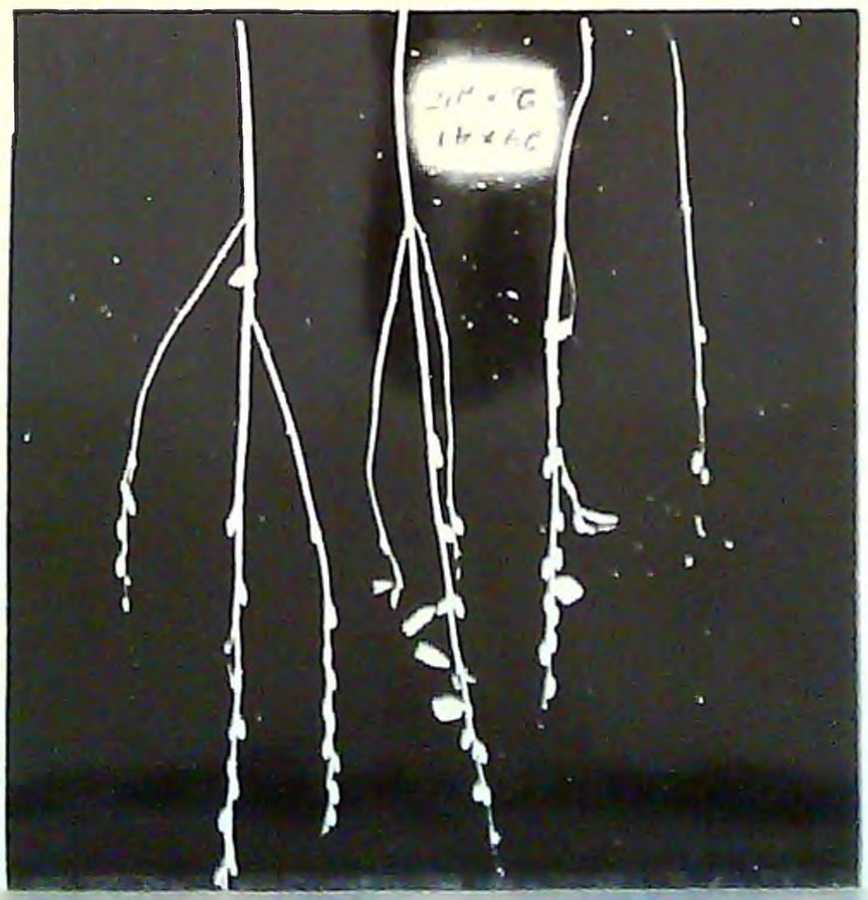


Plate-6. Double cross hybrids showing variation



DISCUSSION

DISCUSSION

The development of plant breeding strategy hinges mainly on the support provided by genetic information on the pattern of inheritance and behaviour of major quantitative characters associated with yield and quality. In addition, a knowledge on the basic information on the extent of variability present in the different cultivars, heritability of characters, genetic association between various characters and the type of gene action operating in their expression, enable the choice of appropriate parental material for employing the most suitable breeding methodology for a crop. The present study provides the above basic informations, from the analyses on the heterotic effects, combining ability and patterns of segregation for the different quantitative characters in Sesamum indicum. The results obtained are discussed in the ensuing sections.

Variability, heritability and genetic advance

Sesamum is an essentially self-pollinated crop and hence the expected natural variability is low. However, the present study revealed that appreciable amount of variability in respect of several characters still prevails within the species. This may be as a result of the attempts made for creation of varieties due to different stress conditions.

Statistical analysis of the data pertaining to plant height, number of primary productive branches, number of productive nodes on main axis, number of pods on main axis, total pods per plant, seed yield per plant, number of seeds per pod, 1000-seed weight, oil content and duration for first flowering in a total number of forty four varieties showed significant variation for all the characters analysed. Total number of pods per plant, seed yield per plant and number of primary productive branches per plant showed wide range of variability while seeds per pod, duration for first flowering and 1000-seed weight exhibited less variability. Osman and Khidir (1974) and Chavan et al. (1982) in Sesamum indicum L. observed high amount of variability for total pods per plant, seed weight per plant and primary productive branches per plant.

Highest phenotypic variance recorded for total pods per plant in the present investigation confirms the results reported by Solanki and Paliwal (1981). For plant height also phenotypic variance was very high. Phenotypic variance was minimum for number of seeds per pod and number of primary productive branches per plant in the present study. Genotypic variance was maximum for total pods per plant which is in agreement with the findings of Solanki and Paliwal (1981). Genotypic variance was less for number of seeds per pod, number of primary productive branches per plant and weight of seeds per plant in the present study. As

reported by Rai et al. (1981) in total pods per plant and plant height, the environmental variance was very high and it was very low in the oase of number of seeds per pod, number of primary productive branches, weight of seeds per plant and oil content in the present study. Further, environmental variance was comparatively less for the number of produotive nodes on main axis and number of pods on main axis, 1000-seed weight and duration for first flowering. Agreeing with the results obtained by Sanjeeviah and Joshi (1974), in the present study also less environmental variance was observed in the case of number of productive nodes and pods on main axis. Earlier report made by Krishnamoorthy et al. (1964) that the number of branches per plant and number of seeds per pod in sesamum were least affected by environment also supports the present findings. Results obtained by Rai et al. (1981) also confirms the present result that number of branches per plant is less influenced by environment.

High phenotypic and genotypic coefficients of variability were obtained for total pods per plant, weight of seeds per plant and number of primary branches per plant. Osman and Khidir (1974) reported high phenotypic as well as genotypic coefficients for the above character. Sanjeeviah and Joshi (1974) and Rai et al. (1981) obtained high genotypic coefficient of variation. The high genotypic coefficient of variation reported by Sanjeeviah and Joshi (1974) for

seed yield per plant was also in favour of the present result. The phenotypic and genotypic coefficients of variation were very low in the case of duration for first flowering, 1000-seed weight, oil content, number of seeds per pod and height of plant in the present study. In the case of plant height the result obtained by Rai et al. (1981) was also the same.

Heritability estimates provide an exact and precise information of the influence of environment on various characters. In the present study high heritability was estimated only in the case of oil content. Studies by Osman and Khidir (1974) supports the present finding. In the case of pods on main axis medium heritability was observed in the present study. But high heritability estimates were reported by Sanjeeviah and Joshi (1974) and Chavan et al. (1982). For number of days for first flowering medium heritability was observed in the present study as against the high heritability estimate reported by Osman and Khidir (1974) for the character. For number of seeds per pod high heritability estimates were reported by Osman and Khidir (1974) and Solanki and Paliwal (1981). But only medium heritability estimate was obtained in the present study for number of seeds per pod. For total pods per plant the medium heritability estimate obtained by Solanki and Paliwal (1981) completely agrees with the present result for the character. But high heritability estimate was obtained by Chavan et al.

(1982) for the same character. For number of productive branches per plant the heritability estimate obtained was medium in the present study. But high heritability estimates were reported by Osman and Khidir (1974), Sanjeeviah and Joshi (1974), Rai et al. (1981) and Chavan (1982). Medium heritability was observed in the present study for number of seeds per pod. But high heritability estimates were reported by Osman and Khidir (1974) and Solanki and Paliwal (1981).

Weight of seeds per plant recorded low heritability estimate in the present investigation which is in line with the findings of Sanjeeviah and Joshi (1974). But medium heritability was reported by Solanki and Paliwal (1981) for the same character. Low heritability estimate was obtained for height of plant in the present investigation. But contradictory to this high heritability estimates were reported by Osman and Khidir (1974), Sanjeeviah and Joshi (1974) and Rai et al. (1981).

For oil content eventhough the heritability estimate was high, genetic advance was found to be very low.

On the contrary low heritability and low genetic advance was reported for the character by Osman and Khidir (1974).

The observed low value for heritability seems to raise a sense of suspicion, since it gives chance to believe that percentage oil content is an attribute that could be adjusted well for manipulation at the environmental level, which is neither observed during the study, nor reported elsewhere. There is great significance to maintain the percentage content of oil constant, since any

enhancement in this attribute can be facilitated only at the loss of advantage of the protein and carbohydrate content, which are essential to keep up the yield standard of seeds. Estimates of heritability and genetic advance were very low for plant height and number of productive nodes on main axis in the present study. For plant height Rai et al. (1981) reported high heritability followed by low genetic advance. Number of productive branches showed medium heritability but genetic advance was comparatively high in the present study. High genetic advance was also reported for this character by Rai et al. (1981) and Solanki and Paliwal (1981). Number of pods on main axis which was having medium heritability also showed comparatively high genetic advance. High genetic advance was reported by Chavan et al. (1982) for the character. Total pods per plant which had medium heritability showed comparatively high genetic advance as reported by Osman and Khidir (1974), Solanki and Paliwal (1981) and Chavan et al. (1982). Genetic advance was low in the case of number of seeds per pod which was having medium heritability in the present study. But Solanki and Paliwal (1981) reported high heritability and genetic advance for the character. For duration for first flowering the results indicated that it had only low genetic advance inspite of medium heritability. Contradictory results were reported by Osman and Khidir (1974) for this character. For 1000-seed weight also genetic advance was low in spite of its having medium heritability in

the present study. Comparatively high genetic advance was observed in the present study for weight of seeds per plant eventhough its heritability value was slightly less. Johnson and Bernard (1963) had stated that there was no single basis for comparing the various reported estimates of heritability and in applying this concept to plants. They, however, suggest that the data could provide information of value.

Estimates of high heritability values have been found to be helpful in making selection of superior genotypes on the basis of phenotypic performance of the quantitative characters. But, heritability alone conveys no clear cut indication of the amount of genetic progress. Johnson et al. (1955) had suggested that heritability estimates alongwith genetic gain was more useful than heritability value alone in predicting the resultant effect and selecting the best individuals. Hence from the foregoing discussion and as suggested by Johnson et al. (1955) the characters, number of primary productive branches per plant, number of pods on main axis and total number of pods per plant and weight of seeds per plant which had moderate values for genotypic coefficient of variation coupled with moderate heritability and genetic advance would provide the scope for selection in these characters to bring about further genetic improvement in sesamum.

