COMBINING ABILITY, GENE ACTION AND HETEROSIS IN SESAME

BY

ELIZABETH GEORGE

THESIS
submitted in partial fulfilment of the requirement
for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture
Kerala Agricultural University

Department of Plant Breeding
COLLEGE OF AGRICULTURE
Vellayani, Trivandrum

1989

DECLARATION

I hereby declare that this thesis entitled "Combinining ability, gene action and heterosis in sesame" 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.

Vellayani,
18.09.1988

Elizabeth George
ELIZABETH GEORGE

CERTIFICATE

Certified that this thesis entitled "Combining ability, gene action and heterosis in sesame" is a record of research work done independently by Smt. ELIZABETH GEORGE, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Dr. SVERUP JOHN
Chairman
Advisory Committee
Assistant Professor
Department of Plant Breeding
College of Agriculture.

Vellayani,
18.09.1988

Approved by:

Chairman:

Dr. SVERUP JOHN

Members:

1. Dr. V. GOPINATHAN NAIR
2. Dr. (Mrs.) P. SARASWATHY
3. Shri. C. NANDAKUMAR

External Examiner:

(S. THANGAVELU)

ACKNOWLEDGEMENT

I wish to place on record my great indebtedness to Dr. Sverup John, Assistant Professor of the Department of Plant Breeding and the Chairman of my Advisory Committee for suggesting the research programme, constant guidance, helpful suggestions, constructive criticisms, inspiration and encouragement throughout the course of this investigation and also in the preparation of this thesis.

I owe deep sense of gratitude to the members of the Advisory Committee Dr. V. Gopinathan Nair, Professor and Head of the Department of Plant Breeding, Dr. (Mrs.) P. Saraswathy, Associate Professor of the Department of Statistics and Shri C. Nandakumar, Assistant Professor of the Department of Entomology for their sincere help, ueful suggestions, and constant encouragement rendered during the endeavour.

The whole-hearted cooperation and assistance of the staff and students of the Department of Plant Breeding are gratefully acknowledged. My sincere thanks are also due to the Kerala Agricultural University for awarding me a fellowship for my post graduate programme. I also wish to place on record my gratitude to my husband, Shri Thomas P. Mathew for the help extended during the course of this work.

Elizabeth George

ELIZABETH GEORGE

C O N T E N T S

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

INTRODUCTION

The production of food, to be consumed either as grain or oil, is the problem of major concern throughout all of South and South East Asia. With the rapidly expanding populations in this area of the world, the food supply, already grossly inadequate, needs to be expanded greatly in the years ahead. While increases in productivity have been quite spectacular in respect of crops like paddy and wheat, no such breakthrough has been discernible in oil seeds and pulses. The gap between indigenous production of edible oils and its demand is continuously increasing. As against the import of 27000 tonnes of edible oil worth of Rupees 15 crores in 1975-'76, the import during 1983-'84 shot up to 16.34 lakh tonnes valued at about Rupees 1319 crores. It marks a whopping eighty fold increase in the import bill of edible oils in a period of just eight years. The National Oilseeds Development Project (NODP) is being implemented in 180 selected districts which have been identified after taking into account their contribution to oilseeds production as well as the potential for future development. The NODP is to be given highest priority as it is a key programme aimed at achieving self sufficiency in the production of oilseeds. It is also a part of the twenty point programme and is also the main programme of the Oil Technology Mission set up recently by the Government of India.

One of the main approaches adopted to boost oil production has been the improvement programmes of oil seed crops, especially annuals. In this context, groundnut (*Arachis hypogeae*) has received considerable impetus for development. Notable work is currently being carried out in linseed (*Linum usitatissimum*), rape and mustard (*Brassica* sp.), sesame (*Sesamum indicum*) and castor (*Ricinus communis*). Of these, sesame is the most important annual oilseed crop as far as Kerala is concerned.

Sesame, also called 'til' or 'gingelly' is one of the oldest cultivated oilseed crop and finds mention in the Rig and Yajur Vedic Scriptures. The origin of sesame is variously reported from Southern Africa to Central Asia, but the diversity of wild species growing in Africa, would tend to favour its origin in that location. India is the world's major producer of sesame with a third of the world's acreage and approximately a quarter of total global production. In India, sesame is cultivated in about 22.42 lakh hectares with an annual production of about 4.93 lakh tonnes, with Rajasthan standing first. In Kerala, sesame occupies an area of 0.144 lakh hectares with an annual production of 0.035 lakh tonnes, of which the maximum contribution is from Alleppey district (Anon, 1987).

Sesame belongs to the genus Sesamum of the Pedaliaceae family. More than thirty six species have been described in the genus Sesamum. In addition to the cultivated sesame, Sesamum indicum, two wild species viz. Sesamum prostratum and Sesamum laciniatum are also found in India. Morinaga et al. (1929) first reported the chromosome number of cultivated sesame as 2n=26. Sesame seeds are very nutritive containing upto 60% oil and 19.3% protein, with an exceptionally high amount of Methionine (3.4%) (Dixit, 1978). It is rich in Calcium (about 1%), Phosphorus (0.7%) and lacks Vitamin A. The most useful property of sesame oil is its high stability because of the presence of powerful antioxidants which prevents rancidity. The antioxidant synergistic properties are provided by Sesamolin (0.3 to 0.5%) and Sesamin (0.5 to 1%) present in the oil (Yermanos et al., 1964; Nayar and Mehra, 1970).

The basic studies leading to plant improvement in sesame is meagre. The oilseed crops, from the breeding viewpoint are a heterogenous population, with different breeding and pollination mechanisms. Diallel crossing is an important mating system enjoying universal application in plant breeding. The present investigation was undertaken to study the combining ability, gene action and heterosis in sesame. A basic understanding of the genetic phenomena underlying the mode of inheritance of different characters and the sorting out of elite parents and superior combinations based on g.c.a and s.c.a effects will pave the foundation for launching any plant breeding programme.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

In India, the average productivity of sesame (Sesamum indicum L) is very low and while considering the genetic improvement for seed yield, combining ability and gene action for yield components must be understood. There is also scope for exploitation of hybrid vigour in this crop. The studies conducted by various workers in these fields in sesame are reviewed here.

2.1 Combining ability

Combining ability is the ability of a strain to produce superior progeny upon hybridisation with other strains. Information on the nature of general and specific combining ability with respect to parents and hybrids will facilitate the breeder to plan the breeding programme effectively.

Veena et al. (1983) and Rathnaswamy (1984) observed that variances due to g.c.a and s.c.a were significant for the character, plant height. Sharma and Chauhan (1985) in a set of 10 x 10 diallel, observed that in addition to significant g.c.a and s.c.a variances, reciprocal effects were also significant, but general combining ability was pronounced for this character. This is in line with the findings of Murty (1975), Kotecha and Yermanos (1978), Shrivas and Singh (1981), Gupta (1981) and Fatteh et al. (1982). On the contrary, Murty and Hashim (1974), Dora and Kamala (1987) and Krishnadoss et al. (1987) reported that specific combining ability was predominant for plant height.

For days to flower, Kotecha and Yermanos (1978) observed that the variances due to g.c.a, s.c.a and reciprocal effects were significant, but general combining ability was found to be predominant. Similar results were also obtained by Murty (1975), Veena et al. (1983) and Sharma and Chauhan (1985), whereas, specific combining ability was reported to be high by Murty and Hashim (1974), Godawat and Gupta (1985) and Dora and Kamala (1987).

Studies undertaken by Fatteh et al. (1982), Chaudhari et al. (1984) and Sharma and Chauhan (1985) revealed that general combining ability was higher for the character days to mature. On the contrary, Dora and Kamala (1987) reported predominant specific combining ability for this character.

With respect to number of branches per plant, both g.c.a and s.c.a variances were significant according to Rathnaswamy (1984). Sharma and Chauhan (1985) also reported significant g.c.a, s.c.a and reciprocal variances for this character, but general combining ability was found to be predominant. Similar results were also obtained by Murty

(1975) and Gupta (1981). On the contrary, specific combining ability was observed to be pronounced by Murty and Hashim (1974), Shrivas and Singh (1981), Fatteh et al. (1982), Veena et al. (1983) and Dora and Kamala (1987).

Significant variances for g.c.a and s.c.a were noticed by Veena et al. (1983) for capsule number per plant. Sharma and Chauhan (1985) observed that although the variances due to g.c.a, s.c.a and reciprocal effects were significant for this character, general combining ability was pronounced. The works of Kotecha and Yermanos (1978), Gupta (1981), Fatteh et al. (1982) and Rathnaswamy (1984) also revealed pronounced general combining ability for capsule number per plant, whereas, specific combining ability was reported to be predominant for this character by Murty and Hashim (1974), Shrivas and Singh (1981), Dora and Kamala (1987) and Krishnadoss et al. (1987).

Rathnaswamy (1984) observed that for length of the capsule, although the variances due to g.c.a and s.c.a were significant, general combining ability was predominant. This was in line with the results obtained by Kotecha and Yermanos (1978) and Fatteh et al. (1982). On the contrary, Dora and Kamala (1987) reported that specific combining ability was more important for this character.

Studies on combining ability in sesame by Fatteh et al. (1982) revealed that for number of seeds per capsule, general combining ability was predominant. But contradictory to this, Chavan et al. (1981), Veena et al. (1983), Chaudhari et al. (1984), Shivaprakash (1986) and Dora and Kamala (1987) reported that specific combining ability was pronounced for this character.

Combining ability studies by Veena et al. (1983) and Sharma and Chauhan (1985) revealed significant g.c.a and s.c.a variances but general combining ability was found to be predominant, for 1000 seed weight. Dixit (1978) in a five parental diallel also observed similar results and indicated that the variety Kanpur Local was the best general combiner for test weight and Kanpur Local x T 4 and Jhansi Local x Kanpur Local were the best combinations for this character. On the contrary, Murty (1975) and Dora and Kamala (1987) reported that specific combining ability was pronounced for 1000 seed weight.

Sharma and Chauhan (1985) reported that for the character oil content, the variances due to g.c.a, s.c.a and reciprocal effects were significant but general combining ability was predominant. The works of Murty (1975), Fatteh et al. (1982), Veena et al. (1983), Chaudhari et al. (1984) and Dora and Kamala (1987) revealed that specific combining ability was more important for this character.

The most important character, seed yield, according to Veena et al. (1983) was characterised by significance of both g.c.a and s.c.a variances, but general combining ability was reported to be predominant. The works of Kotecha and Yermanos (1978), Gupta (1981) and Rathnaswamy (1984) confirmed the importance of g.c.a for yield. On the contrary, specific combining ability was observed to be pronounced for this character, by the works of Murty (1975), Shrivas and Singh (1981), Sharma and Chauhan (1985), Krishnadoss et al. (1987) and Kumar and Sreerangaswamy (1987). Reddy et al. (1984) revealed that high F_1 performance for seed and oil yields were determined either by positive g.c.a of one or both the parents. A combination of positive g.c.a as well as s.c.a also determined high F_1 yield.

2.2. Gene action

The development of a plant breeding strategy hinges mainly on the support provided by genetic information on the inheritance and behaviour of major quantitative characters. Review of the studies on gene action in sesame is presented here, characterwise.

Plant height

Plant height was observed to be influenced by the action of additive gene effects (Murty, 1975; Kotecha and Yermanos, 1978; Fatteh et al., 1982; Veena et al., 1983; Rathnaswamy, 1984).

Chavan et al. (1981), Shrivas and Singh (1981), Chaudhari et al. (1984) and Dora and Kamala (1987) opined that non-additive gene effects controlled plant height. Similar results were also obtained by Sharma and Chauhan (1985); Godawat and Gupta (1985) and Shivaprakash (1986).

Days to flower

Diallel analysis by Murty and Hashim (1974) revealed that significant maternal effects occurred for days to flowering, along with partial dominance. Studies by Dixit (1976) indicated that both additive and non-additive gene effects were important for this character.

Additive gene effects were found to control days to flowering as shown by higher estimates of g.c.a (Murty, 1975; Fatteh et al., 1982; Chaudhari et al., 1984).

High s.c.a variance estimates indicated that this character was under the action of non-additive gene effects (Godawat and Gupta, 1985; Sharma and Chauhan, 1985). Dora and Kamala (1987) observed that additive X additive type of epistasis controlled this character.

Days to mature

Higher estimates of g.c.a variance than s.c.a variance for days to mature showed that it was under additive genic control (Fatteh et al., 1982; Chaudhari et al., 1984).

Studies by Sharma and Chauhan (1985) revealed that the inheritance of this character was predominantly governed by additive and additive X additive epistatic components of genetic variance, whereas, Dora and Kamala (1987) opined that this character was under non-additive genic control.

Number of branches per plant

In a complete diallel cross, Murty and Hashim (1974) showed that significant additive and dominance variance occurred for number of branches per plant.

Studies conducted by Murty (1975); Rathnaswamy (1984) and Chandramony and Nayar (1985) revealed that g.c.a variance was predominant for this character suggesting the importance of additive gene effects.

Non-additive gene effects were found to control the number of branches (Dixit, 1976; Shrivas and Singh, 1981;

Fatteh et al., 1982; Veena et al., 1983; Chaudhari et al., 1984; Sharma and Chauhan, 1985; Shivaprakash, 1986; Dora and Kamala, 1987).

Number of capsules per plant

Murty and Hashim (1974) observed that the character number of capsules per plant was conditioned by both additive and non-additive genetic variances.

Additive gene effects were found to control capsule number (Kotecha and Yermanos, 1978; Janardhanam et al., 1981; Fatteh et al., 1982; Veena et al., 1983; Rathnaswamy, 1984; Chandramony and Nayar, 1985).

Trials by Shrivas and Singh (1981), Chavan et al. (1981), Chaudhari et al. (1984), Godawat and Gupta (1985), Sharma and Chauhan (1985), Shivaprakash (1986) and Dora and Kamala (1987) observed the preponderance of non-additive gene effects in controlling capsule number.

Capsule length

The inheritance of capsule length was reported to be under additive genic control (Kotecha and Yermanos, 1978; Fatteh et al., 1982; Rathnaswamy, 1984). On the contrary, Dora and Kamala (1987) observed that non-additive gene effects were important for capsule length.

Number of seeds per capsule

Janardhanam et al. (1981) reported that both additive and non-additive gene effects governed the character seed number per capsule.

High g.c.a variance estimates obtained by Fatteh et al. (1982) for this character indicated that it was under additive genic control.

Trials by Veena et al. (1983), Chavan et al. (1981), Chaudhari et al. (1984), Shivaprakash (1986) and Dora and Kamala (1987) showed that non-additive gene effects were found to control number of seeds per capsule.

Weight of 1000 seeds

A higher magnitude of g.c.a variance showed the preponderance of additive gene effects governing 1000 seed weight (Dixit, 1976; Fatteh et al., 1982).

Combining ability analysis by Sharma and Chauhan (1985) revealed that the inheritance of 1000 seed weight was predominantly governed by additive and additive X additive epistatic components of genetic variance.

Veena et al. (1983), Chaudhari et al. (1984) and Dora and Kamala (1987) reported that non-additive gene effects exerted control over 1000 seed weight.

Oil content

Culp (1959) in studies on segregating progenies of a cross indicated that additive and non-additive gene effects were important. This was also shown by Sharma and Chauhan (1985) and Reddy et al. (1986).

Non-additive gene effects were found to be predominant for oil content inheritance (Murty, 1975; Fatteh et al., 1982; Veena et al., 1983; Chaudhari et al., 1984; Chandramoy and Nayar, 1985; Dora and Kamala, 1987).

Seed yield

This important character was observed to be influenced by both additive and non-additive gene effects (Dixit, 1976; Chavan et al., 1981; Sharme and Chauhan, 1985).

Combining ability studies by Fatteh et al. (1982) revealed a higher estimate of g.c.a than s.c.a variance for this character suggesting the predominance of additive gene effects.

Non-additive gene effects were found to be of importance in the control of yield (Murty, 1975; Kotecha and Yermanos, 1978; Shrivas and Singh, 1981; Veena et al., 1983; Chaudhari et al., 1984; Rathnaswamy, 1984; Godawat and Gupta, 1985; Reddy et al., 1986; Dora and Kamala, 1987).

2.3 Heterosis

Exploitation of hybrid vigour in economic crop plants is by far the most important application of the science of genetics to agriculture. Pal (1945) pioneered studies on heterosis for yield and other traits in sesame.

Plant height

Pal (1945) observed that there was no hybrid vigour with respect to height in most of the hybrids from different sesame crosses. Murty (1975) reported that for plant height, the overall heterosis percent was low and ranged from 4.69 to 8.81 percent. However, high degree of heterosis for this character was reported by Dixit (1976) and Tyagi and Singh (1981).

Heterosis determined as the amount by which the F_1 hybrid mean exceeded its higher parent was found to range from 23.20 to 12.50 percent (Kotecha and Yermanos, 1978); 6.57 percent (Shrivas and Singh, 1981); 7.4 percent (Chavan et al., 1982); 5.85 to 16.42 percent (Paramasivan et al., 1982) and 26.81 percent (Sharma and Chauhan, 1983).

Heterosis studies by Chaudhari et al. (1979) showed that none of the hybrids gave significant increase in height over their respective mid and better parental values. Only one hybrid showed heterosis to the extent of 25.61 percent over the mid-parent. The magnitude of heterosis over mid-parent was 9.26 percent (Shrivas and Singh, 1981) and ranged from 0.06 to 24.91 percent (Rathnaswamy, 1984).

