STUDIES ON INTERVARIETAL HYBRIDS IN COWPEA

BY

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College of Horticulture

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DECLARATION

I hereby declare that this thesis entitled "STUDIES ON INTERVARIETAL HYBRIDS IN COWPEA" is a bonafide record of research work done by me during the course of research and that the thesis has not 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.

Vellanikkara,
12-7-1980.

K.A. INASI

CERTIFICATE

Certified that this thesis is a record of research work done independently by Mr. Inasi, K.A. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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Introduction

INTRODUCTION

In India pulses are cultivated over an area of 22.8 million hectares and yield about 13.1 million tonnes of grains. Pulses which constitute a major group of crops of the Legume family, form the chief source of protein in the vegetarian diet. This is true in the case of cowpea as well.

Cowpea is the major pulse crop cultivated in Kerala. Here it is raised mainly in two seasons, viz., south-west monsoon (June-September) and north-east monsoon (October-January). Cultivation is confined to the uplands during the south-west monsoon period and to the fallow lands during the second and to a limited extent during the third crop seasons.

Even with wide adoption of modern agronomic practices, average yield of pulses in Kerala is coming only 340 kg per hectare. This low productivity is mainly due to the local, low yielding cultivars. As a result of the repeated set backs in pulse cultivation, even the progressive farmers are switching over to new cash crops, thus creating a decline in the total available pulse produce.

To save the situation, it is of utmost necessity to evolve new varieties which respond well to the new agronomic practices. At present farmers are demanding a dual purpose high yielding early maturing, dwarf, erect variety which will respond under moderate or low management practices. Among the varieties available at present none has the above attributes to the satisfaction of farmers. Varieties to suit the specific seasons and also the specific conditions of cowpea culture, are also in great demand. For instance during the rainy khariff season, high yielding dual purpose varieties are preferred. But in summer rice fallows there exists a specialised system of cowpea culture for vegetable purpose alone, as practiced in certain areas like Manjeri in the State. This requires trailing varieties with long fleshy pods and good flowering spread to assure vegetable over a longer period. Varieties with large number of small pods but giving high grain yields will be of no use at all for this situation. Usually number of pods per plant is very few in the vegetable types now under cultivation. Improvement of this character and also incorporation of wider flowering spread to vegetable types, synchronised flowering to grain types improvement of yield etc. are some of the problems which require immediate attention.

As the different system of cultivation in the State require suitable varieties, it has become necessary to identify proper donor varieties for these characters to enable the planning of fruitful breeding programmes. The present study was, therefore, taken up with a view to estimating the extent of heterosis expressed by the different intervarietal hybrids between genotypes possessing different degrees of genetic relationships among them.

Review Of Literature

REVIEW OF LITERATURE

Detailed studies were conducted by Brittingham (1950) on the inheritance of plant height in southern pea *Vigna sinensis*. Based on the data obtained from a cross between two widely separated varieties of cowpea belonging to two subspecies of *Vigna* ie., asparagus bean (*Vigna sinensis* subsp. *sequipedalis*) and catjang (*Vigna sinensis* subsp. *cylindrica*) he could observe that climbing habit was dominant to bushy habit.

Norton (1961) from the study of four intervarietal crosses of southern pea, *Vigna sinensis*, suggested that tallness and vining habits were dominant over dwarfness and non-vining habits and it depended upon two genes, T for tall habit and V for vining. Experiments conducted by Singh and Jindla (1971) revealed that trailing habit was dominant over erect habit, the character being controlled by three interacting genes, T1, T2 and T3 the first two of which were complementary.

Hilpert (1949) from his works in *Phaseolus vulgaris* found that indeterminate plant habit behaved as a simple dominant character over determinate plant habit. Patil (1959) reported that in *Cicer arietinum*, the erect type was dominant over lowgrowing spreading type. From the studies conducted by Bliss (1971) in beans, *Phaseolus vulgaris*, he could conclude that growth habit was controlled by a single gene with spreading habit dominant to bushy. He further stated that indeterminate habit was controlled by a single dominant gene.

Prem Sagar and Chandra (1979) found that in Phoseolus vulgaris the plant habit was predominantly controlled by the additive action of gene.

Ortega Ybarra (1968) suggested that in Phaseolus vulgaris the length of the main stem was controlled by a single dominant gene, but was influenced by the action of modifier genes which in the case of Goiana x Costa Rica had an additive effect and in Goiana x Mexico 450 and Costa Rica x Mexico 450, an over dominance effect. It is to be inferred that conflicting results reported in the inheritance of growth habit may probably be due to the varietal nature of the quantitative modifiers.

Kalinov (1968) has reported that hybrids between fodder pea varieties differing in plant height manifested heterosis for this character in every developmental stage; but, in later stages of growth tall character proved to be partially or completely dominant over short.

Malinowski (1955) observed hybrid vigour for plant height in the F_1 generation of crosses between inbred lines of *Phaseolus vulgaris*. When seven varieties of mung bean were crossed, Sing and Jain (1969) could notice hybrid vigour over better parent in 20 of the F_1's.

Thus it appears that so far scientists have not reached a general agreement on the nature of inheritance of plant height in most of the pulse crops.

Number of branches:

Premsekar *et al*. (1964) conducted studies on the inheritance of branching in cowpea through intervarietal hybridization. When he crossed *Vigna sinensis* subsp. *sesquipedalis* with *Vigna sinensis*, hybrids were found to be of intermediate character for number of branches. Davis and Frazier (1966) while conducting genetic studies in *Phaseolus vulgaris* reported that two varieties namely White Seeded Tendercrop and Puregold Wax appeared to contain more of recessive alleles for number of branches than did Blue Lake bush lines. Lamprecht (1954) based on his studies on peas explained that branching of the stem was conditioned by at least two pairs of genes Fr-fr and Fru-fru, their recessive alleles resulting in highest degree of branching. Singh and Jain (1971) have reported the expression of heterosis for number of branches in the intervarietal crosses of mung bean.

Flowering duration:

Hybridization carried out by Ojomo (1971) between two early flowering exotic cultivars and three late flowering local cultivars, indicated that early flowering was dominant to late flowering. The number of days to flowering appeared to be controlled by the action of duplicate dominant epistasis between two major genes, designated as Ef1 and Ef2, in the presence of some minor modifying genes. Tika et al. (1976) from their experiments with late flowering and early flowering varieties of cowpea, Vigna unguiculata, reported that there was significant negative heterosis (increased earliness) in some of the hybrids and significant positive heterosis (increased lateness) in few others. Flower initiation was governed by additive genetic variance and it was highly heritable. Cowpea variety Pusa Phalguni displayed complementary gene action for earliness. Borida et al. (1973) found that in cowpea there was high heritability for number of days to flowering.

When Sakurov (1952) crossed a late flowering pea variety with another late flowering variety, heterotic effect could be observed in the hybrids. The intervarietal hybridization work carried out by Malinowski (1955) in Phaseolus vulgaris, showed that F_1 plants flowered a little earlier than the two parents. In hybrids obtained by Hilpert

(1949) in *Phaseolus vulgaris*, it appeared that the time of flowering was influenced primarily by one pair of major genes, the late flowering being completely dominant over the early. Johnson (1957) from his studies in *Pisum sativum* understood that flowering time was probably determined by one or two major genes and some partially dominant modifiers for late flowering.

Brittingham (1950) found in a cross between Asparagus bean and catjung bean that the F_1 showed intermediate character for the time of flowering. Kalinov (1968) observed that in crosses between early and late maturing peas the F_1 plants were intermediate in time of flowering, without any reciprocal difference. Hamad (1976) from his studies in snap beans has suggested that heterosis could be obtained by crossing an early flowering variety with a late flowering one. Singh and Dhaliwal (1971) understood that, in black gram, lateness was dominant over earliness. Kolot (1968) found in soyabean that under irrigated conditions hybrids of most combinations tended to follow the later parent in respect of vegetative period, or to occupy an intermediate position. Bliss (1971) carried out a cross between two varieties of *Plaseolus vulgaris* and concluded that two epistatic genes controlled flowering habit, with indeterminateness being dominant.

Barber and Paton (1952) revealed that in garden peas time of flowering was controlled by the presence or absence of an inhibitor, which might be of hormonal nature. Premsekar et al. (1964) have also recorded heterosis for earliness in flowering in the F_1 hybrids of a cross between Vigna sinensis subsp. sesquipedalis and Vigna sinensis.

Number of flowers per plant:

Norton (1961) subjected the character namely the number of flowers produced per plant, in cowpea F_1 hybrids, to his observation and reached to a conclusion that F_1's produced more flowers in the spring and less flowers in the fall than the most abundant and sparse flowering parents. Colins (1967) collected 21 varieties from Boliwia, Peru, El Salvador, Guatemala etc. and crosses were effected between them. Heterosis was observed for the number of flowers per plant.

Number of pods per plant:

Wester and Jorgensen (1957) conducted studies on the inheritance of the number of pods per plant in lima bean. When the variety Clark's Bush was crossed with Trimph, the F_1 hybrids showed hybrid vigour in respect of number of pods per plant. Studies on the expression of heterosis for number of pods per plant in Pisum sativum were carried out by Johnson (1957). It was revealed that the factors governing number of pods were partially dominant.

Bhatnagar and Balaram Singh (1964) reported that F_1 hybrids of Phaseolus aureus showed heterosis for the number of pods. They were superior to the mean of the parents for the character. Again in F_1 hybrids pod number was considerably higher than the same in the better parent. Heterotic effects were exhibited in the F_1 hybrids of mung bean as reported by Singh and Jain (1971).

Voysest (1972) analysed six F_1 hybrids and their parents (four small seeded lines and five large seeded ones) for number of pods per plant and heterosis could be observed in some of the crosses. Bordia (1973) could obtain high genetic advance in some of the F_1 hybrids of cowpea Vigna sinensis regarding the number of pods per plant. Heterosis for pod number was observed in few of the hybrids of Phaseolus vulgaris, by Hamad(1976).

Krarup and Davis (1970) based on their studies in six hybrids in Pisum sativum stated that number of pods per plant was mainly controlled by an additive gene system. Sometimes deviations might be exhibited due to epistasis or linkage as indicated by a deflection of the F_1 from the mid-parental value.

Premsekar *et al.* (1964) conducted hybridization work between two species of cowpea, namely *Vigna sinensis* subsp. *sesquipedalis* and *Vigna sinensis*, the latter producing large number of pods. Hybrids showed an inclination towards the better parent. Ibarbia (1968) crossed some double and triple poded varieties of peas to a single poded line and obtained double poded type in F_1 generation. He arrived at a conclusion that triple pod character was governed by two to three genes and the double poded character - by eight to nine genes.

Length of pod:

Inheritance of pod length in southern pea was investigated by Brittingham (1950). He crossed two varieties of cowpea namely Yard Long bean and Lady Cream bean and obtained heterosis for pod length. It was understood that eight genes were operative for pod length. According to Menezes (1956) the mode of inheritance of pod size was uncertain in the pigeon pea. Premsekar *et al.* (1964) found that in cowpea F_1 hybrids, character pod length showed an intermediate condition. Bhatnagar and Balaram Singh (1964) reported that in mung bean, hybrids were superior to the mean of the parents.

When Colins (1967) crossed 21 varieties of Lima bean, heterosis could be reported in some of the F_1 hybrids, while in some others, intermediate character was expressed. Singh and Jain (1969) conducted an inheritance study in mungbean involving six varieties. Graphical analysis of the data indicated the presence of additive gene effects with some overdominance for pod length. Again, Singh and Jain (1971) from a study on F_1 plants derived from a diallel cross involving seven varieties reported that all the hybrids exceeded their respective parents with regard to pod length.

Roy and Richharia (1948) reported from a study of a cross between Vigna sinensis and Vigna sinensis subsp. sesquipedalis that in respect of the length of pods the F_1 was found to be intermediate, tending towards a reduction in pod length. From a detailed study performed by Lamprecht (1954) in cowpea on the inheritance of pod length it has been elucidated that intermediately inherited gene Cotr, which controlled pod length, was carried on chromosome V in the position Cp-Gp-To-Cotr-Ust.

Number of seeds per pod:

Wester and Jorgensen (1951) have carried out some hybridization work between Clark's bush, Early market, Peerless, Triumph and Henderson of Lima bean. The F_1 derived from a cross of Clark's Bush x Triumph showed hybrid vigour in respect of number of seeds per pod. According to Krarup and Davis (1970) ovule number in *Pisum sativum* was determined by a simple additive genetic system. Dominance effects were of only very little influence. They have also stated that genes governing low ovule number was partially dominant over the high ovule number.

Premsekar *et al*. (1964) who carried out a cross between two species of cowpea, reported that the hybrid mean value for number of seeds per pod was lower than the parental mean. Bhatnagar and Balaram Singh (1964) while conducting intervarietal hybridization in green gram obtained heterosis in all the hybrids. Empig *et al*. (1970) observed least variability and heritability for seeds per pod in green gram hybrids. Partial to overdominance could be noted in the diallel crosses in *Phaseolus aureus* by Singh and Jain (1969). Dominant genes seemed to govern the inheritance of the number of seeds per pod.

High degree of heterosis for number of seeds per pod could be observed in all the six hybrids of French bean by Voysest (1972). Domingo (1945) has assumed that in soyabean hybrids, the expression of the character number of seeds per pod, has been influenced by environment at a trivial rate and has been governed by a few major and several minor genes at a larger scale.

Weight of pod:

Experiments were conducted on the inheritance of single pod weight in snap beans (*Phaseolus vulgaris*) by Hamad (1976). Diallel crosses were effected between five cultivars and hybrid vigour for single pod weight could be observed in all the cases. Bhatnagar and Balaram Singh (1964) from their studies in mung bean found that F_1 hybrids of this cross were superior to the mean of the parents for single pod weight.

Weight of 100-seeds:

Heterosis for 100-weight could be noted by Sakurov (1952) in peas. He crossed a vigorous variety with a dwarf variety, large seeded with a small seeded and a late flowering variety with an early flowering variety. Suzuki (1957) could evolve a dwarf strain of cowpea, named as 62-14-6 with a 1000-seed weight of 139 g from a combination of [Manbu (Dwarf)] x (Azuki) x Fukushimazairai (Fukushima Common). Johnson (1957) who performed hybridization in *Pisum sativum* noted heterosis for average seed weight and proposed that factors governing them were partially dominant.

Zafar and Khan (1968) have reported that in Cicer arietinum the mode of inheritance of 100-seed weight was additive with little dominance. F_1 hybrids obtained by Bhatnagar and Balaram Singh (1964), in green gram were superior to the mean of the parents for average seed weight.

Six F_1 hybrids and their parents were analysed for 100-seed weight by Voysest (1972). Expression of heterosis was low for this character compared to average seed yield. Bordia et al. (1973) carried out detailed genetic studies in 32 varieties of Vigna for the inheritance of 100-seed weight. It was found that heritability was higher for this character in some of the hybrids.

Based on their studies in Phaseolus vulgaris Patil D'Cruz (1964) stated that factors governing 100-seed weight were digenic in nature. Premsekar et al. (1964) have recorded the better performance of interspecific hybrids in cowpea with respect to 100-seed weight.

Seed size:

Seed size is determined by three components namely length, breadth and thickness of seed. Change in any one or all of these components can bring about a change for seed size. Sakurov (1952) could observe heterosis for seed size in some of the pea hybrids.

A detailed and informative study regarding the inheritance of seed size in green gram was undertaken by Sen and Murthy (1961). They crossed the small seeded variety Sonamung with a medium seeded BR3 and a large seeded EB6 varieties. The results from the F_1 hybrids indicated that small seeded nature was more or less completely dominant over the medium and large classes. The F_1's of crosses between two medium seeded parents and between two large seeded parents exhibited negative heterosis for seed size. It was suggested that medium and large seeded varieties of *Phaseolus aureus* had evolved from small seeded types through accumulation of additive recessive genes with an effect on seed weight.

Colins (1967) experimented on 21 varieties of Lima bean and reported heterosis for seed size, when the hybrids were derived from parents with same sized seeds. When a large seeded variety was crossed with a small seeded variety the hybrids were of intermediate nature. Graphical analysis of the data collected by Singh and Jain (1969) in mung bean indicated presence of additive growth effects with some overdominance for seed size.

Voysest (1972) obtained heterosis for seed size in some of the six F_1 hybrids of French bean, four of the parents were small seeded and five were large seeded.

Rawal *et al*. (1976) undertook hybridization between two wild accessions of cowpea and six cultivated varieties. In every cross involving two wild accessions the seed weight along with size was reduced significantly.

Yield of pods per plant:

Bhatnagar and Balaram Singh (1964) reported that in *Phaseolus aureus*, F_1 hybrids out yielded the better parent. Inheritance study for pod yield in soybean was carried out by Strohm (1966) who observed high heritability for all the characters except pod yield.

Colins (1967) undertook hybridization in Lima bean between 21 varieties having similar characters and noticed heterosis for pod yield in the F_1 generation. Singh and Jain (1971) have carried out diallel crosses involving seven varieties and found that F_1 plants had exceeded their respective parents in yield. The heterotic effects observed in the F_1 were maintained in the F_2 in some crosses.

Solomon *et al*. (1957) studied the inheritance of yielding characters in *Cajanus cajan* and have reported heterosis in some of the hybrids. Capinpin and Irabagon (1950) reported heterosis for pod yield in the F_2 generation of vigna. Hamad (1976) in his studies on the inheritance of yield components in some of the hybrids in *Phaseolus* *vulgaris* reported heterosis for number of pods per plant.

Yield of seeds per plant:

Wester and Jorgensen (1951) who were working in Lima bean hybrids, reported heterosis for seed yield per plant. It was further explained that closer genetical relationship between two parents could account for the total absence of hybrid vigour in their F_1 progeny. Solomon *et al*. (1957) conducted studies on heterosis in *Cajanus cajan*. They reported an increase in grain yield upto 24.51 per cent over that of the parents.

Bhatnagar and Balaram Singh (1964) while conducting studies in F_1 hybrids of *Phaseolus aureus* reported that seed yield was considerably higher in them than that in the better parent. Premsekar *et al*. (1964) have reported that the hybrids obtained from a cross between *Vigna sesquipedalis* and *Vigna sinensis*, have come on par with *Vigna sinensis* in respect of seed yield per plant.

Varieties of Lima bean possessing similar characters were crossed by Colins (1967) and he has reported heterosis for seed yield per plant in some of the hybrids. Crosses between varieties differing in various characters gave intermediate values for seed yield. Bruter (1965) obtained a new variety of cowpea by conducting an interspecific hybridization between *Vigna sinensis*, *Vigna sesquipedalis* and *Vigna catjung*. Variety showed high seed weight when compared to parents.

Singh and Jain (1971) based on their observation on some of the hybrids in *Phaseolus aureus*, suggested that seed yield per plant was governed by factors which were partially dominant. Rawal *et al.* (1976) crossed some of the cultivated varieties of cowpea with two wild forms and reported significant reduction for seed weight in F_1 hybrids. They suggested that the presence of genetic barriers prevented the exchange of genes between various forms of cowpea. Diallel crosses were carried out by Hamad (1976) between five cultivars of snap bean. Results indicated high degree of heterosis for seed yield in the F_1 population. Inheritance study indicated that it was additive in nature.

Krarup and Davis (1970) observed in peas that the weight of seeds per plant was mainly controlled by an additive gene system. Some deviation from additivity, probably due to epistasis or linkage, was indicated by a deviation of the F_1 from the mid-parental value.

Materials and Methods

MATERIALS AND METHODS

The investigations reported herein were undertaken in the Department of Agricultural Botany, College of Horticulture, Vellanikkara during the years 1978-80.

A. Materials:

In a previous study on the genetic divergence of cowpea germ plasm conducted in the Department, it has been observed that 56 genotypes studied, have fallen into 17 clusters. Based on this information, 15 genotypes representing one from each cluster, were selected for a particular character, the details of which are furnished below in Table I.

(TABLE I)

Selfed seeds of these 15 genotypes kept in the Department were made use of for the present investigations.

B. Methods:

Fifty seeds in each of 15 varieties were sown in a plot of 20 x 15 metres size during June - September 1979. After digging the plot thoroughly, Farm Yard Manure at the rate of 1000 kg/ha was applied and incorporated. The land was then thrown into ridges and furrows. Seeds were sown at the rate of two seeds per hill giving a spacing of one metre between plants. Later it was thinned out to one plant

TABLE I

Details of genotypes selected

Sl. No.	Cluster No.	Name	Characters for which selection is done
1.	1	N. 62	Low 100 - seed weight.
2.	2	GP.PLS.63	Maximum flower number.
3.	3	Pusa Phalguni	Minimum number of branches, flowers, pod yield and seed yield.
4.	5	GP.PLS. 139	Low 100-seed weight and maximum flowering duration.
5.	6	Red Seeded Selection	Flowering spread maximum and minimum seed per pod.
6.	7	GP.MS. 9314	Bushy habit and medium flowering duration.
7.	8	Kolingi payar	Maximum number of pods; pod and seed yields per plant and maximum seeds per pod. Minimum flowering spread.
8.	9	GPT. 536	Bushy habit and minimum flowering spread.
9	10	IC. 20729	Maximum 100-seed weight, maximum pod length and maximum pod weight.
10	12	Pattambi local-1	Medium seed size and low pod weight.
11	13	C.152 x N.E.-I	Bushy habit.
12	14	Pannithodan-early	Breadth and thickness of the seed maximum.
13	15	P.118	Spreading habit and minimum flowering duration.
14	16	Kolingipayar-white	Low weight of pod, low length and breadth of seed.
15	17	Manoheri-black	Seed length maximum.

at each hill. Ammonium sulphate, Super phosphate and Muriate of potash to supply N, P and K, at the rate of 20 : 30 : 10 kg/ha respectively, were applied one week after sowing. Appropriate plant protection measures were taken to ensure the safety of the crop. At the time of earthing up, which was done 20 days after sowing, a top dressing with Ammonium sulphate to supply nitrogen at the rate of 10 kg/ha was given.