The estimates of heritability (narrow sense) for the nine characters from the F_1 and F_2 generations are presented

in tables 5 and 23. Higher heritability estimates were recorded for number of days for first flowering and number of primary productive branches per plant in the F_1 and F_2 generations. The consistency of heritability from F_1 to F_2 generation for these traits indicated considerable amount of additive and additive x additive component in controlling the inheritance of these traits. The heritability values were lower in the F_2 than in the F_1 for all the characters indicating the predominance of over dominance in the F_1 generation. Over dominance was most prevalent in the case of plant height. Heritability value in the F_1 was very high compared to that in the F_2. For seed weight also the F_1 heritability value was much higher than the F_2 heritability indicating the prevalence of non-additive factors in the F_1. For number of pods on main axis the heritability values in the F_1 and F_2 did not show much difference indicating the action of additive factors. Heritability estimates were very low in both the generations for oil content. The principal role of non-additive genetic variance is evident in this case. Analysis of the data relating to varietal evaluation and hybrid and segregating populations clearly demonstrated that oil yielding ability in sesamum is much influenced by environment and hence management practices can induce variation in this particular character.

Correlations

Genotypic correlations, in general, were higher in magnitude than the corresponding phenotypic correlation. This is in close confirmity with the findings of Yadava et al. (1980) and Chavan and Chopde (1981) in sesamum.

Seed yield had significant positive correlation with five out of the ten characters studied. It was positively and significantly correlated with plant height, number of primary productive branches, productive nodes on main axis, pods on main axis and total pods per plant.

Correlation between plant height and seed yield in sesamum was studied by several workers and the results reported were uniform. Sikka and Gupta (1949), Khidir and Osman (1970), Ramachandran et al. (1972), Osman and Khidir (1974) and Zhan (1983) reported positive correlation of seed yield with plant height. Seed yield showed positive and significant correlation with number of primary productive branches per plant. This result is in confirmity with the findings of Sikka and Gupta (1949), Ramachandran et al. (1972), Chaudhary et al. (1977), Sanjeeviah and Joshi (1974), Yadava et al. (1980) and Chavan and Chopde (1981). Seed yield showed significant positive correlation with number of productive nodes and pods on main axis. In confirmity with the present finding significant positive correlation of seed yield with number of pods on main axis was reported by other workers in sesamum including Shukla and Verma (1974) and

Rai et al. (1981). The correlation between seed yield and number of total pods per plant was significantly very high and positive. The positive correlation between seed yield and total pods per plant was reported by several workers in sesamum (Sikka and Gupta, 1949; Muhammed and Dorairaj, 1964; Osman and Khidir, 1974; Shukla and Verma, 1974; Chaudhary et al., 1977; Yadava et al., 1980; Rai et al., 1981 and Chavan and Chopde, 1981). In the present study maximum positive correlation with seed yield was shown by total number of pods per plant followed by plant height, number of pods on main axis, number of productive nodes on main axis and number of primary productive branches per plant. Present study showed very low correlation between seed yield and 1000-seed weight. Positive correlation between these two traits in sesamum was also reported by Mohammed and Durairaj (1968), Yadava et al. (1980) and Zhan (1983).

Negative correlations were observed between seed yield and number of days for first flowering in the present study. This is in confirmity with the report of Shukla and Verma (1974). But contradictory to this Osman and Khidir (1974) and Chaudhary et al. (1977) reported positive correlation between these two traits in sesamum. In the present study correlation was found negative between seed yield and number of seeds per pod. Chavan and Chopde (1981) also reported negative correlation between these two traits in sesamum as

was noted in the present study. But contradictory to this Zhan (1983) reported that number of seeds per capsule was positively correlated with yield. In the case of oil content also correlation with seed yield was negative in the present study.

In the present study, phenotypic correlations were more than genotypic correlations in about all the yield components. Plant height had an appreciable amount of positive correlation with number of productive branches per plant, productive nodes and pods on main axis and total pods. The genotypic correlation between plant height and number of primary productive branches was not significant. Positive correlation of plant height and number of branches in sesamum was reported by Khidir and Osman (1970) and Sanjeeviah and Joshi (1974). The correlation of plant height with number of productive nodes on main axis was positive in the present study. Sanjeeviah and Joshi (1974) reported a positive correlation of plant height with number of nodes on main axis which is in agreement with the present study. Positive correlation was also observed for plant height and number of pods on main axis. Similar results were reported by Shukla and Verma (1974) and Rai et al. (1981). Height was positively correlated with total pods per plant which was in agreement with the results obtained by Khidir and Osman (1970) and Chavan and Chopde (1981). Plant height recorded a very low positive correlation with 1000-seed weight and number of days for

first flowering. But Khidir and Osman (1970) reported negative correlation between height and 1000 seed weight in sesamum. Positive correlation between height and number of days for first flowering in soybean was reported by Kaw and Menon (1972).

Plant height had negative correlation with oil content both at phenotypic and genotypic level suggesting that tall varieties produce seeds with less oil content. Plant height showed negative genotypic correlation with seeds per pod. Similar results were reported by Chavan and Chopde (1981) in sesamum.

Number of primary productive branches was positively correlated with number of productive nodes on main axis but it was negative at genotypic level. Number of primary productive branches showed very little positive correlation with number of pods on main axis and it was also negative at genotypic level as in the previous cases. In general it is indicated that there is not much relation of number of primary productive branches either with number of productive nodes on main axis or with number of productive nodes on main axis or with number of pods on main axis. Number of primary productive branches had significantly high positive genotypic and phenotypic correlation with total pods per plant. Similar results were reported by Khidir and Osman (1970) in sesamum. The results indicated that number of primary productive branches is an important contributing character to be considered

in selection programmes.

In the present study, number of primary productive branches both at phenotypic and genotypic levels recorded negative correlations with 1000-seed weight, number of days to flowering, oil content and number of seeds per capsule. Chavan and Chopde (1981) also reported that number of primary productive branches had negative correlation with number of seeds per pod. Thus it is very clear that plants with high number of primary productive branches will be high yielding but will be poor in respect of 1000-seed weight, number of seeds per capsule and oil yield.

Number of productive nodes on main axis had significantly high positive correlation with number of pods on main axis and total pods per plant both at phenotypic and genotypic levels. But it showed very little relationship with 1000-seed weight, number of days to first flowering, oil content and number of seeds per capsule. Number of pods on main axis was also highly correlated with total number of pods per plant. But it showed negative relationship with 1000-seed weight, number of days for first flowering and seeds per capsule. Correlation with oil content also was very poor.

Number of total pods per plant had negative correlation with 1000-seed weight, number of days for first flowering, oil content and seeds per capsule. Thousand seed weight had very little correlation with number of days for first

flowering and very low negative relationship with oil content. But it showed positive significant correlation with number of seeds per capsule. Number of days for first flowering had very little positive correlation with oil content and seeds per capsule. Correlation between oil content and seeds per capsule also was very low and negative.

In general the different correlations project the fact that tall plants with high number of productive nodes and pods on main axis will give maximum yield of pods and seeds per plant. Number of primary productive branches is also a decisive character for yield of pods and seeds. But it is not much related to number of productive nodes and pods on main axis. If for ideal plant type non-branching type is preferred, selection should be concentrated on maximum number of pods on main axis. Association of other characters pointed out that the high yielding plants will be poor oil yielders, with less number of seeds per capsule, 1000-seed weight and with late flowering habit. Osman and Khidir (1974) conducted simple partial and multiple correlation studies in sesamum and reported that yield was significantly and positively correlated with late flowering, late maturity, plant height to first pod, number of pods per plant and total number of seeds per plant. He also reported that all the above characters were intercorrelated.

of productive nodes and pods on main axis are also positive but comparatively less.

Number of productive nodes on main axis showed positive direct effect on seed yield. But its indirect effect on seed yield via total pods per plant was very high. Indirect effects through plant height and number of primary productive branches were also positive while that through number of pods on main axis was negative. This suggests that number of productive nodes on main axis does not give a correct indication of number of pods on main axis.

Number of pods on main axis showed negative direct effect on seed yield in the present study. But Dixit (1975) reported that maximum direct effect on seed yield was shown by number of capsules on main fruiting branch. However the high positive correlation observed between number of pods on main axis and seed yield was mainly by its indirect effect through total pods per plant. The indirect effects through plant height and number of productive nodes on main axis were also positive. But indirect effect via number of primary productive branches was negative. The negative direct effect of this character to seed yield may be due to this negative indirect effect on number of primary productive branches. This suggests that in plants with high number of productive branches, the number of pods on main axis will be less.

Path analysis

Path analysis at the genotypic level revealed that number of pods per plant had the highest direct effect on seed yield. Similar results were reported by several workers in sesamum including Kaushal et al. (1974), Yadava et al. (1980) and Shukla (1983).

It is apparent that plant height also had marked direct influence on seed yield indicating that selection for tall varieties would enhance unit area production in sesamum. This result is in agreement with the findings of Kaushal et al. (1974). But contradictory to this, Dixit (1975) and Murugesan et al. (1979) reported that plant height recorded negative direct effect on seed yield. The significant positive correlation between plant height and seed yield was mainly due to the indirect effect of plant height via total number of pods per plant. Shukla (1983) also reported that plant height showed positive direct effect on yield mainly through number of capsules per plant. The indirect effect of plant height through number of primary productive branches and productive nodes on main axis were also positive but very low.

Number of primary productive branches per plant also showed positive direct effect on seed yield. Dixit (1975), Murugesan et al. (1979) and Yadava et al. (1980) also obtained similar results in sesamum. The indirect effect through number of total pods per plant is higher than its direct effect on seed yield. The indirect effect via, plant height and number

Number of total pods recorded the maximum direct effect on seed yield. Similar results in sesamum were reported by Kaushal et al. (1974), Gupta and Gupta (1977), Yadava et al. (1980) and Shukla (1983). The indirect effects of plant height, primary productive branches and productive nodes on main axis on seed yield were also positive. Yadava et al. (1980) also reported that total number of capsules had indirect positive effects via plant height. The indirect effect through number of pods on main axis was negative which suggests that number of pods on main axis has a negative influence or reduces the total number of pods per plant which will be reflected in the seed yield also.