Gupta (1980) reported the highest value of 10.79 percent heterosis in the cross Til Black X Shahabad, for this character.

<u>Days to flower</u>

Dixit (1976) studied heterosis in six F_1's developed from six strains of sesame and reported a high degree of heterosis for the character days to flower. Kotecha and Yermanos (1978) from an eight parent diallel cross, observed that heterosis over the mean of the superior parent ranged from -2.00 to 34.00 percent for this character.

Studies on heterosis in six hybrids of sesame by Srivastava and Prakash (1977) revealed that number of days to first flowering and duration of the flowering period was less than the parental average.

Sharma and Chauhan (1983) reported negative heterosis for days to flower, a desirable character upto the maximum of -19.63 percent in N.128 X SH 62.

<u>Days to mature</u>

The heterosis studies by Pal (1945) for the character number of days from sowing to maturity showed that no hybrid vigour was manifested by most of the hybrids from different sesame crosses studied. Sarafi (1976) compared the crosses between four Iranian and foreign varieties with the average of the parental traits and reported that one hybrid exhibited heterosis for late maturity.

Heterosis based on the mean of the higher parent was observed to range from -1.7 to 28.1 percent for this character (Kotecha et al., 1978).

Tyagi and Singh (1981) reported that the hybrids from crosses between a locally adapted sesame variety with intermediate and early maturing lines were early maturing.

Significant positive heterosis was observed in two crosses for days to mature by Chavan et al. (1982).

Number of branches per plant

Pal (1945) found no evidence of hybrid vigour for the character number of branches per plant in different sesame crosses. In a cross between two varieties, Srivastava and Singh (1968) reported that heterosis was displayed for this character. Murty (1975) found that for number of branches, the overall heterosis was low and ranged from 4.69 to 8.61 percent. However, Dixit (1976) opined that this character showed a high degree of heterosis.

Heterosis studies by Srivastava and Prakash (1977) revealed that the F_1 from 78/67 X Nagpur 128 had the highest heterosis for number of branches per plant.

The magnitude of heterosis over mid-parental value was reported to be 80.95 percent (Chaudhari et al., 1979), from -27.84 to 22.33 percent (Gupta, 1980), 47.68 percent (Shrivas and Singh, 1981) and from -17.65 to 63.64 percent (Rathnaswamy, 1984). Dora and Kamala (1986) reported that the heterosis over the mid-parental value was the most pronounced and heterobeltiosis was positive and significant. The range of heterosis over better parental value was shown to be from -23.73 to 21.15 percent (Gupta, 1980) and 36.34 percent (Shrivas and Singh, 1981).

Number of capsules per plant

According to Pal (1945), hybrid vigour was not manifested for capsule number per plant in sesame.

Studies on heterosis by Srivastava and Singh (1968) revealed that for this character, heterosis was displayed over better parent. High degree of heterosis for this character was also noticed by Sarathe and Dabral (1969), Dixit (1976), Tyagi and Singh (1981), Appadurai and Krishnaswamy (1984), Godawat and Gupta (1985) and Dora and Kamala (1986).

Heterosis as determined by the hybrid deviation from mid parental value, was found to be 43.24 percent (Srivastava and Prakash, 1977), 2.91 percent (Chaudhari et al., 1979), from 31.73 to 32.54 percent (Gupta, 1980), 19.34 percent (Shrivas and Singh, 1981) and from -0.64 to 45.57 percent (Rathnaswamy, 1984). Dora and Kamala (1986) reported that heterosis over mid parental value was the most pronounced for this character.

Heterosis over the better parental value was seen to be 25.75 percent (Srivastava and Prakash, 1977), 18.52 percent (Shrivas and Singh, 1981), 41.23 percent (Paramasivan et al., 1982) and to range from -28.80 to 122.60 percent (Kotecha and Yermanos, 1978), for this character.

Analysis of the components of heterosis by Chavan et al. (1982) revealed that the cross D.7.11.1 X Visubdar exhibited maximum heterosis over better parent for this character. For capsule number, the highest value of heterosis was observed to be 146.32 percent (Sharma and Chauhan, 1983) while Murty (1975) recorded a value of 16 percent.

Capsule length

Studies by Srivastava and Singh (1968) and Srivastava and Prakash (1977) observed heterosis over better parent for capsule length.

Heterosis over better parental value ranged from -25.70 to 10.60 percent (Kotecha and Yermanos, 1978) and from -15.00 to 19.72 percent over mid parental value (Rathnaswamy, 1984).

Tyagi and Singh (1981) reported that vigour was less marked for this character.

Number of seeds per capsule

Heterosis was found to be less marked for the character seed number per capsule, as reported by Sarathe and Dabral (1969) and Tyagi and Singh (1981). However, Paramasivan et al. (1982) reported an increase of 36.42 to 45.77 percent over the superior parent for this character.

Trials conducted by Dora and Kamala (1986) revealed that heterosis over the mid parental value was most pronounced for seed number per capsule.

Weight of 1000 seeds

The vigour was seen to be less marked for the character thousand seed weight (Sarathe and Dabral, 1969; Tyagi and Singh, 1981). Studies by Srivastava and Singh (1968) revealed that the 1000 seed weight of the hybrid was higher than the mid parental weight.

Heterosis over superior parent was found to range from 0.18 to 50.66 percent (Paramasivan et al., 1982). A maximum heterosis of 25.51 percent was reported by Sharma and Chauhan (1983) for this character.

Oil content

Hybrid vigour was found to be less marked for oil content (Sarathe and Dabral, 1969; Tyagi and Singh, 1981; Reddy et al., 1986).

Heterosis of 18.13 to 44.22 percent and -14.88 to 14.08 percent (Sharma and Chauhan, 1983) and 0.00 to 41.20 percent and 13.00 to 65.50 percent (Reddy et al., 1986) was reported over better and mid parental values respectively.

Seed yield

Pal (1945) reported that no hybrid vigour was manifested for seed yield per plant in sesame. However, an increased vigour with regard to seed yield was reported by Sarathe and Dabral (1969). Heterosis was shown to be the highest for seed yield, viz. 33 percent by Murty (1975). The exotic lines used were found to be helpful in improving the seed yield. Dixit (1976) reported that the best hybrid yielded 77.39 percent more than its superior parent.

Heterosis of the F_1 hybrid mean over its higher parent ranged from -6.76 to 75 percent (Kotecha and Yermanos, 1978); 59.56 percent (Gupta, 1980); 7.52 percent (Shrivas and Singh, 1981); 0.20 to 19.91 percent (Paramasivan et al., 1982); 34.99 to 60.27 percent (Sharma and Chauhan, 1983); 0.00 to 71.40 percent (Reddy et al., 1986) and -64.91 to 0.56 percent (Krishnadoss et al., 1987).

Heterosis was observed to range from -2.04 to 67.94 percent for seed yield per plant (Rathnaswamy, 1984).

The deviation of the F_1 mean over mid parental value was found to be 116.78 percent (Chaudhari et al., 1979); 69.86 percent (Gupta, 1980); 15.22 percent (Shrivas and Singh, 1981); from -16.76 to 105.70 percent (Sharma and Chauhan, 1983); 23.40 to 113 percent (Reddy et al., 1986) and -47.13 to 174.47 percent (Krishnadoss et al., 1987).

MATERIALS AND METHODS

MATERIALS AND METHODS

Materials

The experimental material consisted of twenty three varieties of sesame (Sesamum indicum L.) collected from the germplasm assembled at the College of Agriculture, Vellayani and T.N.A.U., Coimbatore. These varieties showed much variability in their morphological characters and yield. The name and source of these varieties are given in Table 1.

Six distinct sesame varieties with varying phenotypic expression were selected based on their general performance and yield and used as parents for the hybridisation programme. The performance of the selected varieties are given in Table 2. The six parents and the fifteen hybrids obtained by crossing them in all possible combinations, without reciprocals, were used for the present study and are enumerated below:

Sl. No.	Treatment No.	Name of Variety/Cross
1.	T_1	ACV.1
2.	T_2	CO.1
3.	T_3	IC.284
4.	T_4	S.8

Sl. No.	Treatment No.	Name of Variety/Cross
5.	T_5	VS.27
6.	T_6	K.1
7.	T_7	ACV.1 x CO.1
8.	T_8	ACV.1 x IC.284
9.	T_9	ACV.1 x S.8
10.	T_{10}	ACV.1 x VS.27
11.	T_{11}	ACV.1 x K.1
12.	T_{12}	CO.1 x IC.284
13.	T_{13}	CO.1 x S.8
14.	T_{14}	CO.1 x VS.27
15.	T_{15}	CO.1 x K.1
16.	T_{16}	IC.284 x S.8
17.	T_{17}	IC.284 x VS.27
18.	T_{18}	IC.284 x K.1
19.	T_{19}	S.8 x VS.27
20.	T_{20}	S.8 x K.1
21.	T_{21}	VS.27 x K.1

Methods

The field experiment was laid out in the uplands at the College of Agriculture, Vellayani. The purity of

Table 1. Details of varieties tested

Sl. No.	Name of the variety	Source
1.	ACV.1	College of Agriculture, Vellayani
2.	ACV.2	-do-
3.	Cul.16	-do-
4.	Cul.28	-do-
5.	Cul.40	-do-
6.	P_{10-1}	-do-
7.	N_{62-32}	-do-
8.	S.1275	-do-
9.	IC.284	-do-
10.	S.8	-do-
11.	Vinayak	-do-
12.	Multiloculed mutant	-do-
13.	Multiloculed mutant (white seeded)	-do-
14.	Kayamkulam-1	-do-
15.	CO.1	T.N.A.U., Coimbatore
16.	T.N.A.U.-6	-do-
17.	T.N.A.U.-10	-do-
18.	T.N.A.U.-11	-do-
19.	T.S.S-4	-do-
20.	VS.27	-do-
21.	VS.81	-do-
22.	BS-5-18-6	-do-
23.	BS-129	-do-

Table 2. Performance of the selected parents for diallel analysis

Treatment No.	Variety	Plant height (cm)	Duration upto (days)		Number of branches per plant	Number of capsules per plant	Capsule length (cm)	Number of seeds per capsule	Oil content (% age)	Seed yield per hectare (kg)
			Flowering	Maturity						
T_1	ACV.1	148.60	37.20	81.30	1.97	35.07	2.22	100.87	53.57	683.77
T_2	CO.1	103.80	37.20	81.60	2.20	15.77	2.11	53.80	55.50	225.93
T_3	IC.284	132.80	36.97	83.70	2.37	23.50	2.05	75.50	48.00	351.23
T_4	S.8	128.90	36.97	82.00	2.73	44.70	2.26	56.97	50.50	551.57
T_5	VS.27	103.40	37.77	83.50	2.73	20.30	2.18	55.67	35.50	245.10
T_6	K.1	120.00	36.00	82.00	1.97	32.50	2.16	51.00	38.33	334.90

the twenty three varieties were tested by selfing them for one generation. They were sown in two batches in October 1986 and were selfed by adopting the method developed by John (1980). Based on the general performance and yield, six superior varieties viz. ACV.1, CO.1, IC.284, S.8, VS.27 and K.1 were chosen. The pure selfed seeds collected from them were used for the Experiment 1 which consisted of crossing these six parental varieties in all possible combinations, without reciprocals.

3.1 Inter varietal hybridisation programme

The selected six varieties ie. T_1 to T_6 were sown in three batches between February 1987 and June 1987. Each variety was grown in five rows with fifteen plants per row. They were crossed in all possible combinations, without reciprocals, so as to get fifteen cross-combinations, viz. T_7 to T_{21}. The female parent was emasculated the previous evening by adopting the clipping method (John, 1980) and protected by covering with butter paper cover. The next morning, pollen from the desired male parent was collected and dusted on the receptive stigmatic surface of the emasculated flowers between 05.30 and 08.00 hours. The crossed flowers were then tagged and again protected by butter paper cover. In the evening, the previously pollinated stigmatic surface, which would have lost its receptivity by then, was cut off. This was continued till the flowering phase declined. The tagged capsules were separately collected upon maturity and hybrid seeds were obtained.

3.2 Estimation of combining ability, gene action and heterosis

The experimental material consisted of the six parental varieties and the fifteen hybrids viz. T_1 to T_{21}. They were raised in three randomised blocks with plot size, 2 m x 1.5 m. The experiment was conducted during Rabi, 1987 in uplands at the College of Agriculture, Vellayani.

Seeds were sown in lines. The rows were spaced 20 cm apart. Thinning of the seedlings was done within a row with a spacing of 10 cm. Agronomic practices were done as per the Package of Practices recommendations of the K.A.U. (Anon, 1986). In all the varieties and the fifteen hybrids, observations were taken from 10 plants earmarked at random, from each plot. The observational plants were harvested separately, the pods were sun dried and seeds extracted. Pods from the remaining plants were collected as bulk plotwise.

The observational plants were scored for the following eleven characters and the mean values were used for statistical computation.

(i) Height of the plant

Measured in centimetres from the ground level to the tip of the plant, at harvest stage.

(ii) Days to flower

The number of days from sowing of the seeds to the appearance of the first flower in the ten observational plants per plot.

(iii) Days to mature

The number of days from sowing of the seeds to the maturity of the majority of the capsules.

(iv) Number of branches

Total number of primary branches per observational plant was counted at harvest.

(v) Number of capsules per plant

Total number of capsules from each observational plant was counted at harvest.

(vi) Length of the capsule

Three capsules were selected at random from each observational plant and their length was measured in centimetres.

(vii) Number of seeds per capsule

Seeds were extracted from the three capsules selected at random from each observational plant and counted.

(viii) Weight of thousand seeds

Three seed samples, each weighing 5 g were taken from the bulk of each variety, from three replications. The number of seeds per 5 g was counted and the weight of 1000 seeds was recorded and the mean 1000 seed weight estimated.

(ix) Oil content (percentage)

The percentage of oil in the seeds of each variety was estimated by the cold percolation method discussed by Bhandari (1974).

(x) Seed yield per plant (g)

Seeds were extracted from the pods of the ten observational plants and weighed. The mean yield per plant was then computed.

(xi) Seed yield per plot (g)

Weight of seeds collected from the observational plants and from the remaining plants from each plot of size 2×1.5 m^2 were added to obtain the seed yield per plot.

3.3. Statistical analysis

Data from the parents and hybrids were subjected to Diallel analysis. The following parameters were estimated.

1. Combining ability

   (a) General Combining Ability

   (b) Specific Combining Ability

2. Gene Action

   (a) Additive gene action

   (b) Non-additive gene action

3. Heterosis

   (a) Heterosis over the mid-parent

   (b) Heterosis over the better parent

   (c) Heterosis over the check variety

3.3.1. Testing the significance differences

Initially, analysis of variance for each character was carried out.

Analysis of variance for each character

Source of variation	df		MSS	F
Replication	(r-1)	= 2	MSR	MSR/MSE
Treatments	(v-1)	= 20	MSV	MSV/MSE
Error	(r-1)(v-1)	= 40	MSE	
Total	(rv-1)	= 62		

where,

r = number of replications

v = number of treatments

MSR = Replication mean square

MSV = Treatment mean square

MSE = Error variance

3.3.2 Combining ability analysis

The g.c.a and s.c.a were estimated in cases where the varieties were found to differ significantly with respect to the character under study (Singh and Chaudhari, 1985). The combining ability analysis was carried out following the Method 2 under Model 1 as suggested by Griffing (1956). The Model 1 was selected because the varieties were a chosen fixed set. It follows that the variety and block effects are fixed. The statistical model it follows is,

$$X_{ij} = \mu + gi + gj + Sij + \frac{1}{bc} \sum_{k} \sum_{l} e_{ijkl}$$

where,

$i, j = 1, 2 \ldots\ldots p$

$k = 1, 2 \ldots\ldots b$

$l = 1, 2 \ldots\ldots c$

μ = General mean

gi = General combining ability (g.c.a) effect of i^{th} parent.

gj = General combining ability (g.c.a) effect of j^{th} parent.

Sij = Specific combining ability (s.c.a) effect of ij^{th} cross such that Sij = Sji

e_{ijkl} = Environmental component pertaining to $ijkl^{th}$ observation

p = number of parents involved in the diallel mating system

i and j = male and female parents respectively for producing the ij^{th} hybrid

b = number of blocks or replications

c = number of observational plants

The mathematical restrictions imposed to this analysis were $\sum_{i} gi = 0$ and $\sum_{j} (Sij + Sii) = 0$

The sum of squares due to g.c.a and s.c.a were calculated as follows:

Sum of squares due to g.c.a

$$Sg = \frac{1}{p+2} \left[\sum_{i=1} (Yi. + Yii)^2 - \frac{4}{p} \; y..^2 \right]$$

Sum of squares due to s.c.a

$$Ss = \sum_{i} \sum_{\leq j} Y_{ij}^2 - \frac{1}{p+2} \sum_{i=1} (Y_{i.} + Y_{ii})^2 + \frac{2}{(p+1)(p+2)} Y^2..$$

Where

p = number of parents

Y_i = Total of i^{th} (row) array in the diallel table

Y_{ii} = Mean value of i^{th} parent

Y_{ij} = Mean value of $(ixj)^{th}$ cross

$Y..$ = Grand total of 'p' parental lines and

$\frac{p(p-1)}{2}$ progenies of the diallel table

The mean squares of g.c.a and s.c.a were obtained by dividing the respective sum of squares by the corresponding degrees of freedom. In combining ability analysis, the error mean square obtained in the analysis of variance is divided by the number of replications to get the adjusted error variance ($M\acute{e}$)

$M\acute{e}$ = MSE/r

where, r = number of replications.