Just before sowing, the 15 varieties were grouped into three, as late, medium and early varieties based on the time of flowering. Sowing dates were so adjusted in such a way that flowering synchronised in all the varieties.

At the time of flowering intervarietal crosses in 16 combinations were effected adopting the following procedure. Emascultation of the mature buds was carried out in the previous evening, adopting the method described by Oliver (1910) and Hays and Gurber (1927). Selected flower bud was held in between thumb and fore-finger holding the keel upwards. A needle tip was run along the ridge where the two edges of the standard united and thus the standard was forced to open. Standard halves on each side was held down using thumb and forefinger and the exposed keel was split open on one side. Using needle, tip of the keel was pushed underneath the thumb. Using a fine pointed forceps immature stamens were removed one by one to ensure that none was left behind. Other mature and unemasculated flower buds were removed from the inflorescence to avoid contamination. Emasculated flowers were protected using pollen proof butter paper bags. Pollination was done in the next day morning between 6:00 A.M. and 7:30 A.M. Details of the crosses effected are presented in Table II.

(TABLE II)

Hybrid seeds along with selfed seeds of parents were collected separately, dried and kept in moisture proof containers.

C. Field plot technique and study of F_1 generation:

F_1 hybrids along with the parents were raised at the Instructional Farm, Mannuthy during November - January season of 1979-80. Thirty-one ridges were taken in a plot of 20 x 40 metres. Sixteen intervarietal hybrids along with their parents were sown in a completely Randomised Design giving one metre spacing either way. Cultural practices remained the same as mentioned earlier.

Observations on plant height, number of primary branches, flowering commencement, flowering completion,

TABLE II

Details of crosses effected

Sl. No.	Female parent	Cluster No.	Male parent	Cluster No.	No.of crosses made	No.of pods set	No.of seeds obtained	Characters for which they are crossed
1	Mancheri-black	17	Kolinjipayar-white	16	9	6	54	Maximum seed length x Minimum seed length
2	Kolinjipayar-white	16	Mancheri-black	17	15	4	45	Minimum length of seed x Maximum length of seed
3	Pannithodan-early	14	Kolinjipayar-white	16	6	4	30	Maximum breadth and thickness x Minimum breadth and thickness
4	Mancheri-black	17	Kolinjipayar	8	1	1	11	Maximum number of pods x Maximum pod yield
5	N.62	1	I.C.20729	10	25	3	39	Low 100-seed weight x High 100-seed weight.
6	IC. 20729	10	Red Seeded Selection	6	7	1	16	Maximum pod length x Medium pod length
7	Red Seeded Selection	6	Kolinjipayar	8	49	7	43	Minimum seed per pod x Minimum seed per pod
8	Kolinjipayar	8	Red Seeded Selection	6	63	6	67	Minimum-flowering spread x Maximum flowering spread
9	Red Seeded Selection	6	G.P.T. 536	9	21	11	93	Maximum flowering spread x Minimum spread

contd....

Table II contd.

Sl. No.	Female parent	Cluster No.	Male parent	Cluster No.	No. of crosses made	No. of pods set	No. of seeds obtained	Characters for which they are crossed
10	Pattambi-local	12	Kolinjipayar-white	16	48	5	47	Medium seed size x Minimum seed size
11	P.118	15	C.152 x N.E.-I	13	11	3	29	Spreading habit x Bushy habit
12	P.118	15	GP.PLS. 139	5	19	5	33	Minimum flowering duration x Maximum duration
13	GP.PLS.139	5	P.118	15	23	1	13	Maximum flowering duration x Minimum flowering duration
14	GP.MS.9314	7	P.118	15	16	1	7	Bushy habit x Spreading habit
15	Pusa Phalguni	3	Kolinjipayar	8	51	7	36	Minimum seed yield x Maximum seed yield
16	Pusa Phalguni	3	GP.PLS.63	2	37	2	12	Minimum number of flowers x Maximum number of flowers

number of flowers per plant, number of pods per plant, length of pod, weight of pod, number of seeds per pod, 100-seed weight, length of seed, breadth of seed, thickness of seed, pod yield per plant and seed yield per plant were taken as described below.

1) Plant height:

Height was measured in metres from the base of the plant to the tip of the tallest branch after stretching out all vines at the time of the last harvest.

2) Number of branches:

Total number of primary branches from the main stem per plant was counted at maturity of the plants.

3) Flowering commencement:

The number of days from seeding to the opening of the first flower was taken as the flowering commencement.

4) Flowering completion:

Number of days from seeding to the opening of the last flower was taken as the flowering completion.

5) Number of flowers per plant:

Number of flowers opened was estimated on each day and the total arrived at.

6) Number of pods per plant:

Dry pods were harvested at regular intervals and the total number of pods per plant was counted on all the varieties.

7) Length of pod:

Ten pods were selected at random from each individual plant and the length in cm was measured. The average length of these ten pods was then calculated.

8) Weight of pod:

The same 10 pods used for length measurements were used for recording pod weight also. The pod weight in g was recorded using an electric balance.

9) Number of seeds per pod:

Pods which were used in the above two cases were used to estimate seeds per pod. Later average seed number per pod was found.

10) Weight of 100-seed:

From each plant 100 well developed and dried seeds were selected and weight in g was estimated using a highly sensitive top-loading balance.

11) Length, breadth and thickness of seed:

Length, breadth and thickness of 10 seeds were estimated using vernier calipers and average was estimated.

12) Pod yield per plant:

Weight of the total pods per plant was recorded in g after drying and before threshing and extraction of seeds.

13) Seed yield per plant:

Pods collected from each plant were dried and threshed and seeds were extracted and weight of seeds per plant was estimated. The mean value for each character was noticed on individual plant basis. The data collected above were statistically analysed and $\sum X$, $\sum X^2$, $\bar{X}$, heterosis etc. were estimated.

Results

RESULTS

Observation on the behaviour of the F_1 hybrids along with their parents with reference to fifteen characters, namely plant height, number of branches, commencement and completion of flowering, number of flowers per plant, number of pods per plant, length of pod, pod weight, number of seeds per pod, weight of 100-seeds, length of seed, breadth of seed, thickness of seed, pod yield per plant and seed yield per plant have been collected from all the available F_1 hybrids and from 20 plants in each of the respective parents and the means were arrived at. The data are presented in Tables III to XVIII.

Plant height:

Observations on plant height obtained from the 16 hybrids and their 15 parents are presented in Table III.

(TABLE III)

The results presented in the above table reveal that among the parents varieties-8, 13 and 17 are the tallest with a mean of 1.40 m and variety-15 - the shortest with 0.33 m. The rest of the varieties have exhibited values in between this range. Among the 16 F_1's studied, there is a range in plant height from 2.06 m to 0.40 m.

TABLE III

Behaviour of Parents and F_1's for plant height (m)

Sl. No.	Female parent	Mean	Male parent	Mean	Mean of parents	Mean of F_1	+ or -	Percentage over Mean of parents	Percentage over Better of parents
1	17	1.31	16	0.96	1.14	0.95	- 0.19	16.67	00
2	16	0.96	17	1.31	1.14	0.52	- 0.62	54.39	00
3	14	0.43	16	0.96	0.70	0.48	- 0.22	31.43	00
4	12	0.65	16	0.96	0.81	0.56	- 0.25	30.86	00
5	10	1.10	6	0.38	0.74	1.04	+ 0.30	40.54	00
6	8	1.40	6	0.38	0.89	0.85	- 0.04	4.49	00
7	6	0.38	8	1.40	0.89	0.40	- 0.49	55.06	00
8	6	0.38	9	0.52	0.45	0.44	- 0.01	2.22	00
9	1	0.97	10	1.10	1.04	1.83	+ 0.79	75.96	66.36
10	15	0.33	5	0.52	0.43	0.43	00	.00	00
11	5	0.52	15	0.33	0.43	0.40	- 0.03	6.98	00
12	3	0.38	2	0.63	0.51	0.48	- 0.03	5.88	00
13	15	0.33	13	1.40	0.87	1.74	+ 0.87	100.00	24.29
14	3	0.38	8	1.40	0.89	0.48	- 0.41	85.42	00
15	7	0.53	15	0.33	0.65	1.60	+ 0.95	146.15	201.89
16	17	1.31	8	1.40	1.36	2.06	+ 0.70	51.47	47.14

Data in the above table also reveal that in four out of 16 cases studied, the F_1's exhibit values over both the parents, the maximum mean being in the cross 7 x 15 with 201.89 per cent over the better parent. In the remaining 12 cases, the F_1's have exhibited values in between the two parents in 9 cases, of which only in one cross the F_1 value is greater than the mean of the two parents. In the remaining eight cases the F_1 values are lesser than the means of their respective parents. In three crosses the mean heights of F_1-hybrids are observed to be lesser than their corresponding short parents. Reciprocal differences are also seen in some cases.

Number of branches:

Data pertaining to the mean number of branches per plant of parents and F_1's are presented in Table IV.

(TABLE IV)

From the results presented in the above table it is seen that variety-5 has the maximum number of branches with a value of 13.33 and variety - 15 the minimum number of branches with a value of 3.22. Among the different F_1's studied, considerable variation in number of branches per plant is observed. In six out of 16 cases studied, the

TABLE IV

Behaviour of Parents and F_1's for number of hrnaches per plant

Sl. No.	Female parent	Mean	Male parent	Mean	Mean of parents	Mean of F_1	+ or -	Percentage over Mean of parents	Percentage over Better parent.
1	17	9.25	16	5.93	7.59	10.30	+ 2.71	35.70	11.35
2	16	5.93	17	9.25	7.59	6.36	- 1.23	16.21	00
3	14	5.56	16	5.93	5.75	6.33	+ 0.58	10.09	6.75
4	12	9.18	16	5.93	7.56	8.92	+ 1.36	17.99	00
5	10	7.08	6	7.57	7.33	6.88	- 0.45	6.14	00
6	8	8.69	6	7.57	8.13	7.31	- 0.82	10.09	00
7	6	7.57	8	8.69	8.13	10.55	+ 2.42	29.77	21.40
8	6	7.57	9	7.07	7.32	5.94	- 1.38	18.85	00
9	1	9.25	10	7.08	8.17	6.45	- 1.72	21.05	00
0	15	3.22	5	13.33	8.28	8.23	- 0.05	0.60	00
1	5	13.33	15	3.22	8.28	7.67	- 0.61	7.37	00
2	3	9.29	2	6.78	8.04	10.5	+ 2.46	30.60	13.02
3	15	3.22	13	6.13	4.68	6.43	+ 1.75	37.39	4.89
4	3	9.29	8	8.69	8.99	8.43	- 0.56	6.23	00
5	7	6.47	15	3.22	4.85	4.00	- 0.85	17.53	00
6	17	9.25	8	8.69	8.97	11.33	+ 2.36	26.31	22.49

F_1's have surpassed both the parents in the expression of mean number of branches per plant. In the remaining 10 cases, five hybrids have exhibited mean values in between the respective parents of which in one case the F_1 value is more than the mean of the parents, while, in the other four cases it is less than the same. In the remaining five hybrids the F_1's showed mean values which are lower than those exhibited by their corresponding lower parents. Reciprocal differences are also observed in certain cases.

Commencement of flowering in days:

Observations on the mean number of days taken by the F_1's and their parents for commencement of flowering are presented in Table V.

(TABLE V)

From the results in the above table it is seen that variety-1 is the earliest and variety-9 the latest to commence flowering with mean values of 39.0 and 46.77 respectively. Among the F_1's also, a range of 39.0 to 50.0 is observed with reference to this character. Out of 16 F_1 hybrids studied, three have exhibited values which are above those of both the corresponding parents. In five hybrids the values are observed to be in between

TABLE V

Behaviour of Parents and F_1's for commencement of flowering in days

Sl. No.	Female parent	Mean	Male parent	Mean	Mean of parents	Mean of F_1	+ or −	Percentage over Mean of parents	Percentage over Better parent
1	17	43.19	16	40.50	41.85	42	+ 0.15	0.36	00
2	16	40.50	17	43.19	41.85	42	+ 0.15	0.36	00
3	14	43.22	16	40.50	41.86	47.33	+ 5.47	13.07	9.51
4	12	44.73	16	40.50	42.62	46.67	+ 4.05	9.50	4.34
5	10	46.00	6	41.57	43.79	41.13	− 2.66	6.07	00
6	8	44.69	6	41.57	43.13	40.94	− 2.19	5.08	00
7	6	41.57	8	44.69	43.13	41.55	− 1.58	3.66	00
8	6	41.57	9	46.77	44.17	40.76	− 3.41	7.72	00
9	1	39.00	10	46.00	42.50	43.00	+ 0.50	1.18	00
10	15	42.06	5	44.60	43.33	40.69	− 2.64	6.09	00
11	5	44.60	15	42.06	43.33	50.00	+ 6.67	15.39	12.11
12	3	40.00	2	44.39	42.20	39.00	− 3.20	7.58	00
13	15	42.06	13	46.07	44.00	42.71	− 1.36	3.09	00
14	3	40.00	8	44.69	42.35	41.57	− 0.78	1.84	00
15	7	44.40	15	42.06	43.23	40.67	− 2.47	5.71	00
16	17	43.19	8	44.69	43.94	41.83	− 2.11	4.80	00

the same of their corresponding parents and in eight cases they are lower than their corresponding lower parents. In the five hybrids, where the values are observed to be in between the parental limits, in three cases they are above the parental means, and in two below the same.

Completion of flowering in days:

Data on the completion of flowering in the hybrids and their parents are presented in the Table VI.

(TABLE VI)

From the results it is seen that the mean number of days to complete flowering among the parents varies from 53.0 in variety-1 to 66.31 in variety-10. Among the hybrids also there is considerable variation with reference to the expression of the character. Four out of 16 hybrids have surpassed both the parental limits, while, one hybrid has exhibited values lower than that of the lower parent. The remaining 11 are seen to possess values which lie in between the parental limits and of this 11, three have exhibited values above the parental means and eight below them.

TABLE VI

Behaviour of Parents and F_1's for completion of flowering in days

Sl. No.	Female parent	Mean	Male parent	Mean	Mean of parents	Mean of F_1	+ or -	Percentage over Mean of parents	Percentage over Better parent
1	17	60.13	16	55.21	57.67	59.10	+ 1.43	2.48	00
2	16	55.21	17	60.13	57.67	58.36	+ 0.69	1.20	00
3	14	61.89	16	55.21	58.55	64.33	+ 5.78	9.87	3.94
4	12	60.45	16	55.21	57.85	65.17	+ 7.34	12.69	7.81
5	10	66.31	6	57.14	61.73	57.75	- 3.98	6.45	00
6	8	63.56	6	57.14	60.35	58.19	- 2.16	3.58	00
7	6	57.14	8	63.56	60.35	57.91	- 2.44	4.04	00
8	6	57.14	9	65.08	61.11	58.94	- 2.17	3.55	00
9	1	53.00	10	66.31	59.66	57.82	- 1.84	3.08	00
10	15	53.06	5	64.67	58.87	54.23	- 4.64	7.88	00
11	5	64.67	15	53.06	58.87	68.17	+ 9.30	15.80	5.41
12	3	54.64	2	63.72	59.18	58.00	- 1.18	1.99	00
13	15	53.06	13	63.67	58.37	57.29	- 1.08	1.85	00
14	3	54.64	8	63.56	59.10	59.64	+ 0.54	0.91	00
15	7	64.00	15	53.06	58.53	66.17	+ 7.64	13.05	3.39
16	17	60.13	8	63.56	61.85	59.17	- 2.68	4.33	00

Flowering-spread in days:

Data regarding the spread of flowering are presented in Table VII.

(TABLE VII)

Much variation can be noticed in the expression of this character in parents and hybrids. Among the parents the maximum spread is noticed in variety-10 (20.39) and minimum in variety-15 (11.63). Among the hybrids the range is from 25.17 days to 13.54 days. For this character only three of the 16 hybrids have dominated their better parents. At the same time only in one hybrid, the flowering spread has come below the lower value of the parents. Of the remaining 12 out of 16, seven are above the parental means and five below them. Reciprocal difference is also noticed in one case.

Number of flowers:

Table VIII gives the data on the performance of different hybrids and their parents for this character.

(TABLE VIII)

Variations observed among different varieties fall in a range of 11.00 flowers in variety-15 and 109.40 flowers in variety-5. The mean values of hybrids lie in betweeen

TABLE VII

Behaviour of Parents and F_1's for flowering spread in days

Sl. No.	Female parent	Mean	Male parent	Mean	Mean of parents	Mean of F_1	+ or -	Percentage over Mean of parents	Percentage over Better parent
1.	17	16.81	16	15.57	16.19	18.30	+ 2.11	13.03	8.86
2.	16	15.57	17	16.81	16.19	16.36	+ 0.17	1.05	00
3	14	18.67	16	15.57	17.12	17.00	- 0.12	0.70	00
4	12	15.64	16	15.57	15.61	18.50	+ 2.89	18.51	18.29
5	10	20.39	6	15.43	17.91	16.63	- 1.28	7.15	00
6	8	18.88	6	15.43	17.16	17.25	+ 0.09	0.52	00
7	6	15.43	8	18.88	16.16	16.36	+ 0.20	1.24	00
8	6	15.43	9	18.62	17.03	18.18	+ 1.15	6.75	00
9	1	14.00	10	20.39	17.20	13.55	- 3.65	21.22	00
10	15	11.63	5	20.06	15.85	13.54	- 2.31	14.57	00
11	5	20.06	15	11.63	15.85	18.17	+ 2.32	14.64	00
12	3	14.43	2	19.50	16.97	19.00	+ 2.03	11.96	00
13	15	11.63	13	17.60	14.62	14.57	- 0.05	0.34	00
14	3	14.43	8	18.88	16.66	18.07	+ 1.41	8.46	00
15	7	19.27	15	11.63	15.48	25.18	+ 9.72	62.91	30.62
16	17	16.81	8	18.88	17.85	17.33	- 0.52	2.91	00

TABLE VIII

Behaviour of Parents and F_1's for number of flowers per plant

Sl. No.	Female parent	Mean	Male parent	Mean	Mean of parents	Mean of F_1	+ or -	Percentage over Mean of parents	Percentage over Better parent
1	17	60.81	16	77.86	69.34	109.10	+ 39.76	57.34	40.12
2	16	77.86	17	60.81	69.34	92.82	+ 23.48	33.86	19.21
3	14	54.40	16	77.86	66.13	36.50	- 29.63	44.81	00
4	12	68.09	16	77.86	72.98	56.75	- 16.23	22.24	00
5	10	55.00	6	74.86	64.93	129.00	+ 64.07	98.68	72.32
6	8	69.50	6	74.86	72.18	72.81	+ 0.63	0.87	00
7	6	74.86	8	69.50	72.18	127.73	+ 55.55	76.96	70.63
8	6	74.86	9	60.93	67.90	90.53	+ 22.63	33.33	20.93
9	1	65.75	10	55.00	60.38	59.18	- 1.20	1.99	00
10	15	11.00	5	109.40	60.20	64.92	+ 4.72	7.84	00
11	5	109.40	15	11.00	60.20	54.66	- 5.54	9.20	00
12	3	100.29	2	62.83	81.56	106.00	+ 24.44	29.97	5.69
13	15	11.00	13	55.07	33.04	74.43	+ 41.39	125.27	35.16
14	3	100.29	8	69.50	84.90	98.93	+ 14.03	16.53	00
15	7	41.33	15	11.00	26.17	43.50	+ 17.33	66.22	5.25
16	17	60.81	8	69.50	65.16	108.85	+ 43.67	67.02	56.59

36.50 flowers and 129.00 flowers of hybrids 14 x 16 and 10 x 6 respectively.

Clear evidence for hybrid vigour can be noticed in majority of the crosses. Nine hybrids out of 16, have exhibited considerable amount of heterosis over their better parents. In two cases the hybrids have produced only lesser number of flowers than the parent having the lower value. In the remaining five cases which have performed in between the maximum and the minimum limits of the parents, three hybrids are above the mid parental values, while in two remaining cases they are below it. Reciprocal difference is also noticed in all the three cases in varying degrees.

<u>Number of pods per plant</u>:

Data regarding the number of pods produced per plant are presented in Table IX.