On the basis of this investigation, the major attributes of a suitable 'plant type' which would give maximum yield under optimum conditions can be developed. In the first instance, seed yield had significant positive correlation with plant height, number of productive branches per plant, number of productive nodes and pods on main axis and total number of pods per plant. However, path-coefficient analysis projected that total number of pods per plant and plant height had substantial direct effects on seed yield. The direct effects of number of primary productive branches per plant and number of productive nodes on main axis were also positive. But the positive correlations of plant height, number of productive nodes on main axis and total pods per

plant with seed yield was influenced with the negative indirect effect of pods on main axis. Similarly in the positive association between number of pods on main axis and seed yield, number of productive branches exert negative indirect effect. Based on these results it is possible to suggest a plant type in sesamum with tall stature with maximum number of primary productive branches, productive nodes on main axis and total number of pods per plant for maximising the production of seed yield per plant. Van Rheenen (1981) discussing the breeding objectives of sesamum pointed out that the higher positive correlation between branching and seed yield does not necessarily mean that branching habit is desirable, Non or almost non-branching types could produce well if planted in high densities. However, when farm conditions are tough and the stands are patchy and irregular a branched type can compensate better. So moderate branching potential is a security against poor conditions.

Combining ability and components of genetic variance :-

Results of analysis on combining ability of the six parents chosen for diallel cross and the components of genetic variance are discussed below.

The analysis of variance for combining ability revealed that both additive and non-additive type of gene actions were important in the expression of plant height, total number of pods per plant, seed weight per plant and

1000-seed weight since they possessed significant g.c.a and s.c.a variances. Rathinaswamy (1980) reported significant g.c.a and s.c.a variances for the characters plant height and number of branches per plant as in the present investigation. Fatteh et al. (1982) also reported significant g.c.a and s.c.a variances for plant height, total pods per plant, seed yield, 1000-seed weight and duration for first flowering.

In the present investigation a preponderance of additive gene action was observed over non-additive gene action for number of days for first flowering, number of primary productive branches per plant, number of productive nodes on main axis and number of pods on main axis as evidenced by larger g.c.a variance. In general except in the case of oil content g.c.a variance was higher than s.c.a in all the characters studied, showing the dominant role of additive gene action. In the F_2 generation also the g.c.a and s.c.a variances were significant in all the characters except oil content. For oil content s.c.a variance was higher indicating non-additive gene action as in the case of F_1.

The high g.c.a variance observed for plant height in F_1 is in confirmity with the findings of Murty (1974), Rathinaswamy (1980), Gupta (1981), Singh et al. (1983) and Fatteh et al. (1982). However, the role of non-additive factors indicated for the character in the present study is in agreement with the reports of Rathinaswamy (1980) and Fatteh et al. (1982). In F_2 also g.c.a was higher, showing

preponderance of additive gene action eventhough g.c.a and s.c.a variances were significant in the study as in F_1.

For number of primary productive branches the results of F_1 indicated high g.c.a variance favouring for additive gene action. This is in confirmity with the results reported by Murty (1974), Rathinaswamy (1980), Gupta (1981) and Singh et al. (1983). But contradictory results were reported by Fatteh et al. (1982) where non-additive gene action was reported to be responsible for the expression of productive branches in sesamum.

Singh et al. (1983) reported significant s.c.a variance for the character in the F_1's of some intervarietal crosses in sesamum. In the F_2 of the present study both g.c.a and s.c.a variances were significant. But the magnitude of g.c.a is higher showing the major role of additive gene action for the expression of the character.

In the present study g.c.a variance was higher than s.c.a variance for number of productive nodes on main axis as well as for number of pods on main axis in F_1 showing additive gene action for the two characters. In the F_2 both g.c.a and s.c.a variances were significant indicating additive as well as non-additive types of gene action. But the higher magnitude of g.c.a in both cases indicate the predominent role of additive gene action.

Higher g.c.a variance observed for total number of pods per plant over the s.c.a variance in F_1 indicate much

stress for additive gene action. The s.c.a variance was also significant showing that non-additive factors were also involved in the expression of the character. Parallel reports were made by Murty (1974), Rathnaswamy (1980), Gupta (1981), Singh et al. (1983) and Fatteh et al. (1982). In the F_2 also g.c.a and s.c.a variances were significant confirming the results of F_1. But higher g.c.a variance showed predominance of additive gene action in the present study.

Weight of seeds per plant was also found to be controlled predominantly by additive gene action as it was expressed by higher magnitude of g.c.a variance. Non-additive factors are also involved in the expression of the character since there was significant s.c.a variance. Rathnaswamy (1980), Gupta (1981), Fatteh et al. (1982) and Singh et al. (1983) had reported that weight of seeds per plant is mainly controlled by additive gene action. In the F_2 also both g.c.a and s.c.a variances were significant. But the magnitude of g.c.a variance was higher indicating predominance of additive gene action for the character.

For 1000-seed weight also additive as well as non-additive gene action was indicated by the significant g.c.a and s.c.a variances. But g.c.a variance was higher showing preponderance to additive gene action. Additive type of gene action for this particular character was reported by Fatteh et al. (1982) and Singh et al. (1983). In the present study F_2 also showed significant g.c.a and s.c.a variances

focussing additive and non-additive gene action. But the g.c.a variance was higher indicating predominance of additive gene action.

In the F_1, duration for first flowering showed significant g.c.a variance and the magnitude of g.c.a variance was higher than s.c.a variance favouring for additive gene action. Earlier reports made by Murty (1974), Fatteh et al. (1982) and Singh et al. (1983) are in support of the present results. In the present study F_2 showed significant g.c.a and s.c.a variances indicating additive and non-additive factors in the expression of the character. But the magnitude of g.c.a variance was higher than s.c.a variance giving more stress to additive gene action. Singh et al. (1983) also reported significant s.c.a variance in F_2 favouring for over dominance.

For oil content g.c.a as well as s.c.a variance was not significant in F_1 and the s.c.a variance was found to be higher than g.c.a variance indicating the major role of non-additive gene action. This is in line with the reports made by Murty (1974) and Fatteh et al. (1982). But contradictory to this Singh et al. (1983) reported higher g.c.a variance for oil content in F_1. In the present study the F_2 showed significance for s.c.a variance and the magnitude of s.c.a variance was also higher than g.c.a variance. This indicated a predominent role of non-additive gene action in

this character. Singh et al. (1983) also reported significant s.c.a variance in the F_2 showing non-additive gene action in the expression of the character.

The estimates of g.c.a and s.c.a effects will be of great value in selecting out elite parents and desirable cross combinations to be used in the formulation of systematic crop improvement programme. A perusal of general and specific combining ability effects revealed useful genetic informations.

For plant height maximum positive (tallness) g.c.a effect was expressed by V_{25} followed by V_{41}, V_{29} and V_2. Negative g.c.a effect (dwarfness) was expressed by V_{13} and V_{37}. Among the different cross combinations maximum s.c.a effect was shown by $V_2 \times V_{41}$ followed by $V_{13} \times V_{41}$ and $V_{29} \times V_{41}$. Here the parents involved in the first and third crosses were with positive g.c.a effects. V_{41} was the best general combiner for tallness. In the second cross the parents involved were V_{13} and V_{41} of which the female parent showed negative g.c.a effect and male showed positive g.c.a effect. This indicates dominance of tallness over dwarfness. Moreover V_{25} which showed maximum positive g.c.a effect and V_{13} which showed maximum negative g.c.a effect do not show high s.c.a effect. All these suggest that in addition to additive factors non-additive factors also influence the expression of the character. In the analysis of variance also g.c.a as well as s.c.a variances were significant for the

character. Rathmaswamy (1980) and Sengupta (1980) also recorded similar results in sesamum.

In the case of number of primary productive branches per plant V_{25} recorded maximum positive g.c.a effect followed by V_2, V_{13} and V_{29}. Negative g.c.a effects favouring non-branching character were recorded by V_{37} and V_{41}. Among the different cross combinations maximum positive s.c.a effect was recorded in the cross $V_2 \times V_{37}$ where the parents were with positive and negative g.c.a effects. Maximum negative s.c.a effect was recorded by the cross $V_{25} \times V_{37}$. Here also the parents were with both positive and negative g.c.a effects. This indicates that genes with varying degree of dominance were involved in the expression of the character. In the analysis of variance study of F_1 data, g.c.a variance was significantly higher favouring additive gene action for the character. In the F_2, g.c.a and s.c.a variances were significant indicating the presence of additive and non-additive factors for the character expression. Additive gene action for the character was reported by Murty (1974), Ratinaswamy (1980), Gupta (1981) and Singh et al. (1983). But non-additive gene action was reported by Fatteh et al. (1982). Sengupta (1980) recorded significant g.c.a and s.c.a variances for the character and the magnitude of s.c.a varianoe was much higher than g.c.a varianoe favouring for predominance of non-additive gene action.

Number of productive nodes on main axis showed highest positive g.c.a effect in V_{25} which was followed by V_{29} and V_{37}. Negative g.c.a effects were shbwn by V_{13}, V_{41} and V_2. Among the different crosses highest positive s.c.a effect was recorded in the cross $V_{29} \times V_{41}$ where the parents were with positive and negative g.c.a effects. So dominance is indicated in the above cross. More over positive s.c.a effects were shown by the crosses $V_{13} \times V_{41}$ and $V_2 \times V_{41}$ where the parents involved were with negative effects only. This indicates the effect of over dominance in the expression of the character. In the analysis of variance of F_1, significantly higher g.c.a variance indicate additive gene action in this particular character. But in F_2, g.c.a and s.c.a variances were significant indicating additive and non-additive gene action in the expression of the character.

As regards number of pods on main axis V_{25} was the best general combiner followed by V_{37} and V_{29}, as evidenced by the positive g.c.a effects. Negative g.c.a effect was shown by V_{41}, V_{13} and V_2. In the different crosses s.c.a effect was maximum in $V_{25} \times V_{37}$ followed by $V_2 \times V_{41}$ and $V_{13} \times V_{41}$. In the first cross additive gene action was indicated since V_{25} and V_{37} were good general combiners. In the other two crosses the parents are with negative g.c.a effects. Over dominance may be responsible for the expression of the character. So additive with dominant relationship as well as non-additive factors are involved in the expression of the trait. Analysis

on F_2 data also showed significant g.c.a and s.c.a variances.