Analysis of variance for combining ability

Source of variation	df	SS	MSS	E(M.S)
g.c.a	$(p-1) = 5$	Sg	Mg	$\sigma_e^2 + \frac{p+2}{p-1} \sum_i g_i^2$
s.c.a	$\frac{p(p-1)}{2} = 15$	Ss	Ms	$\sigma_e^2 + \frac{2}{p(p-1)} \sum_{i<j} \sum s^2_{ij}$
Error	$m = 40$	Se	M$\acute{e}$	σ_e^2

where,

m = degrees of freedom for error

Mg = g.c.a mean square

Ms = s.c.a mean square

M$\acute{e}$ = Adjusted error variance

<u>Test of significance</u>

(i) Test of g.c.a effects

$$F_{(p-1),\ m} = \frac{Mg}{M\acute{e}}$$

(ii) Test of s.c.a effects

$$F_{\frac{p(p-1)}{2},\ m} = \frac{Ms}{M\acute{e}}$$

3.3.2.2. (i) Estimation of g.c.a effects

The general combining ability (g.c.a) effects of the parents were calculated as follows:

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

(ii) Estimation of standard errors

The standard errors for g.c.a were estimated using the formulae,

$$SE\ (gi) = \left[(n-1) \quad \sigma_e^2 / p(p+2)\right]^{\frac{1}{2}}$$

$$SE\ (gi-gj) = \left[2 \quad \sigma_e^2/(p+2)\right]^{\frac{1}{2}}$$

3.3.2.3. (i) Estimation of s.c.a effects

The s.c.a effects of all the fifteen cross combination for the different characters were estimated as:

$$S_{ij} = Y_{ij} - \frac{1}{p+2}(Y_{i.} + Y_{ii} + Y_{.j} + Y_{jj}) + \frac{2}{(p+1)(p+2)} \quad Y_{..}$$

where,

S_{ij} = s.c.a effect of $(i \times j)^{th}$ cross

Y_{jj} = Mean value of j^{th} parent

$Y_{.j}$ = Total of j^{th} (column) array in the diallel table.

(ii) Estimation of standard errors

The standard errors of s.c.a effects were estimated as:

$$SE\ (sij) = \left[n(n-1)\ \sigma_e^2/(p+1)\ (p+2) \right]^{\frac{1}{2}}$$

$$SE\ (sij - sik) = \left[2(n+1)\ \sigma_e^2/(n+2) \right]^{\frac{1}{2}}$$

$$SE\ (sij - skl) = \left[2n\ \sigma_e^2/(n+2) \right]^{\frac{1}{2}}$$

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

$$t = \frac{\hat{gi}}{SE(\hat{gi})} \quad \text{and}$$

$$t = \frac{\hat{Sij}}{SE(\hat{Sij})}$$

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

For testing the significance of difference between two effects, the critical difference was calculated by multiplying the respective standard error of difference with 't' value at 'm' degrees of freedom.

3.3.3. Gene action

The analysis of variance for combining ability was used to decide the type of gene action controlling a character. Griffing (1956) demonstrated the method of working out g.c.a and s.c.a effects and pointed out that twice the g.c.a variance was related to additive or additive x additive or higher order interactions and s.c.a variance included all of the dominence and the remaining epistatic variance.

Further, the genetic components were estimated and their ratios calculated.

3.3.3.1. Estimation of genetic components

The genetic components were estimated as under:

(i) Component due to g.c.a

$$\frac{1}{p-1} \sum_{i} gi^2 = \frac{Mg-Me'}{p+2}$$

(ii) Component due to s.c.a

$$\frac{2}{P(p-1)} \sum_{i} \sum_{<j} Sij^2 = Ms-Me'$$

(iii) The ratio of g.c.a to s.c.a variance was calculated as,

$$\frac{1}{p-1} \sum_{i} gi^2 / \frac{2}{p(p-1)} \sum_{i} \sum_{<j} S^2_{ij}$$

The values of this ratio was used to interpret the relative significance of additive and non-additive gene effects (Paroda and Joshi, 1970). Values of the ratio above unity indicates the predominance of ( )-additive gene action and vice versa.

3.3.4. Heterosis

The overall mean value of each parent and hybrid in all the three replications for each character was taken for the estimation of heterosis. Heterosis was calculated as the percent deviation of the mean performance of F_1's from its mid parent (M.P.), better parent (B.P.) and check variety (C.P.) for each cross combination as suggested by Hayes et al. (1955) and Briggle (1963).

(i) Deviation of hybrid mean from the mid parental value (Relative heterosis) $= \dfrac{\overline{F_1} - \overline{M.P.}}{\overline{M.P.}} \times 100$

(ii) Deviation of hybrid mean from the better parental value (Heterobeltiosis) $= \dfrac{\overline{F_1} - \overline{B.P.}}{\overline{B.P.}} \times 100$

(iii) Deviation of hybrid mean from the check parental value (Standard heterosis) $= \dfrac{\overline{F_1} - \overline{C.P.}}{\overline{C.P.}} \times 100$

For each character under study, the average value of the two parents involved in each cross combination was taken as the mid-parental value ($\overline{M.P.}$), the superior value between those of the parents in each cross as better parental value ($\overline{B.P.}$) and the value of the check variety as the check parental value ($\overline{C.P.}$).

To test the significance of difference of F_1 mean over mid, better and check parent, critical difference was calculated from their Standard errors of differences as mentioned below. (Briggle, 1963).

To test the significance over mid parent,

$$C.D._{(0.05)} = t_{e\ (0.05)} \sqrt{\frac{3 \times MSE}{2r}}$$

To test the significance over better and check parent,

$$C.D._{(0.05)} = t_{e\ (0.05)} \sqrt{\frac{2 \times MSE}{r}}$$ where,

e = Error degrees of freedom

MSE = Error variance

r = number of replications

RESULTS

RESULTS

The data relating to the experiment were analysed statistically and the results are presented.

The mean values for the eleven characters studied for the twentyone treatments and the mean values for the best parent and hybrid for each character are presented in Tables 3(i) and 3(ii).

For the character plant height, the mean values recorded by the parents ranged from 103.40 cm in VS.27 to 148.60 cm in ACV.1, whereas, it ranged from 116.20 cm to 151.40 cm in the hybrids CO.1 x K.1 and ACV.1 x K.1 respectively. Among the hybrids, plant height was intermediate to those of the parents. The variation in plant height of parents and hybrids is represented in Figure 1(a).

The range of variation for number of days to flower in the parents was from 36.00 days recorded by K.1 to 37.77 days recorded by VS.27. Among the hybrids, the range was from 33.53 days recorded by IC.284 x S.8 to 38.57 recorded by ACV.1 x CO.1. The hybrids showed only a narrow range of variation. The variation in the duration of flowering in the parents and hybrids is represented in Figure 1(b).

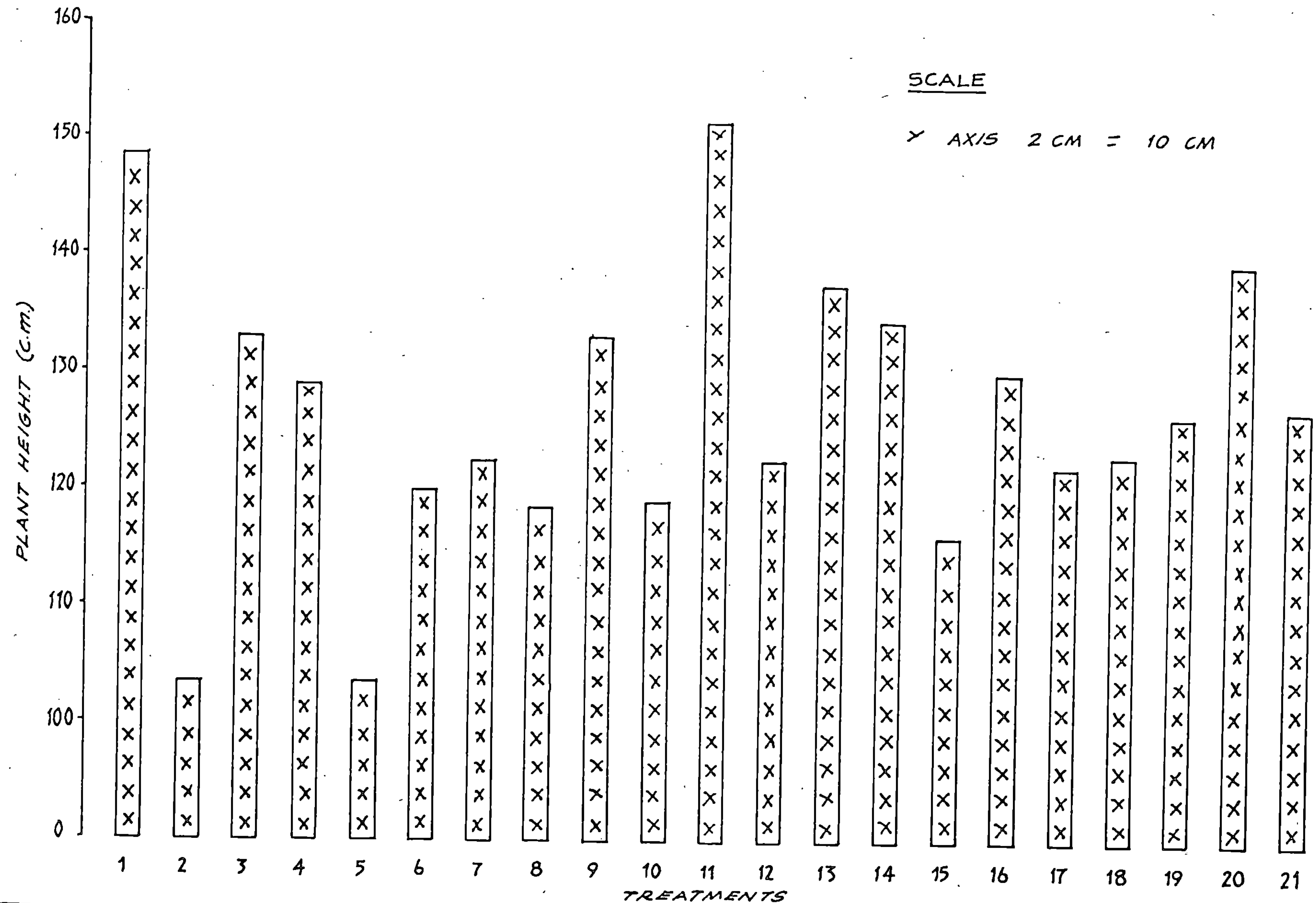
Table 3(i). Phenotypic expression for eleven characters in parents and F_1's

Sl. No.	Treatments	Plant height (cm)	Days to flower	Days to mature	No of branches per plant	No. of capsules per plant	Capsule length (cm)	No of seeds per capsule	Weight of 1000 seeds(g)	Oil content(%)	Seed yield per plant (g)	Seed Yield per plot (g)
1	ACV.1	148 60	37 20	81.30	1.97	35 07	2 22	100 87	3 29	53.57	5.82	205 13
2	CO.1	103.80	37.20	81 60	2.20	15.77	2.11	53 80	2.76	55.50	2 18	67 78
3.	IC 284	132.80	36.97	83 70	2.37	23.50	2.05	75.50	2.22	48.00	3.07	105 37
4	S.8	128 90	36.97	82 00	2.73	44.70	2.26	56.97	2.74	50.50	4 68	165 47
5.	VS.27	103.40	37.77	83.50	2.73	20.30	2 18	55.67	2.37	35.50	2.43	73.53
6.	K.1	120.00	36 00	82.00	1.97	32 50	2 16	51.00	2.58	38.33	3.08	100.47
7.	ACV 1xCO 1	122 50	38.57	81.90	2.13	16.53	2.27	57 03	2 16	36.33	2 13	61 22
8.	ACV.1xIC 284	118.50	35 87	83.00	1 57	16 33	2 18	83.70	2.62	36 50	2.91	92 57
9.	ACV 1xS.8	132 90	36.80	81.90	1 80	20.87	2.27	58 00	2 52	31 67	2 57	78.67
10.	ACV.1xVS 27	118.50	37.00	83.40	2.03	31.27	2.27	57 67	2 67	32.67	3.49	124.82
11	ACV.1xK 1	151.40	35.43	82.70	1.97	26.40	2 33	57 70	2 72	26.67	2 97	100.70
12	CO 1xIC 284	122 30	36 70	81.70	2 57	23.63	2 24	56.57	2.28	30 33	2.35	74 50
13.	CO 1xS.8	137.70	35 77	82 70	2 47	41.03	2.45	70.33	2.66	38.16	4.93	161.84
14	CO 1xVS.27	134.60	36 93	81.90	2.93	49.20	2.32	59.70	2.65	36.33	4.75	172 87
15	CO 1xK.1	116.20	36 43	81.00	2.60	23.17	2.06	52.57	2.84	25.50	2.58	84 33
16	IC.284xS 8	129.80	33 53	81 70	2.17	26 00	2.29	59.47	2.32	36.83	2.92	90.73
17.	IC.284xVS.27	122.10	37 37	82.90	2.20	27.77	2.24	57.77	2.13	45.83	2 88	86.97
18.	IC.284xK.1	122.70	36.37	84.20	2.60	48.03	2.20	54.40	2.29	35.67	4.13	156.43
19.	S.8xVS.27	126.60	36 40	82.60	2.37	40 90	2.21	61 23	2.57	44.67	4 58	162 53
20.	S 8xK.1	139.40	35.33	82.20	2.37	38 83	2 30	59 03	2 16	44.50	3.88	132 83
21.	VS.27xK.1	126.80	36.30	81.70	3.17	46 40	2.18	59.23	2.45	40.17	4.38	167.93
	CD (0 05)	4.66	1.82		0.80	3.58	0 13	5.52	0.03	2 81	0.57	18 17

Table 3(ii). Phenotypic expression of the best parents and hybrid for the eleven characters

Sl. No.	Characters	Best parent		Best hybrid	
		Variety	Mean value	Cross combination	Mean value
1.	Plant height	ACV.1	148.60 cm	ACV.1 x K.1	151.40
2.	Days to flower	K.1	36.00 days	IC.284 x S.8	33.53 days
3.	Days to mature	ACV.1	81.30 days	CO.1 x K.1	81.00
4.	Number of branches per plant	S.8 & VS.27	2.73	VS.27 x K.1	3.17
5.	Number of capsules per plant	S.8	44.70	CO.1 x VS.27	49.20
6.	Capsule length	S.8	2.26 cm	CO.1 x S.8	2.45 cm
7.	Number of seeds per capsule	ACV.1	100.87	ACV.1 x IC.284	83.70
8.	Weight of 1000 seeds	ACV.1	3.29 g	CO.1 x K.1	2.84 g
9.	Oil content	CO.1	55.50%	IC.284 x VS.27	45.83
10.	Seed yield per plant	ACV.1	5.82 g	CO.1 x S.8	4.93 g
11.	Seed yield per plot	ACV.1	205.13 g	CO.1 x S.8	181.84 g

FIG. 1(a)



SCALE
Y AXIS 2 CM = 10 CM
PLANT HEIGHT (C.M.)
160
150
140
130
120
110
100
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
TREATMENTS

FIG. 1(b)

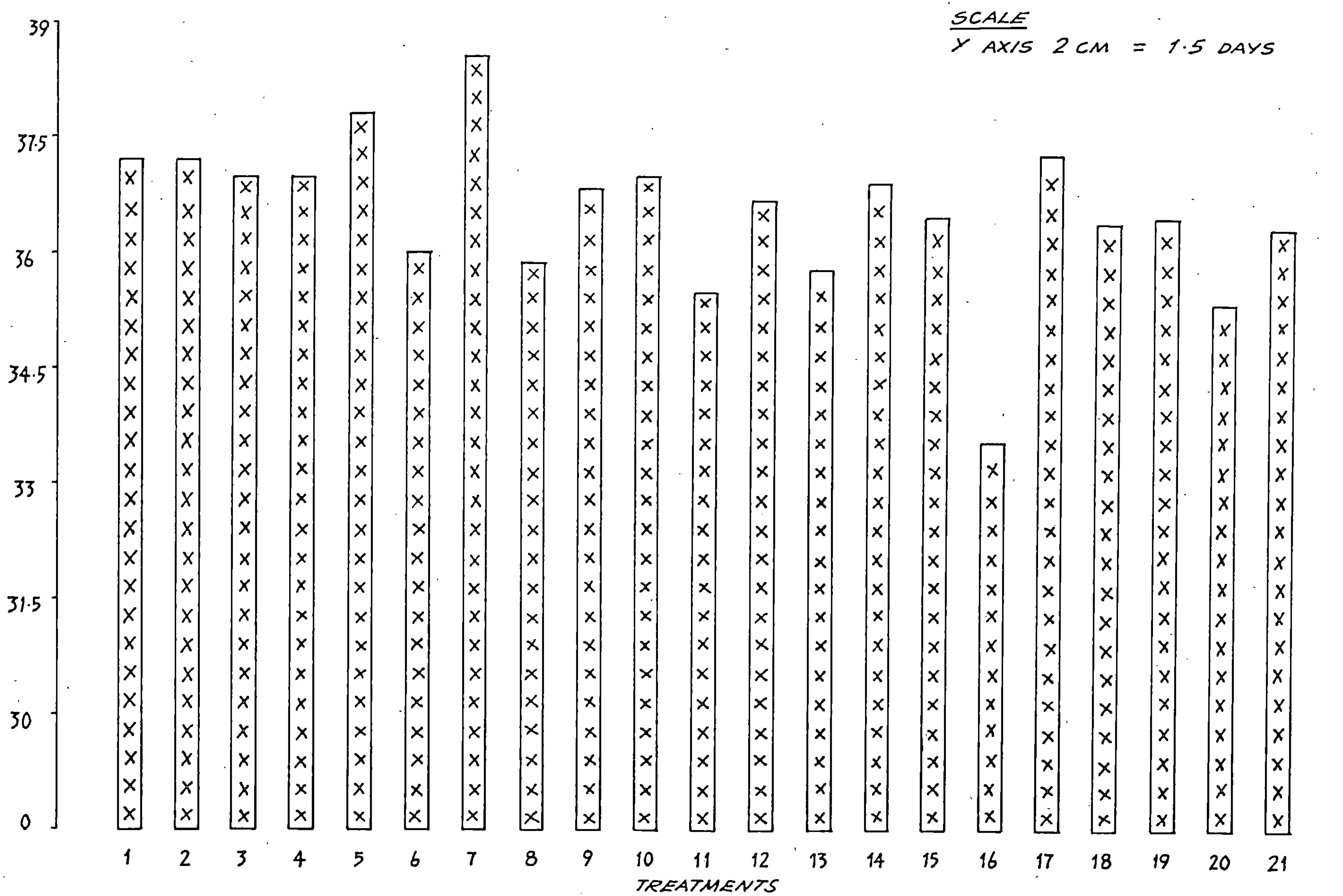

SCALE
Y AXIS 2 CM = 1·5 DAYS
DAYS TO FLOWER
39
37.5
36
34.5
33
31.5
30
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
TREATMENTS

Figure 1(b). Mean values of parents and hybrids for days to flower in a 6 x 6 diallel.