(TABLE IX)

As it is seen above, in the case of number of flowers per plant, much variation can be noticed among parents and hybrids. With respect to parents the variation ranges from 76.13 in variety-5 to 4.94 in variety-15. So also in the case of hybrids, the range being from 66.0 of hybrid

TABLE IX

Behaviour of Parents and F_1's for number of pods per plant

Sl. No.	Female parent	Mean	Male parent	Mean	Mean of parents	Mean of F_1	+ or -	Percentage over	
								Mean of parents	Better parent
1.	17	26.75	16	52.36	39.56	65.80	+ 26.24	66.33	25.67
2	16	52.36	17	26.75	39.56	11.74	- 27.82	70.32	00
3	14	21.11	16	52.36	36.74	20.00	- 16.74	45.56	00
4	12	33.64	16	52.36	43.00	36.33	- 6.67	15.51	00
5	10	28.23	6	31.57	29.90	58.50	+ 28.60	95.65	85.30
6	8	36.69	6	31.57	35.13	36.44	+ 1.31	3.73	00
7	6	31.57	8	38.69	35.13	21.75	- 13.38	38.09	00
8	6	31.57	9	34.36	32.97	38.35	+ 5.38	16.32	11.61
9	1	41.08	10	28.23	34.66	26.18	- 8.48	24.47	00
10	15	4.94	5	76.13	40.54	35.15	- 5.39	13.30	00
11	5	76.13	15	4.94	40.54	31.33	- 9.21	22.72	00
12	3	34.64	2	35.72	35.18	66.00	+ 30.82	87.61	84.77
13	15	4.94	13	20.87	12.91	58.14	+ 45.23	350.35	175.58
14	3	34.64	8	38.69	36.67	49.21	+ 12.54	34.20	27.19
15	7	28.67	15	4.94	16.81	27.00	+ 10.19	60.62	00
16	17	26.75	8	38.69	32.72	61.67	+ 28.95	88.48	59.40

3 x 2 to 11.74 of hybrid 16 x 17. Seven out of 16 hybrids have shown improvement over the corresponding better parents. In the remaining nine cases, in four hybrids, the mean value is below that of the lower limit of the parents and in the rest five it falls in between the upper and lower limits of the parents. Out of this five hybrids only two F_1's have produced values over the mid-parental value and in the remaining three it is below that. High degree of reciprocal difference is noticed in two out of three cases where both direct and reciprocal crosses are studied.

Pod length (cm):

The data on the performance of hybrids as well as parents on pod length are furnished in Table X.

(TABLE X)

From the table it can be understood that variety-16 has shown the minimum pod length of 10.25 cm and variety-10 the maximum pod length of 20.90 cm. The rest 13 of the parents have their pod lengths in between this range. Among hybrids the range is from 23.93 cm to 12.94 cm of hybrids 14 x 16 and 5 x 15 respectively.

Of the 16 hybrids, seven have shown values beyond

TABLE X

Behaviour of Parents and F_1's for pod length (cm)

Sl. No.	Female parent	Mean	Male parent	Mean	Mean of parents	Mean of F_1	+ or −	Percentage over	
								Mean of parents	Better parent
1	17	20.60	16	10.25	15.43	17.26	+ 1.83	11.86	00
2	16	10.25	17	20.60	15.43	16.63	+ 1.20	7.78	00
3	14	18.71	16	10.25	14.48	23.93	+ 9.45	65.26	27.90
4	12	15.09	16	10.25	12.67	18.66	+ 5.99	47.28	23.66
5	10	20.90	6	18.32	19.61	20.17	+ 0.56	2.86	00
6	8	15.82	6	18.32	17.07	15.89	− 1.18	6.91	00
7	6	18.32	8	15.82	17.07	16.69	− 0.38	2.23	00
8	6	18.32	9	17.49	17.91	19.81	+ 1.90	10.61	8.13
9	1	11.31	10	20.90	16.11	19.63	+ 3.52	21.85	00
10	15	13.00	5	12.80	12.90	18.33	+ 5.43	42.09	41.00
11	5	12.80	15	13.00	12.90	12.94	+ 0.04	0.31	00
12	3	12.42	2	16.64	14.53	16.62	+ 2.09	14.38	00
13	15	13.00	13	14.65	13.83	16.10	+ 2.27	16.41	9.90
14	3	12.42	8	15.82	14.12	16.76	+ 2.64	18.70	5.94
15	7	19.37	15	13.00	16.19	19.96	+ 3.77	23.29	3.05
16	17	20.60	8	15.82	18.21	17.20	− 1.01	5.55	00

the better parents and in nine remaining hybrids, the mean values have remained within parental limits. Out of this nine, six hybrids are above the mid-parental values and in the remaining three, they are below the same. Only in one case high reciprocal difference is noticed.

Pod weight (g):

Observations on the performance of 16 hybrids and 15 parents on pod weight are given in Table XI.

(TABLE XI)

It is evident from the table that not much variation occurs between varieties with respect to this character. Maximum parental mean is noted in variety-7 (3.46 g) and the minimum in variety-16 (0.80 g). All the other remaining parental means fall within these two limits. With respect to hybrids, the maximum mean is exhibited by hybrid 14 x 16 and the minimum, by hybrid 5 x 15, the respective values being 2.95 g and 1.14 g.

Out of the 16 cases studied, in five the hybrids have surpassed the better parents and only in one case the hybrid value comes below that of the lower parental mean. Remaining 10 hybrids have exhibited values within the lower

TABLE XI

Behaviour of Parents and F_1's for pod weight (g)

Sl. No.	Female parent	Mean	Male parent	Mean	Mean of parents	Mean of F_1	+ or -	Percentage over Mean of parents	Percentage over Better parent
1	17	2.22	16	0.80	1.51	1.80	+ 0.29	19.21	00
2	16	0.80	17	2.22	1.51	1.48	- 0.03	1.99	00
3	14	1.98	16	0.80	1.39	2.95	+ 1.56	112.23	48.99
4	12	1.88	16	0.80	1.34	2.87	+ 1.53	114.18	52.66
5	10	2.74	6	1.34	2.04	2.39	+ 0.35	17.16	00
6	8	1.87	6	1.34	1.61	1.92	+ 0.31	19.25	2.67
7	6	1.34	8	1.87	1.61	1.59	- 0.02	1.24	00
8	6	1.34	9	3.03	2.19	2.23	+ 0.04	1.83	00
9	1	0.98	10	2.74	1.86	1.74	- 0.12	6.45	00
10	15	1.57	5	1.40	1.49	2.51	+ 1.02	68.46	59.87
11	5	1.40	15	1.57	1.49	1.14	- 0.35	23.49	00
12	3	1.06	2	2.31	1.69	1.74	+ 0.05	2.96	00
13	15	1.57	13	1.73	1.65	2.22	+ 0.57	34.55	28.32
14	3	1.06	8	1.87	1.47	1.85	+ 0.38	25.85	00
15	7	3.46	15	1.57	2.52	2.70	+ 0.18	7.14	00
16	17	2.22	8	1.87	2.05	2.01	- 0.04	1.95	00

and the upper parental limits. Out of this 10, six hybrids have values above that of the mean of the two parents and in four cases, they are below the mid-parental values but above the lower parental limit. Reciprocal difference at a higher degree is noticed in one case.

Seeds per pod:

Data are presented in Table XII.

(TABLE XII)

It is clear from the above table that there exists much variation among parents with respect to this character. As in the previous case, variety-10 has the maximum number of seeds per pod and variety-15 - the minimum. In hybrids the variation ranges from 11.00 to 16.63 of the hybrids 5 x 15 and 10 x 6 respectively. In all other hybrids the mean values fall in between these two limits.

A closer examination of the table shows that only in three out of 16 crosses, the hybrids have surpassed the better parents, but in the remaining thirteen cases, hybrid performance is in between the two parental limits. In none of the cases, hybrid performance is below that of the lower parent. Of the above 13 hybrids, 12 hybrids have shown better performance over the mid-parental values and in the

TABLE XII

Behaviour of Parents and F_1's for number of seeds per pod

Sl. No.	Female parent	Mean	Male parent	Mean	Mean of parents	Mean of F_1	+ or -	Percentage over Mean of parents	Percentage over Better parent
1	17	15.13	16	11.36	13.25	14.10	+ 0.85	6.42	00
2	16	11.36	17	15.13	13.25	13.36	+ 0.11	0.83	00
3	14	14.00	16	11.36	12.68	13.67	+ 0.99	7.81	00
4	12	14.18	16	11.36	12.77	16.42	+ 3.65	28.58	15.80
5	10	16.54	6	12.43	14.49	16.63	+ 2.14	14.77	0.54
6	8	15.56	6	12.43	14.00	13.81	- 0.19	1.36	00
7	6	12.43	8	15.56	14.00	14.73	+ 0.73	5.21	00
8	6	12.43	9	16.36	14.40	16.18	+ 1.78	12.36	00
9	1	10.92	10	16.54	13.73	14.64	+ 0.91	6.63	00
10	15	8.25	5	14.07	11.16	13.77	+ 2.61	23.39	00
11	5	14.07	15	8.25	11.16	11.00	- 0.16	1.43	00
12	3	10.57	2	16.00	13.29	11.50	- 1.79	13.47	00
13	15	8.25	13	13.93	11.09	12.29	+ 1.2	10.82	00
14	3	10.57	8	15.56	13.07	15.07	+ 2.00	15.30	00
15	7	15.27	15	8.25	11.75	13.67	+ 1.92	16.34	00
16	17	15.13	8	15.56	15.35	16.50	+ 1.15	7.49	6.04

remaining one case it is below the mid-parental value. Not much reciprocal difference is noted in all the three cases.

100-seed weight (g):

Observations regarding 100-seed weight are presented in Table XIII.

(TABLE XIII)

From the data presented in the Table it can be seen that much variation occurs among different varieties and hybrids. Among varieties maximum 100-seeds weight is expressed by variety-7 and minimum by variety-16, the respective values being 18.68 g to 6.13 g. In the case of hybrids the maximum value of 17.60 g is exhibited by the hybrid 7 x 15 while the minimum value of 7.60 g is shown by the hybrid 17 x 16.

Out of the 16 hybrids studied only five have produced values over the better parents and of the remaining 11, two hybrids are below that of the lower limit of the parental mean. Remaining nine hybrids are in between the upper and the lower parental limits and of these, six hybrids have shown improvement over the mid-parental values and the last three have shown the performance below that of

TABLE XIII

Behaviour of Parents and F_1's for 100-seed weight (g_1)

Sl. No.	Female parent	Mean	Male parent	Mean	Mean of parents	Mean of F_1	+ or -	Percentage over Mean of parents	Percentage over Better parents
1	17	11.62	16	6.13	8.88	7.60	- 1.28	14.41	00
2	16	6.13	17	11.62	8.88	9.76	+ 0.88	9.91	00
3	14	10.88	16	6.13	8.51	15.24	+ 6.73	79.08	40.07
4	12	10.36	16	6.13	8.25	12.89	+ 4.64	56.24	24.42
5	10	12.62	6	8.81	10.72	10.94	+ 0.22	2.05	00
6	8	10.97	6	8.81	9.89	11.64	+ 1.75	17.69	6.11
7	6	8.81	8	10.97	9.89	9.03	- 0.86	8.70	00
8	6	8.81	9	13.26	11.04	10.67	- 0.37	3.35	00
9	1	7.55	10	12.62	10.09	10.36	+ 0.27	2.68	00
10	15	15.55	5	9.37	12.46	16.48	+ 4.02	32.26	5.98
11	5	9.37	15	15.55	12.46	7.80	- 4.66	37.40	00
12	3	8.33	2	11.17	9.75	11.93	+ 2.18	22.36	6.80
13	15	15.55	13	9.50	12.53	14.78	+ 2.25	17.96	00
14	3	8.33	8	10.97	9.65	10.13	+ 0.48	4.97	00
15	7	18.68	15	15.55	17.12	17.60	+ 0.48	2.80	00
16	17	11.62	8	10.97	11.30	10.04	- 1.26	11.15	00

the mid parental values but above the lower parental limit.

Seed length (cm):

Data pertaining to this character are presented in Table XIV.

(TABLE XIV)

From the data it can be seen that not much variation occurs among the varieties. The range observed among the parents is from 0.54 cm in variety-16 to 0.88 cm in variety-17. In respect of hybrids, 14 x 16 and 5 x15 show the maximum and minimum values of 1.00 cm and 0.65 cm respectively.

Out of 16 hybrids studied, eight F_1's are found to have their length beyond that of the respective better parents and three hybrids have their seed length below that of the lower parental value. Out of the remaining five cases, three hybrids are found to have their respective seed lengths lying in between the upper parental limit and the mid-parental value and in the remaining two cases the hybrid mean has equalled that of the lower parent. Reciprocal difference is also noticed in some cases.

TABLE XIV

Behaviour of Parents and F_1's for seed length (cm)

Sl. No.	Female parent	Mean	Male parent	Mean	Mean of parents	Mean of F_1	+ or −	Percentage over	
								Mean of parents	Better parent
1	17	0.88	16	0.54	0.71	0.86	+ 0.15	21.13	00
2	16	0.54	17	0.88	0.71	0.78	+ 0.07	9.86	00
3	14	0.83	16	0.54	0.69	1.00	+ 0.31	44.93	20.48
4	12	0.63	16	0.54	0.59	0.88	+ 0.39	49.15	39.68
5	10	0.83	6	0.83	0.83	0.78	−0.05	6.02	00
6	8	0.76	6	0.83	0.80	0.76	− 0.04	5.00	00
7	6	0.83	8	0.76	0.80	0.76	− 0.04	5.00	00
8	6	0.83	9	0.62	0.73	0.76	+ 0.03	4.11	00
9	1	0.68	10	0.83	0.76	0.88	+ 0.12	15.79	6.02
10	15	0.83	5	0.74	0.79	0.87	+ 0.08	10.13	4.82
11	5	0.74	15	0.83	0.79	0.65	− 0.14	17.72	00
12	3	0.65	2	0.64	0.65	0.83	+ 0.18	27.69	27.69
13	15	0.83	13	0.66	0.75	0.88	+ 0.13	17.33	6.02
14	3	0.65	8	0.76	0.71	0.77	+ 0.06	8.45	1.32
15	7	0.62	15	0.83	0.73	0.92	+ 0.19	26.03	10.84
16	17	0.88	8	0.76	0.82	0.73	− 0.09	10.98	00

Seed breadth (cm):

The data are presented in Table XV.

(TABLE XV)

Here also as in the previous case, wide variation is not noticed among varieties unlike in the hybrids. Parental mean ranges from 0.40 cm of variety-16 to 0.64 cm of variety-15. Remaining 13 parental means lie within this range. In hybrids, maximum seed breadth is shown by the hybrid 15 x 5 and minimum by hybrids 16 x 17 and 5 x 15. The remaining hybrid means lie in between 0.49 cm and 0.72 cm.

Out of the 16 crosses studied only in five, the hybrids have surpassed that of the better parent and in two cases the hybrid values are below that of the lower parental limit. In nine crosses the F_1 mean values range between the upper and the lower parental means. Out of this nine cases, seven have shown values above the mid-parental values and in two cases it is inbetween the mean of parents and the lower parental mean. Reciprocal differences are also noticed.

Seed thickness (cm):

Data regarding the performance of both the parents

TABLE XV

Behaviour of Parents and F_1's for seed breadth (cm)

Sl. No.	Female parent	Mean	Male parent	Mean	Mean of parents	Mean of F_1	+ or -	Percentage over	
								Mean of parents	Better parent
1	17	0.51	16	0.40	0.46	0.59	+ 0.13	28.26	15.69
2	16	0.40	17	0.51	0.46	0.49	+ 0.03	6.52	00
3	14	0.55	16	0.40	0.48	0.63	+ 0.15	31.25	14.55
4	12	0.52	16	0.40	0.46	0.66	+ 0.20	43.48	26.92
5	10	0.63	6	0.50	0.57	0.59	+ 0.02	3.51	00
6	8	0.59	6	0.50	0.55	0.56	+ 0.01	1.82	00
7	6	0.50	8	0.59	0.55	0.58	+ 0.03	5.45	00
8	6	0.50	9	0.61	0.56	0.55	- 0.01	1.78	00
9	1	0.45	10	0.63	0.54	0.58	+ 0.04	7.41	00
10	15	0.64	5	0.51	0.58	0.72	+ 0.14	24.14	12.50
11	5	0.51	15	0.64	0.58	0.49	- 0.09	15.52	00
12	3	0.46	2	0.56	0.51	0.52	+ 0.01	1.96	00
13	15	0.64	13	0.58	0.61	0.63	+ 0.02	3.28	00
14	3	0.46	8	0.59	0.54	0.53	- 0.01	1.85	00
15	7	0.58	15	0.64	0.61	0.65	+ 0.04	6.56	1.56
16	17	0.51	8	0.59	0.55	0.50	- 0.05	9.09	00

and hybrids are presented in Table XVI.

(TABLE XVI)

Among different characters studied so far least variation between varieties can be noticed only for this character. When variety-15 possesses a maximum mean of 0.47 cm variety-16 shows the minimum value of 0.33 cm. Among the 16 hybrids studied, maximum seed thickness is exhibited by the hybrid 15 x 5 and the minimum by the hybrid 16 x 17.

Of all the 16 hybrids observed, seven hybrids have surpassed the better parent. Out of the remaining nine hybrids, four hybrids have shown values below their respective lower parental mean and in five cases the values range in between the upper and the lower parental limits of the respective parents. Out of these five hybrids, only two hybrids are above the mid-parental value and in one case it equals with the mid-parental value and in the remaining two cases it is below the lower parental mean. Reciprocal difference is noticed in two of the three cases.

<u>Pod yield (g)</u>:

Observations on the performance of the 15 parents and 16 hybrids are presented in Table XVII.

TABLE XVI

Behaviour of Parents and F_1's for seed thickness (cm)

Sl. No.	Female parent	Mean	Male parent	Mean	Mean of parents	Mean of F_1	+ or −	Percentage over: Mean of parents	Percentage over: Better parent
1	17	0.40	16	0.33	0.37	0.47	+ 0.10	27.03	17.50
2	16	0.33	17	0.40	0.37	0.38	+ 0.01	2.70	00
3	14	0.45	16	0.33	0.39	0.47	+ 0.08	20.51	4.44
4	12	0.42	16	0.33	0.38	0.51	+ 0.13	34.21	21.43
5	10	0.44	6	0.41	0.43	0.39	− 0.04	9.30	00
6	8	0.46	6	0.41	0.44	0.48	+ 0.04	9.09	4.35
7	6	0.41	8	0.46	0.44	0.42	− 0.02	4.55	00
8	6	0.41	9	0.44	0.43	0.39	− 0.04	9.30	00
9	1	0.37	10	0.44	0.41	0.41	00	00	00
10	15	0.47	5	0.44	0.46	0.52	+ 0.06	13.04	10.63
11	5	0.44	15	0.47	0.46	0.43	− 0.03	6.52	00
12	3	0.38	2	0.44	0.41	0.42	+ 0.01	2.43	00
13	15	0.47	13	0.44	0.46	0.49	+ 0.03	6.52	4.26
14	5	0.38	8	0.46	0.42	0.41	− 0.01	2.38	00
15	7	0.43	15	0.47	0.45	0.51	+ 0.06	13.33	8.51
16	17	0.40	8	0.46	0.43	0.41	− 0.02	4.65	00

(TABLE XVII)

Among the parents maximum pod yield is given by the variety-5 and minimum by variety-15, their mean pod yields being 93.04 g and 7.57 g respectively. High degree of variation can be observed in the hybrids also. Hybrid mean values range from 29.68 g of hybrid 5 x 15 and 113.23 g of hybrid 10 x 6.

Among the 16 hybrids, 8 hybrids have shown mean values over their respective better parents and two hybrids have given a mean value below that of the respective lower parental mean limits. Of the remaining six hybrids, five hybrids are over the mid-parental values and one hybrid is in between the mid-parental value and the lower parent. Thus totally six hybrids have performed in the range of upper and lower limits of the parents. Recíprocal difference is very prominent for this character.

Seed yield (g):

Data pertaining to the seed yield per plant are given in Table XVIII.

(TABLE XVIII)

High degree of variation is noticed among hybrids and parents. Among the 15 parents, highest value for seed yield is shown by variety-5 and lowest by variety-15, their

TABLE XVII

Behaviour of Parents and F_1's for pod yield per plant (g)

Sl. No.	Female parent	Mean	Male parent	Mean	Mean of parents	Mean of F_1	+ or -	Percentage over	
								Mean of parents	Better parent
1	17	49.25	16	39.35	44.30	87.10	+ 42.8	96.61	76.85
2	16	39.35	17	49.25	44.30	46.40	+ 2.1	4.74	00
3	14	42.65	16	39.35	41.00	38.16	- 2.4	6.93	00
4	12	49.42	16	39.35	44.39	71.85	+ 27.46	61.86	45.39
5	10	66.38	6	30.98	48.68	113.23	+ 64.55	132.60	70.58
6	8	65.51	6	30.98	48.25	53.79	+ 5.54	11.48	00
7	6	30.98	8	65.51	48.25	73.03	+ 24.78	51.36	11.48
8	6	30.98	9	80.59	55.79	64.85	+ 9.06	16.24	00
9	1	37.75	10	66.38	52.07	34.48	-17.59	33.78	00
10	15	7.57	5	93.04	50.31	68.50	+ 18.19	36.16	00
11	5	93.04	15	7.57	50.31	29.68	- 20.63	41.01	00
12	3	27.75	2	60.08	43.92	89.99	+ 46.07	104.90	49.78
13	15	7.57	13	30.83	19.20	101.83	+ 82.63	430.36	230.30
14	3	27.75	8	65.51	46.63	74.63	+ 28.00	60.05	13.92
15	7	74.40	15	7.57	40.99	64.10	+ 23.11	56.38	00
16	17	49.25	8	65.51	57.38	101.09	+ 43.71	76.18	54.31

TABLE XVIII

Behaviour of Parents and F_1's for seed yield per plant (g)

Sl. No.	Female parent	Mean	Male parent	Mean	Mean of parents	Mean of F_1	+ or −	Percentage over	
								Mean of Parents	Better Parent
1	17	30.09	16	25.01	27.55	58.88	+ 31.33	113.72	95.68
2	16	25.01	17	30.09	27.55	28.80	+ 1.25	4.54	00
3	14	30.69	16	25.01	27.70	25.12	− 2.58	9.31	00
4	12	30.03	16	25.01	27.52	45.88	+ 18.36	66.72	52.78
5	10	42.56	6	23.51	33.04	80.60	+ 47.56	143.95	89.38
6	8	47.77	6	23.51	35.64	38.87	+ 3.23	9.06	00
7	6	23.51	8	47.77	35.64	53.28	+ 17.64	49.49	11.53
8	6	23.51	9	58.20	40.86	46.51	+ 5.65	13.83	00
9	1	24.76	10	42.56	33.66	23.11	− 10.55	31.34	00
10	15	5.79	5	69.50	37.65	35.74	− 1.91	5.07	00
11	5	69.50	15	5.79	37.65	18.60	− 19.05	50.60	00
12	3	16.88	2	45.95	31.42	66.46	+ 35.26	112.22	44.64
13	15	5.79	13	20.32	13.06	59.69	+ 46.63	357.04	193.75
14	3	16.88	8	47.77	32.33	52.37	+ 20.04	61.99	9.63
15	7	55.84	15	5.79	30.82	43.21	+ 12.39	40.20	00
16	17	30.09	8	75.21	52.65	75.21	+ 22.56	42.85	00

mean values range from 69.50 g to 5.79 g respectively. Wide variation is also noticed among hybrids. Hybrid 10 x 6 ranks on the top and hybrid 5 x 15 on the bottom with seed yields of 80.60 g and 18.60 g respectively.