In the case of total pods per plant the good general combiners were V_{29} and V_2. The other parents showed negative g.c.a effects. Maximum s.c.a effect was expressed in V_{29} x V_{41} where the parents were with positive and negative g.c.a effects. Here also dominance is indicated for higher number of pods. In the cross V_{13} x V_{41}, where the parents were with negative g.c.a effect, positive s.c.a effect was manifested favouring over dominance in the expression of the trait. In the analysis of variance of F_1 and F_2 the g.c.a and s.c.a variances were significant indicating both additive and non-additive factors in the expression of the character. The high mag nitude of g.c.a variance indicate predominance of additive gene action. Earlier workers (Murty, 1974; Rathinaswamy, 1980; Gupta, 1981; Fatteh et al., 1982 and Singh et al., 1983) had recorded additive gene action for the character as evidenced by high g.c.a variance. But Sengupta (1980) recorded predominance of non-additive factors as evidenced by high s.c.a variance.

For seed weight per plant V_{29} was the best general combiner with maximum g.c.a effect. It was followed by V_2, V_{25} and V_{13}. Negative g.c.a effects were recorded by V_{37} and V_{41}. Maximum s.c.a effect was manifested in V_{29} x V_{41} where the parents were with positive and negative g.c.a effects indicating dominance effect for high seed yield.

In crosses like V_{13} x V_{41} and V_{25} x V_{41} also the same results were obtained. In the analysis of variance of F_1 and F_2 g.c.a as well as s.c.a variances were significant indicating additive as well as non-additive gene action in the expression of the trait. Additive gene action based on high g.c.a values were reported by Murty (1974), Rathinaswamy (1980), Gupta (1981), Fatteh et al. (1982) and Singh et al. (1983). Additive gene action was also reported by Sengupta (1980) based on g.c.a/s.c.a ratios for the character. As regards 1000-seed weight high g.c.a effects were observed in V_{41} and V_{29}. For all other parents g.c.a effects were negative. The s.c.a effect was maximum in V_2 x V_{13} followed by V_{29} x V_{37} and V_2 x V_{37}. In the first and third crosses parents were with negative g.c.a effects. Hence the positive s.c.a effect may be due to over dominance. In the second cross the parents were with positive and negative effects thereby showing dominance in the expression of the character. In the analysis of variance g.c.a as well as s.c.a variances were significant in F_1 and F_2 indicating the role of additive as well as non additive gene action. Additive variance based on high g.c.a values was reported by Fatteh et al. (1982) and Singh et al. (1983) in sesamum.

For oil content the best general combiner was V_{29} followed by V_{13} and V_{41} based on their g.c.a effects. Other parents recorded negative g.c.a effects. Positive s.c.a effects were recorded in V_{13} x V_{37}, V_{13} x V_{41}, V_{25} x V_{13},

$V_{29} \times V_{41}$ and $V_2 \times V_{29}$. Here first, third and fourth crosses possess parents with positive and negative effects. In the second cross both parents were with positive g.c.a effects. In the last cross both the parents were with negative g.c.a effects. The results indicate dominance and over dominance in the expression of the character. In the analysis of variance g.c.a and s.c.a variances were not significant and the magnitude of s.c.a variance was high. In F_2 also the s.c.a variance was higher than g.c.a variance and it was significant. Non-additive type of gene action based on high s.c.a variance for this particular trait was reported by Murty (1974) and Fatteh et al. (1982). But Singh et al. (1983) reported high g.c.a variance for the same character.

In the case of duration for first flowering maximum possible g.c.a effect was recorded by V_{41}. It was followed by V_{37}, V_{25} and V_2. Negative g.c.a effects were recorded by V_{13} and V_{29}. Among the different crosses maximum s.c.a effect was recorded in $V_{25} \times V_{37}$ where both the parents were good general combiners. Maximum negative s.c.a effect (for early flowering) was recorded in the cross $V_2 \times V_{13}$ where the parents were with positive and negative effects. Dominance is indicated for earliness. In $V_{13} \times V_{29}$ where both the parents were negative, positive s.c.a effect was recorded indicating over-dominance for the expression of the character. In the analysis of variance g.c.a variance was higher and significant in F_1 indicating additive gene action. In F_2

both g.c.a and s.c.a variances were significant and g.c.a variance was higher in magnitude. Additive gene action based on high g.c.a values were reported by Murty (1974), and Fatteh et al. (1982).

The parental lines involved in the study were ranked for their general combining ability effects with respect to the various characters and are presented in table 27.In this study V_{29}, the best general combiner for seed yield per plant was also a good combiner for most of the other yield contributing traits. Thus, combining ability for number of pods per plant seemed to be influenced by combining ability of its component characters like plant height, number of productive branches, number of productive nodes and number of pods on main axis as was evidenced by correlation studies. In the light of the combining ability effects the varieties V_{41}, V_{29}, V_{13} and V_{37} should be given due consideration while framing breeding programmes. Crosses involving these parents viz., $V_2 \times V_{41}$ (maximum plant height), $V_{25} \times V_{37}$ (non-branchingness and maximum number of pods on main axis), $V_{29} \times V_{41}$ (maximum productive nodes on main axis, total pod and seed yield per plant), $V_2 \times V_{13}$ (early flowering and maximum 1000-seed weight) and $V_{13} \times V_{37}$ (maximum oil content) were the best specific combinations for the different characters.

The component analyses of the F_1 and F_2 diallels have also thrown considerable light on the nature of expression of

Table 27. Ranking of parental lines for their general combining ability effects with respect to various characters.

Characters	Parents					
	2	25	13	29	37	41
Plant height at maturity	P	$G_{(T)}$	$G_{(D)}$	$G_{(T)}$	$G_{(D)}$	$G_{(T)}$
Number of primary productive branches per plant	$G_{(B)}$	$G_{(B)}$	$G_{(B)}$	$G_{(B)}$	$G_{(NB)}$	$G_{(NB)}$
Number of productive nodes on main axis	P	G	P	G	P	P
Number of pods on main axis	P	G	P	G	G	P
Total number of pods per plant	G	P	P	G	P	P
Seed yield/plant	G	G	P	G	P	P
1000-seed weight	P	P	P	G	P	G
Oil content (Percentage)	P	P	G	G	P	G
Number of days for first flowering	P	$G_{(L)}$	$G_{(E)}$	$G_{(E)}$	$G_{(L)}$	$G_{(L)}$

G = Good
P = Poor
E = Early
L = Late

T = Tall
D = Dwarf
B = Branching
NB = Non branching

various quantitative characters studied and in the type of gene action. Additive and non-additive variances were significant in most of the characters in both generations. More or less similar results were obtained in the component analysis also.

For plant height g.c.a and s.c.a variances were significant in F_1 and F_2. In the component analysis also additive ($\hat{D}$) as well as non-additive ($\hat{H}_1$) variances were significant in F_1 and F_2.

For number of primary productive branches per plant g.c.a variance was significant in F_1 and F_2. But in F_2 only s.c.a variance was significant. In the component analysis both additive and non-additive variances were significant in F_1 and F_2.

Combining ability analysis showed significant g.c.a variance im F_1 and F_2. But s.c.a variance was significant only in F_2. In the component analysis additive variance was significant only in F_1 while non-additive variances were significant in F_1 and F_2. For number of pods on main axis g.c.a variance was significant in F_1 and F_2 while s.c.a variance was significant in F_2 only in the combining ability analysis. In component analysis additive and non-additive variances were not significant in F_1 but non-additive variance was significant only in F_2.

Total pods per plant showed significant g.c.a and s.c.a variances in F_1 and F_2 in the combining ability analysis.

In the component analysis additive variance was significant in F_1 and non-additive variance was significant in F_1 and F_2.

For 1000-seed weight g.c.a and s.c.a variances were significant in F_1 and F_2 in the combining ability analysis. But in component analysis additive and non-additive variances were significant in F_1.

In the combining ability analysis seed yield per plant showed significant g.c.a and s.c.a variances in F_1 and F_2, while in component analysis additive and non-additive variances in F_1 were significant. But in F_2 only non-additive variance was significant. For oil content g.c.a and s.c.a variances were not significant in F_1 and s.c.a variance was significant in F_2 in the combining ability analysis. Additive and non-additive variances were not significant in F_1 and F_2 in the component analysis. In the combining ability analysis, for number of days for first flowering g.c.a variance was significant in F_1 and F_2 and s.c.a variance was significant in F_2. In the component analysis both additive and non-additive variances were significant in F_1 and F_2.

In F_1, only in the case of number of pods on main axis, additive variance was not significant in spite of significant g.c.a variance. But the non-additive variance was also not significant for the character.

In F_2, number of productive nodes on main axis, total pods per plant and seed yield per plant showed significant g.c.a variance in the combining ability analysis. But in

the component analysis non-additive variance was found to be significant. Similar results as is noted in the present investigation were reported in other crops in respect of various traits. Singh and Singh (1972) obtained significant g.c.a variance for number of seeds per pod in mung bean, whereas component analysis revealed that additive ($\hat{D}$) and non-additive ($\hat{H}_1$) components of variance were significantly high for number of seeds per pod. Singh et al. (1974) observed in soybean that only g.c.a variance was significant for 100-seed weight. But components of genetic variance revealed that non-additive component played an important role in the expression of this trait. They also reported that only non-additive gene action was significant for seed yield, though the variance due to g.c.a and s.c.a were significant for the character in the combining ability analysis. Singh et al. (1974) asserted that this discrepancy in the estimates of components of variance might be attributed partly to the presence of inter-allelic interactions, the magnitude of which cannot be ascertained through this analysis.

Number of days to flowering, plant height, number of productive nodes on main axis, total pods per plant, 1000-seed weight and seed weight in F_1 showed significant difference in $\hat{F}$ test indicating the availability of excess of dominant alleles in the parents.

In both F_1 and F_2, the ratio $(\hat{H}_1/\hat{D})^{\frac{1}{2}}$ indicated over-dominance for plant height, number of productive nodes

on main axis, number of pods on main axis, 1000-seed weight, seed yield per plant and oil content. For number of days for first flowering, primary productive branches per plant and total number of pods per plant, partial dominance was observed in F_1. But in F_2 over-dominance was observed. As was noted in the present investigation, partial dominance for days to maturity and days to flowering was reported by Srivastava et al. (1978) in soybean. Over-dominance observed for seed yield per plant is similar to the result obtained by Srivastava et al. (1978) in soybean.