Treatment No.	Varieties/hybrids
1	ACV.1
2	CO.1
3	IC.284
4	S.8
5	VS.27
6	K.1
7	ACV.1 x CO.1
8	ACV.1 x IC.284
9	ACV.1 x S.8
10	ACV.1 x VS.27
11	ACV.1 x K.1
12	CO.1 x IC.284
13	CO.1 x S.8
14	CO.1 x VS.27
15	CO.1 x K.1
16	IC.284 x S.8
17	IC.284 x VS.27
18	IC.284 x K.1
19	S.8 x VS.27
20	S.8 x K.1
21	VS.27 x K.1

Figure 1(a). Mean values of parents and hybrids for plant height in a 6 x 6 diallel.

Treatment No.	Varieties/hybrids
1	ACV.1
2	CO.1
3	IC.284
4	S.8
5	VS.27
6	K.1
7	ACV.1 x CO.1
8	ACV.1 x IC.284
9	ACV.1 x S.8
10	ACV.1 x VS.27
11	ACV.1 x K.1
12	CO.1 x IC.284
13	CO.1 x S.8
14	CO.1 x VS.27
15	CO.1 x K.1
16	IC.284 x S.8
17	IC.284 x VS.27
18	IC.284 x K.1
19	S.8 x VS.27
20	S.8 x K.1
21	VS.27 x K.1

There was only little variation among the parents and hybrids regarding the days to mature. The mean values recorded by the parents ranged from 81.30 to 83.70 in ACV.1 and IC.284 respectively, whereas, it ranged from 81.00 to 84.20 in the hybrids CO.1 x K.1 and IC.284 x K.1 respectively. The variation exhibited by parents and hybrids for this character is represented in Figure 1(c).

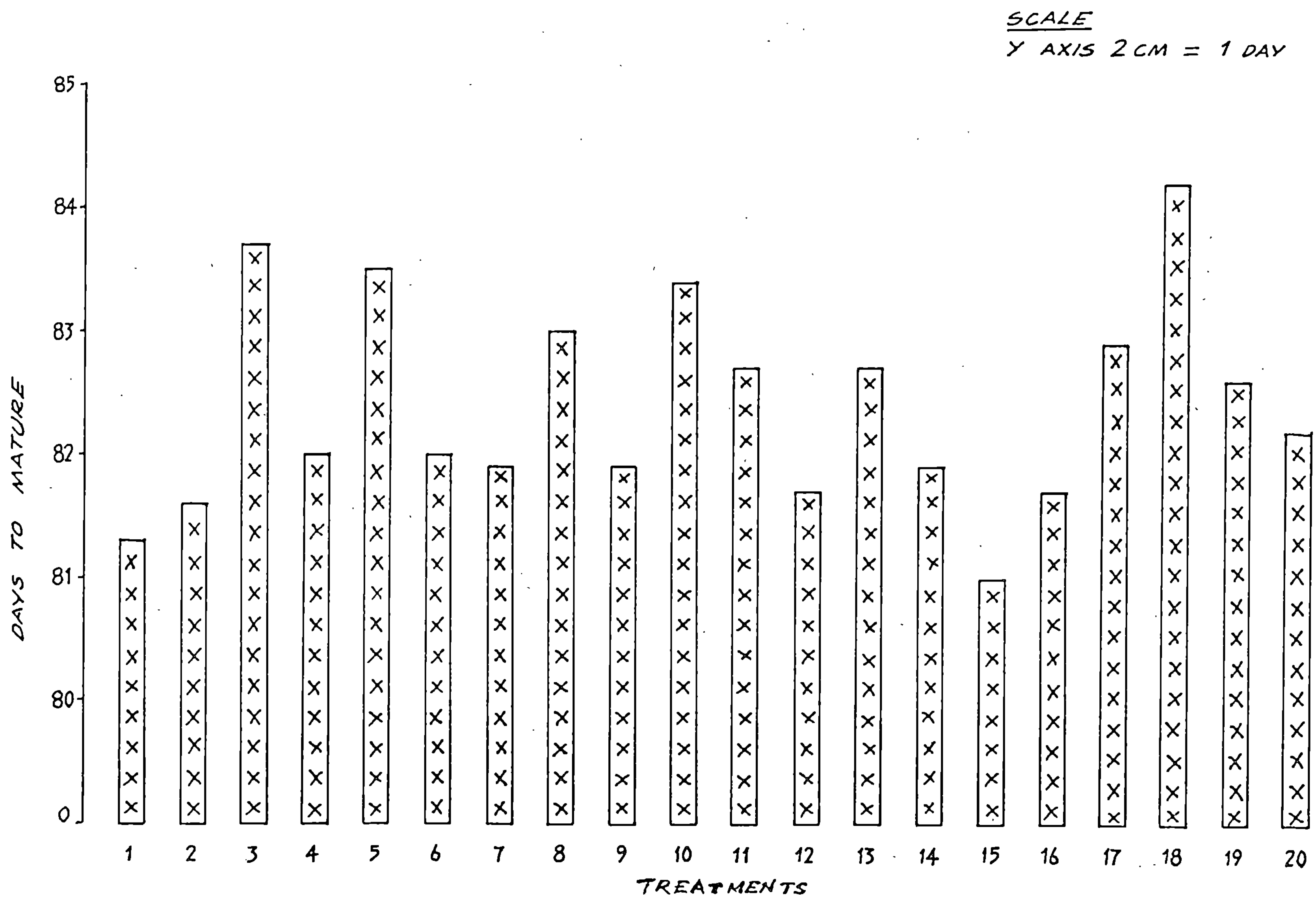
The mean number of branches per plant in the parents ranged from 1.97 to 2.73. The minimum was recorded by ACV.1 and K.1 and the maximum by S.8 and VS.27. Among the hybrids, the minimum number of branches (1.57) was recorded in the ACV.1 x IC.284 and the maximum of 3.17 in the cross VS.27 x K.1. In most of the crosses, the number of branches were intermediate to those of the parents. The variation shown by the parents and hybrids for this character is represented in Figure 1(d).

The number of capsules per plant in the parental varieties ranged from 15.77 recorded by CO.1 to 44.70 recorded by S.8, whereas, the value ranged from 16.33 recorded by ACV.1 x IC.284 to 49.20 recorded by CO.1 x VS.27 among the hybrids. Considerable variation was seen among the hybrids for this character. The variation for number of capsules per plant in the parents and hybrids is represented in Figure 1(e).

Figure 1(c). Mean values of parents and hybrids for days to mature in a 6 x 6 diallel.

Treatment No.	Varieties/hybrids
1	ACV.1
2	CO.1
3	IC.284
4	S.8
5	VS.27
6	K.1
7	ACV.1 x CO.1
8	ACV.1 x IC.284
9	ACV.1 x S.8
10	ACV.1 x VS.27
11	ACV.1 x K.1
12	CO.1 x IC.284
13	CO.1 x S.8
14	CO.1 x VS.27
15	CO.1 x K.1
16	IC.284 x S.8
17	IC.284 x VS.27
18	IC.284 x K.1
19	S.8 x VS.27
20	S.8 x K.1
21	VS.27 x K.1

FIG. 1(c)



SCALE
Y AXIS 2 CM = 1 DAY
85
84
83
82
81
80
0
DAYS TO MATURE
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
TREATMENTS

Figure 1(d). Mean values of parents and hybrids for number of branches per plant in a 6 x 6 diallel.

Treatment No.	Varieties/hybrids
1	ACV.1
2	CO.1
3	IC.284
4	S.8
5	VS.27
6	K.1
7	ACV.1 x CO.1
8	ACV.1 x IC.284
9	ACV.1 x S.8
10	ACV.1 x VS.27
11	ACV.1 x K.1
12	CO.1 x IC.284
13	CO.1 x S.8
14	CO.1 x VS.27
15	CO.1 x K.1
16	IC.284 x S.8
17	IC.284 x VS.27
18	IC.284 x K.1
19	S.8 x VS.27
20	S.8 x K.1
21	VS.27 x K.1

FIG. 1(d)

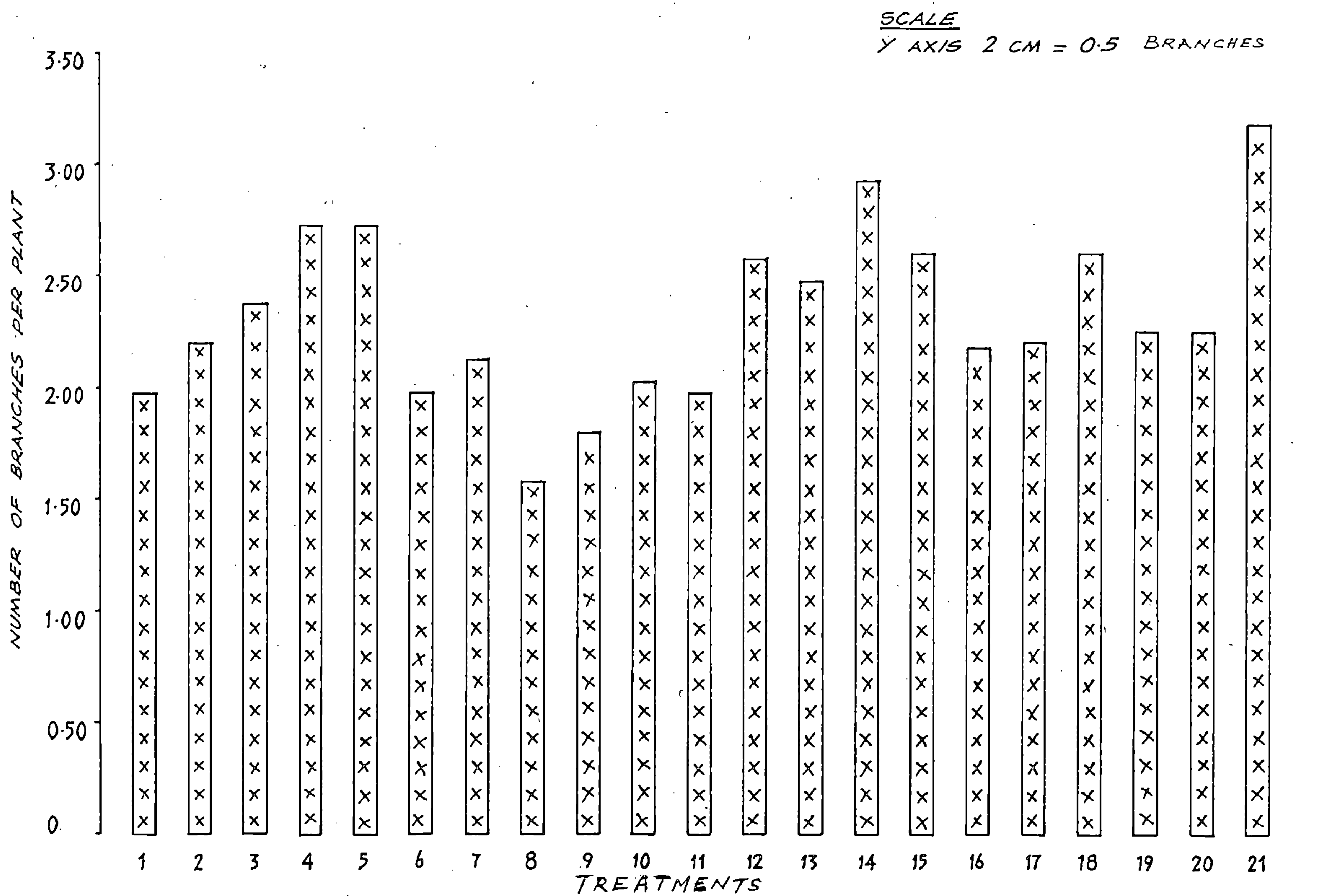
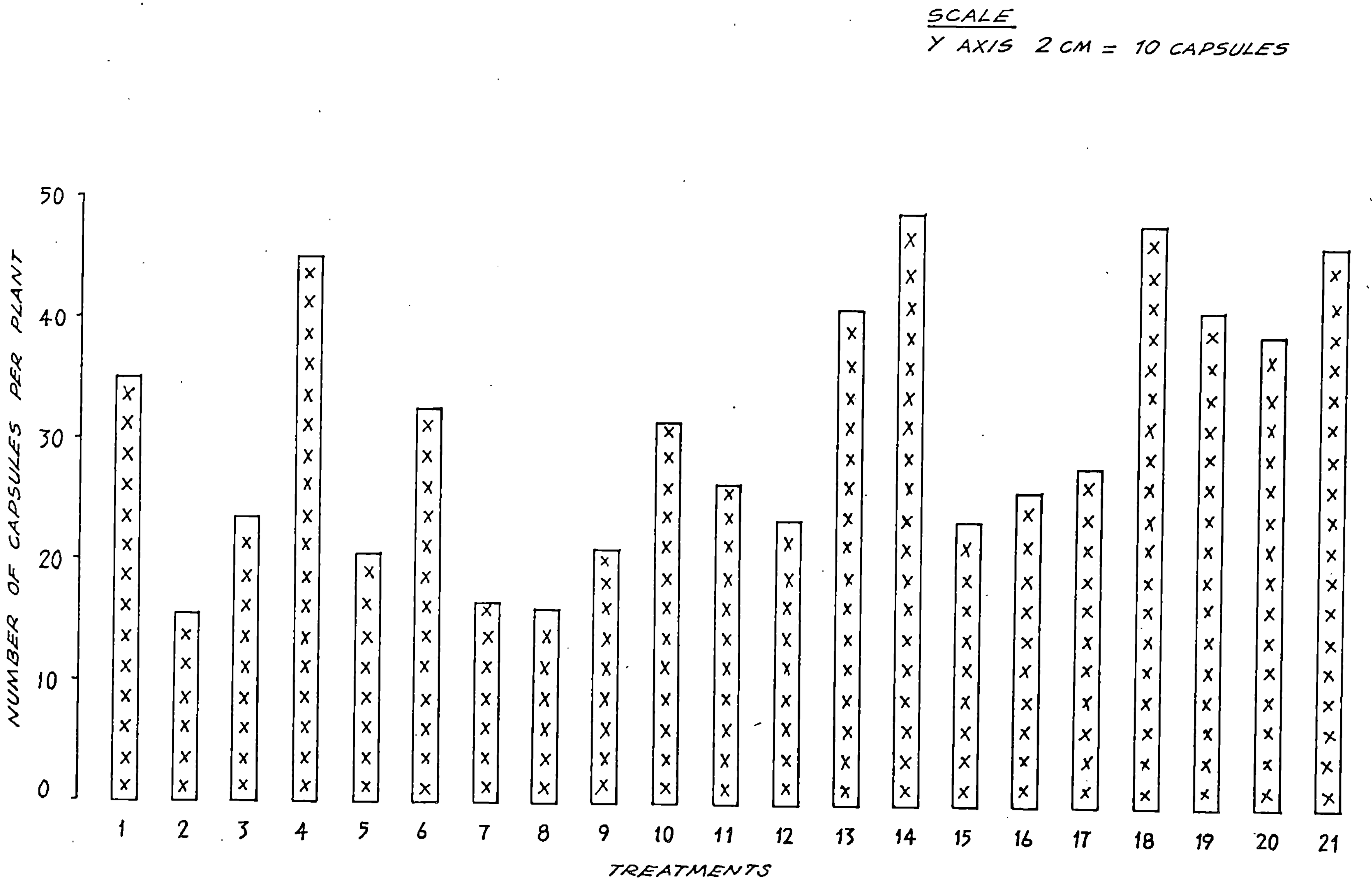

SCALE
Y AXIS 2 CM = 0·5 BRANCHES
NUMBER OF BRANCHES PER PLANT
3·50
3·00
2·50
2·00
1·50
1·00
0·50
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
TREATMENTS

Figure 1(e). Mean values of parents and hybrids for number of capsules per plant in a 6 x 6 diallel.