Out of the 16 hybrids studied, in 7 cases, hybrids are above their respective better parents and in one case it is lower than the respective low yielding parent. In the remaining eight cases the hybrid performance ranges in between the parental limits. Out of this eight cases, in five the hybrid performance is above the mid-parental values and in three cases, it is below that. Reciprocal difference is also noticed in all the three cases.

Discussion

DISCUSSION

Results of observations on 16 characters recorded from the 16 intervarietal hybrids of cowpea and from the respective parents have been analysed and presented. An attempt to discuss the results as a whole so as to draw valid conclusions is made hereunder.

Cowpea in Kerala is a unique pulse crop grown under contrasting situations. The grain-production-oriented rice fallow culture would require high yielding erect varieties with early flowering and highly condensed flowering spread to make the cultivation economic, avoiding huge expenditure on multiple harvest. Even varieties with smaller pods, if they have large number of pods and good number of heavy seeds per pod, will be highly suited for this system.

The highly specialised system of cowpea culture in summer rice fallows specifically for vegetable purpose, as practiced in certain areas like Manoheri in the state, would require trailing varieties with long fleshy pods and with a reasonably prolonged flowering spread to ensure continuous supply of green pods over a larger period. Here the highly synchronised flowering is not of much importance since a good amount of labour comes as self or family labour.

Varieties with large number of small pods giving good seed yield, will be of no use at all under this situation.

The third winter system of cowpea culture is during the Khariff season. Here the cultivation is mainly in the uplands and homesteads, where varieties with medium pod size, bold seed and medium flowering duration and spread are useful. The varieties would be either erect orsemi-erect or trailing. They should also be of dual purpose ones with tolerably good yield both as tender vegetable pod and also as vegetable grain.

As is the case, the present tasks of the cowpea breeders in the state are of diverse nature, since varieties suited for vivid situations are to be evolved in order to satisfy the demands of the growers.

It would be too much imaginative and far from reality to expect a single variety to possess all the desirable attributes to the maximum. Thus in any programme of improvement of this crop through combination breeding, desirable genes are to be pooled from different sources in so far as they are found distributed among the different varieties. Thus selection of 15 parental varieties belonging to 15 clusters, each variety possessing one or the other contrasting trait expressed to the maximum, as parents in the present programme, is fully justifiable.

In recent years the concept of plant type is gaining momentum. An ideal morphological frame work of a plant will be more efficient in its performance in a particular environment. As such, instead of considering individual characters, plant breeders are now looking for a plant having an ideal combination of different characteristics. In any crop as a matter of fact, stature and branching are two main aspects which decide the physical frame work of the plant contributing much of its appearance and the efficiency of cropping. Short stature and profuse branching makes the plant bushy in appearance, while, tall plants with sparse branches will give a lean and lanky appearance.

In cowpea both tall and dwarf plants are desirable under different situations. An examination of the data for plant height in the parents and hybrids reveals the following. If tallness is desirable, five out of 16 hybrids studied have exhibited heterosis, out of which in one of the F_1's, the heterotic effect is over the parental mean alone, whereas, in the remaining four, it is over the tall parent as well. In places where dwarfness is desirable, 11 out of 16 hybrids studied have exhibited heterosis, out of which in eight of the F_1 hybrids, the heterotic effect is over the parental mean and in the remaining three it is over the dwarf parent as well (Fig.2).

Results of observations on the number of branches in the 16 hybrids and their respective parents have indicated a clear possitive evidence of hybrid vigour only in seven out of the 16 hybrids, out of which in one the F_1 mean is found to surpass the mean of the two parents only, while in the remaining six it is found to be superior to the better parent as well (Fig.1). The differential behaviour of the hybrids with reference to the expression of heterosis may, perhaps, be due to the differences in the genetic architecture of the parents involved.

Yield is the primary criterion in any breeding programme. Next to it in importance is duration. From the economic point of view it is always desirable to have short term varieties with high yielding ability. It is from here that the concept of per day yield has come into being. This per day yield is obtained by dividing the total yield of the plant with the number of days it occupies the land. Thus selection on per day yield will take into account both the factors simultaneously.

In the present investigation, commencement of flowering, completion of flowering and flowering spread have been

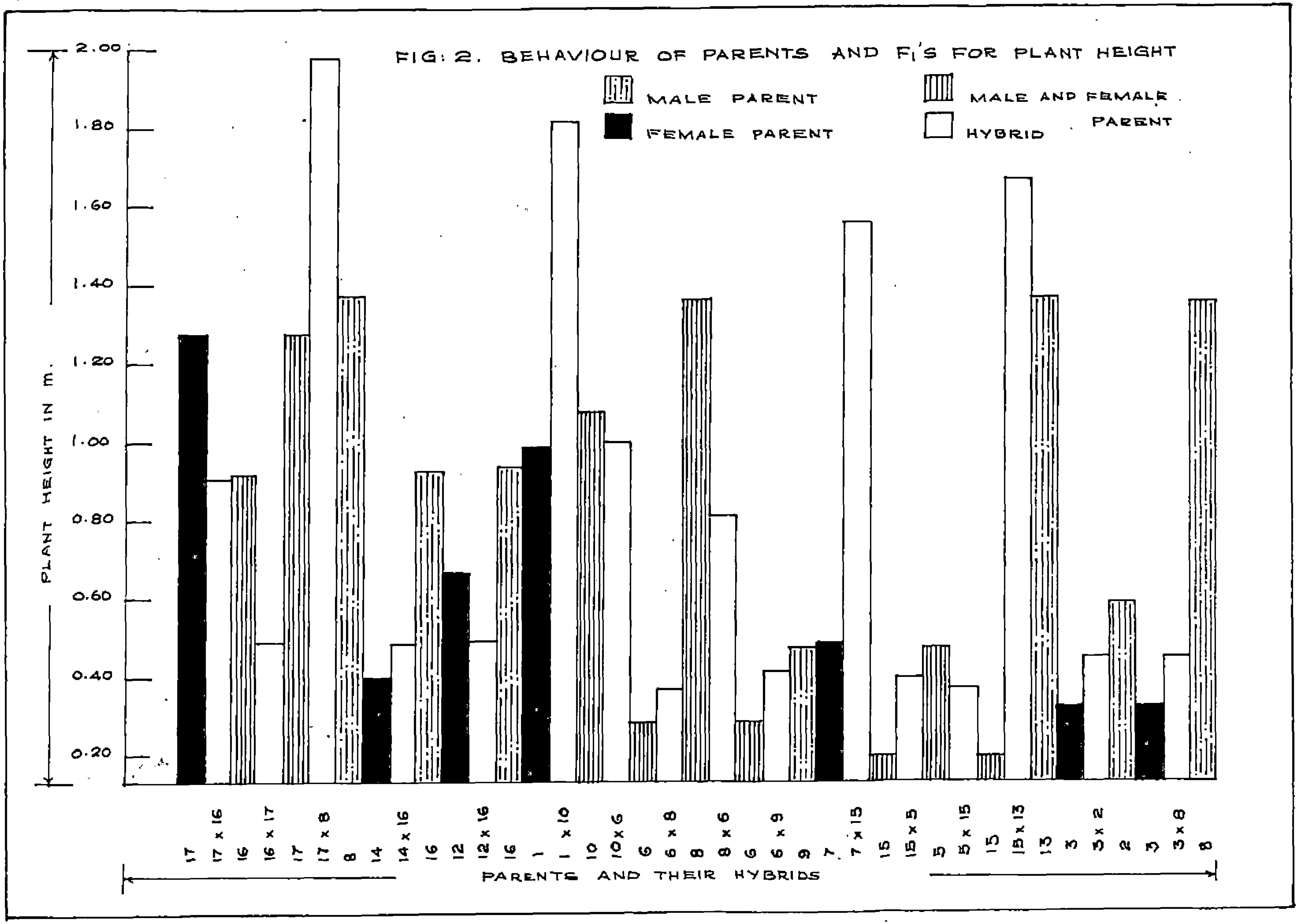
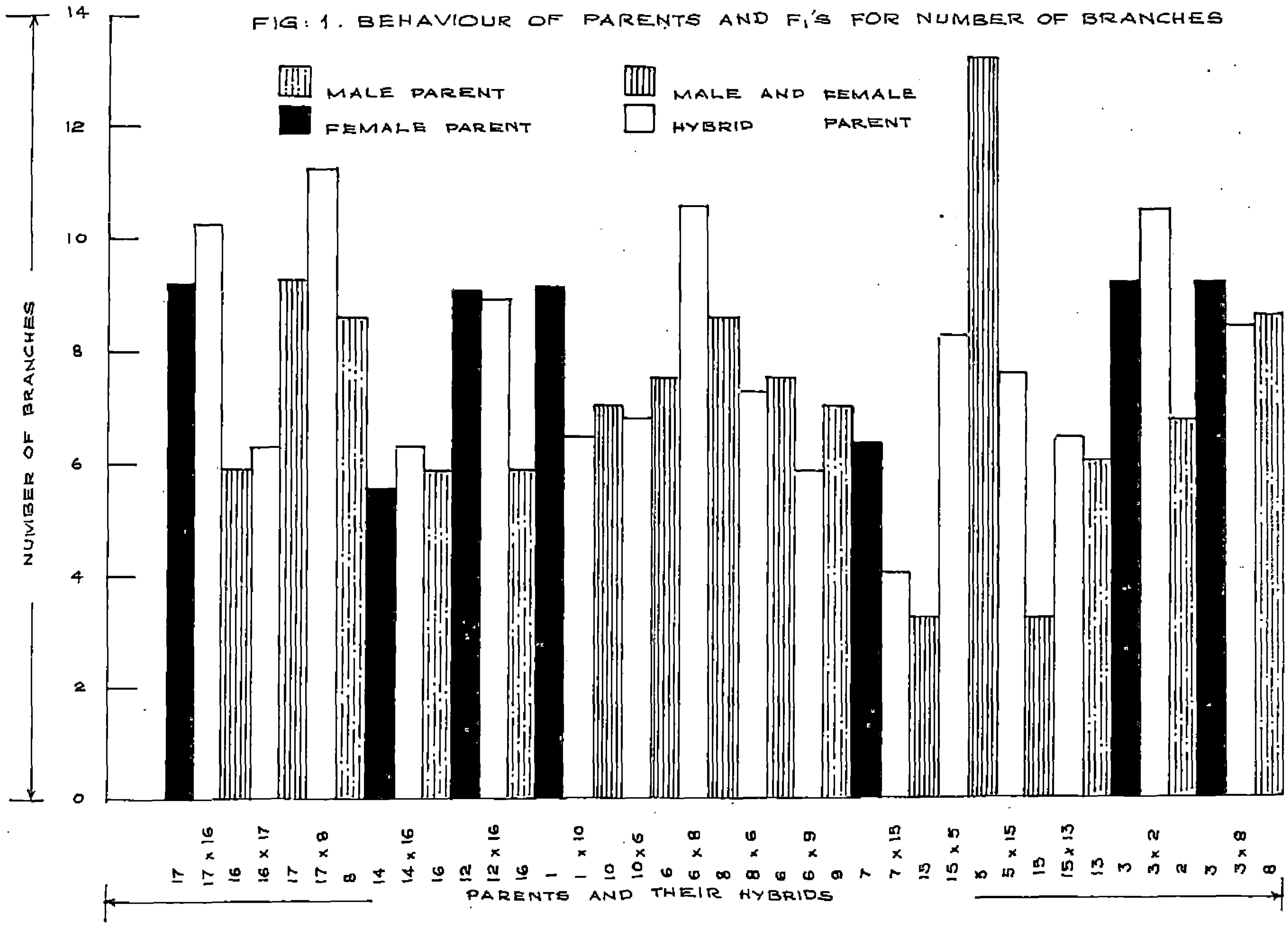


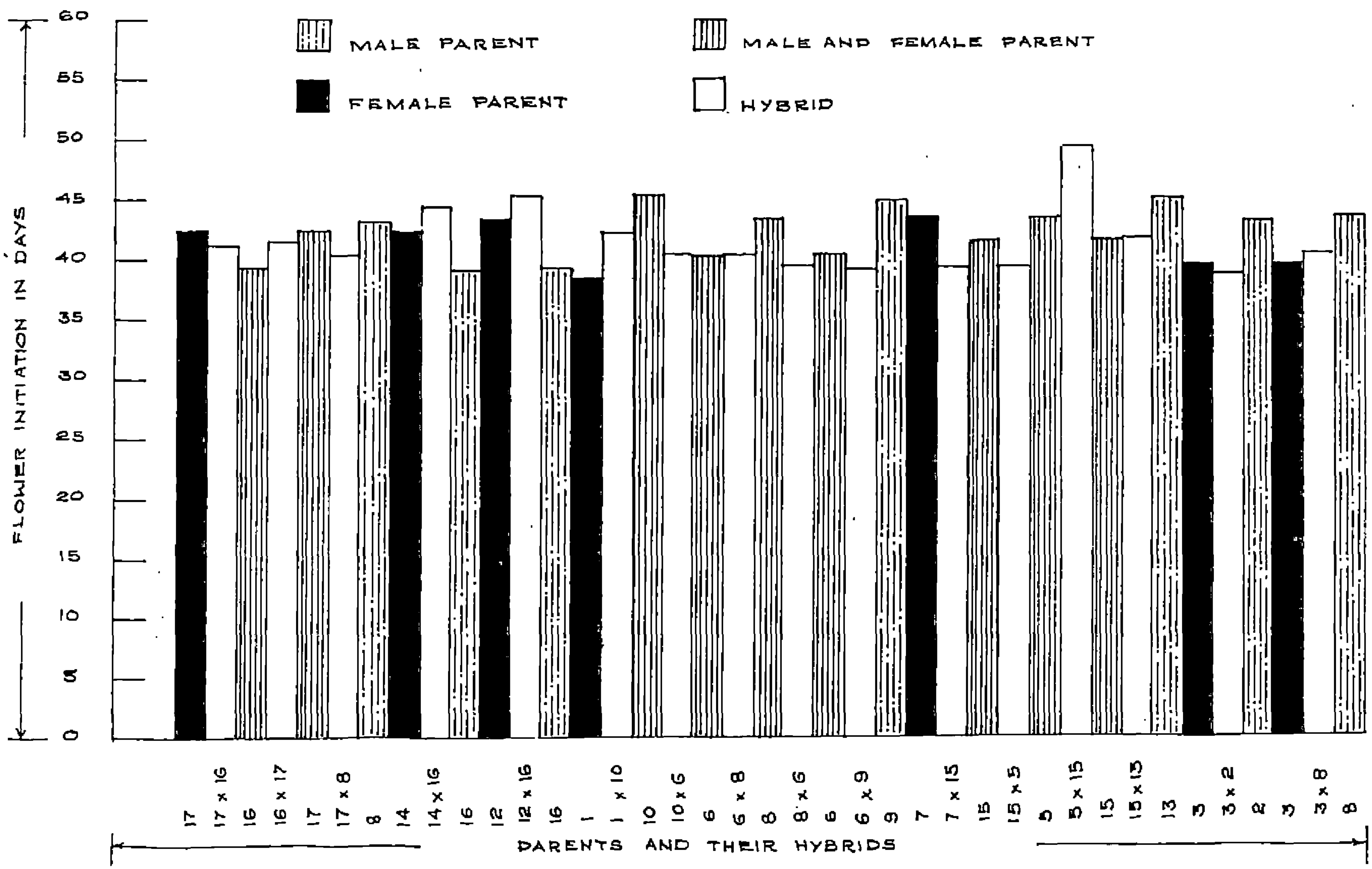
FIG: 2. BEHAVIOUR OF PARENTS AND F1'S FOR PLANT HEIGHT

FIG: 1. BEHAVIOUR OF PARENTS AND F_1'S FOR NUMBER OF BRANCHES



studied in both the hybrids and the respective parents. Early commencement of flowering is always desirable in so far as it ensures the early harvest and early return of the produce to the grower against his investment. Again a crop which flowers early will occupy the field for a lesser number of days and will consequently be subjected to the hazards of incliment weather to a lesser degree. Contrary to this, completion of flowering and flowering spread have two aspects. Early completion of flowering, resulting in a lesser flowering spread is advantageous under conditions where expenditure on multiple harvest has to be reduced. On the other hand late completion of flowering resulting in a wider flowering spread will be desirable in places where the crop is grown for vegetable purpose when continuous supply of green pods is of primary importance. Considering the data obtained in the present study from these angles, it is noticed that 10 out of 16 hybrids have expressed heterosis with reference to commencement of flowering. Out of this 10, eight F_1 hybrids have flowered earlier than the early parent, while, the remaining two have expressed a value lesser than the mean of the two parents (Fig. 14). These results indicate that there is great scope for obtaining early derivatives of the crosses involving the parents selected in the present study.

FIG: 14. BEHAVIOUR OF PARENTS AND F_1'S FOR COMMENCEMENT OF FLOWERING

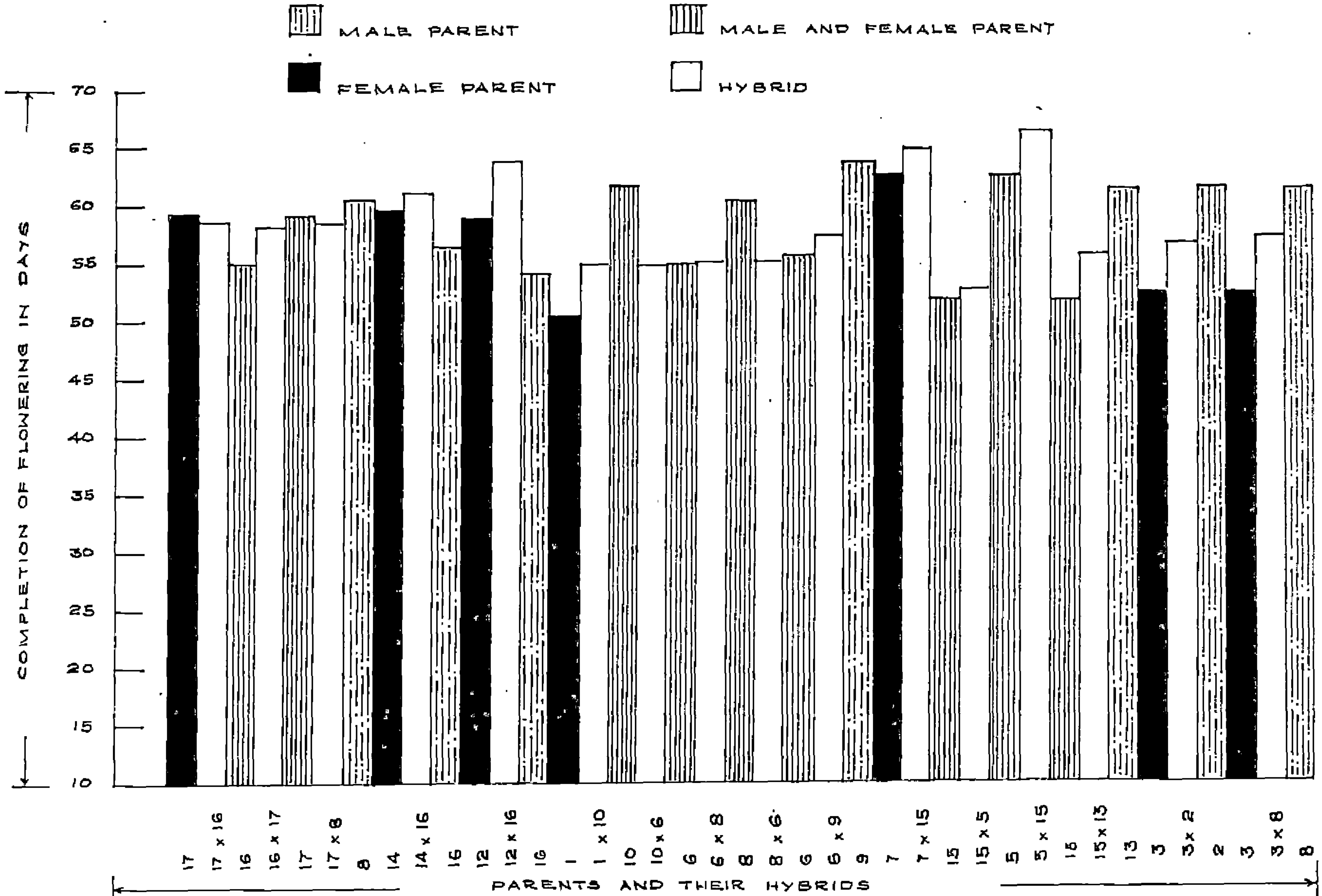


In the case of completion of flowering, seven out of the 16 hybrids have expressed heterosis towards lateness and nine towards earliness (Fig.15). With reference to flowering spread also 10 out of the 16 hybrids have expressed values above the mean of the parents and six below the mean of the parents (Fig.16). These results indicate the great amount of genetic variability available among the parents selected for the study and consequently the possibility of realising the desired recombinant in the further segregating generations of the present intervarietal hybrids.