The distribution of genes with positive and negative effects was not symmetrical for all the traits as indicated by the ratio $\hat{H}_2/4\hat{H}_1$.

The comparative evaluation of results of different statistical analyses used to study the genetic architecture for various characters in F_1 and F_2 is presented in table 28. The results showed that the genetic information suggested by Hayman (1954 b) and Jinks (1954, 1956), supplemented with the genetic information on combining ability analysis by Griffing (1956 b) would help the plant breeders to make important conclusions regarding the selection of suitable parents for breeding programmes and to unveil the genetic architecture of various quantitative characters. In this study both methods i.e. combining ability analysis and component analysis for estimating the type of gene action have given

Table 28. Comparative evaluation of results of different statistical analyses used to study the gene action for various characters in F_1 and F_2.

Characters		Combining ability		Components of variances			Average degree of dominance	Heritability % (Narrow sense)
		General	Specific		D	H_1		
Number of days for first flowering	F_1	S	N.S.	F_1	S	S	Partial dominance	74.40
	F_2	S	S	F_2	S	S	Over dominance	21.68
Plant height	F_1	S	S	F_1	S	S	do	60.00
	F_2	S	S	F_2	S	S	do	3.59
Number of primary productive branches per plant	F_1	S	N.S.	F_1	S	S	Partial dominance	66.00
	F_2	S	S	F_2	S	S	Over dominance	28.90
Number of productive nodes on main axis	F_1	S	N.S.	F_1	S	S	do	46.00
	F_2	S	S	F_2	N.S.	S	do	7.79
Number of pods on main axis	F_1	S	N.S.	F_1	N.S.	N.S.	do	25.98
	F_2	S	S	F_2	N.S.	S	do	9.35
Total number of pods per plant	F_1	S	S	F_1	S	S	Partial dominance	32.30
	F_2	S	S	F_2	N.S.	S	Over dominance	5.40
1000-seed weight	F_1	S	S	F_1	S	S	do	25.82
	F_2	S	S	F_2	N.S.	N.S.	do	3.75
Seed yield per plant	F_1	S	S	F_1	S	S	do	27.00
	F_2	S	S	F_2	N.S.	S	do	2.15
Oil content percentage	F_1	N.S.	N.S.	F_1	N.S.	N.S.	do	16.50
	F_2	N.S.	S	F_2	N.S.	N.S.	do	2.14

S = Significant N.S. = Not significant

comparable results for most of the characters.

Heterosis

During the course of the present investigation marked heterotic effeot was observed in various single cross combinations for most of the characters studied with the maximum heterotic expression for number of pods and seed yield per plant.

A maximum of 75.54% to 30.90% heterosis over mid-parent and better parent respectively was observed in the case of plant height. Positive heterosis was recorded by 11 hybrids over mid-parent and 7 hybrids over better parent. Two hybrids $V_2 \times V_{41}$ and $V_{13} \times V_{41}$ showed significant heterosis over better parent. The s.c.a effects were also significant for these two crosses in the combining ability analysis. The other hybrids which excelled the better parent were $V_{37} \times V_{41}$, $V_{29} \times V_{41}$, $V_{25} \times V_{41}$, $V_{13} \times V_{37}$ and $V_2 \times V_{25}$. Eventhough Pal (1945) reported that heterosis was not manifested in sesamum for plant height, Sverup John (1980) and Tyagi and Singh (1981) reported positive heterosis for this character as was noted in the present investigation. In the present study among the double cross hybrids only one of the total twenty seven viz., ($V_{29} \times V_{37}$) ($V_{25} \times V_{13}$) showed positive heterosis over mid parent and none showed positive heterosis over better parent.

As regards number of primary productive branches per plant maximum heterosis of 86.93% over mid-parent and 16.13% over better parent was observed in the single cross hybrids. Positive heterosis was recorded by 11 hybrids over mid-parent and 6 hybrids over better parent. The hybrids which surpassed the better parent were $V_2 \times V_{41}$, $V_{13} \times V_{37}$, $V_{13} \times V_{41}$, $V_2 \times V_{29}$, $V_2 \times V_{25}$, $V_2 \times V_{13}$ and $V_{25} \times V_{13}$. Eventhough these crosses recorded positive s.c.a effects, they were not statistically significant. Maximum negative heterosis over mid parent, favouring non-branching nature was expressed in $V_{25} \times V_{37}$ followed by $V_{25} \times V_{41}$. Pal (1945) evaluated the number of branches for heterotic effect and reported that heterosis was not manifested for this character. But Sarathe (1969), Sverup John (1980) and Tyagi and Singh (1981) recorded good heterotic effect for number of branches in sesamum. The double cross hybrids recorded only negative heterosis over mid parents as well as better parents. Maximum negative heterosis was recorded in the cross ($V_{25} \times V_{41}$)($V_2 \times V_{37}$) only in the present study.

Number of productive nodes on main axis exhibited a maximum heterosis of 67.52% over mid-parent and 61.98% over better parent in the single cross hybrids. Positive heterosis was recorded by 11 hybrids over mid-parent and 4 hybrids over better parent. Hybrids which surpassed the better parent were $V_{13} \times V_{41}$, $V_2 \times V_{41}$, $V_2 \times V_{37}$ and $V_{29} \times V_{41}$.

Heterosis was significantly higher in the first cross, $V_{13} \times V_{41}$. The positive s.c.a effects were also significant in the crosses $V_{13} \times V_{41}$, $V_2 \times V_{41}$ and $V_{29} \times V_{41}$. In the double cross hybrids the heterotic effect was negative in almost all cases in the present study.

Among the single cross hybrids as regards number of pods on main axis, a high degree of positive heterosis was exhibited by 11 hybrids over mid parent with a maximum of 77.35%. Four hybrids showed positive heterosis over better parent with a maximum of 62.39%. The hybrids which showed positive heterosis over better parent were $V_{13} \times V_{41}$, $V_{25} \times V_{37}$, $V_2 \times V_{41}$ and $V_{25} \times V_{29}$. In the second cross, $V_{25} \times V_{37}$, heterosis was significant. All these hybrids recorded positive s.c.a effects and the s.c.a effects of the crosses $V_{25} \times V_{37}$ and $V_2 \times V_{41}$ were statistically significant.

A very high degree of positive heterosis for total number of pods per plant was manifested among the single cross hybrids of the 15 crosses. Nine hybrids showed positive heterosis over mid parent with a maximum of 209.82%. Seven hybrids recorded positive heterosis over better parent with a maximum of 204.49%. The hybrids which dominated over the better parent were $V_{13} \times V_{41}$, $V_{29} \times V_{41}$, $V_2 \times V_{13}$, $V_2 \times V_{37}$, $V_{13} \times V_{37}$, $V_{37} \times V_{41}$ and $V_2 \times V_{41}$. The s.c.a effects of the first four crosses were positive and significant in the combining ability analysis. Eventhough

Pal (1945) reported that the hybrids of sesamum showed heterosis for seed yield only upto the mark of better parent, several other workers reported positive heterosis in sesamum. Sarathe (1969) reported positive heterosis over mid-parent while Murty (1974) reported high amount of heterosis for the character over the best parent. Sverup John (1980), Tyagi and Singh (1981), Chavan and Chopde (1981) and Paramasivan et al. (1982) reported positive heterosis for total pod production in sesamum. In double crosses heterotic expression was all negative in the present study.

The positive heterosis exhibited over mid-parent extended upto a maximum of 126.46% in the case of seed yield per plant in the single cross hybrids. Ten hybrids showed positive heterosis over mid-parent and four hybrids over better parent. The percentage of heterosis over better parent extended to a maximum of 50.11. The hybrids $V_2 \times V_{13}$, $V_{13} \times V_{29}$, $V_{25} \times V_{41}$ and $V_2 \times V_{37}$ surpassed the better parent for the character. All these hybrids exhibited positive s.c.a effects of which that of $V_2 \times V_{13}$ was significant. Pal (1945) had reported that six hybrids of sesamum recorded heterosis over better parent for seed yield. Sarathe (1969), Tyagi and Singh (1981) and Chavan and Chopde (1981) also reported high magnitude of positive heterosis for this trait in sesamum. In the double cross hybrids heterosis was negative for the character in the present study.

The heterosis manifested for 1000-seed weight in the single cross hybrids was very limited. Negative heterosis was manifested in a large number of hybrids. Positive heterosis over mid-parent was manifested only in 3 hybrids and maximum heterosis was only 9.16%. Two hybrids showed heterosis over better parent which extended to a maximum of 7.19%. These hybrids possessed positive s.c.a effects and in the first cross, $V_2 \times V_{13}$, it was significant also. The present finding is in line with the reports of Sarathe (1969) that heterosis was very low for 1000-seed weight in sesamum and it was slightly higher than the mid-parental value. In the present study most of the double cross hybrids showed positive heterosis for the character.

Heterosis was limited in the case of oil content in the single cross hybrids. The percentage of heterosis over mid-parent extended upto a maximum of 46.23. Thirteen hybrids recorded positive heterosis over mid-parent while 10 hybrids recorded positive heterosis over better parent upto a maximum of 40.84. The hybrids which dominated over better parent were, $V_{13} \times V_{37}$, $V_{13} \times V_{41}$, $V_{25} \times V_{13}$, $V_2 \times V_{25}$, $V_{37} \times V_{41}$, $V_{25} \times V_{41}$, $V_{29} \times V_{41}$, $V_2 \times V_{29}$, $V_2 \times V_{13}$ and $V_2 \times V_{41}$. Heterosis of the first two crosses over mid-parent was significant. The s.c.a effects were positive and that of $V_{13} \times V_{37}$ was statistically significant. Sarathe (1969) reported that heterosis was not manifested for oil content

in sesamum. Tyagi and Singh (1981) reported that the vigour shown by the hybrids was very little for this character in sesamum. Among the 27 double cross hybrids 15 recorded positive heterosis. Maximum positive heterosis was recorded in the cross (V_{25} x V_{41})(V_2 x V_{37}). Positive heterosis of 5 hybrids were statistically significant.