Treatment No.	Varieties/hybrids
1	ACV.1
2	CO.1
3	IC.284
4	S.8
5	VS.27
6	K.1
7	ACV.1 x CO.1
8	ACV.1 x IC.284
9	ACV.1 x S.8
10	ACV.1 x VS.27
11	ACV.1 x K.1
12	CO.1 x IC.284
13	CO.1 x S.8
14	CO.1 x VS.27
15	CO.1 x K.1
16	IC.284 x S.8
17	IC.284 x VS.27
18	IC.284 x K.1
19	S.8 x VS.27
20	S.8 x K.1
21	VS.27 x K.1

FIG. 1(e)


SCALE
Y AXIS 2 CM = 10 CAPSULES
NUMBER OF CAPSULES PER PLANT
0
10
20
30
40
50
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
TREATMENTS

There was only little variation for the character capsule length among the parents and hybrids. The mean length recorded by the parents ranged from 2.05 cm to 2.26 cm in IC.284 and S.8 respectively. Among the hybrids, the minimum length of 2.06 cm was recorded by the cross CO.1 x K.1 and the maximum of 2.45 cm by the cross CO.1 x S.8. The capsule length of most of the hybrids were intermediate or higher than the parental values. The variation exhibited by the parents and hybrids for this character is represented in Figure 1(f).

The number of seeds per capsule in the parental varieties ranged from 51.00 recorded by K.1 to 100.87 recorded by ACV.1. Among the hybrids, it ranged from 52.57 in CO.1 x K.1 to 83.70 in the cross ACV.1 x IC.284. In all the crosses, the values were intermediate or higher than the parental values. Variation for seed number per capsule in the parents and hybrids is represented in Figure 1(g).

Weight of 1000 seeds ranged from a minimum of 2.22 g in IC.284 to a maximum of 3.29 g in ACV.1 from among the parents. The range for this character among the hybrids was from a minimum of 2.13 g recorded by IC.284 x VS.27 to a maximum of 2.84 g recorded by CO.1 x K.1. The hybrids

Figure 1(f). Mean values of parents and hybrids for length of the capsule in a 6 x 6 diallel.

Treatment No.	Varieties/hybrids
1	ACV.1
2	CO.1
3	IC.284
4	S.8
5	VS.27
6	K.1
7	ACV.1 x CO.1
8	ACV.1 x IC.284
9	ACV.1 x S.8
10	ACV.1 x S.27
11	ACV.1 x K.1
12	CO.1 x IC.284
13	CO.1 x S.8
14	CO.1 x VS.27
15	CO.1 x K.1
16	IC.284 x S.8
17	IC.284 x VS.27
18	IC.284 x K.1
19	S.8 x VS.27
20	S.8 x K.1
21	VS.27 x K.1

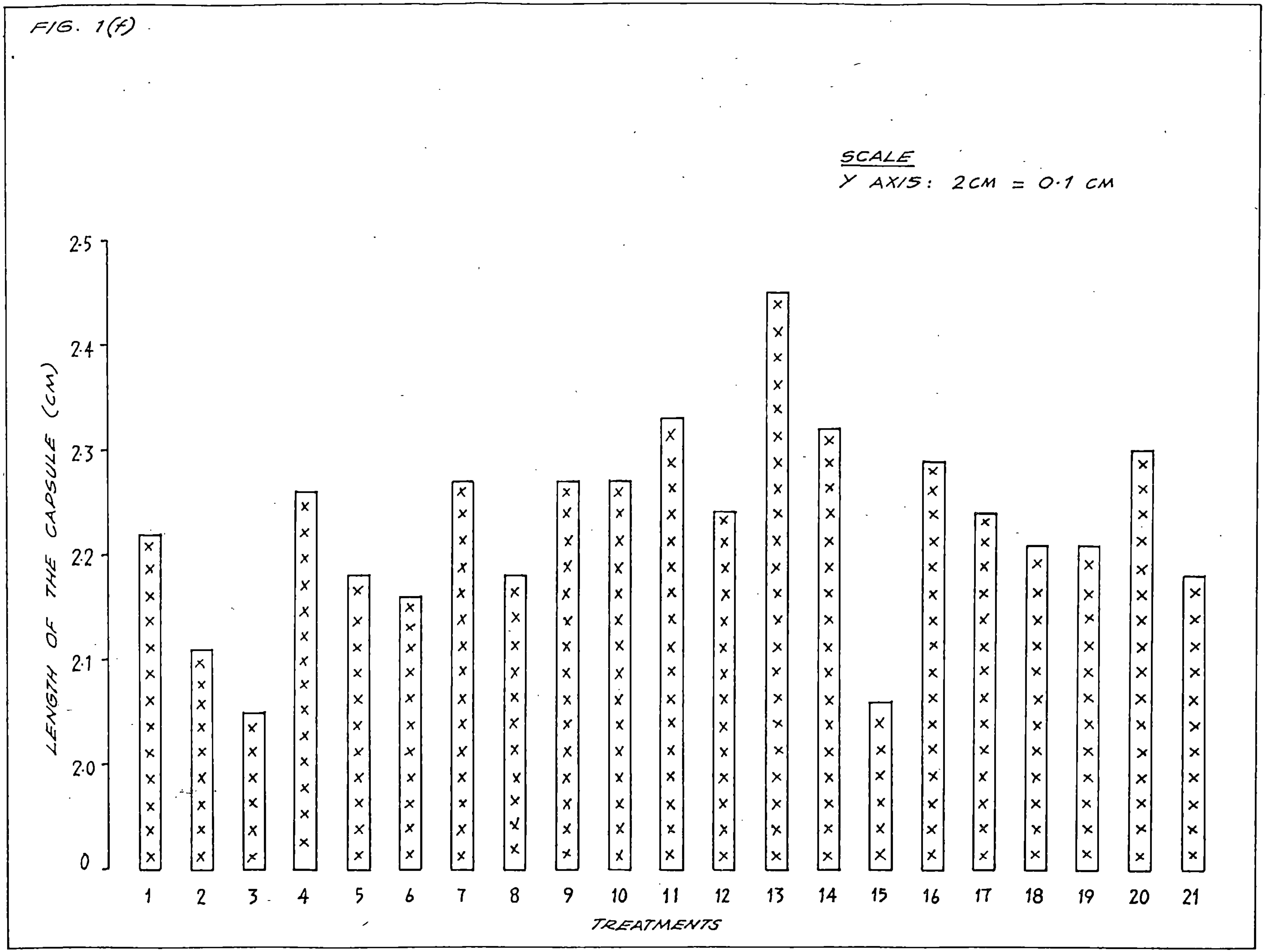
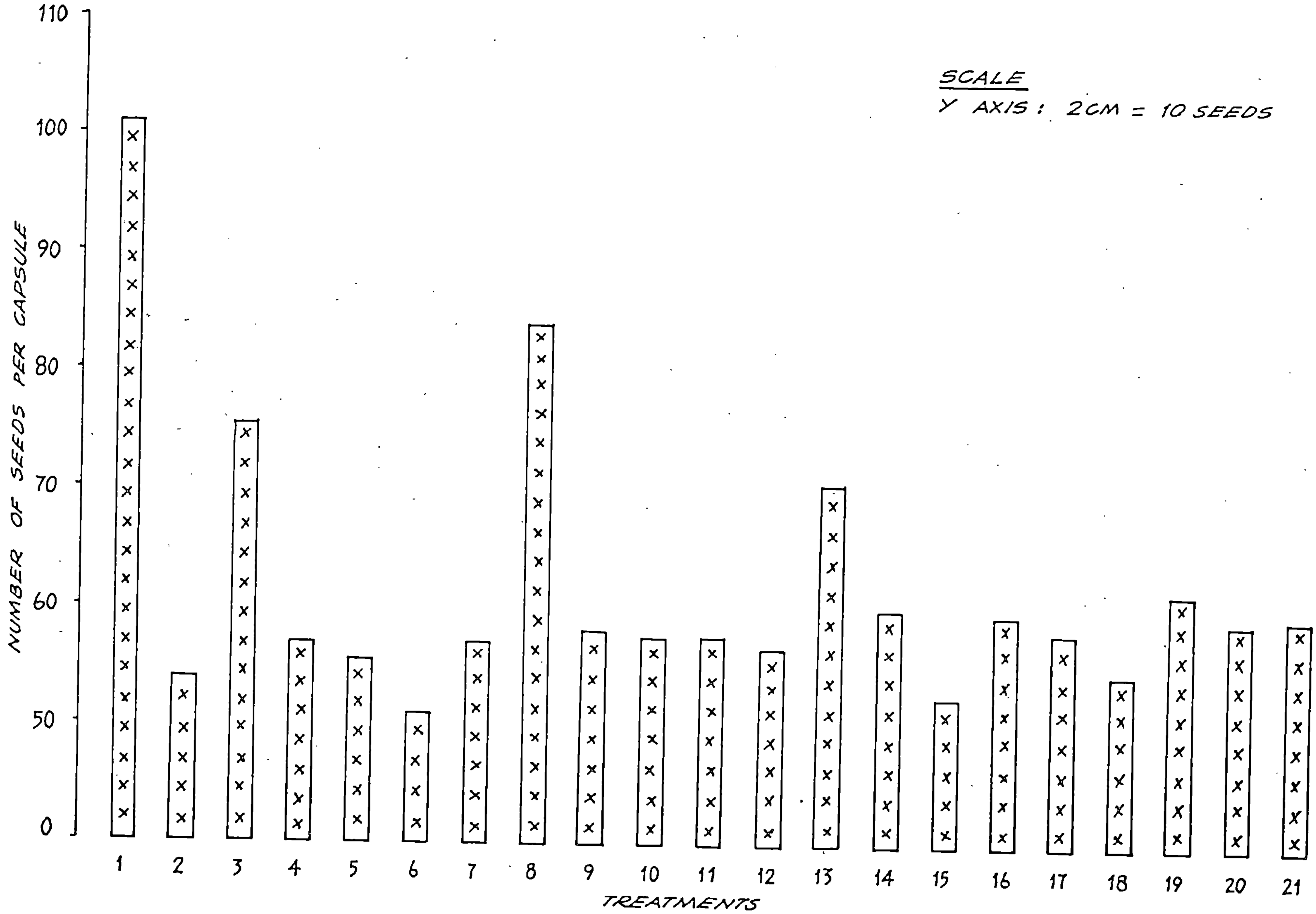


FIG. 1(f)
SCALE
Y AXIS: 2CM = 0·1 CM
LENGTH OF THE CAPSULE (CM)
2·5
2·4
2·3
2·2
2·1
2·0
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
TREATMENTS

Figure 1(g). Mean values of parents and hybrids for number of seeds per capsule in a 6 x 6 diallel.

Treatment No.	Varieties/hybrids
1	ACV.1
2	CO.1
3	IC.284
4	S.8
5	VS.27
6	K.1
7	ACV.1 x CO.1
8	ACV.1 x IC.284
9	ACV.1 x S.8
10	ACV.1 x VS.27
11	ACV.1 x K.1
12	CO.1 x IC.284
13	CO.1 x S.8
14	CO.1 x VS.27
15	CO.1 x K.1
16	IC.284 x S.8
17	IC.284 x VS.27
18	IC.284 x K.1
19	S.8 x VS.27
20	S.8 x K.1
21	VS.27 x K.1

FIG. 1(9)



SCALE
Y AXIS : 2CM = 10 SEEDS
NUMBER OF SEEDS PER CAPSULE
110
100
90
80
70
60
50
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
TREATMENTS

exhibited a narrow range of variation. The variation for 1000 seed weight in the parents and hybrids is represented in Figure 1(h).

The percentage of oil content among the parents showed a range from a 35.50 in VS.27 to 55.50 in CO.1. Among the hybrids, it ranged from 25.50 recorded by CO.1 x K.1 to 45.83 recorded by IC.284 x VS.27. The hybrids in general were inferior to their parents for oil yield. The variation shown by parents and hybrids for this character is represented in Figure 1(i).

Among the parents, seed yield per plant was minimum in CO.1 (2.18 g) and maximum in ACV.1 (5.82 g). The range for this character among the hybrids was from a minimum of 2.13 g recorded by ACV.1 x CO.1 to a maximum of 4.93 g recorded by CO.1 x S.8. The hybrids exhibited only little variation for this character. The variation for seed yield per plant in the parents and hybrids is represented in Figure 1(j).

Seed yield per plot in the parental varieties ranged from a minimum of 67.78 g recorded by CO.1 to a maximum of 205.13 g recorded by ACV.1, whereas, the values ranged from 61.22 g in ACV.1 x CO.1 to 181.84 g in the cross CO.1 x S.8, from the hybrids. The hybrids showed a wide range of variation for this character. Some of the hybrids were better

Figure 1(h). Mean values of parents and hybrids for 1000 seed weight in a 6 x 6 diallel.

Treatment No.	Varieties/hybrids
1	ACV.1
2	CO.1
3	IC.284
4	S.8
5	VS.27
6	K.1
7	ACV.1 x CO.1
8	ACV.1 x IC.284
9	ACV.1 x S.8
10	ACV.1 x VS.27
11	ACV.1 x K.1
12	CO.1 x IC.284
13	CO.1 x S.8
14	CO.1 x VS.27
15	CO.1 x K.1
16	IC.284 x S.8
17	IC.284 x VS.27
18	IC.284 x K.1
19	S.8 x VS.27
20	S.8 x K.1
21	VS.27 x K.1

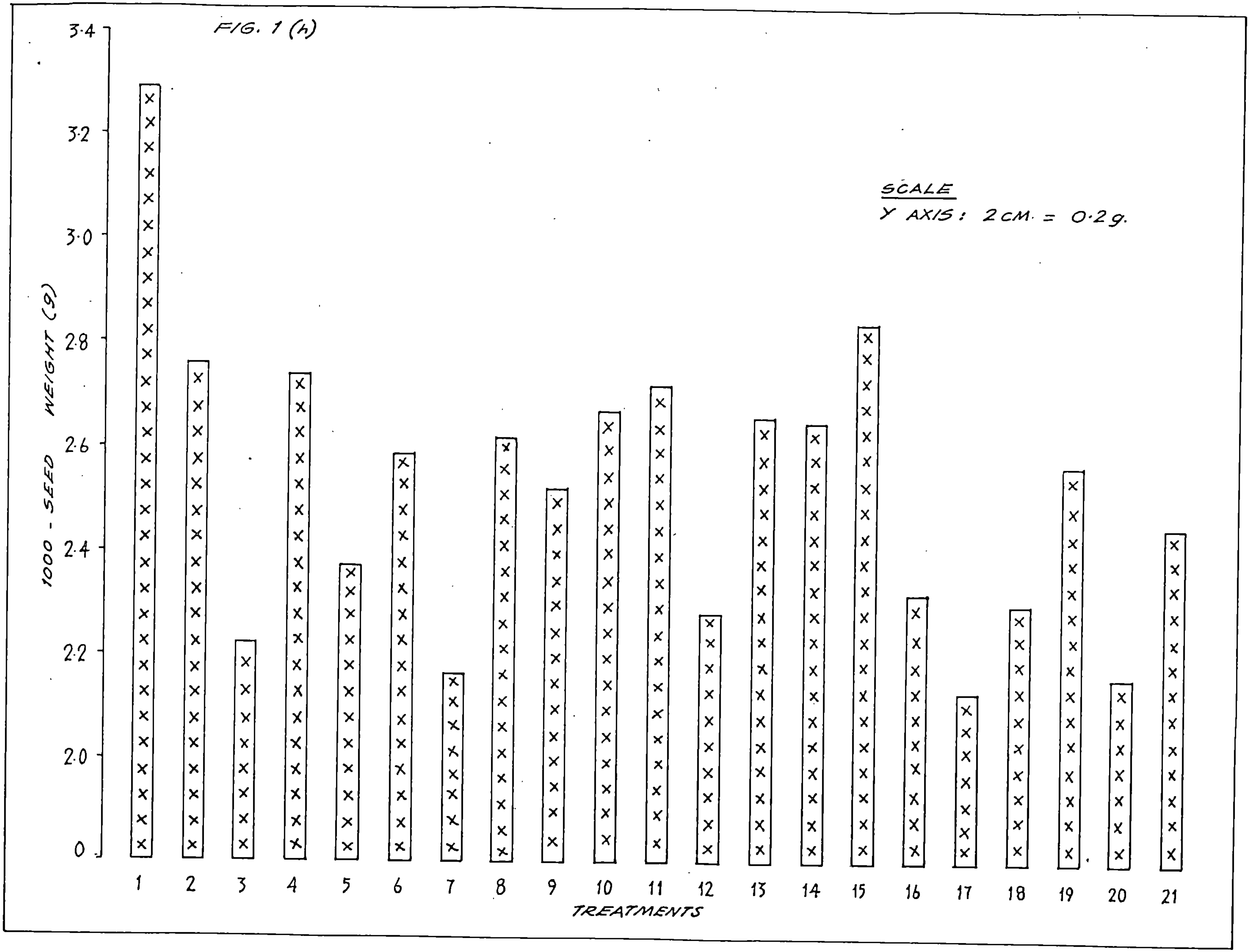


FIG. 1 (h)
SCALE
Y AXIS: 2 CM = 0·2 g.
1000 - SEED WEIGHT (g)
3·4
3·2
3·0
2·8
2·6
2·4
2·2
2·0
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
TREATMENTS

Figure 1(i). Mean values of parents and hybrids for oil content in a 6 x 6 diallel.