Yield as we all know is a complex character which in the case of cowpea is the edible green pod and also mature grains rich in protein. This is primarily determined by number of flowers per plant, number and weight of pods per plant, length and weight of individual pods, number of seeds per pod, size of the individual seed and weight of seeds per plant. These are traits which are normally expected to have a positive relationship with yield and consequently a more intensified expression of them will result in an increased yield.

In the present investigation clear evidence of the hybrid superiority over the mean of the parents is observed in the case of 13 and 12 hybrids out of 16 in

FIG: 15. BEHAVIOUR OF PARENTS AND F_1'S FOR THE COMPLETION OF FLOWERING



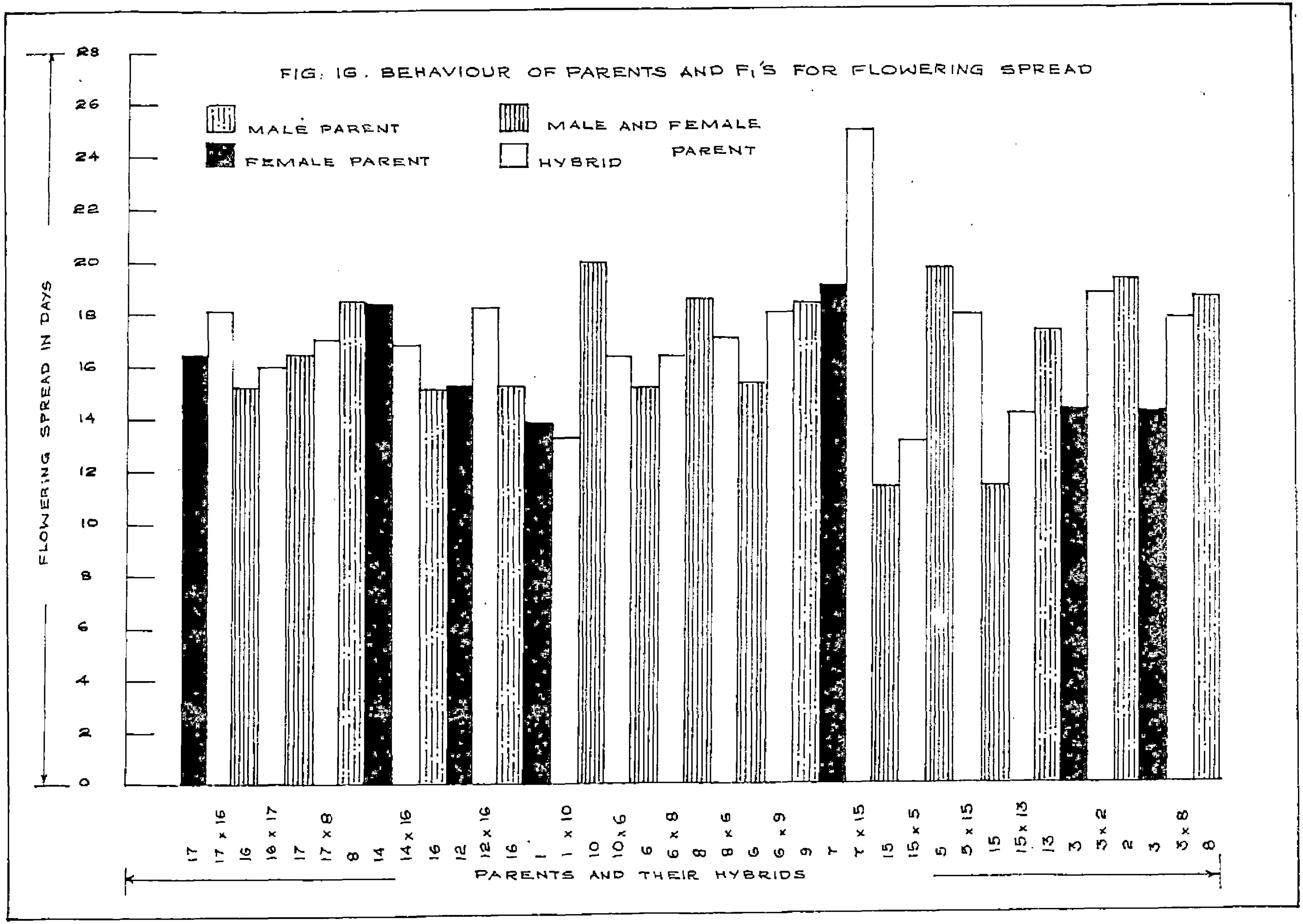
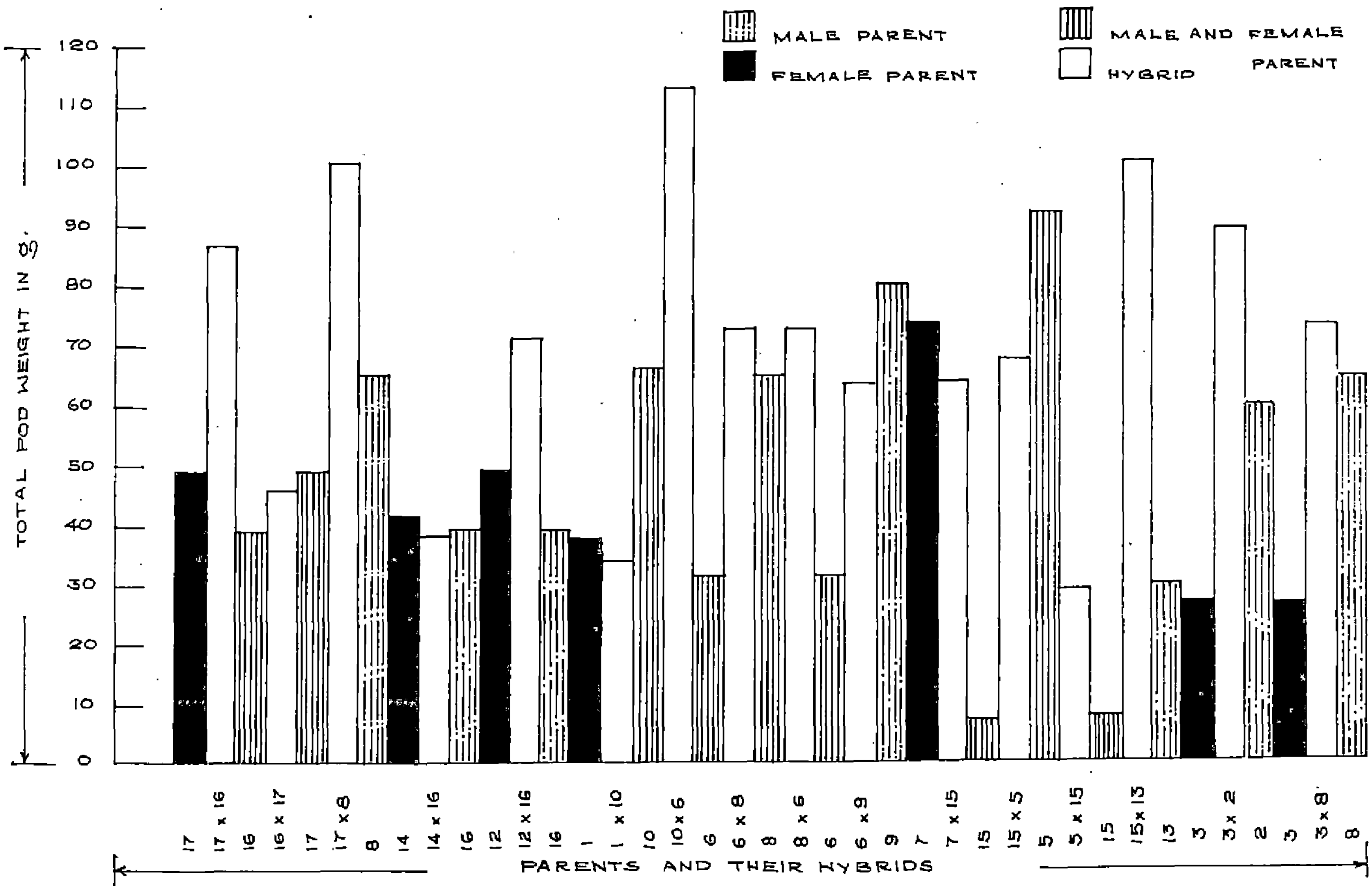


FIG: 16. BEHAVIOUR OF PARENTS AND F_1'S FOR FLOWERING SPREAD in respect of pod as well as seed yields respectively (Figures 8 and 9). This is in agreement with the results of Hofmann (1926) in cowpea, Acs (1964) and Putinoev (1970) in _Pisum sativum_, Singh and Singh (1970) in field pea, Bhatnagar and Singh (1964) and Singh and Jain (1970) in _Phaseolus aureus_ and Colins (1967) in _Phaseolus lunatus_. The F_1 means in the above cases are found to be above the midparental values in 13 and 12 F_1's studied in the case of pod and seed yields respectively. Out of this eight in the case of pod yield and seven in the case of seed yield are observed to be better than the corresponding better parents as well.

Heterosis for total pod yield per plant observed in the present case can either be due to an increase in the number of flowers per plant resulting in the realisation of more number of pods per plant or due to an increase in the length and weight of individual pod or both. Out of 16 hybrids studied in the present investigation, 12 in the case of number of flowers per plant, nine in the case of number of pods per plant, 13 in the case of length of pod and 11 in the case of weight of pod are seen to produce higher value over the corresponding means of their respective parents (Figures 3, 4, 5, 6 and Plates 1 to 6). This is in agreement with the findings of Singh and Singh (1970).

FIG: 8. BEHAVIOUR OF PARENTS AND F1'S FOR TOTAL POD WEIGHT PER PLANT



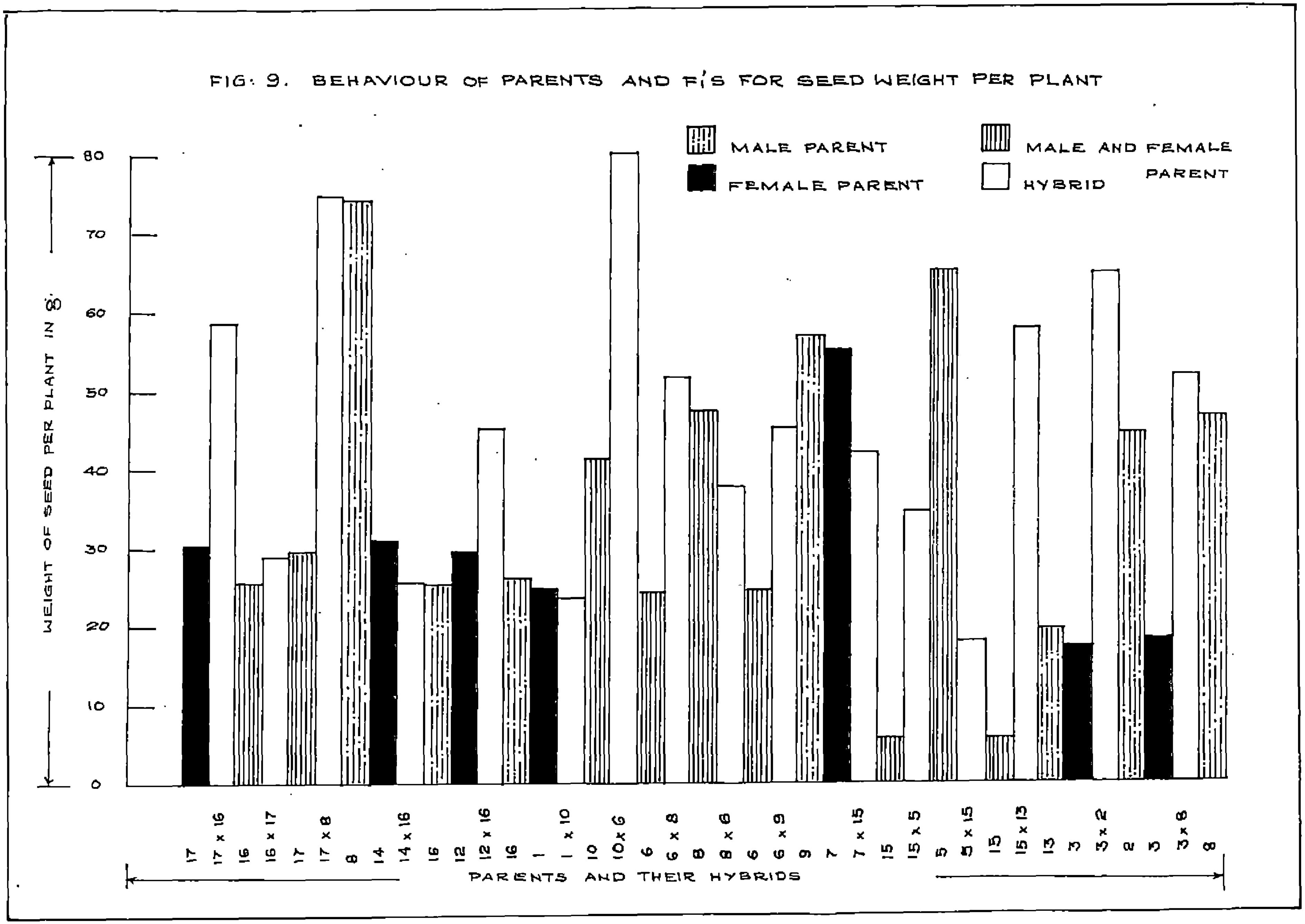
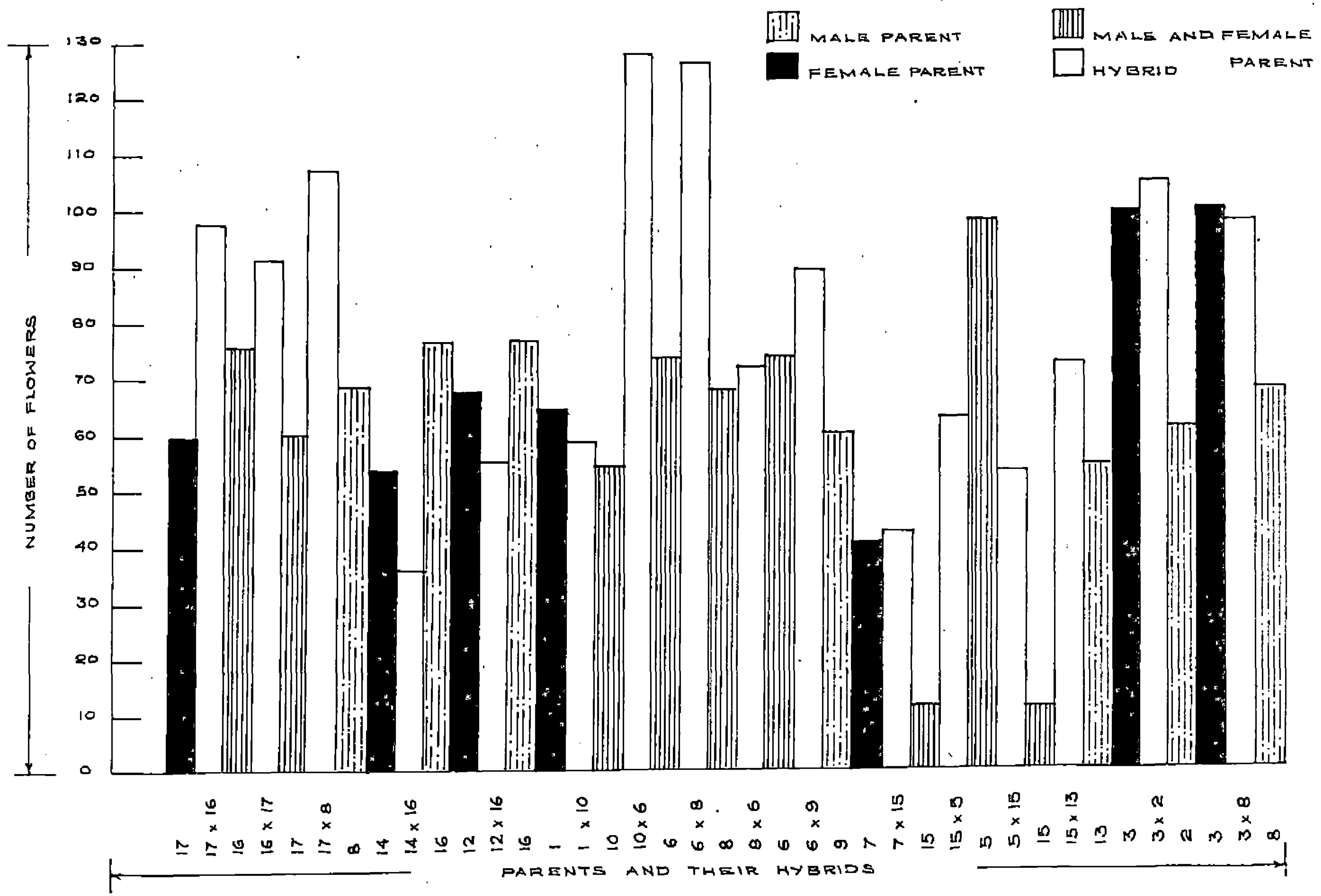


FIG: 9. BEHAVIOUR OF PARENTS AND F1'S FOR SEED WEIGHT PER PLANT
MALE PARENT
FEMALE PARENT
MALE AND FEMALE PARENT
HYBRID
WEIGHT OF SEED PER PLANT IN g
0
10
20
30
40
50
60
70
80
17
17 x 16
16
16 x 17
17
17 x 8
8
14
14 x 16
16
12
12 x 16
16
1
1 x 10
10
10 x 6
6
6 x 8
8
8 x 6
6
6 x 9
9
7
7 x 15
15
15 x 5
5
5 x 15
15
15 x 13
13
3
3 x 2
2
3
3 x 8
8
PARENTS AND THEIR HYBRIDS