For number of days for first flowering the magnitude of positive heterosis as well as the number of hybrids showing heterosis was less in the single crosses. Compared to mid parent, only 5 hybrids recorded positive heterosis with a maximum of 7.34%. Nine hybrids recorded negative heterosis compared to mid-parent and one recorded no heterosis at all. The negative heterosis extended upto a maximum of -9.71%, recorded in the cross V_2 x V_{13} favouring for early flowering. Compared to better parent (early flowering), heterosis was shown by 10 hybrids and the magnitude of heterosis extended upto -4.39%. Two hybrids viz., V_2 x V_{41} and V_{25} x V_{29} showed negative heterosis which also recorded negative s.c.a effects in the combining ability analysis. The heterotic effects and s.c.a effects were not statistically significant. Pal (1945) reported that positive heterosis was not manifested for this character in sesamum. Among the double cross hybrids heterotic effect was all negative for the character.

The details of the expression of heterosis for various characters in this investigation have presented valuable information. From the table 12-1 to 12-3 it was established

that heterozygosity in the single cross hybrids had distinct advantage for boosting up character expression in sesamum. The high frequency of heterotic combinations for various yield and yield contributing components, clearly establish the occurrence of heterosis as a general phenomenon.

In the present study a near perfect positive correspondence was observed between specific combining ability and extent of heterosis in the single cross hybrids. In the double cross hybrids also only for characters like 1000-seed weight and oil content where s.c.a variance is predominant positive heterotic effect was noticed. In the correlation studies it was revealed that seed yield per plant is highly and positively correlated and depended on medium plant height, number of productive nodes on main axis, productive primary branches and total number of pods per plant. Heterosis in seed yield is reflected through heterosis in the above yield components. In the combining ability analysis and component analysis it is established that a large amount of non-additive variance is present in the expression of plant height, total number of pods per plant and seed yield. An important approach for improvement in this crop would be to develop hybrid strains exploiting the hybrid vigour for yield contributing characters. Kannaiyan et al. (1980) rightly pointed out that utilisation of male sterility to eliminate hand emasculation together with the utilisation of bees as

pollinating agents, do at present for the practical possibility for commercial production of hybrid seeds as was confirmed in preliminary field attempts.

Frequency and spectrum of F_2 variants:

Studies on F_2 variants related to yield attributing characters (Tables 24-1 to 24-4 and 25-1 to 25-9 and Figures 11 to 19) enlightens further scope for selecting suitable plant types from among the segregants. As reported by Culp (1960) in the present study also dominance was observed for tallness in the F_2 of all crosses irrespective of the parents involved. In crosses involving medium x medium or short x short varieties the F_2 showed a preponderance for medium height. The specific crosses which showed high amount of positive variability were $V_{29} \times V_{37}$, $V_{25} \times V_{29}$, $V_{37} \times V_{41}$, $V_2 \times V_{25}$ and $V_2 \times V_{41}$. The results discussed in the previous chapters of the present investigation and the segregating pattern available in F_2 clearly demonstrates that tall plant types with high yield potentiality can be identified from the F_2 populations of the above crosses.

The segregation pattern noted in the present study indicated that branching habit is dominant over non-branching habit. This is in line with the reports made by Joshi (1961) in this particular crop variety. In crosses involving

profuse branching types, profuse and medium branching types and profuse and shy branching types predominance was shown for profuse branching habit. In crosses of medium and shy branching types medium branching habit was dominant. The specific crosses in the present study which showed high amount of positive variability favouring branchingness were $V_2 \times V_{29}$, $V_{13} \times V_{29}$ and $V_{25} \times V_{29}$. High amount of negative variability favouring non-branchingness was expressed in crosses such as $V_{13} \times V_{37}$, $V_{29} \times V_{41}$ and $V_{37} \times V_{41}$. Plants with shyness for branching habit and with compact pod bearing nature has been noted in crosses like $V_2 \times V_{25}$ and $V_2 \times V_{41}$. The same crosses showed maximum positive variants for tallness.

Number of productive nodes on main axis does not show positive correlation with number of pods on main axis. It is particularly so in the case of multipoded varieties. Number of pods on main axis is having a negative direct effect on total seed yield since it exerts a negative influence on branching. Hence it is suggestive that the non-branching types are not as high yielders as branching types. In the F_2 analysis it is seen that crosses such as $V_{25} \times V_{37}$, $V_2 \times V_{37}$, $V_{29} \times V_{37}$, $V_2 \times V_{25}$, $V_2 \times V_{41}$ and $V_{25} \times V_{29}$ are with segregants possessing high number of productive nodes on main axis.

Total number of pods per plant is having the maximum direct effect on seed yield. In the F_2, crosses like

$V_2 \times V_{25}$, $V_{25} \times V_{37}$, $V_{25} \times V_{41}$, $V_2 \times V_{41}$, $V_2 \times V_{37}$ and $V_{25} \times V_{29}$ show maximum frequency of positive variants for number of pods per plant. The crosses $V_2 \times V_{25}$ and $V_2 \times V_{41}$ showed an incorporation of all the desirable attributes favouring maximum seed production per plant. These crosses gave maximum frequency of positive variants for tallness, shyness in branching, maximum number of pods on main axis and total number of pods per plant. The phenotypic frequency distribution analyses clearly indicate that a plant type with all desirable attributes favouring maximum unit area production can be isolated from among the different cross combinations involved in the present investigation.

SUMMARY

SUMMARY

The present investigation was carried out at the Department of Agricultural Botany, College of Agriculture, Vellayani during 1980 to 1983. Forty four varieties of Sesamum indicum, both exotic and indigenous were evaluated in a field experiment to assess the extent of variability available in this particular crop variety. Genetic parameters, correlations and path-coefficients were also analysed and included as the first part of the study. The characters studied were plant height at maturity, number of primary productive branches per plant, number of productive nodes and pods on main axis, total number of pods per plant, seed yield per plant, 1000-seed weight, oil content, number of seeds per pod and duration for first flowering.

The second part consists of the analysis on the hybrids and the created variabilities in F_2. Six varieties having maximum expression for the different yield related characters were selected and crossed in random combinations as a diallel set without reciprocals. Combining ability, heterosis and genetic basis of different character expressions in F_1 and combining ability, gene action and inheritance pattern in F_2 were analysed in detail. Double crosses were also carried out and evaluated for the extent of heterosis for various polygenic traits. The different polygenic characters studied in the hybrids and F_2 were

plant height, number of primary productive branches per plant, number of productive nodes on main axis, number of pods on main axis, total number of pods per plant, seed yield per plant, 1000-seed weight, oil content and duration for first flowering.

Investigations on meiotic abnormalities and pollen sterility in the single and double cross hybrids were carried out.

The data collected were analysed using appropriate statistical techniques and the salient points reflected from the results are summarised below:

1. The analysis of variance study conclusively proved that sesamum, in spite of being an essentially self pollinated crop is rich in varietal variability. The range of variability was very wide in the case of total number of pods per plant, seed yield and number of primary productive branches per plant.

2. Phenotypic variance was very high for total number of pods per plant and plant height. In the case of total number of pods per plant the genotypic variance was also maximum. Genotypic as well as phenotypic variance was minimum in the case of number of primary productive branches per plant and number of seeds per pod. Environmental variance was comparatively less for number of productive nodes and pods on main axis, 1000-seed weight and duration

for first flowering.

3. High phenotypic and genotypic coefficients of variation were obtained for total pods per plant, seed yield per plant and number of primary productive branches per plant while they were low in the case of duration for first flowering, 1000-seed weight, oil content, number of seeds per pod and height of plant.

4. High heritability estimates along with low genetic advance was met with in the case of oil content. Number of seeds per pod, 1000-seed weight and duration for first flowering showed very low heritability estimates and genetic advance.

5. Higher heritability values were recorded in F_1 and F_2 consistently in the case of duration for first flowering and number of primary productive branches per plant. In general, heritability values were lower in the F_2 than in F_1 for all the characters indicating the predominance of over dominance in hybrid population.

6. Inheritance of number of primary productive branches and duration for first flowering showed considerable amount of additive and additive x additive component interactions.

7. Total number of pods per plant showed maximum positive genotypic correlation with seed yield.

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6. Inheritance of number of primary productive branches and duration for first flowering showed considerable amount of additive and additive x additive component interactions.

7. Total number of pods per plant showed maximum positive genotypic correlation with seed yield.

8. Number of seeds per pod, duration for first flowering and oil content recorded a negative correlation with total seed yield per plant.

9. Number of total pods per plant had negative correlation with 1000-seed weight, number of days for first flowering, oil content and seeds per capsule.

10. Analysis in cause effect relationship showed that total number of pods per plant is exerting maximum direct effect on seed yield. Plant height, number of productive nodes on main axis and number of primary productive branches also showed positive direct effect on seed yield. But number of pods on main axis showed negative direct effect on seed yield.

11. The analysis of variance for combining ability in F_1 generation revealed that both additive and non-additive gene actions were important in the expression of plant height, total number of pods per plant, seed yield and 1000-seed weight. Except in the case of oil content g.c.a variance was higher than s.c.a in all the characters studied.

12. In F_2 g.c.a and s.c.a variances were significant in all the characters except oil content.

13. Based on the g.c.a effects V_{29} found to be the best general combiner for seed yield and total number of pods per plant. Variety 25 was the best general combiner for plant height and number of primary productive branches

8. Number of seeds per pod, duration for first flowering and oil content recorded a negative correlation with total seed yield per plant.

9. Number of total pods per plant had negative correlation with 1000-seed weight, number of days for first flowering, oil content and seeds per capsule.

10. Analysis in cause effect relationship showed that total number of pods per plant is exerting maximum direct effect on seed yield. Plant height, number of productive nodes on main axis and number of primary productive branches also showed positive direct effect on seed yield. But number of pods on main axis showed negative direct effect on seed yield.

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12. In F_2 g.c.a and s.c.a variances were significant in all the characters except oil content.

13. Based on the g.c.a effects V_{29} found to be the best general combiner for seed yield and total number of pods per plant. Variety 25 was the best general combiner for plant height and number of primary productive branches

per plant. For non-branchingness V_{37} and V_{41} were good general combiners.

14. Based on the significance of s.c.a effects the specific combinations showing maximum hybrid vigour for the different characters were as follows:

$V_2 \times V_{41}$ - Maximum plant height, productive nodes and pods on main axis.