Treatment No.	Varieties/hybrids
1	ACV.1
2	CO.1
3	IC.284
4	S.8
5	VS.27
6	K.1
7	ACV.1 x CO.1
8	ACV.1 x IC.284
9	ACV.1 x S.8
10	ACV.1 x VS.27
11	ACV.1 x K.1
12	CO.1 x IC.284
13	CO.1 x S.8
14	CO.1 x VS.27
15	CO.1 x K.1
16	IC.284 x S.8
17	IC.284 x VS.27
18	IC.284 x K.1
19	S.8 x VS.27
20	S.8 x K.1
21	VS.27 x K.1

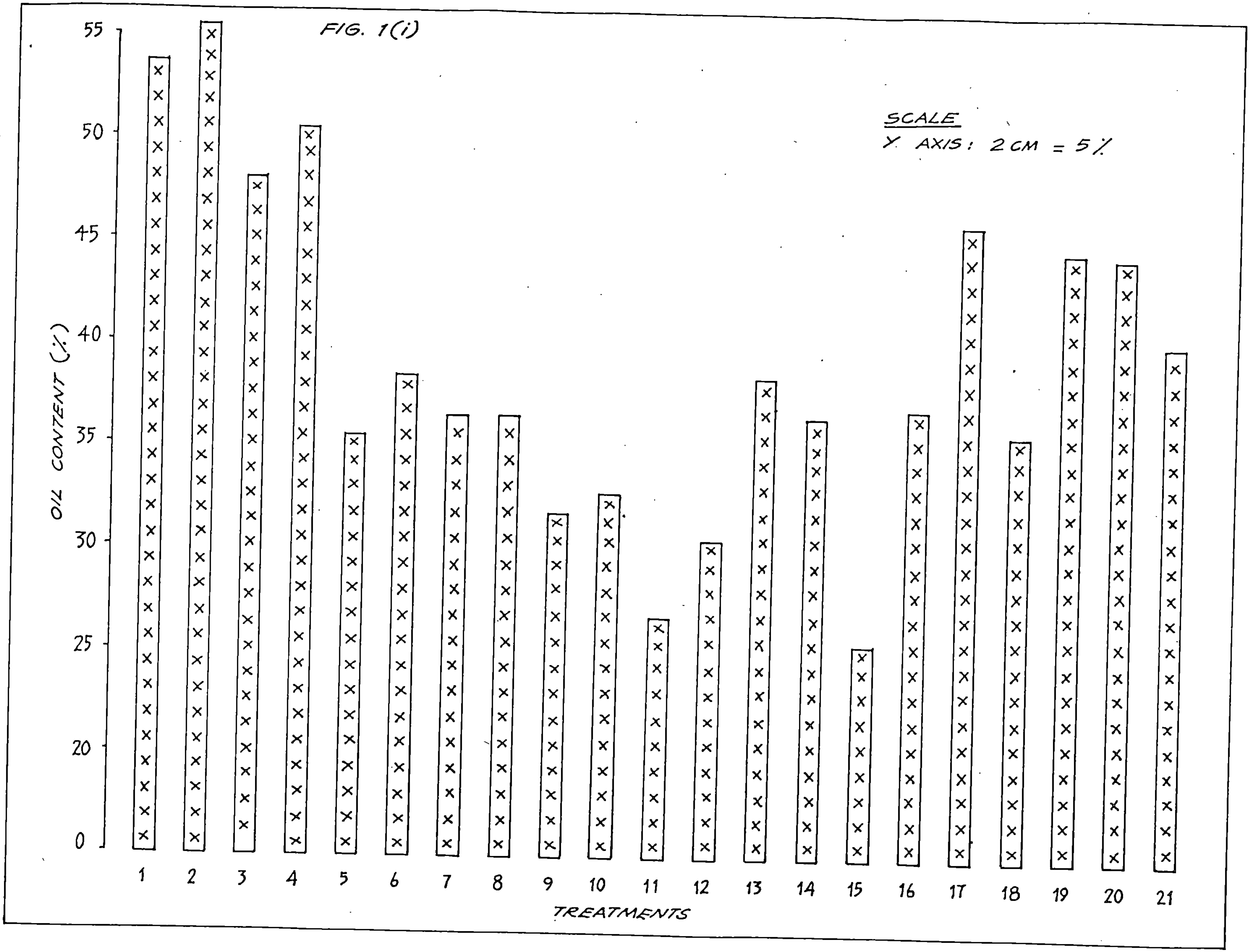
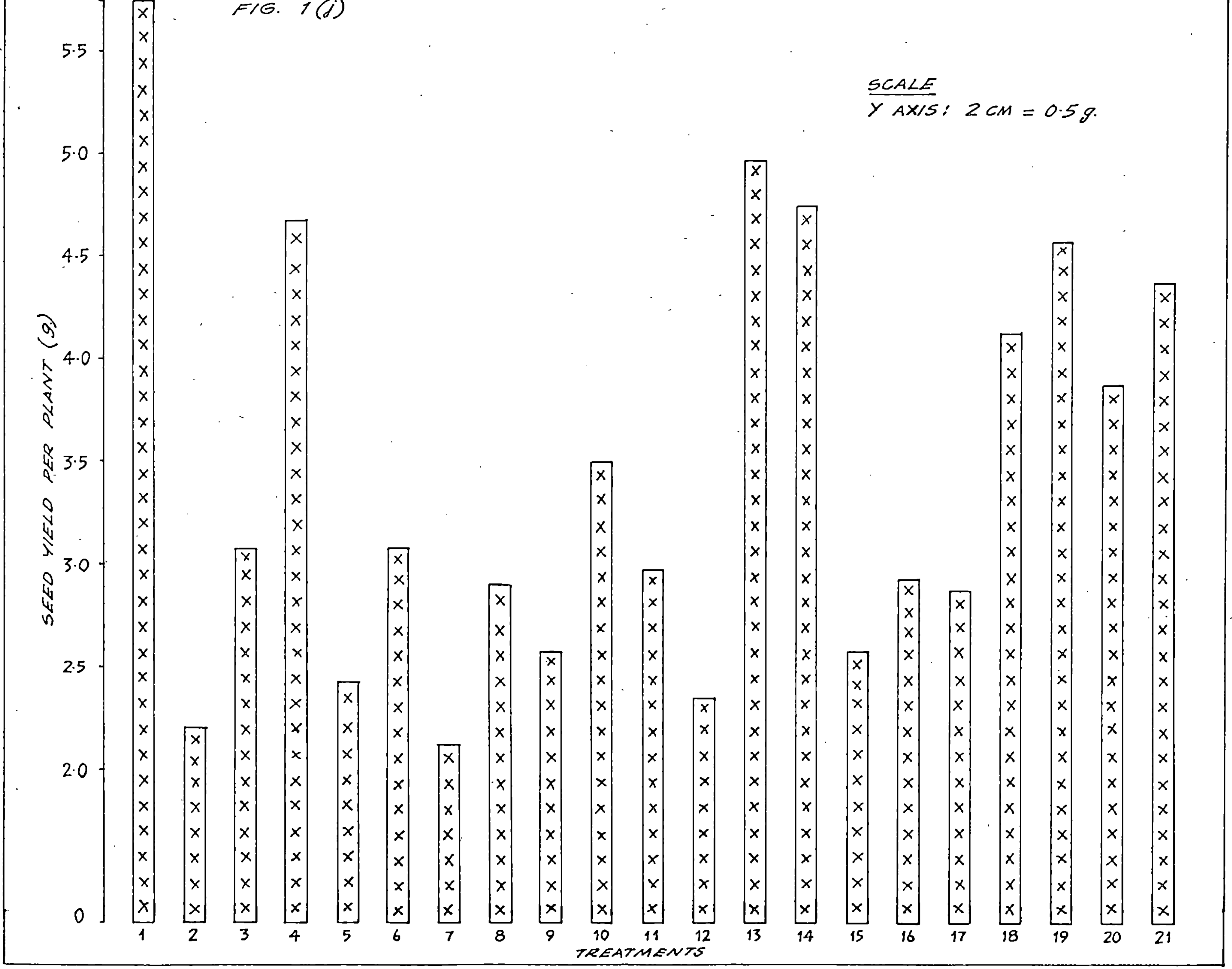


FIG. 1(i)
SCALE
Y AXIS: 2 CM = 5%
OIL CONTENT (%)
0
20
25
30
35
40
45
50
55
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
TREATMENTS

Figure 1(j). Mean values of parents and hybrids for seed yield per plant in a 6 x 6 diallel.

Treatment No.	Varieties/hybrids
1	ACV.1
2	CO.1
3	IC.284
4	S.8
5	VS.27
6	K.1
7	ACV.1 x CO.1
8	ACV.1 x IC.284
9	ACV.1 x S.8
10	ACV.1 x VS.27
11	ACV.1 x K.1
12	CO.1 x IC.284
13	CO.1 x S.8
14	CO.1 x VS.27
15	CO.1 x K.1
16	IC.284 x S.8
17	IC.284 x VS.27
18	IC.284 x K.1
19	S.8 x VS.27
20	S.8 x K.1
21	VS.27 x K.1

FIG. 1(d)


SCALE
Y AXIS: 2 CM = 0·5 g.
SEED YIELD PER PLANT (g)
5·5
5·0
4·5
4·0
3·5
3·0
2·5
2·0
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
TREATMENTS

than their parents in their yielding ability. The variation exhibited by the parents and hybrids for this character is represented in Figure 1(k).

It was seen that in general among the parents the variety ACV.1 had the highest mean values for plant height, seed number per capsule, 1000 seed weight and seed yield and the variety S.8 for branch number and capsule number per plant and for capsule length. Among the hybrids, CO.1 x S.8 exhibited the highest mean values for capsule length, seed yield per plant and seed yield per plot and CO.1 x K.1 for 1000 seed weight and it was the earliest to mature.

4.1 Combining ability

The analysis of variance of the eleven characters studied is presented in Table 4. The results clearly showed significant difference for all the attributes among the twentyone treatments except for days to mature. As the significant differences among the treatments were established for the ten characters, combining ability analysis was carried out following the Method 2 under Model 1 as suggested by Griffing (1956). The analysis of variance for combining ability is presented in Table 5.

The mean squares due to general combining ability (g.c.a) were significant for the characters, viz. plant

Table 4. Analysis of variance for eleven characters in a 6 x 6 diallel

Sl. No.	Characters	Mean squares		
		Treatments	Error	$F_{20, 62}$
1.	Plant height	440.39	7.99	55.14**
2.	Days to flower	3.17	1.21	2.62**
3.	Days to mature	2.07	2.45	0.84
4.	Number of branches per plant	0.46	0.24	1.95*
5.	Number of capsules per plant	364.03	4.71	77.26**
6.	Capsule length	0.026	0.0064	4.07**
7.	Number of seeds per capsule	418.06	11.17	37.42**
8.	Weight of 1000 seeds	0.24	0.00034	704.95**
9.	Oil content	204.04	2.89	70.49**
10.	Seed yield per plant	3.35	0.12	27.92**
11.	Seed yield per plot	5784.48	121.29	47.69**

* Significant at 5 percent level

** Significant at 1 percent level

Table 5. Analysis of variance for combining ability for ten characters in a 6 x 6 diallel

Sl. No.	Character	Mean squares		
		g.c.a	s.c.a	Error
1.	Plant height	192.78**	546.51**	2.662
2.	Days to flower	1.33	3.97**	0.404
3.	Days to mature	1.33	3.97	2.45
4.	Number of branches per plant	0.27	0.54*	0.078
5.	Number of capsules per plant	124.73**	466.59**	1.570
6.	Capsule length	0.0079	0.034**	0.0021
7.	Number of seeds per capsule	244.14**	492.61**	3.720
8.	Weight of 1000 seeds	0.12**	0.29**	0.00011
9.	Oil content	25.46**	280.58**	0.960
10.	Seed yield per plant	0.77**	4.46**	0.040
11.	Seed yield per plot	1097.84**	7793.04**	40.43

* Significant at 5 percent level

** Significant at 1 percent level

Figure 1(k). Mean values of parents and hybrids for seed yield per plot in a 6 x 6 diallel.

Treatment No.	Varieties/hybrids
1	ACV.1
2	CO.1
3	IC.284
4	S.8
5	VS.27
6	K.1
7	ACV.1 x CO.1
8	ACV.1 x IC.284
9	ACV.1 x S.8
10	ACV.1 x VS.27
11	ACV.1 x K.1
12	CO.1 x IC.284
13	CO.1 x S.8
14	CO.1 x VS.27
15	CO.1 x K.1
16	IC.284 x S.8
17	IC.284 x VS.27
18	IC.284 x K.1
19	S.8 x VS.27
20	S.8 x K.1
21	VS.27 x K.1

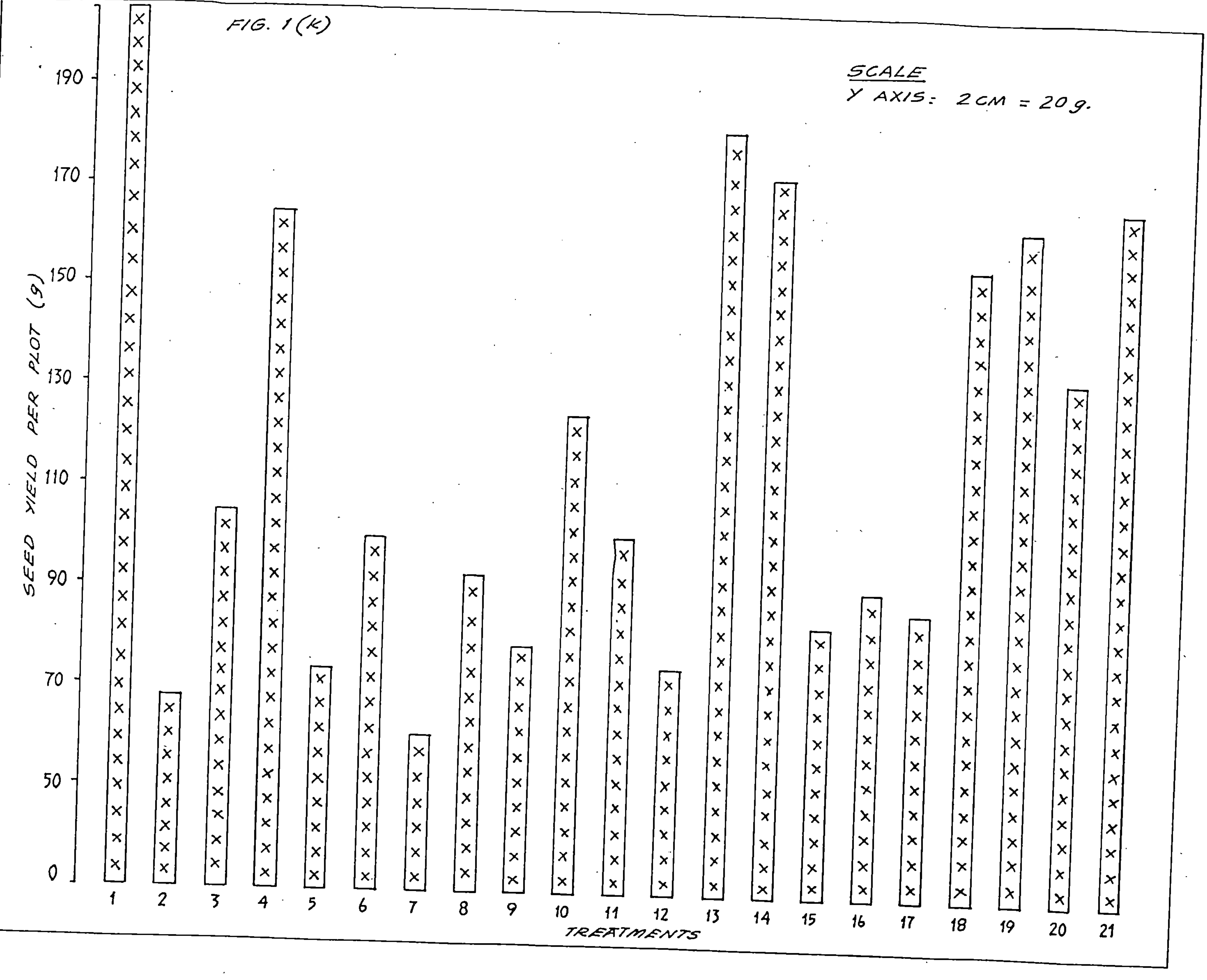


FIG. 1(k)
SCALE
Y AXIS: 2CM = 20g.
SEED YIELD PER PLOT (g)
190
170
150
130
110
90
70
50
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
TREATMENTS

height, number of capsules per plant, number of seeds per capsule, weight of 1000 seeds, oil content, seed yield per plant and seed yield per plot. However, the variance due to specific combining ability (s.c.a) was significant for all the ten characters. The s.c.a variance was greater in magnitude than g.c.a for all the characters indicating the importance of s.c.a for these characters.