FIG: 3. BEHAVIOUR OF PARENTS AND F_1'S FOR NUMBER OF FLOWERS PER PLANT



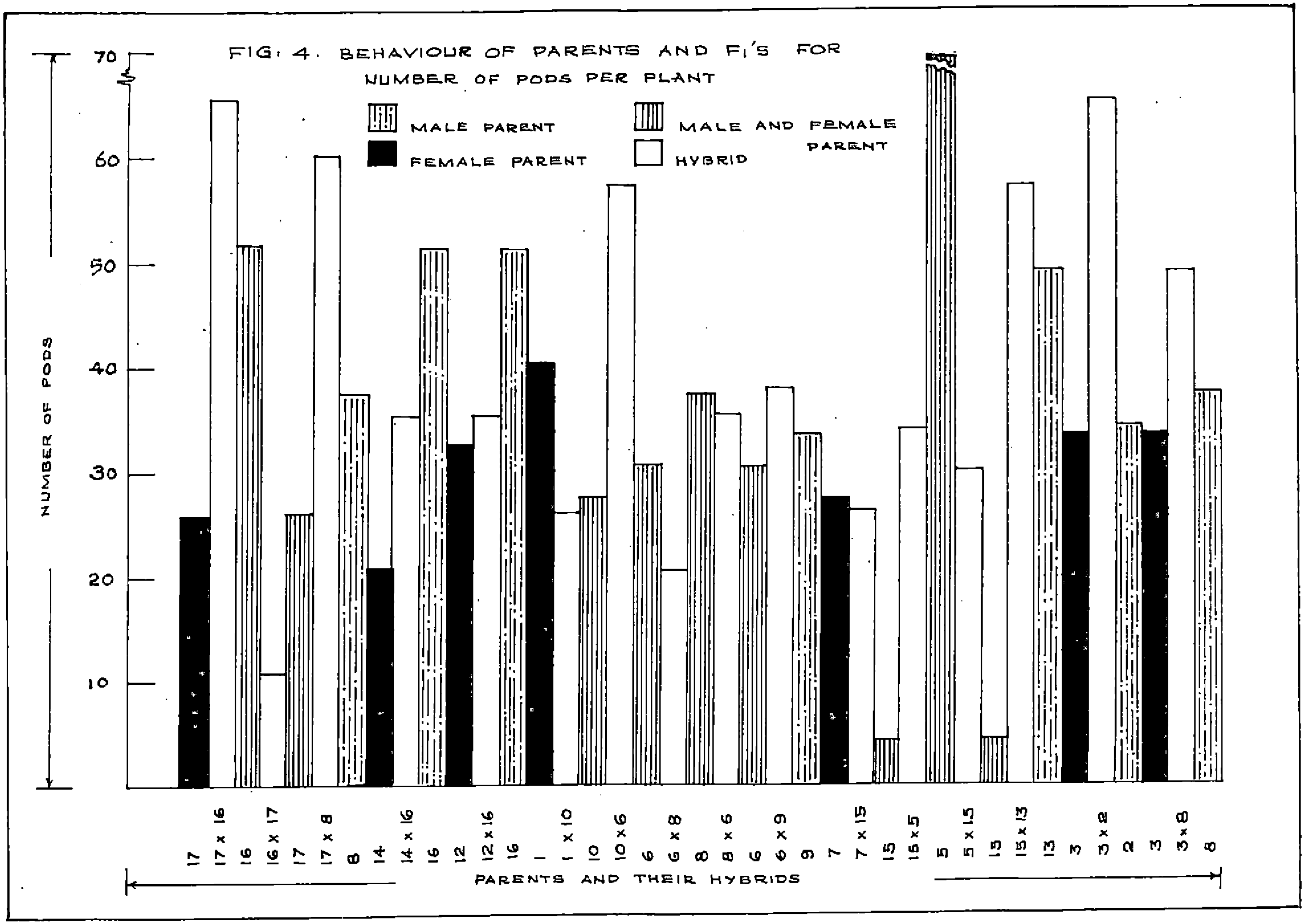
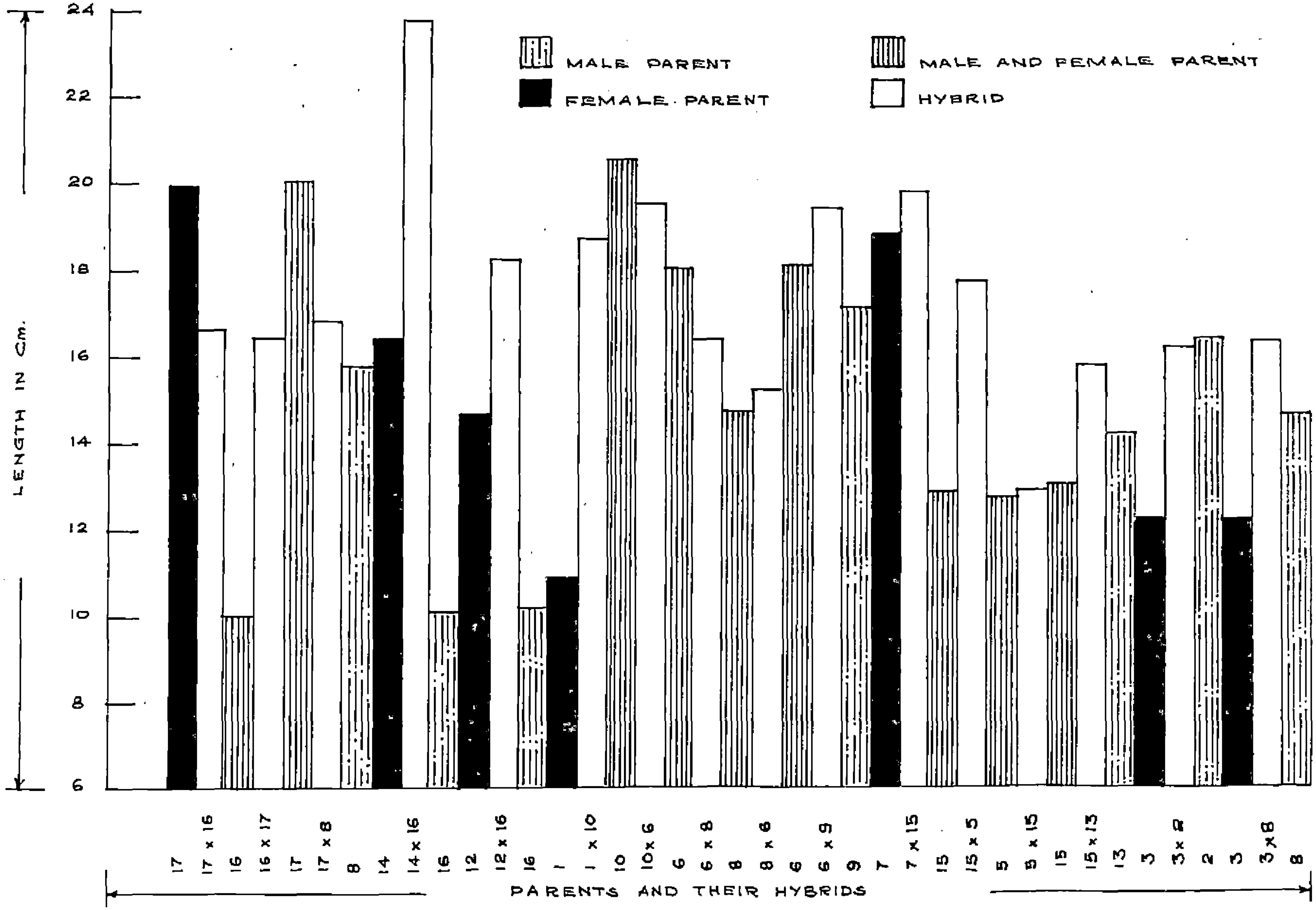


FIG. 4. BEHAVIOUR OF PARENTS AND F1'S FOR NUMBER OF PODS PER PLANT
MALE PARENT
FEMALE PARENT
MALE AND FEMALE PARENT
HYBRID
NUMBER OF PODS
70
60
50
40
30
20
10
17
17 x 16
16
16 x 17
17
17 x 8
8
14
14 x 16
16
12
12 x 16
16
1
1 x 10
10
10 x 6
6
6 x 8
8
8 x 6
6
6 x 9
9
7
7 x 15
15
15 x 5
5
5 x 15
15
15 x 13
13
3
3 x 2
2
3
3 x 8
8
PARENTS AND THEIR HYBRIDS

FIG: 5. BEHAVIOUR OF PARENTS AND F1'S FOR POD LENGTH IN Cm.



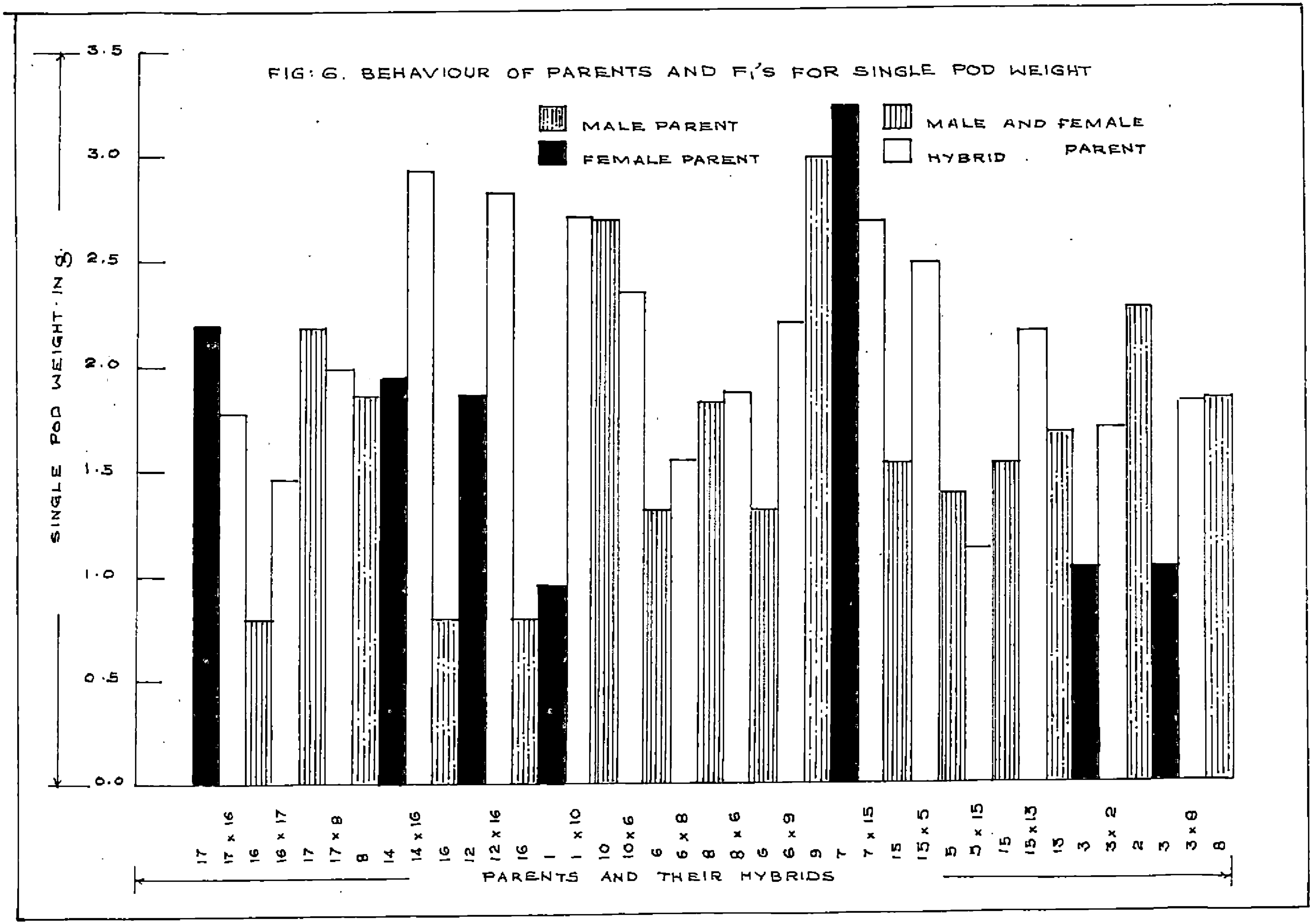


FIG: 6. BEHAVIOUR OF PARENTS AND F1'S FOR SINGLE POD WEIGHT

As stated earlier clear expression of the hybrid superiority over the parents is observed in the case of total seed yield per plant in 12 out of 16 hybrids studied. Increase in seed yield per plant is brought about by either an increase in the number of seeds per pod or by an increase in size and weight of individual seeds or both. The results in the present case indicate that 15 in the case of number of seeds per pod and 11 in the case of 100-seed weight, out of 16 hybrids studied, exhibit means over the corresponding mid-parental values (Figs.7 and 10). Out of this, three in the case of number of seeds per pod and five in the case of 100-seed weight are found to surpass the respective better parents as well.

Seed size is determined by length, breadth and thickness of individual seed. Results of the present study have indicated clear expression of heterosis in the case of 11 in seed length, 12 in seed breadth and nine in seed thickness out of the 16 hybrids studied, since they have exhibited values over the mean of their respective parents (Figures 11, 12, 13 and Plate 7). Again out of this eight in seed length, five in seed breadth and seven in seed thickness have surpassed the values of their corresponding better parents as well.