$V_{13} \times V_{41}$ - Maximum height, productive nodes and pods on main axis, total number of pods/plant and seed yield.

$V_{25} \times V_{37}$ - Maximum non-branchingness, late flowering and maximum pods on main axis.

$V_2 \times V_{37}$ - Maximum number of primary productive branches and pods.

$V_{29} \times V_{41}$ - Maximum productive nodes on main axis, total pod and seed yield.

$V_2 \times V_{13}$ - Early flowering, maximum 1000-seed weight and pod yield.

$V_{13} \times V_{37}$ - Maximum oil yield.

Considering the yielding ability, the crosses $V_{29} \times V_{41}$ and $V_{13} \times V_{41}$ were the best combinations.

15. Studies on meiosis and pollen sterility in the single and double cross hybrids showed that there is no cytological barriers for intervarietal crosses in sesamum.

16. Marked heterotic effect was observed for number of pods and seed yield per plant in single crosses.

17. In double cross hybrids positive heterosis was recorded in the case of productive nodes and pods on main axis, 1000-seed weight and oil content.

18. For seed yield, plant height, number of primary productive branches, total pods and duration for first flowering all the double cross hybrids recorded negative heterosis.

19. Analysis on components of variation in F_1 and F_2 showed that except in oil content all the other eight characters studied were governed by both additive as well as non-additive factors. All the characters were mostly controlled by dominant alleles and expressed over dominance in F_1 and F_2.

20. The F_2 segregants of different crosses showed wide range of variability for the different characters. The spectrum and frequency of F_2 variants revealed that crosses such as $V_2 \times V_{25}$, $V_2 \times V_{41}$ and $V_{25} \times V_{37}$ possessed high percentage of positive variants with ideal plant type characters like tallness, shyness in branching, maximum number of productive nodes, maximum number of pods per plant and maximum seed yield per plant.

21. Combination breeding in sesamum reveals scope for further improvement in the existing genotypes for increasing the unit area production.

REFERENCES

REFERENCES

Anonymous. (1977). Sesamum commodity profile. Mimeo. Directorate of oilseeds development, Government of India Publication.

Anonymous. (1978). Package of practices. Page 54 . Kerala Agricultural University, Trichur.

Anonymous. (1978). Directorate of Economics and Statistics, Government of India.

*Anonymous. (1979 b). Annual Progress Report. O.D.S.(S). 1979-80 of oilseeds Extension Officer, Junagadh.

Anonymous. (1983). Agricultural Guide, Department of Agriculture, Kerala.

Ali Mohammed and Gupta, N.D. (1941). Inheritance of alternate and opposite arrangements of leaves in S. indicum. Indian J. Agric. Sci., 11: 659-661.

Allard, R.W. (1960). Principles of plant breeding. John Wiley and Sons, London, 75-99, 213-24.

Batade, S.S., Singh, C.B. and Tiwari, A.S. (1977). Diallel Analysis of yield and its components in soybean. Indian J. Agric. Sci., 47: 322-324.

*Bowman, J.C. (1959). Selection for heterosis. Anim. Breed. Abst., 27: 261-273.

Briggle, L.M. (1963). Heterosis in wheat - A Rev. Crop Sci., 3: 407-412.

Burton, G.W. (1952). Quantitative inheritance in grasses. Proc. 6th inst. Grassld. Congr., 1: 277-283.

Chaudhary, P.N., Patil, G.D. and Zope, R.E. (1977). Genetic variability and correlation studies in sesame. J. Maharashtra Agric. Univ., 2: 30-33.

Chavan, G.V. and Chopde, P.R. (1981). Correlation and path analysis of seed yield and its components in sesame. Indian J. Agric. Sci., 51: 627-630.

Chavan, G.V. and Chopde, P.R. (1982). Polygenic variability, heritability and genetic advance in irradiated sesame. J. Maharashtra Agric. Univ., 7: 17-19.

Chavan, A.A., Makne, V.G. and Chorpde, P.R. (1982). Components of heterosis and inbreeding depression studies in sesame (S. indicum L.). J. Maharashtra Agric. Univ., 7: 15-16.

Comstock, R.S. and Robinson, H.F. (1948). Components of genetic variances in populations of biparental progenies and their use in estimating the average degree of dominance. Biometrics, 4: 254-256.

Crow, J.H. and Kimura, M. (1970). An introduction to Population genetics Theory, Harper and Row, New York. page 409 - 414.

Culp, T.W. (1960). Inheritance of paper shell capsules, capsule number and plant colour. J. Heredity, 51: 146-148.

De Candolle, A. (1886). Origin of cultivated plants. Keganpaul French Co., London.

Dewey, D.R. and Lu, H.K. (1959). A correlation and path coefficient analysis of components of crested wheat grass seed production. Agron. J., 51: 515-518.

Dixit, R.K. (1975). Path analysis for some quantitative traits in sesame. . Plant Science 7 : 9-12.

Dixit, R.K. (1978). Combining ability analysis in sesame. Indian J. Agric. Sci., 48: 362-364.

Fatteh, U.G., Shah, R.M. and Bodar, D.G. (1982). Studies on combining ability in sesame (Sesamum indicum). Madras Agric. J., 69: 145-150.

Fisher, R.A. (1918). The correlation between relatives on the supposition of Mendelian inheritance. Trans. Roy. Soc. Edinb., 5: 399-433.

Fisher, R.A. (1930). The genetical theory of natural selection. Oxford: Claredon Press.

Gaul, H. (1967). Studies on the population of micromutant in barley and wheat without and with selection. Induced mutations and their utilization, Proc. Symp. Erwin-Bauer. Gedachicreles ungen IV Gaterslehen, 1966, Akademie-Verley, Berlin: 269-289.

Gill, K.S., Dhillon, S.S. and Bains, K.S. (1972). Combining ability and inheritance of yield components in crosses involving Indian and Exotic wheat germ plasm. Indian J. Genet., 32: 421-430.

Grafius, J.E. (1959). Heterosis in barley. Agron. J., 51: 551-554.

Griffing, B. (1956a). A generalised treatment of the use of diallel cross in quantitative inheritance. Heredity, 10: 31-50.

Griffing, B. (1956 b). Concept of general and specific combining ability in relation to diallel crossing systems. Aust. J. Biol. Sci., 9: 463-93.

Gupta, V.K. and Gupta, Y.K. (1977). Variability interrelationships and path coefficient analysis for some quantitative characters in sesame (S. indicum L.). Indian J. Heredity, 9: 31-37.

Gupta Tilak Raj. (1981). Combining ability analysis of yield components in sesamum. Madras Agric. J., 68: 281-288.

Hayes, H.K., Immer, F.A. and Smith, D.C. (1955). Methods of plant breeding. :52-60 McGraw Hill Book Company Inc. New York,

Hayman, B.I. (1954 b). The theory and analysis of diallel crosses Genetics, 39: 789-809.

Hayman, B.I. (1957). The theory and analysis of diallel crosses II. Genetics, 43: 63-85.

Hayman, B.I. (1958). The separation of epistatic from additive and dominance variation in generation means. Heredity, 12: 371-390.

*Hull, F.H. (1945). Recurrent selection and specific combining ability in corn. J. Am. Soc. Agron., 37: 134-145.

*Hull, F.H. (1949). Tests for over- dominance. Proc. VIII Int. Congr. Genet. Stockholm, 1948. Heriditas, (Suppl.) 600-601.

Jinks, J.L. (1954). The analysis of continuous variation in a diallel cross of Nicotiana rustica varieties. Genetics, 39: 767-88.

Jinks, J.L. (1955). A survey of the genetical basis of heterosis in a variety of diallel crosses. Heredity, 9: 223-238.

Jinks, J.L. (1956). The F_2 and back cross generations from a set of diallel crosses. Heredity, 10: 1-30.

Jinks, J.L. and Hayman, B.I. (1953). The analysis of diallel crosses. Maize Genetics Co-op. News Lett., 27: 48-54.

Johnson, H.W., Robinson, H.F. and Comstock, R.E. (1955). Estimates of genetic and environmental variability in soybean. Agron. J., 47: 314-318.

*Johnson, H.W. and Bernard, R.L. (1963). The soy bean genetics and breeding. A.G. Norman, Academic Press, New York, 1-73.

Joseph, C.A. (1979). Genetic studies in sweet potato (Ipomoea batatas) - a biometric approach. Ph.D. Thesis submitted to the Kerala Agricultural University.

Joshi, A.B. (1961). 'Sesamum'. Indian Central Oilseeds Committee, Hyderabad.

Kartha, A.R.S. and Sethi, A.S. (1957). A cold percolation method for rapid gravimetric estimation of soil in small quantities of oilseeds. Indian J. Agric. Sc 27 Part II: 217.

Katiyar, R.P. and Singh, D. (1979). Genetic architecture of yield and its components in chick pea. Indian J. Genet., 39: 146-149.

Kaushal, P.K., Srivastava, P.S., Shrivas, S.R. and Goswami, (1974). Study on correlation and path analysis of some yield attributing characters in erect type of sesame. JNKVV Res. J., 8: 103-113.

Kaw, R.N. and Menon, M.P. (1972). Association between yield and its components in soybean. Indian J. Genetic 32: 276-280.

Kempthorne, O. (1957). An introduction to genetic statistic Page 513. John Wiley and Sons, Inc., New York.

Ketata, H., Smith, E.L., Edwards, L.H. and Mc New, R.W. (19 Detection of epostatic, additive and dominance variation in winter wheat (Triticum aestivum). Crop Sci., 16: 1-4.

Khidir Osman, M. and Gizouli Osman, H.El. (1970). Correl studies of some agronomic characters in sesame. Expt. Agric., 6: 27-31.

Khidir, M.O. (1981). International Research Co-operation Sesame improvement. Sesame: Status and improvemen FAO plant production and protection paper. 29,

Krishnamoorthy, T.N., Ponnaiya, B.W.X. and Santhanum, V.(19 Breeding methodology and selection index for yield S. indicum L. Madras Agric. J., 51: 360.

Mak, C. and Yap, T.C. (1980). Inheritance of seed protein content and other agronomic characters in long bean (Vigna sesquipedalis). Theor. Appl. Genet., 56: 233-239.