The estimates of the g.c.a effects of the six parents and s.c.a effects of the fifteen F_1 population for the ten characters are presented in Table 6.

4.1.1. Plant height

The combining ability analysis for plant height showed that the variances due to g.c.a and s.c.a were significant but s.c.a variance was higher in magnitude than the g.c.a variance. This suggested the importance of specific combining ability for this character.

The g.c.a and s.c.a effects for this character is presented in Table 6(i). The parents ACV.1, CO.1, S.8, VS.27 and K.1 exhibited significant g.c.a effects. Among these, significant positive g.c.a effects were shown by ACV.1 (6.813), S.8 (4.713) and K.1 (1.250), while VS.27 showed significant negative g.c.a effect (-6.388). Thus ACV.1 is the best general combiner for tallness followed by S.8 and K.1 and for dwarfness, VS.27.

Table 6. G.c.a and s.c.a effects for the ten characters in a 6 x 6 diallel
(The figures in the diagonal are the g.c.a effects and those in the off diagonal are s.c.a effects)

(i) g.c.a and s.c.a effects for plant height

Parents	ACV.1	CO.1	IC.284	S.8	VS.27	K.1
ACV.1	6.813*	-5.260*	-14.270*	-5.270*	-8.570*	16.690*
CO.1		-5.700*	2.044	12.040*	20.040*	-5.990*
IC.284			-0.688	-0.870	2.530*	-4.510*
S.8				4.713*	1.630	6.790*
VS.27					-6.388*	5.290*
K.1						1.250*

SE (gi) = 0.530
SE (gi-gj) = 0.860
CD (0.05) (gi-gj) = 1.649

SE (Sij) = 1.194
SE (Sij-Sik) = 2.158
SE (Sij-Skl) = 1.998
CD (0.05) (Sij-Sik) = 4.361
CD (0.05) (Sij-Skl) = 4.038

(ii) g.c.a and s.c.a effects for days to flower

Parents	ACV.1	CO.1	IC.284	S.8	VS.27	K.1
ACV.1	0.304	1.350*	-0.720	0.460	-0.310	-0.920
CO.1		0.395	0.020	-0.660	-0.470	-0.010
IC.284			-0.232	-2.270*	0.590	0.550
S.8				-0.483*	-0.120	-0.230
VS.27					0.488*	-0.240
K.1						-0.472*

SE (gi) = 0.205
SE (gi-gj) = 0.318
CD (0.05) (gi-gj) = 0.643

SE (Sij) = 0.465
SE (Sij-Sik) = 0.841
SE (Sij-Skl) = 0.778
CD (0.05) (Sij-Sik) = 1.699
CD (0.05) (Sij-Skl) = 1.572

The s.c.a effect estimates of the F_1's ranged from -14.270 in ACV.1 x IC.284 to 20.040 in CO.1 x VS.27. Twelve out of the fifteen hybrids had significant s.c.a effects. But it was positive only in 6 crosses, viz. CO.1 x VS.27 (20.040), ACV.1 x K.1 (16.690), CO.1 x S.8 (12.040), S.8 x K.1 (6.790), VS.27 x K.1 (5.290) and IC.284 x VS.27 (2.530). The significant negative s.c.a effects were recorded by IC.284 x K.1 (-4.510), ACV.1 x CO.1 (-5.260), ACV.1 x S.8 (-5.270), CO.1 x K.1 (-5.990), ACV.1 x VS.27 (-8.570) and ACV.1 x IC.284 (-14.270).

4.1.2 <u>Days to flower</u>

The s.c.a variance was alone significant for this character, and was three times the g.c.a variance indicating the importance of s.c.a.

The estimates of g.c.a and s.c.a effects are presented in Table 6(ii). The g.c.a effects were comparatively less for days to flower. It was significant in the three parental varieties S.8, VS.27, and K.1. Of these, positive g.c.a effect was exhibited by VS.27 (0.488) alone, whereas, K.1 and S.8 showed negative g.c.a effects of -0.472 and -0.483 respectively. The best general combiner for earliness to flowering was S.8.

The s.c.a effects were also comparatively low and ranged from -2.270 to 1.350. Of the fifteen cross combinations, only two crosses exhibited significant s.c.a effects. The cross ACV.1 x CO.1 showed significant positive s.c.a effect of 1.350 whereas the s.c.a effect of IC.284 x S.8 was significant, but negative.

4.1.3 Number of branches per plant

Variance due to s.c.a alone was significant for the character number of branches per plant and was twice the g.c.a variance. An insignificant g.c.a variance supported the importance of s.c.a for this character.

The estimates of g.c.a and s.c.a effects are presented in Table 6(iii). The g.c.a effects ranged from - 0.359 to 0.231. It was significant in two parental varieties. The parent ACV.1 had significant negative g.c.a effect (-0.359) and VS.27, significant positive effect (0.231). So VS.27 is a good general combiner for incorporating higher branching ability and ACV.1 for non-branchingness.

The s.c.a effect estimates of the hybrids were comparatively low and ranged from - 0.345 to 0.567. Only one F_1 showed significant s.c.a effect viz. VS.27 x K.1 (0.567), suggesting that it was the best specific combination for the character, number of branches per plant.

Table 6 contd.

(iii) g.c.a and s.c.a effects for the number of branches per plant

Parents	ACV.1	CO.1	IC.284	S.8	VS.27	K.1
ACV.1	-0.359*	0.059	-0.345	-0.213	-0.173	-0.043
CO.1		0.099	0.197	0.097	-0.093	-0.127
IC.284			-0.058	-0.143	-0.303	0.287
S.8				0.042	-0.233	-0.043
VS.27					0.231*	0.567*
K.1						0.043

SE (gi) = 0.090
SE (gi-gj) = 0.140
CD (0.05) (gi-gj) = 0.283

SE (Sij) = 0.204
SE (Sij-Sik) = 0.369
SE (Sij-Skl) = 0.342
CD (0.05) (Sij-Sik) = 0.746
CD (0.05) (Sij-Skl) = 0.691

(iv) g.c.a and s.c.a effects for number of capsules per plant

Parents	ACV.1	CO.1	IC.284	S.8	VS.27	K.1
ACV.1	-4.320*	-6.150*	-6.610*	-10.800*	2.210*	-4.120*
CO.1		-3.870*	0.050	8.910*	19.690*	-7.800*
IC.284			-3.410*	-6.570*	-2.190*	+16.610*
S.8				5.120*	2.400*	-1.130
VS.27					2.510*	9.050*
K.1						3.970*

SE (gi) = 0.404
SE (gi-gj) = 0.626
CD (0.05) (gi-gj) = 1.265

SE (Sij) = 0.917
SE (Sij-Sik) = 1.658
SE (Sij-Skl) = 1.535
CD (0.05) (Sij-Sik) = 3.351
CD (0.05) (Sij-Skl) = 3.102

4.1.4 Number of capsules per plant

In the case of number of capsules per plant, the variances due to g.c.a and s.c.a were significant, but s.c.a variance was three times higher than that of g.c.a This suggested the importance of s.c.a for this character.

The estimates of g.c.a and s.c.a effects for number of capsules per plant are presented in Table 6(iv). The g.c.a effects were significant for all the six parental varieties. It was negative and significant in the parents ACV.1 (-4.320), CO.1 (-3.870) and IC.284 (-3.410), whereas, it was positive and significant in S.8 (5.120), K.1 (3.970) and VS.27 (2.510). This indicated that the variety S.8 was the best general combiner for this character followed by K.1 and VS.27.

The estimates of s.c.a effects for capsule number per plant was comparatively high. It was significant in all the cross combinations except CO.1 x IC.284 and S.8 x K.1. Significant, negative s.c.a effects were exhibited by IC.284 x VS.27 (-2.190), ACV.1 x K.1 (-4.120), ACV.1 x CO.1 (-6.150), IC.284 x S.8 (-6.570), ACV.1 x IC.284 (-6.610), CO.1 x K.1 (-7.800) and ACV.1 x S.8 (-10.800). Six hybrids showed significant positive s.c.a effects, viz. CO.1 x VS.27 (19.690), IC.284 x K.1 (16.610), VS.27 x K.1 (9.050), CO.1 x S.8 (8.910), S.8 x VS.27 (2.400) and ACV.1 x VS.27 (2.210). It indicated that these are the specific combinations which could yield maximum number of capsules per plant.

4.1.5 Length of the capsule

The variance due to s.c.a alone was significant for the character capsule length. The insignificant g.c.a variance and the magnitude of s.c.a variance being four times that of g.c.a suggested the predominance of s.c.a for this character.

The estimates of g.c.a and s.c.a effects are presented in Table 6(v). The g.c.a effects for capsule length was low and was significant in two parental varieties. Significant negative g.c.a effect was recorded by IC.284 (-0.043), while S.8 recorded significant, positive, g.c.a effect (0.055). The variety S.8 is the best general combiner for capsule length.

The s.c.a effect estimates were comparatively low for this character also. Only five crosses showed significant s.c.a effects. Significant negative s.c.a effects were recorded by S.8 x VS.27 (-0.070) and CO.1 x K.1 (-0.140). Significant positive, s.c.a effects were exhibited by the hybrids, CO.1 x S.8 (0.170), ACV.1 x K.1 (0.110) and CO.1 x

Table 6 contd.

(v) g.c.a and s.c.a effects for capsule length

Parents	ACV.1	CO.1	IC.284	S.8	VS.27	K.1
ACV.1	0.020	0.020	-0.030	-0.040	0.020	0.110*
CO.1		-0.005	0.060	0.170*	0.100*	-0.140*
IC.284			-0.043*	0.050	0.050	0.050
S.8				0.055*	-0.070*	0.040
VS.27					-0.003	-0.020
K.1						-0.025

SE (gi) = 0.015
SE (gi-gj) = 0.023
CD (0.05) (gi-gj) = 0.046

SE (Sij) = 0.034
SE (Sij-Sik) = 0.061
SE (Sij-Skl) = 0.056
CD (0.05) (Sij-Sik) = 0.123
CD (0.05) (Sij-Skl) = 0.113

(vi) g.c.a and s.c.a effects for number of seeds per capsule

Parents	ACV.1	CO.1	IC.284	S.8	VS.27	K.1
ACV.1	10.390*	-11.570*	7.720*	-12.870*	-11.320*	-8.540*
CO.1		-3.620*	-5.410*	13.460*	4.720*	0.340
IC.284			3.770*	-4.780*	-4.600*	-5.220*
S.8				-1.340*	3.970*	4.520*
VS.27					-3.230*	6.610*
K.1						-5.980*

SE (gi) = 0.622
SE (gi-gj) = 0.964
CD (0.05) (gi-gj) = 1.948

SE (Sij) = 1.412
SE (Sij-Sik) = 2.551
SE (Sij-Skl) = 2.362
CD (0.05) (Sij-Sik) = 5.156
CD (0.05) (Sij-Skl) = 4.774

VS.27 (0.100). These are the best specific combinations which could yield capsules with maximum length.

4.1.6 Number of seeds per capsule

Regarding the number of seeds per capsule combining ability analysis showed significant g.c.a and s.c.a variances. The s.c.a variance was twice higher in magnitude than the g.c.a variance suggesting the importance of s.c.a for this character.

The estimates of g.c.a and s.c.a effects for number of seeds per capsule are presented in Table 6(vi). The g.c.a effect estimates were comparatively high and significant in all the six parental varieties. Significant negative g.c.a effects were recorded by the varieties S.8 (-1.340), VS.27 (-3.230), CO.1 (-3.620) and K.1 (-5.980). Two varieties, viz. ACV.1 and IC.284 exhibited positive, significant g.c.a effects of 10.390 and 3.770 respectively. The best general combiner for number of seeds per capsule was ACV.1 followed by IC.284.

The s.c.a effect estimates were also comparatively high and was significant in fourteen out of the fifteen cross combinations. Significant, negative s.c.a effects were exhibited by eight hybrids viz. IC.284 x VS.27 (-4.600), IC.284 x S.8 (-4.780), IC.284 x K.1 (-5.220), CO.1 x IC.284

(-5.410), ACV.1 x K.1 (-8.540), ACV.1 x VS.27 (-11.320), ACV.1 x CO.1 (-11.570) and ACV.1 x S.8 (-12.870). The hybrids, CO.1 x S.8, ACV.1 x IC.284, VS.27 x K.1, CO.1 x VS.27, S.8 x K.1 and S.8 x VS.27 recorded significant, positive s.c.a effects of 13.460, 7.720, 6.610, 4.720, 4.520, and 3.970 respectively. These were the best specific combinations for seed number per capsule.

4.1.7 Weight of 1000 seeds

Both g.c.a and s.c.a variances were significant for 1000 seed weight. The s.c.a variance was more than twice the g.c.a variance suggesting the predominance of s.c.a for this character.

The estimates of g.c.a and s.c.a effects for 1000 seed weight are presented in Table 6(vii). The g.c.a effect estimates were low and were significant in four parental varieties. Significant negative g.c.a effect was exhibited by the varieties IC.284 (-0.199) and VS.27 (-0.580) and significant, positive g.c.a effects by ACV.1 (0.200) and CO.1 (0.055). The best general combiner for 1000 seed weight was ACV.1 followed by CO.1.

The estimates of s.c.a effects were low and were significant in eleven cross combinations. Six hybrids showed significant negative s.c.a effects viz. IC.284 x K.1

Table 6 contd.

(vii) g.c.a and s.c.a effects for weight of 1000 seeds

Parents	ACV.1	CO.1	IC.284	S.8	VS.27	K.1
ACV.1	0.200*	-0.620*	0.090*	-0.210*	0.003	0.003
CO.1		0.055*	-0.100*	0.070*	0.120*	0.260*
IC.284			-0.199*	-0.010	-0.140*	-0.030*
S.8				0.005	0.090*	-0.370*
VS.27					-0.580*	-0.010
K.1						-0.006

SE (gi) = 0.0034
SE (gi-gj) = 0.0052
CD (0.05) (gi-gj) = 0.011

SE (Sij) = 0.008
SE (Sij-Sik) = 0.014
SE (Sij-Skl) = 0.013
CD (0.05) (Sij-Sik) = 0.028
CD (0.05) (Sij-Skl) = 0.026

(viii) g.c.a and s.c.a effects for oil content

Parents	ACV.1	CO.1	IC.284	S.8	VS.27	K.1
ACV.1	-0.430	-2.850*	-3.120*	-9.910*	-5.640*	-8.950*
CO.1		0.410	-10.120*	-4.250*	-2.810*	-10.950*
IC.284			0.840*	-6.020*	6.250*	-1.220
S.8				2.800*	3.130*	5.650*
VS.27					-0.470	4.590*
K.1						-3.160*

SE (gi) = 0.316
SE (gi-gj) = 0.490
CD (0.05) (gi-gj) = 0.990

SE (Sij) = 0.717
SE (Sij-Sik) = 1.296
SE (Sij-Skl) = 1.200
CD (0.05) (Sij-Sik) = 2.619
CD (0.05) (Sij-Skl) = 2.425

(-0.030), CO.1 x IC.284 (-0.100), IC.284 x VS.27 (-0.140), ACV.1 x S.8 (-0.210), S.8 x K.1 (-0.370) and ACV.1 x CO.1 (-0.620). Significant positive s.c.a effects were recorded by CO.1 x K.1 (0.260), CO.1 x VS.27 (0.120), ACV.1 x IC.284 (0.090), S.8 x VS.27 (0.090) and CO.1 x S.8 (0.070). These were the best specific combinations for 1000 seed weight.

4.1.8. Oil content

The combining ability analysis for oil content showed that both g.c.a and s.c.a variances were significant for the character oil content. The variance due to s.c.a was about ten times higher than that due to g.c.a establishing the predominance of s.c.a for this character.

The estimates of g.c.a and s.c.a effects for oil content are presented in Table 6 (viii). The g.c.a effects were significant for three parental varieties. Significant negative g.c.a was shown by K.1 (-3.160) while significant positive g.c.a was recorded by S.8 (2.800) and IC.284 (0.840). The best general combiner for oil content was S.8 followed by IC.284.

The estimates of s.c.a effects showed a predominance of negative effects over positive effects. Out of the fifteen cross combinations, significant s.c.a effects were noticed in fourteen hybrids. Significant negative s.c.a effects were recorded by the crosses viz. CO.1 x VS.27 (-2.810), ACV.1 x CO.1 (-2.850), ACV.1 x IC.284 (-3.120), CO.1 x S.8 (-4.250), ACV.1 x VS.27 (-5.640), IC.284 x S.8 (-6.020), ACV.1 x K.1 (-8.950), ACV.1 x S.8 (-9.910), CO.1 x IC.284 (-10.120) and CO.1 x K.1 (-10.950). Only four crosses, viz. IC.284 x VS.27 (6.250), S.8 x K.1 (5.650), VS.27 x K.1 (4.590) and S.8 x VS.27 (3.130) recorded positive s.c.a effects. These were the best specific combinations for oil content.

4.1.9. Seed yield per plant

The analysis for combining ability showed significant g.c.a and s.c.a variances for seed yield per plant. The s.c.a variance was six times higher than the g.c.a variance indicating the predominant role of s.c.a for this character.

The g.c.a and s.c.a effects for seed yield per plant is presented in Table 6(ix). The estimates of g.c.a effects were low and were significant in four parental varieties. The varieties IC.284 and CO.1 recorded significant negative g.c.a effects of -0.360 and -0.390 respectively. Significant positive g.c.a effects were shown by S.8 (0.500) and ACV.1 (0.180). Hence the best general combiner for seed yield per plant was S.8 followed by ACV.1.