FIG: 7. BEHAVIOUR OF PARENTS AND F_1'S FOR NUMBER OF SEEDS PER POD

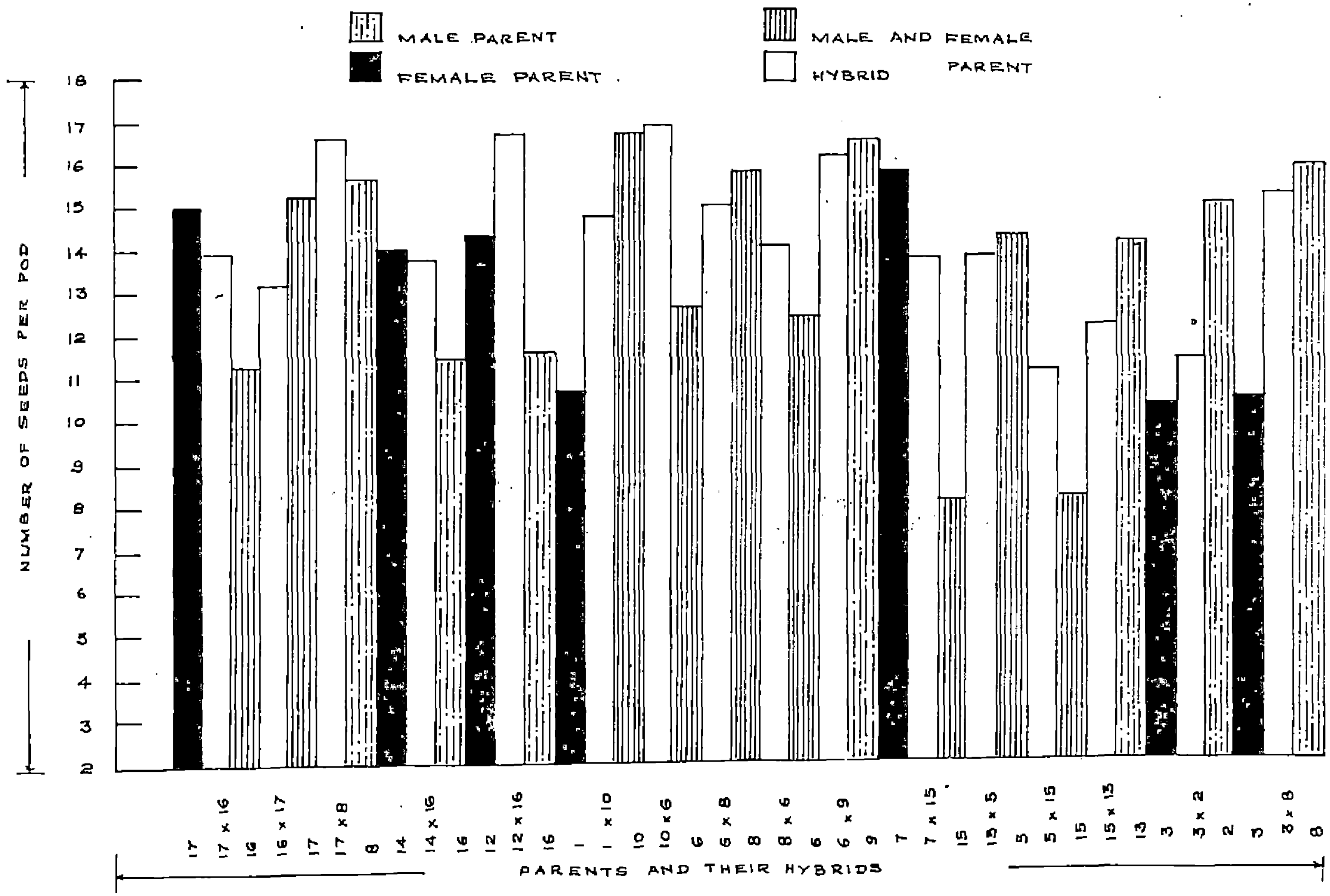


FIG: 10 BEHAVIOUR OF PARENTS AND F_1'S FOR 100-SEED WEIGHT

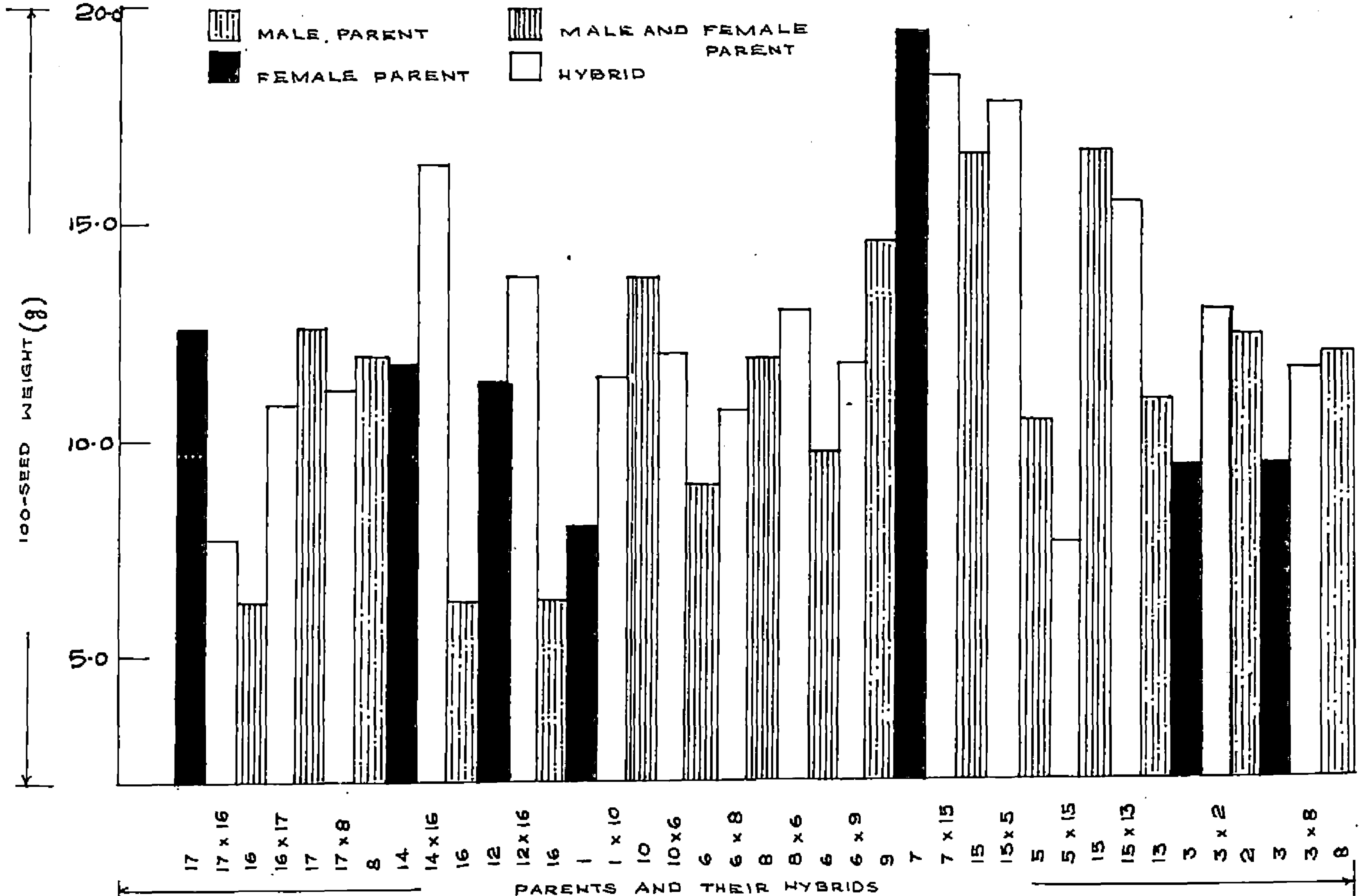


FIG: 11. BEHAVIOUR OF PARENTS AND F1'S FOR SEED LENGTH

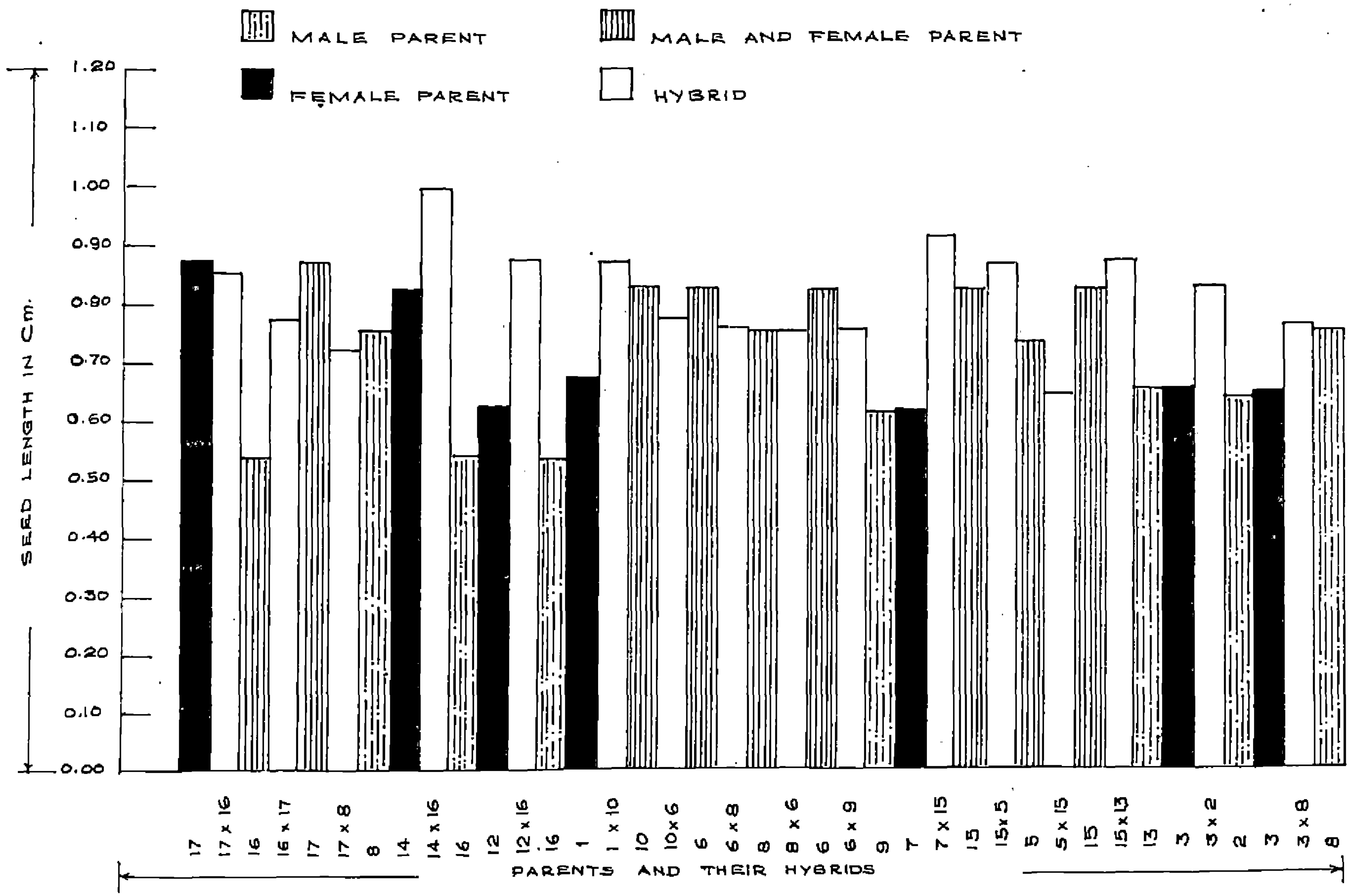


FIG: 12. BEHAVIOUR OF PARENTS AND F_1'S FOR SEED THICKNESS

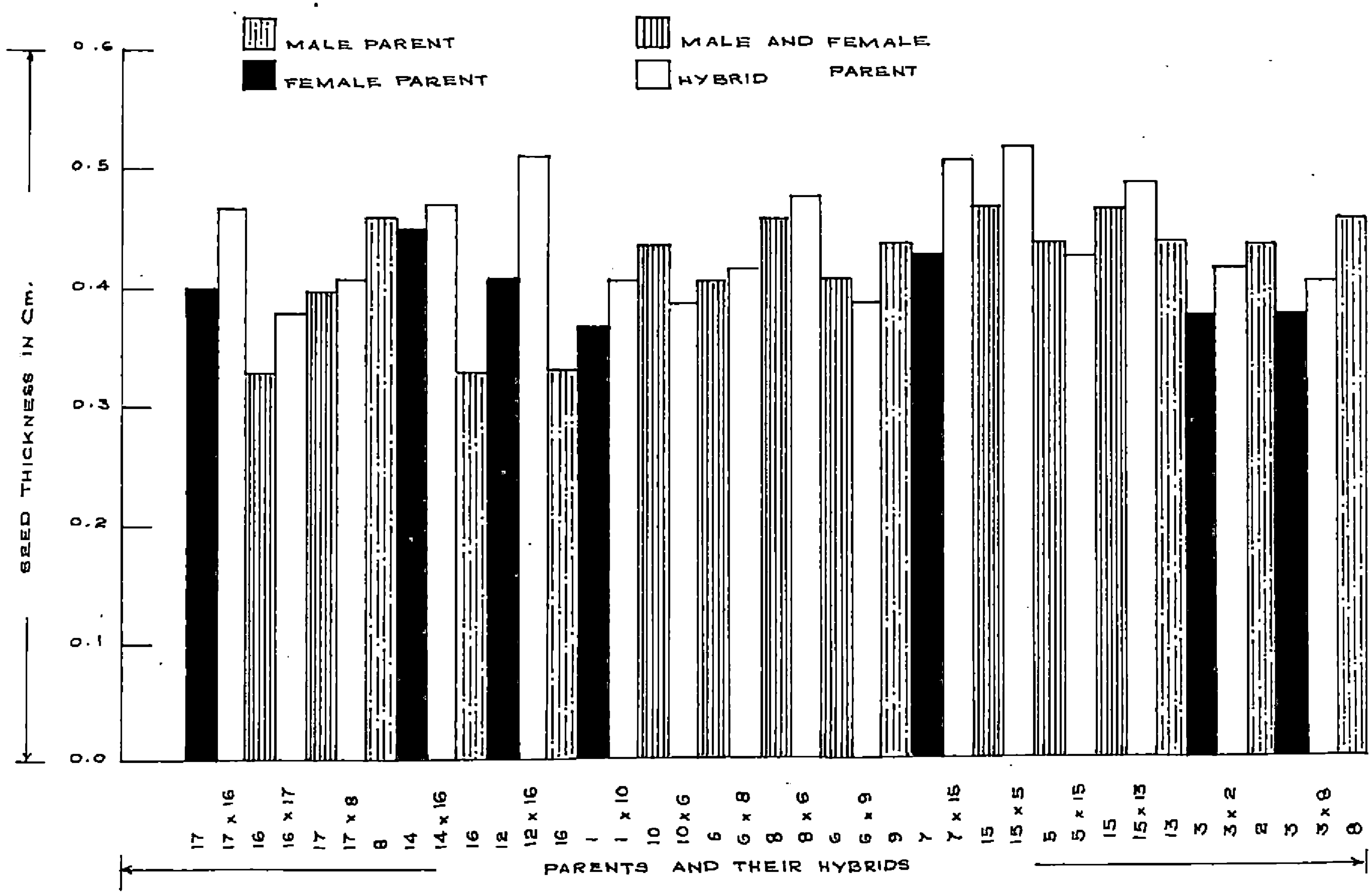
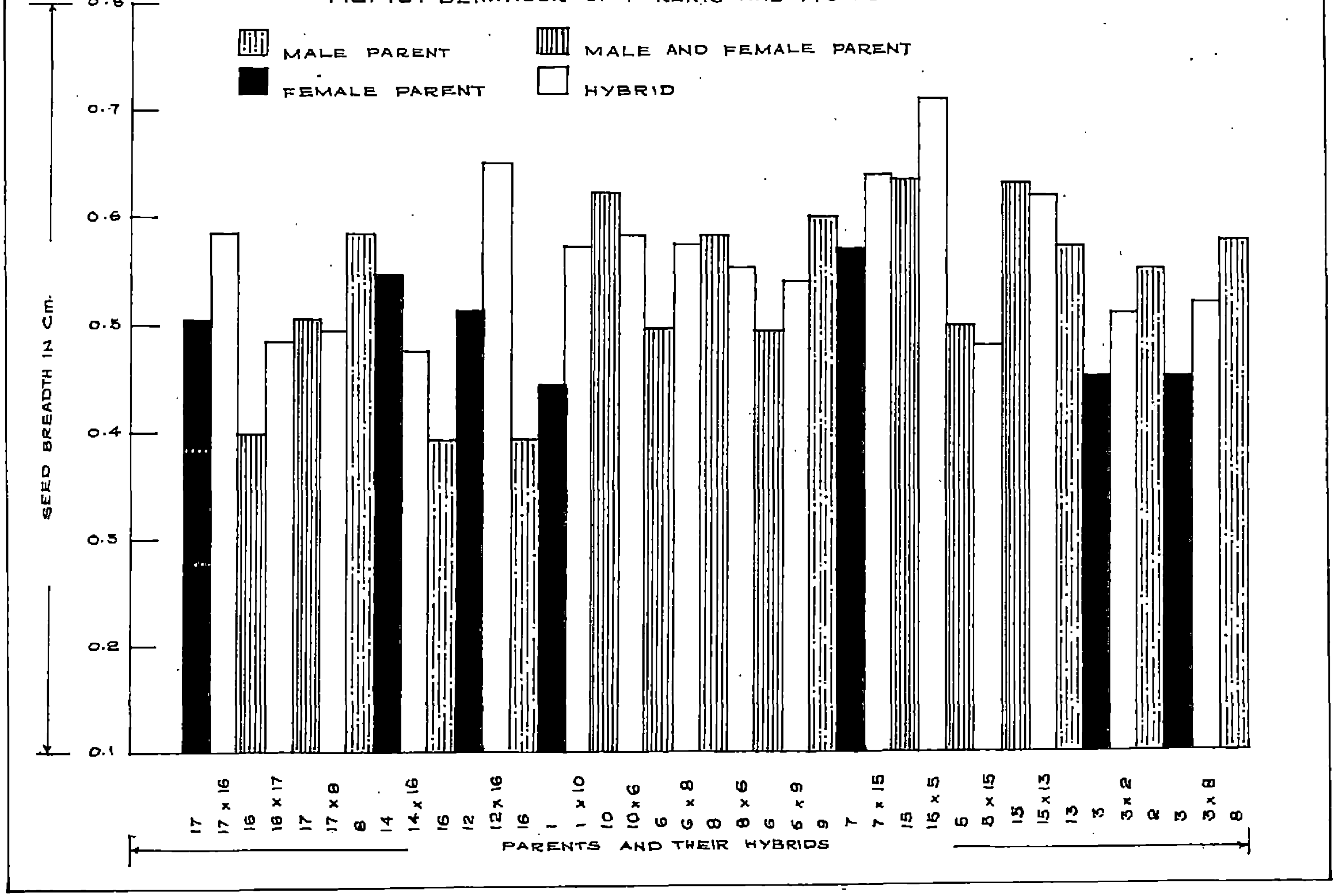


FIG: 13. BEHAVIOUR OF PARENTS AND F1'S FOR SEED BREADTH



Hybrid vigour is the general vegetative luxuriance, increased size, yield etc., observed in the F_1 of certain crosses as compared to the parents. According to Shull (1938) "heterosis is recognised as a result of the interaction of unlike gametes". Thus it is to be pressumed that depending upon the extent of dissimilarity between the uniting gametes there can be varying degrees of the expression of vigour. In otherwords the more the dissimilarity between the uniting gametes, the greater will be the vigour in the resulting hybrids. It is reasonable for one to expect that the gametes contributed by genetically wider parents will be much more dissimilar as compared to those contributed by genetically closer parents.

This normal expectation is not supported by the present observation. The results of the present investigation indicate that the hybrids of the parents of high, medium and law genetic distances are equally heterotic or vice versa in the expression of 16 characterestics studied here. For example in the expression of plant height, the four F_1's which have surpassed their corresponding better parents have been derived from crosses of parents having genetic distances of 18.9, 23.1, 32,6 and 55.9. The three F_1 hybrids which have exhibited values below that of the corresponding dwarf parents have been derived from crosses of parents having a genetic distance of 50.0, 50.0 and 36.7. This holds good with reference to the expression of the rest of the traits as well. Thus the widely accepted idea that the wider the parents, the greater will be the expression of heterosis, cannot be regarded as universally true based on the results of the present investigation.

Summary

SUMMARY

The investigations reported herein were undertaken in the Department of Agricultural Botany, College of Horticulture, Vellanikkara during the years 1978-80. Based on a previous study conducted in the department on the genetic divergence in cowpea, 15 varieties belonging to 15 clusters were selected. Intervarietal crosses were effected in 16 combinations between the selected varieties and the hybrids were compared with their respective parents for the expression of 16 economic characters and the following conclusions were drawn.

In plant height 25 per cent of hybrids were taller than the tall parent; 18.75 per cent of the hybrids - shorter than the short parent and the rest of the hybrids were in between the parental limits.

In the case of number of branches 37.5 per cent of the hybrids produced increased number of branches than the corresponding better parent, while, 31.25 per cent of the hybrids were in between the two parental limits.

Half of the total number of hybrids studied flowered earlier than the early parent while, in 31.25 per cent of them, commencement of flowering was within the two parental limits.

In 6.25 per cent of the hybrids flowering completed quickly and consequently they had short flowering spread. About 70 per cent of the hybrids were in between the parental limits with reference to completion of flowering and also flowering spread, while, the rest of the hybrids completed flowering later than the late parent and hence had wide flowering spread.

In case of pod yield, 50 per cent of the hybrids surpassed the better parent, while, 37.5 per cent were in between the parental limits.

In case of seed yield 43.75 per cent of the hybrids out-yielded the better parent, while, 50 per cent of them remained within the parental limits.

Components of yield viz., number of flowers per plant, number of pods per plant, length and weight of pod, number of seeds per pod, length, breadth and thickness of individual seed and 100-seed weight, expressed varying degrees of heterosis in the crosses studied.

References

REFERENCES

Acs, A. (1964). Investigation on the heterosis effect in pea.
Plant breeding Abstracts 34: 3210.

Barber, H.N. and Paton, D.M. (1952). A gene-controlled flowering inhibition in Pisum.
Nature, Lond. 1952. 169: 592.

Bhatnagar, P.S. and Balaram Singh (1964). Heterosis in mung bean.
Ind. J. Genet., 24: 89 - 91.

Bliss, F.A. (1971). Inheritance of growth habit and time of flowering in beans, Phaseolus vulgaris(L.).
J. Amer. Soc. Hort. Sci. 96(6): 715-717.

Bordia, P.C., Yadevendra, J.P. and Sudhirkumar, (1973). Genetic variability and correlation studies in cowpea (Vigna sinensis (L.) Savi.).
Rajasthan J. Agric. Sci. (1973) 4 : 1: 39-44.

Brittingham, W.T. (1950). The inheritance of date of pod maturity, pod length, seed shape and seed size in the southern pea, Vigna sinensis.
Proc. Amer. Soc. Hort. Sci. 56: 381-88.

*Bruter, D.P. (1965). Interspecific hybrids of the cowpea (Vigna) and prospects for their use in Maladavia.
Bul. Akad. Stii. RSS Moldov (Bull. Acad. Sci. Moldar. SSR) 1965: No.9: 89-94; from Ref. Z (Ref. J.) 1966: Abst. 7. 55.112 (Russian) P.B.A. 39 : 4 : 7898.

Capinpin, J.M. and Irabagon, T.A. (1950). A genetic study of pod and seed characters in Vigna.
Philipp. Agric. 1950: 33: 263-77.

*Colins, S. (1967). Heterosis in Phaseolus lunatus L.(Lima bean
Agric. tec. Mex. 1967: 2: 291-98.
P.B.A. 39: 3: 5870.

Davis, D.W. and Frazier, W.A. (1966). Inheritance of some growth habit components in certain types of bush lines of Phaseolus vulgaris, (L.). Proc. Amer. Soc. Hort. Sci. 88: 384-92.

Dhaliwal, H.S. and Singh, K.B. (1970). Combining ability and inheritance of pod and cluster number in Phaseolus. Theor. appl. Genet. 40: 117-20.

Domingo, W.E. (1945). Inheritance of number of seeds per pod and leaflet shape in soybean. J. Agric. Res. 70: 251-68.

Empig, L.T., Lantican, R.M. and Escuro, P.B. (1970). Heritability estimates of quantitative characters in mung bean, (Phaseolus aureus Roxb.). Crop. Sci. 10: 240-41.

*Hamad, I.A. (1976). Inheritance of yield, yield components, number of days to flowering, plant height and incidence of interlocular cavitation of pods in snap beans (Phaseolus vulgaris L.). Diss. Abstr. (1976): 36: 8: 3701B-3702B. P.B.A. 47:12: 12183.

*Hays and Gurber (1927). Thesis submitted by Kuruvila Thomas (1972) and approved for M.Sc. (Ag.) Degree of Kerala Agricultural University.

*Hilpert, M.M. (1949). Genetic studies in Phaseolus vulgaris. Summ. Ph.D. Thes. Univ. 1949: 3: 19-20. P.B.A. 20(2): ~~1986~~. 1950

Hofmann, F.W. (1962). Hybrid vigour in cowpea. J. Heredity 17: 209-211.

*Ibarbia, (1968). Inheritance of pod number pernode and other characters affecting yield of peas, Pisum sativum L. Diss. Abstr. 1968: 28: Order No.67-15, 748: 21991B-200DB. P.B.A. 39: 3856.

*Johnson, K.W. (1957). Inheritance studies in peas, *Pisum sativum* L.
Diss. Abstr. 1957: 17: Publ. No.22, 369: 1862. P.B.A. 28: 3 : 3530.

*Kalinov, B. (1968). A study of the inheritance of plant height and growth period in peas.
Genet. and *Pl. Breed.*, Sofia, 1968: No.4: 295-310. P.B.A. 39: 5909.

*Kolot, V.N. (1968). Some problems of inheritance of characters and in F_1 generation soybean hybrids in irrigated conditions in S. Ukraine.
Irrig. Agric. Interden. Sci. Rec. 1968: 3: 83-87. P.B.A. 40: 1: 1992.

Krarup, A. and Davis, D.W. (1970). Genetic control of ovule number in peas, (*Pisum sativum* L.).
Crop. Sci. 10: 517-518.

*Lamprecht, H. (1954). Further studies on inheritance of pod width in *Pisum*. *Agric. Hort. Genet. Landskrona* 1954: 12: 202-210. P.B.A. 25: 4: 2532.

*Malinowski, E. (1955). Hybrid vigour in *Phaseolus* and *Petunia*.
Bull. Acad. Polon. Sci. 1955 cl. 11: 3: 181-88. P.B.A. 26: 1: 1955.

Menezes, O.B. (1956). Genetics and improvement of the peigion pea, (*C. indicus Spreng.*).
Ceres. Minas Gerais 1956. 10: No.55: 20-44.

*Norton, J.D. (1961). Inheritance of growth habit and flowering response of southern pea, *Vigna sinensis*.
Diss. Abstr. 1961: 22: Order No.Mil. 61-2126: 36, (Abst.). P.B.A.32: 3: 4082.

Ojomo, O.A. (1971). Inheritance of flowering date in cowpeas (*Vigna unguiculata* (L.) Walp.
Trop. Agric. 1971: 48: 279-282.

*Oliver,(1910). Thesis submitted by Kuruvila Thomas (1972) and approved for M.Sc.(Ag.) Degree of Kerala Agricultural University.

Ortega Ybarra, S. (1968). Contribution to the study of heritability of growth habit in Ph. vulgaris L.
Agron. Trop. Venezuela 1968: 18: 87-115.

Patil, J.A. and D'Cruz, R. (1964). Inheritance of seed size in gram, Cicer arietinum.
Poona Agric. Coll. Mag. 1964: 54: Nos. 3 & 4: 21-22.

Patil, J.A. (1959). Inheritance a study in gram.
Curr. Sci. 1959. 28: 508.

Prem Sagar and Chandra, S. (1979). Heterosis and combining ability in Urd bean.
Ind. J. Genet. 37: 3: 420-424.

Premsekar, S. (1967). Studies on interspecific hybrids in Vigna (V. sesquipedalis (L.) Fruw. X V. sinensis (L.) Savi.) and their derivatives.
Dissertation approved for M.Sc. (Ag.) Degree of TNAU.

*Putincev, A.F. (1966). Variation of the period from germination to flowering on crossing peas.
P.B.A. 36: 4: 7212.

Rawal, K.M., Rachie, K.O. and Franckowiak, J.P. (1976). Reduction in size of the seed in crosses between wild and cultivated species of cowpeas.
Journal of Heredity (1976) 67: 4: 253-254.

Roy, R.S. and Richharia, R.H. (1948). Breeding and inheritance studies in cowpea - Vigna sinensis.
J. Amer. Soc. Agron. 40: 479-89.

*Sakurov, V.Z. (1952). Increasing the vitality of pea varieties Selekcija i Semenovodstvo (Breeding and Seed growing) 1952. No.7. 43-49 (Russian).
P.B.A. 23: 3 : 1053.

Sen, N.K. and Murthy, A.S.N. (1960). Inheritance of seed weight in green gram (Phaseolus aureus Roxb.).
Genetics 45: 1559-62.

* Shull, A.F. (1938). Heredity. Mc. Graw Hill Book Co., Ltd., New York. Cytogenetics and Plant Breeding P.V. Varadhachari & Co., Madras p. 351.

Singh, K.B. and Jain, R.P. (1971). Combining ability for pod length and seed size in mung bean.
Ind. J. Genet. 1971: 31: 1 : 145-148.

Singh, K.B. and Jindla, L.N. (1971). Inheritance of bud and pod colour, pod attachment and growth habit in cowpea.
Crop Science. 11: 6: 928-929.

Singh, K.B. and Jain, R.P. (1969). Heterosis of mungbean.
Ind. J. Genet. 1969: 29: 251-260.

Singh, K.B. and Dhaliwal, H.S. (1971). Combining ability and genetic of days to 50% flowering in blackgram (Phaseolus mungo Roxb.).
Ind. J. Agrl. Sciences 1971: 41: 8: 719-723.

Singh, K.B. and Jain, R.P. (1971). Combining ability for pod length and seed size in mungbean.
Ind. J. Genet. 1971: 31: 1 : 145-148.

Singh, K.B. and Jain, R.P. (1970). Heterosis in mungbean.
Ind. J. Genet. 1970: 30: 1 : 251-260.

Singh, K.B. and Jain, R.P. (1971). Analysis of diallel cross in Phaseolus aureus Roxb.
Theoretical and Applied Genetics (1971) 41: 6 : 279-281.

Singh, T.P. and Singh, K.B. (1970). Heterosis in field pea.
Ind. J. Genet. 1920. 30: 3: 619-624.

Solomen, S., Argkar, G.P., Salanki, M.S. and Morbad, I.R.(1957). A study of heterosis in Cajanus Cajan (L.).
Ind. J. Genet. 1957: 17: 1 : 90-95.

*Strohm, J.L. (1966). The inheritance of height, maturity, seed weight and yield and their association in four soybean crosses. Diss. Abstr. Ser. B. 1966: 27 : Order No.66-12, 248: 1738-39 (Abst.). P.B.A. 38: 1: 1647.

*Suzuki, A. (1957). On breeding a dwarf cowpea. Nippon. Agric. Res. Inst. 1957. No.8: 53-58 (Japanese).P.B.A. 28: 4 : 4873.

*Tika, S.B., Sharma, R.K. and Mathu, J.R. (1976). Genetic analysis of flower initiation in cowpea (Vigna unguiculata) (L.) Walp.). Zeitschrift fur Pflanzenzuchtung (1976) 77 : 1 : 23-29 (En, de, 6 ref) Cotton Res. P.B.A. 47: 3: 3829.

*Voysest, V.O. (1972). The effect of heterosis on yield and its primary components in French bean, Phaseolus vulgaris L. Investigaciones Agropecuarias (1972) 3 : 1: 10-16. P.B.A. 44: 2 : 9131.

Wester, R.E. and Jorgensen, H. (1951). Hybrid vigour in Lima beans. Proc. Amer. Soc. Horti. Sci. 1951 : 57 : 305-309. P.B.A. 22 : 1 : 1546.

Zafar, A.M. and Khan, M.A. (1968). Genetic studies in gram (Cicer arietinum L.). Comparative studies on gram hybrids and their parents. W. Pak. J. Agric. Res. 1968. 6. No.3.

* Originals not seen.

APPENDIX

Appendix I. Abstract of the thesis.