Mather, K. (1949). Biometrical genetics. Methven & Co. Ltd., London.

Mather, K. and Jinks, J.L. (1971). Biometrical Genetics. Page 65 Chapman and Hall, London.

Mazzani, B., Mantilla, D., Rivas, N. and Allievi, C. (1981). Breeding and evaluation of F_1 hybrid cultivars of Venezuela. Sesame: Status and improvement. FAO Plant Production and Protection Paper. 29- Rome.

Muhammed, S.V. and Durairaj, M.S. (1964). Interspecific hybrid between S. indicum x S. laciniatale. Madras Agric. J., 55: 140-141.

*Morinaga, T.E., Fukushima, E., Kano, T. and Yamasaki, Y. (1929). Chromosome numbers of cultivated plants. II. Bot. Mag., 43: 589.

Murty, D.S. (1974). Heterosis-combining ability and reciprocal effects for agronomic and chemical characters in sesame. Theor. Appl. Genet., 45: 294-299.

*Murty, D.S. and Hashim, M. (1973). Inheritance of oil and protein content in a diallel cross of sesame. Can. J. Genet. Cytol., 15: 177-184.

Murugesan, M., Dhamu, K.P. and Arokiaraj, A. (1979). Genotypic, phenotypic correlations and path analysis of some quantitative characters in sesamum. Madras Agric. J., 66: 631-634.

Nayar, N.M. and Mehra, K.L. (1970). Sesame. Its uses, botany, cytogenetics and origin. Econ. Bot., 24: 20-31.

Osman Gizouli, H.A. and Osman Khidir, M. (1974). Estimates of genetic and environmental variability in sesame. Expt. Agric., 10: 105-12.

Pal, B.P. (1945). Studies in hybrid vigour.I. Notes on the manifestation of hybrid vigour in gram and sesamum, chillies and maize. Indian J. Genet., 5: 106-121.

Panse, V.G. and Sukhatme, P.V. (1957). Statistical methods for agricultural workers. page 155-156 Indian Council of Agricultural Research, New Delhi.

Paramasivan, K.S., Varadharajan, S., Soundarapandian, G. and Venkataraman, N. (1982). Study of heterosis in hybrids of sesamum. Madras Agric. J., 69: 51-55.

*Powers, L. (1944). An explanation of Jone's Theory for the explanation of heterosis. Amer. Nat., 78: 275-280.

Prabhakara Reddy, G., Reddy, P.S. and Raghunathan, G. (1971). Inheritance studies in Sesamum indicum L. Andhra Agric. J., 18: 34.

Premnarayanan, Bhatia, V.K. and Malhotra, P.K. (1979). Handbook of Statistical Genetics, I.C.A.R., New Delhi.

Rai Vinaya, R.S., Venkateswaran, A.N., Ramachandran, T.K. and Srinivasan, G. (1981). Genetic variability and correlation studies in S. indicum. Indian J. Agric. Res., 15: 119-122.

Ramachandran, M., Ramanathan, T. and Sridharan, C.S. (1972). Association of certain morphological characters with yield in Sesamum indicum. Madras Agric. J., 59: 567-568.

Ramakrishna, A., Marappan, P.V. and Sivaswamy, N. (1979). Genetic divergence in horse gram. Indian J. Agric. Sci., 49: 719-23.

Rathinaswamy, R. (1980). Genetic analysis in S. indicum L. Ph.D. Thesis, unpublished, TNAU, Coimbatore.

Sandhu, J.S. and Anand, S.C. (1972). Inheritance of kernal weight in wheat. Indian J. Genet., 32: 299-302.

Sanjeeviah, B.S. and Joshi, M.S. (1974). Correlation and genetic variability in sesamum. Curr. Res., 3: 144-145.

Sarathe, M.L. and Darbal, K.C. (1969). Heterosis studies in Sesamum orientale L. Sci. Cult., 35: 572-573.

Sayed, H.I. (1978). Inheritance of five quantitative characters of Bread wheat. Theor. Appl. Genet., 52: 73-76.

Sengupta, K. (1980). Combining ability in sesame (Sesamum indicum L.). Indian Agric., 24: 95-100.

Seshadri, C.R. (1957). Future of oilseeds research - Sesamum. Indian Oilseeds J., 1: 96-98.

Shakhbazov, V.G. (1978). Some biophysical phenomena and the mechanism of heterosis in plants. Plant Breeding Abstracts, 47, 26.

Sharma, C. (1965). Studies on hybrid vigour in bhindi (Abelmoschus esculentus L. Moench). Ph.D. Thesis, IARI, New Delhi.

Shukla, G.P. (1983). Path coefficient analysis in sesame. Indian J. Agric. Sci., 53: 407-408.

Shukla, G.P. and Verma, G. (1974). Correlation and heritability in sesame. Indian J. Agric. Sci., 46(6): 283-285.

*Shull, G.H. (1914). Z. Induktive Abstam U. Vererbungslehre, 12: 97-149.

Duplicate genes for capsule form in Bursa pastoris.

Sikka, S.M. and Gupta, N.D. (1949 a). Pollination studies in Sesamum orientale. Indian J. Genet., 9: 33-41.

Sikka, S.M. and Gupta, N.D. (1949 b). Correlation studies in Sesamum orientale L. Indian J. Genet., 9: 27-32.

Singh, K.Veena, Singh, H.G. and Chauhan. (1983). Combining ability in sesame. Indian J. Agric. Sci., 53: 305-310.

Singh, R.K. and Chaudhary, B.D. (1979). Biometrical methods in quantitative genetic analysis. Kalyani Publishers, New Delhi.

*Singh, R.K. and Kakar, S.N. (1977). Control on individual trait means during index selection. Proc. Third Congr. SABRAO Canberra, 3(d): 22-25.

Singh, S.P., Singh, H.N., Singh, N.D. and Srivastava, J.P. (1978) Heterosis in pea. Indian J. Agric. Sci., 48: 705-710.

Singh, T.P. and Singh, K.B. (1972). Combining ability in mung bean. Indian J. Genet., 32: 67-72.

Singh, T.P., Singh, K.B. and Brar, J.S. (1974). Diallel analysis in soybean. Indian J. Genet., 34: 427-432.

Solanki, Z.S. and Paliwal, R.V. (1981). Genetic variability and heritability studies on yield and its components in sesamum. Indian J. Agric. Sci., 51: 554-556.

*Sprague, G.F. and Tatum, L.A. (1942). General Vs Specific combining ability in single crosses of corn. J. Amer. Soc. Agron., 34: 923-932.

Srivastava, R.L., Ahmed, Z., Singh, H.G. and Saxena, J.K. (1978). Combining ability for yield and related attributes in soybean. Indian J. Agric. Sci., 48: 148-155.

Swarup, V. and Pal, A.B. (1966). Gene effects and heterosis in Cauliflower-I. Indian J. Genet., 26: 269-281.

Swarup, V. and Sharma, B.R. (1965). Inheritance of some quantitative characters in cabbage. Indian J. Genet., 25: 57-64.

f pod characters in
Sverup John (1980). hesis. Kerala
(S. Indicum
Agricultura
Studies on genetic
Swarup, V. and Chau rrelation of some
variabilit cters contributing towards
important e selection indices for
yield and J. Genet., 22: 37.
varietal
Heterosis in sesame.
Tyagi, B.P. and Si 849-852.
Indian J.
objectives and assessment
Van Rheenen, H.A. rains of sesame. Sasame:
of princ AO Plant production and
Status sme.
protecti
production and their genetic
*Wallace, B. (19 tical Genetics and Plant
consequ ., 982: 3-20.
Breedir
ysis in greengram (Phaseolus
Wilson, D. (198 g.) Thesis submitted to
aureus iversity.
Kerala
on and causation. J. Agric.
Wright, S. (19
Res.,
of path-coefficients. Ann.
*Wright, S. (15.
Math
pretation of multivariate
Wright, S. (1 and mathematics in biology.
syst Press, Ames.
Iow
oefficient and path regression:
Wright, S. (plimentary concepts? Biometrics,
Alt
16

Swerup John (1980). Genetic analysis of pod characters in (S. Indicum L.). M.Sc.(Ag.) Thesis. Kerala Agricultural University.

Swarup, V. and Chaugale, D.S. (1962). Studies on genetic variability in Sorghum I. Correlation of some important quantitative characters contributing towards yield and application of some selection indices for varietal selection. Indian J. Genet., 22: 37.

Tyagi, B.P. and Singh, H.G. (1981). Heterosis in sesame. Indian J. Agric. Sci., 51: 849-852.

Van Rheenen, H.A. (1981). Breeding objectives and assessment of principal commercial strains of sesame. Sasame: Status and improvement. FAO Plant production and protection paper - 29, Rome.

*Wallace, B. (1963). Modes of reproduction and their genetic consequences. In Statistical Genetics and Plant Breeding, N.I.S. - N.R.C., 982: 3-20.

Wilson, D. (1982). Diallel analysis in greengram (Phaseolus aureus Roxb.). M.Sc.(Ag.) Thesis submitted to Kerala Agricultural University.

Wright, S. (1921 a). Correlation and causation. J. Agric. Res., 20: 557-87.

*Wright, S. (1934). The method of path-coefficients. Ann. Math. Statis., 16-215.

Wright, S. (1954). The interpretation of multivariate systems. Statistics and mathematics in biology. Iowa State College Press, Ames.

Wright, S. (1960 a). Path coefficient and path regression: Alternative or complimentary concepts? Biometrics, 16: 189-202.

Wright, S. (1960 b). The treatment of reciprocal interaction with or without lag by path analysis. Biometrics, 16: 189-202.

Yadava, T.P., Kumar, P. and Yadav, A.K. (1980). Association of yield and its components in sesame. Indian J. Agric. Sci., 50: 317-319.

*Yermanos, D.M., Edwards, R.T. and Hemstreet, S.C. (1964). Sesame. California Agric., 18: 2-4.

*Zhen, Y.X. (1983). Studies on the pattern of inheritance of quantitative characters in sesame. Trop. Oilseeds Abst., 8: 474.

Zuberi, M.I., Joarder, O.I. and Eunus, A.M. (1972). Inheritance of some quantitative characters in Brassica campestris L. Indian J. Genet., 32: 247-256.

*Original not seen