STUDIES ON INTERVARIETAL HYBRIDS IN COWPEA

BY

K. A. INASI

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the
Requirements for the degree of
MASTER OF SCIENCE IN AGRICULTURE
Faculty of Agriculture
Kerala Agricultural University

Department of Agricultural Botany
College of Horticulture
VELLANIKKARA :: TRICHUR
1980

ABSTRACT

Among the green vegetables cultivated in Kerala, cowpea (Vigna unguiculata L.) occupies about 70 per cent of the total area. At present cowpea cultivation in the state is showing a declining trend due to the low productivity of the available local varieties. The highly contrasting systems of cultivation of cowpea in the various parts and in different seasons in the State compels cowpea breeders to evolve varieties of different combinations of plant, pod and seed characters. This is possible by combining of desirable characteristics found distributed in different varieties, through hybridisation followed by selection.

Before taking up this programme, 56-varieties of cowpea were subjected to genetic studies and were grouped into 17-clusters. Representing 15-clusters, 15-varieties were chosen for the intervarietal hybridisation programme.

Sixteen intervarietal hybrids were produced and were evaluated in comparison with their respective parents for the expression of 15 economic characters. Varying degrees of hybrid vigour could be noticed for all the 16 characters studied.

Hybrid 15 x 5, which was derived from a cross between P.118 and GP. PLS. 139, could be adjudged as the best among the 16 hybrids. Maximum heterosis of 430.36 per cent was shown by the hybrid 15 x 13 (P.118 x C.152 x N.E. - I) for pod yield per plant.

Based on the results, eight hybrids were found to be superior to the rest in respect of over all performance. An interesting fact noticedwas that heterosis could be observed to the same extent in hybrids of both genetically related and unrelated parents.

Appendix II. Abstract of ANOVA.

ABSTRACT OF ANOVA

Sl. No.	Character	Source	df	SS	MS
1	Plant height	Cultivars	30	71.95	2.39**
		Parents (P)	14	29.88	2.13**
		Hybrids (H)	15	41.96	2.79**
		H vs P	1	0.11	0.11NS
2	Number of branches	Cultivars	30	1588.81	50.69**
		Parents (P)	14	1105.61	78.97**
		Hybrids (H)	15	482.58	32.17*
		H vs P	1	0.62	0.62NS
3	Flowering commencement	Cultivars	30	7510.99	250.37**
		Parents (P)	14	6583.22	470.23**
		Hybrids (H)	15	910.18	60.68*
		H vs P	1	17.59	17.59*
4	Flowering completion	Cultivars	30	9534.90	317.83**
		Parents (P)	14	7704.76	550.34**
		Hybrids (H)	15	1775.51	118.37*
		H vs P	1	54.63	54.63**
5	Flowering spread	Cultivars	30	1733.90	57.79**
		Parents (P)	14	1617.47	115.53***
		Hybrids (H)	15	116.43	7.76**
		H vs P	1	0	0 NS
6	Number of flowers per plant	Cultivars	30	247793.52	8259.78**
		Parents (P)	14	109606.91	7829.07**
		Hybrids (H)	15	104444.96	6962.99**
		H vs P	1	33741.65	33741.65**
7	Number of pods per plant	Cultivars	30	83680.94	2789.36**
		Parents (P)	14	51697.41	3692.67**
		Hybrids (H)	15	25595.30	1706.35*
		H vs P	1	6388.23	6388.23**
8	Pod length	Cultivars	30	3305.09	110.16**
		Parents (P)	14	2187.96	156.28**
		Hybrids (H)	15	695.56	46.37**
		H vs P	1	421.57	421.57**

Anova contd...

Sl. No.	Character	Source	df	SS	MS
9	Pod weight	Cultivars	30	148.17	4.94**
		Parents (P)	14	112.90	8.06**
		Hybrids (H)	15	33.34	2.22**
		H vs P	1	1.93	1.93*
10	Seeds per pod	Cultivars	30	1221.46	40.72**
		Parents (P)	14	1123.19	80.23**
		Hybrids (H)	15	33.00	2.20NS
		H vs P	1	65.27	65.27**
11	100-seed weight	Cultivars	30	3601.03	120.03**
		Parents (P)	14	2454.31	175.31**
		Hybrids (H)	15	1130.96	75.40**
		H vs P	1	15.76	15.76*
12	Seed length	Cultivars	30	3.82	0.127**
		Parents (P)	14	2.02	0.144**
		Hybriss(H)	15	0.86	0.06**
		H vs P	1	0.94	0.94**
13	Seed breadth	Cultivars	30	1.72	0.057*
		Parents (P)	14	0.94	0.067*
		Hybrids (H)	15	0.63	0.042*
		H vs P	1	0.15	0.15**
14	Seed thickness	Cultivars	30	35.34	1.178
		Parents (P)	14	0.29	0.031[illegible]
		Hybrids (H)	15	0.46	0.021[illegible]
		H vs P		34.59	34.59*[illegible]
15	Seed yield per plant	Cultivars	30	109725.45	3657.52*
		Parents (P)	14	83327.82	5951.99*
		Hybrids (H)	15	12287.11	819.14*
		H vs P	1	4110.52	14110.52*
		Cultivars	30	2 1178.83	6695.96**
		Parents (P)	14	7 4.56	7598.18*
		Hybrids (H)	15	22 .14	4781.60*
		H vs P	1	13	22780.13*

Appendix III. Plates.

PLATE 1. Photograph showing the length of pod of parents and F_1 of the cross cluster 1 x cluster 10.

PLATE 2. Photograph showing the length of pod of parents and F_1 of the cross cluster 14 x cluster 16.


CLUSTER 1
HYBRID
CLUSTER 10

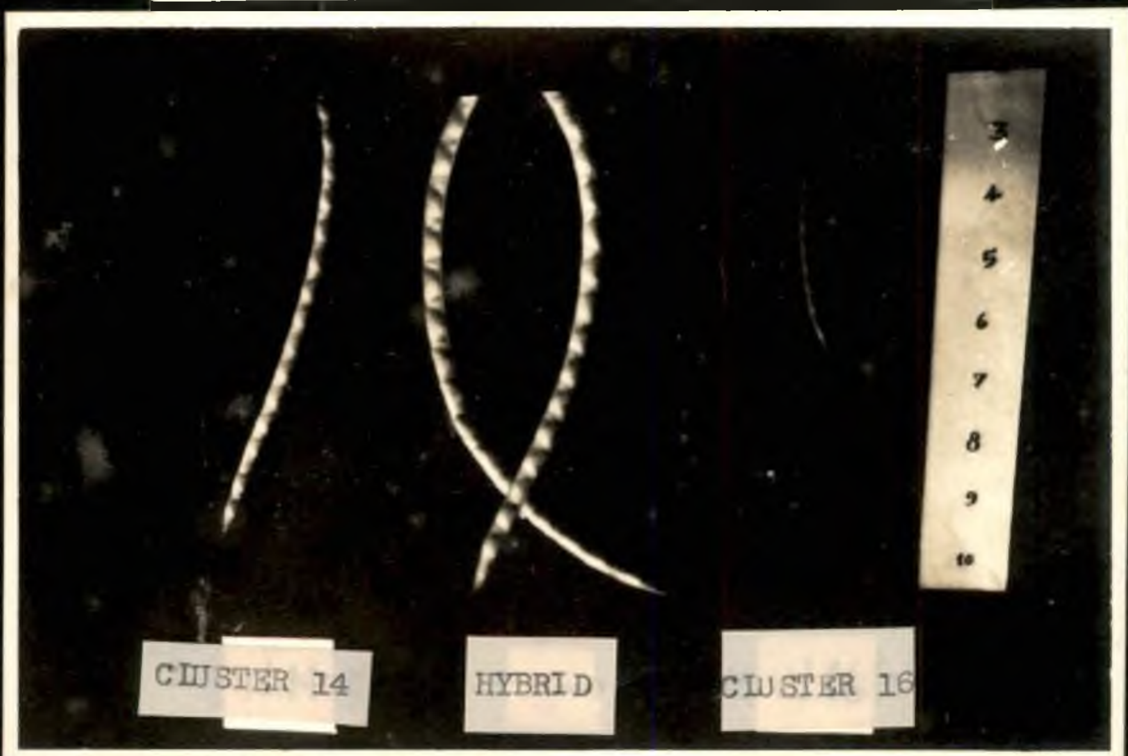
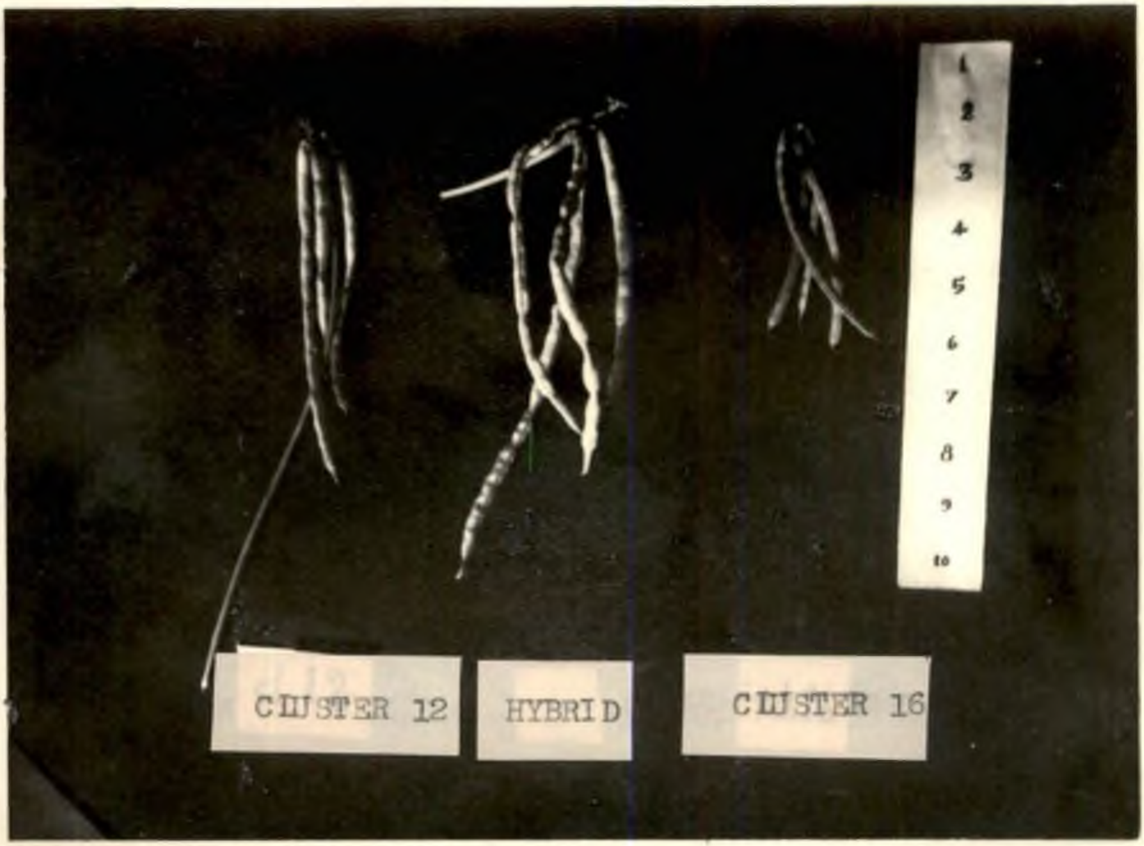

3
4
5
6
7
8
9
10
CLUSTER 14
HYBRID
CLUSTER 16

PLATE 3. Photograph showing the length of pod of parents and F_1 of the cross cluster 12 x cluster 16.

PLATE 4. Photograph showing the length of pod of parents and F_1 of the cross cluster 6 x cluster 8.


1
2
3
4
5
6
7
8
9
10
CLUSTER 12
HYBRID
CLUSTER 16

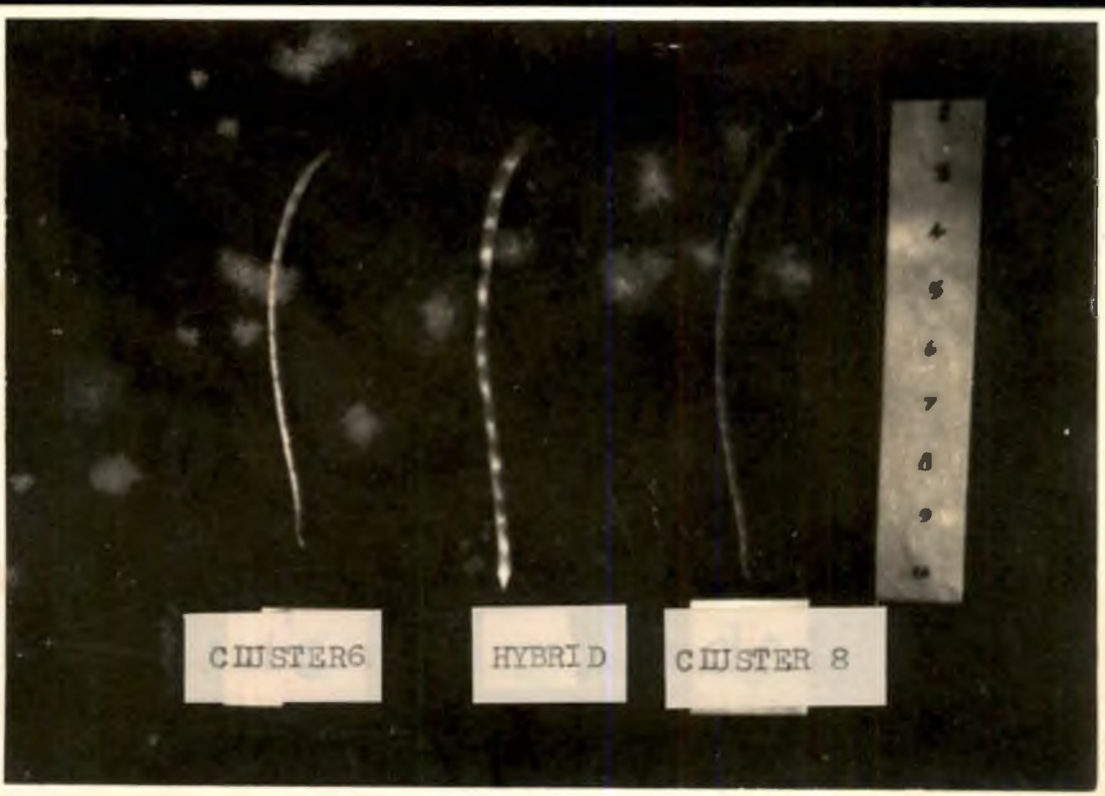
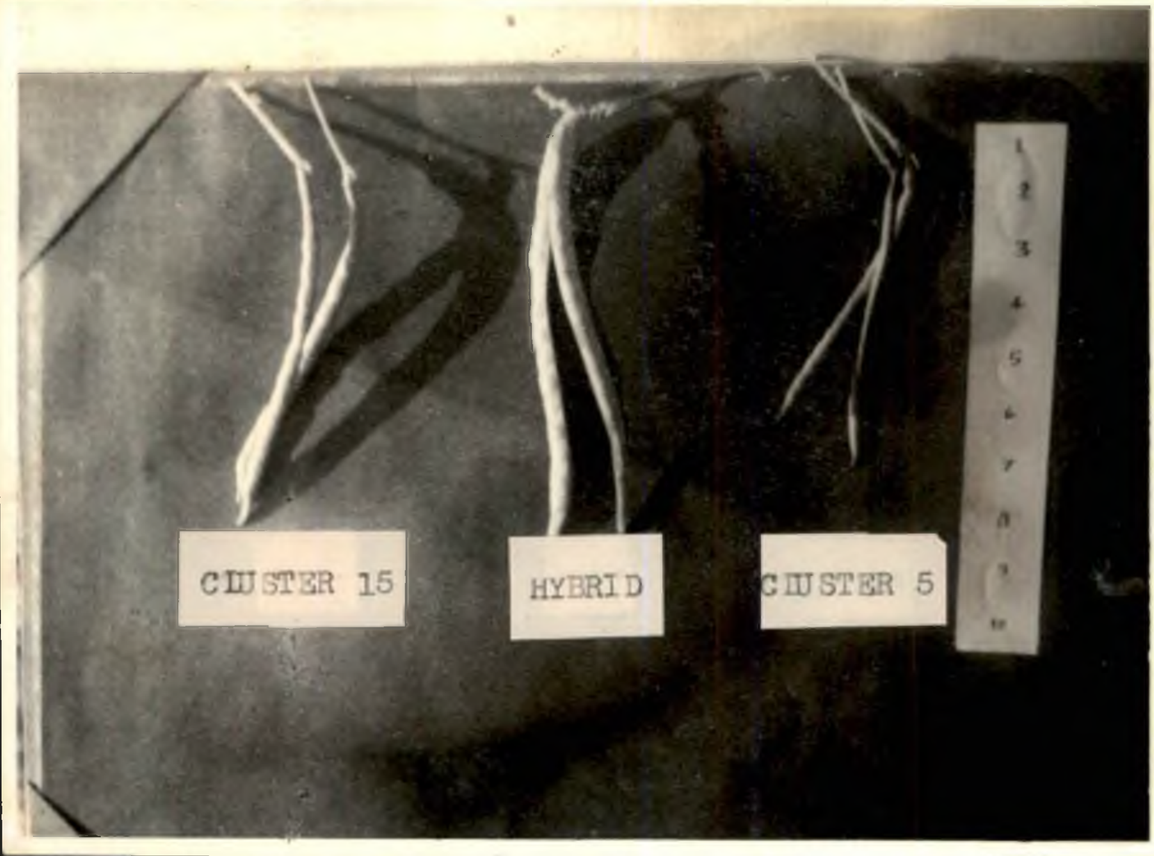

CLUSTER6
HYBRID
CLUSTER 8

PLATE 5. Photograph showing the length of pod of parents and F_1 of the cross cluster 15 x cluster 5.

PLATE 6. Photograph showing the length of pod of parents and F_1 of the cross cluster 5 x cluster 15.


CLUSTER 15
HYBRID
CLUSTER 5

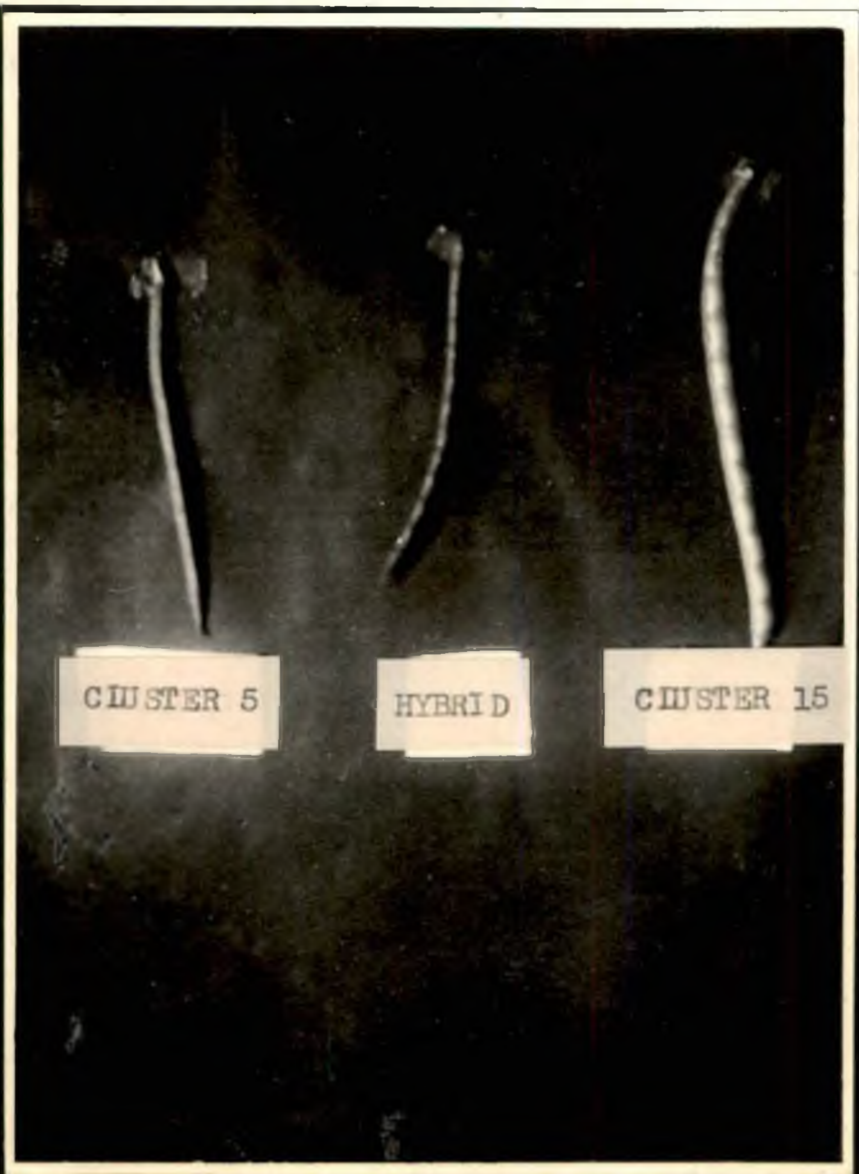

CLUSTER 5
HYBRID
CLUSTER 15

PLATE 7. Photograph showing seed size of parents and F_1's of the crosses cluster 1 x cluster 10 and cluster 14 x cluster 16.


CLUSTER 1
HYBRID
CLUSTER 10
CLUSTER 14
HYBRID
CLUSTER 16