Table 6 contd.

(ix) g.c.a and s.c.a effects for seed yield per plant

PARENTS	ACV.1	CO.1	IC.284	S.8	VS.27	K.1
ACV.1	0.180*	-1.120*	-0.370*	-1.570*	-0.240	-0.660*
CO.1		-0.390*	-0.350*	1.360*	1.590*	-0.470*
IC.284			-0.360*	-0.680*	-0.300*	1.050*
S.8				0.500*	0.530*	-0.060
VS.27					0.090	0.850*
K.1						-0.020

SE (gi) = 0.065
SE (gi-gj) = 0.100
CD (0.05) (gi-gj) = 2.020

SE (Sij) = 0.146
SE (Sij-Sik)= 0.265
SE (Sij-Skl)= 0.245
CD (0.05) (Sij-Sik) = 0.536
CD (0.05) (Sij-Skl) = 0.495

(x) g.c.a and s.c.a effects for seed yield per plot

PARENTS	ACV.1	CO1	IC.284	S.8	VS.27	K.1
ACV.1	4.920*	-47.290*	-16.140*	-63.240*	-2.670	-24.420*
CO.1		-14.820*	-14.470*	59.670*	65.120*	-21.050*
IC.284			-14.620*	-31.650*	-20.990*	50.850*
S.8				18.580*	21.370*	-5.950
VS.27					4.160*	43.570*
K.1						1.780

SE (gi) = 2.050
SE (gi-gj) = 3.179
CD (0.05) (gi-gj) = 6.425

SE (Sij) = 4.654
SE (Sij-Sik) = 8.411
SE (Sij-Skl) = 7.787
CD (0.05) (Sij-Sik) = 16.999
CD (0.05) (Sij-Skl) = 15.738

The estimates of s.c.a effects were significant in thirteen out of the fifteen cross combinations. Significant negative s.c.a effects were recorded by eight crosses viz. IC.284 x VS.27 (-0.300), CO.1 x IC.284 (-0.350), ACV.1 x IC.284 (-0.370), CO.1 x K.1 (-0.470), ACV.1 x K.1 (-0.660), IC.284 x S.8 (-0.680), ACV.1 x CO.1 (-1.120) and ACV.1 x S.8 (-1.570). The s.c.a effects were positive and significant in CO.1 x VS.27 (1.590), CO.1 x S.8 (1.360), IC.284 x K.1 (1.050), VS.27 x K.1 (0.850) and S.8 x VS.27 (0.530). These were the best specific combinations for seed yield per plant.

4.1.10. Seed yield per plot

Both g.c.a and s.c.a variances were significant for seed yield per plot. The variance due to s.c.a was seven times higher in magnitude than the g.c.a variance suggesting the importance of s.c.a for this character.

The g.c.a and s.c.a effect estimates for seed yield per plot are presented in Table 6(x). The estimates of g.c.a effects were comparatively high and were significant in five of the six parental varieties. The varieties CO.1 and IC.284 recorded significant negative g.c.a effects of -14.820 and -14.620 respectively. Significant positive g.c.a effects were shown by three varieties. The best general combiner for this character was S.8 (18.580) followed by ACV.1 (4.920) and VS.27 (4.160).

The cross combinations recorded high estimates of s.c.a effects which were significant in thirteen crosses. Significant negative s.c.a effects were exhibited by eight hybrids viz. CO.1 x IC.284 (-14.470), ACV.1 x IC.284 (-16.140), IC.284 x VS.27 (-20.990), CO.1 x K.1 (-21.050), ACV.1 x K.1 (-24.420), IC.284 x S.8 (-31.650), ACV.1 x CO.1 (-47.290) and ACV.1 x S.8 (-63.240). The s.c.a effects were positive and significant only in five crosses viz. CO.1 x VS.27 (65.120), CO.1 x S.8 (59.670), IC.284 x K.1 (50.850), VS.27 x K.1 (43.570) and S.8 x VS.27 (21.370) which were also the best specific combinations showing maximum seed yield per plot.

The abstract of the best general combiner and specific combination for each character are given in Table 7.

It was seen that the variety ACV.1 was the best general combiner for the characters, plant height (6.813), number of seeds per capsule (10.390) and 1000 seed weight (0.200) and the variety, S.8, for days to flower (-0.483), capsule number per plant (5.120), capsule length (0.055), oil content (2.800), seed yield per plant (0.500) and seed yield per plot (18.580). The best specific cross combination was CO.1 x VS.27 (for plant height (20.400), capsule

Table 7. Best general combiners and specific combinations for the ten characters in a 6 x 6 diallel

Sl. No.	Character	Best General Combiner		Best Specific Combinations	
		Variety	g.c.a effect	Cross combination	s.c.a effect
1.	Plant height	ACV.1	6.813	CO.1 x VS.27	20.040
2.	Days to flower	S.8	-0.483	IC.284 x S.8	-2.270
3.	Number of branches per plant	VS.27	0.231	VS.27 x K.1	0.567
4.	Number of capsules per plant	S.8	5.120	CO.1 x VS.27	19.690
5.	Capsule length	S.8	0.055	CO.1 x S.8	0.170
6.	Number of seeds per capsule	ACV.1	10.390	CO.1 x S.8	13.460
7.	Weight of 1000 seeds (g)	ACV.1	0.200	CO.1 x K.1	0.260
8.	Oil content (%)	S.8	2.800	IC.284 x VS.27	6.250
9.	Seed yield per plant (g)	S.8	0.500	CO.1 x VS.27	1.590
10.	Seed yield per plot (g)	S.8	18.580	CO.1 x VS.27	65.120

number per plant (19.690), seed yield per plot (65.120) and seed yield per plant (1.590) and CO.1 x S.8 for capsule length (0.170) and number of seeds per capsule (13.460).

In general, most of the best specific cross combinations involved atleast one good general combiner for the character.

4.2. Gene action

Most of the economic characters are polygenically inherited and hence it is of prime importance to study their inheritance in terms of the components of genetic variance. Griffing (1956) and Sprague (1966) demonstrated the method of working out g.c.a and s.c.a effects along with their variances. He pointed out that high g.c.a variance contained not only the additive genetic variance but also a portion of the epistatic variance (additive x additive) and that s.c.a included all of the dominance and the remaining epistatic variance.

If the variance due to g.c.a and s.c.a showed high significance for all the characters, it indicated the importance of both additive and non-additive gene action. The estimate of g.c.a variance, if higher than their respective s.c.a variance, indicated predominance of additive gene action and vice-versa. For all the characters, the genetic components viz. the component due to g.c.a and that due to s.c.a have been worked out and their ratios are given in Table 8 and the variance due to g.c.a and s.c.a given in Table 5.

For plant height, both g.c.a and s.c.a variances were found significant at both levels of probability. This implied that both additive and non-additive gene action were important in governing this character. But s.c.a variance was more than twice the g.c.a variance indicating the predominance of non-additive gene action. Also, the value of the ratio of g.c.a to s.c.a variance was 0.044:1 suggesting the importance of non-additive gene action.

For the character days to flower, only the s.c.a variance was significant and that too at both 1% and 5% level of probability. The g.c.a to s.c.a variance ratio was 0.034:1. Both these suggested the importance of non-additive gene action alone in controlling this character.

Similarly, for the character, number of branches per plant, only the s.c.a variance was significant and it was twice the g.c.a variance. The value of g.c.a to s.c.a ratio was 0.052:1. Hence number of branches per plant was also observed to be under complete non-additive genic control.

Table 8. Estimates of components due to g.c.a, s.c.a and their ratio for the ten characters in a 6 x 6 diallel

Sl. No.	Character	Estimates of components due to		Ratio of g.c.a to s.c.a
		g.c.a	s.c.a	
1.	Plant height	23.77	543.85	0.044:1
2.	Days to flower	0.12	3.57	0.034:1
3.	Number of branches per plant	0.024	0.462	0.052:1
4.	Number of capsules per plant	15.4	465.02	0.033:1
5.	Length of the capsule	0.00073	0.032	0.023:1
6.	Number of seeds per capsule	30.05	488.89	0.06:1
7.	Weight of 1000 seeds	0.014	0.29	0.048:1
8.	Oil content	3.06	279.62	0.011:1
9.	Seed yield per plant	0.09	4.42	0.02:1
10.	Seed yield per plot	132.17	7752.61	0.017:1

The capsule number per plant had both g.c.a and s.c.a variances significant at 1% and 5% level of probability. The s.c.a variance was four times the g.c.a variance. The higher magnitude of s.c.a variance and the g.c.a to s.c.a ratio value of 0.033:1 indicated that this character was predominated by non-additive gene action.

The s.c.a variance was only significant for the character capsule length. The value of g.c.a to s.c.a variance ratio was 0.023:1, indicating that non-additive gene action governed this character also.

The variances due to g.c.a and s.c.a were significant for number of seeds per capsule, suggesting that both additive and non-additive gene action were involved in its inheritance. The higher magnitude of s.c.a variance and the value of g.c.a to s.c.a variance ratio viz. 0.06:1 indicated the predominant role of non-additive genes in controlling this character.

Both g.c.a and s.c.a variances were significant for the character 1000 seed weight indicating the importance of both additive and non-additive gene action in its inheritance. The variance due to s.c.a was more than twice the g.c.a variance and the g.c.a to s.c.a ratio was 0.048:1 establishing the predominance of non-additive gene action.

Although oil content was characterised by significant g.c.a and s.c.a variances, the magnitude of s.c.a variance was more than ten times the g.c.a variance. The value of g.c.a to s.c.a variance ratio was 0.011:1, supporting the fact that oil content was influenced by preponderance of non-additive gene action.

The significant g.c.a and s.c.a variances recorded for seed yield per plant showed that both additive and non-additive gene action were involved in the expression of this particular character. The magnitude of s.c.a variance was almost six times as that of g.c.a and the g.c.a to s.c.a ratio was 0.02:1 depicting the predominance of non-additive gene action in controlling this character.

The character seed yield per plot was also characterised by highly significant g.c.a and s.c.a variances. The s.c.a variance was more than seven times greater in magnitude than the g.c.a variance. The value of g.c.a : s.c.a ratio was 0.017:1 indicating that non-additive gene action governed this character.

In general it was seen that for all the ten characters studied non-additive gene action was more predominant than additive gene action in controlling their inheritance. Yield and the important yield attributes were influenced by both additive and non-additive genetic variances.

4.3. Heterosis

Statistical analysis of the data relating to six parents and fifteen hybrids showed significant differences for all the characters studied except for days to mature.

The extent of heterosis was calculated in percentage, in comparison with the mean value of the mid-parent (relative heterosis), better parent (heterobeltiosis) and the check variety (standard heterosis). In the estimation of heterosis for days to flower and days to mature, late flowering and late maturing parents were considered as better parents. The popular variety, Kayamkulam-1 (K.1) was taken as the check variety. The F_1 data and the percentage of heterosis over mid, better and check parental values with respect to the various characters are presented in Table 9.

4.3.1. Plant height

Table 9(i) shows the percentage of heterosis manifested by the fifteen hybrids over their mid-parent, better parent and check parental values. Compared to the mid-parental value, the percentage of heterosis in the fifteen hybrids ranged from -15.74 to 29.73. Positive heterosis was found in nine hybrids, viz. CO.1 x VS.27 (29.73), CO.1 x S.8 (18.40), VS.27 x K.1 (12.92), ACV.1 x K.1 (12.40), S.8 x K.1 (11.65), S.8 x VS.27 (8.90), CO.1 x K.1 (3.84), CO.1 x

Table:9. Percentage heterosis over mid, better, and check parental values for the ten characters in a 6x6 diallel.
(i)Heterosis percentage for plant height, days to flower and days to mature.

Sl. No.	Parents and hybrids	Plant height: Mean (cm)	Plant height: Percentage of heterosis over Mid Parent	Better Parent	Check Parent	No. of days to flower: Mean	Percentage of heterosis over Mid Parent	Better Parent	Check Parent	No of days to mature: Mean	Percentage of heterosis over Mid Parent	Better Parent	Check Parent
1.	ACV.1	148.6				37.20				81.3			
2.	ACV.1xCO.1	122.5	-2.94	-17.65**	2.08	38.57	3.67	3.67	7.14**	81.9	0.55	0.37	-0.12
3.	ACV.1xIC.284	118.5	-15.74**	-20.23**	-1.25	35.87	-3.28	-3.58	-0.36	83.0	0.61	-0.84	1.22
4.	ACV.1xS.8	132.9	-4.32**	-10.65**	10.75**	36.80	-0.76	-1.08	2.22	81.9	0.31	-0.12	-0.12
5.	ACV.1xVS.27	118.5	-5.99**	-20.23**	-1.25	37.00	-1.29	-2.03	2.78	83.4	1.21	-0.12	1.71
6.	ACV.1xK.1	151.4	12.40**	1.93	26.16**	35.43	-3.19	-4.75	-1.58	82.7	1.29	0.85	0.85
7.	CO.1	103.8				37.20				81.6			
8.	CO.1xIC.284	122.3	3.43	-7.91**	1.92	36.70	-1.03	-1.34	-1.94	81.7	-1.15	-2.39	-0.37
9.	CO.1xS.8	137.7	18.40**	6.80**	14.75**	35.77	-3.55	-3.85	-0.64	82.7	1.10	0.85	0.85
10.	CO.1xVS.27	134.6	29.73**	29.67**	12.17**	36.93	-1.49	-2.22	2.58	81.9	-0.79	-1.92	-0.12
11.	CO.1xK.1	116.2	3.84**	-3.56	-3.17	36.43	-0.46	-2.06	1.19	81.00	-0.98	-1.22	-1.22
12.	IC.284	132.8				36.97				83.7			
13.	IC.284xS.8	129.8	-0.80	-2.23	8.17**	33.53	-9.29**	-9.29**	-6.86**	81.7	-1.39	-2.39	-0.37
14.	IC.284xVS.27	122.1	3.33	-8.03**	1.75	37.37	0.00	-1.06	3.81	82.9	-0.84	-0.96	1.10
15.	IC.284xK.1	122.7	-3.31	-7.63**	2.25	36.37	-0.32	-1.62	1.03	84.2	1.63**	-0.60	2.68
16.	S.8	128.9				36.97				82.00			
17.	S.8xVS.27	126.6	8.90**	-1.81	5.50**	36.40	-2.59	-3.62	1.11	82.6	-0.18	-1.08	0.73
18.	S.8xK.1	139.4	11.65**	8.17**	16.17**	35.33	-3.15	-4.42	-1.86	82.2	0.24	0.24	0.24
19.	VS.27	103.4				37.77				83.5			
20.	VS.27xK.1	126.8	12.92**	4.82**	5.67**	36.30	-1.58	-3.88	0.83	81.7	-1.27	-2.16	-0.37
21.	K.1	120.0				36.00				82.0			
CD	CD(0.05)		4.04	4.66	4.66		1.57	1.82	1.82		2.24	2.58	2.58
	CD (0.01)		5.40	6.24	6.24		2.10	2.43	2.43		2.99	3.46	3.46

IC.284 (3.43) and IC.284 x VS.27 (3.33). Six hybrids recorded negative heterosis. They were IC.284 x S.8 (-0.80), ACV.1 x CO.1 (-2.94), IC.284 x K.1 (-3.31), ACV.1 x S.8 (-4.32), ACV.1 x VS.27 (-5.99) and ACV.1 x IC.284 (-15.74). The positive heterosis recorded by ACV.1 x K.1, CO.1 x S.8, CO.1 x VS.27, CO.1 x K.1, S.8 x VS.27, S.8 x K.1 and VS.27 x K.1 and the negative heterosis exhibited by ACV.1 x IC.284, ACV.1 x S.8 and ACV.1 x VS.27 were statistically significant.

Most of the hybrids exhibited negative heterosis compared to their better parent. The percentage of heterosis over the better parent ranged from -20.23 to 29.67. Seven hybrids recorded significant negative heterosis. They were IC.284 x K.1 (-7.63), CO.1 x IC.284 (-7.91), IC.284 x VS.27 (-8.03), ACV.1 x S.8 (-10.65), ACV.1 x CO.1 (-17.65), ACV.1 x IC.284 (-20.23) and ACV.1 x VS.27 (-20.23). The positive heterosis exhibited by CO.1 x VS.27 (29.67), S.8 x K.1 (8.17), CO.1 x S.8 (6.80) and VS.27 x K.1 (4.82) were significant.

Compared to the check parent, K.1, the percentage of heterosis ranged from -3.17 to 26.16. Negative heterosis was exhibited by three hybrids, viz. ACV.1 x IC.284 (-1.25), ACV.1 x VS.27 (-1.25) and CO.1 x K.1 (-3.17). Twelve hybrids expressed positive heterosis of which statistical significance were shown by eight hybrids, viz. ACV.1 x K.1 (26.16), S.8 x K.1 (16.17), CO.1 x S.8 (14.75), CO.1 x VS.27 (12.17), ACV.1 x S.8 (10.75), IC.284 x S.8 (8.17), VS.27 x K.1 (5.67) and S.8 x VS.27 (5.50).

Maximum heterosis was exhibited for plant height by CO.1 x VS.27 followed by CO.1 x S.8 and ACV.1 x K.1. The heterosis percentage over mid, better and check parental values is represented in Figure 2(a).

4.3.2. Days to flower

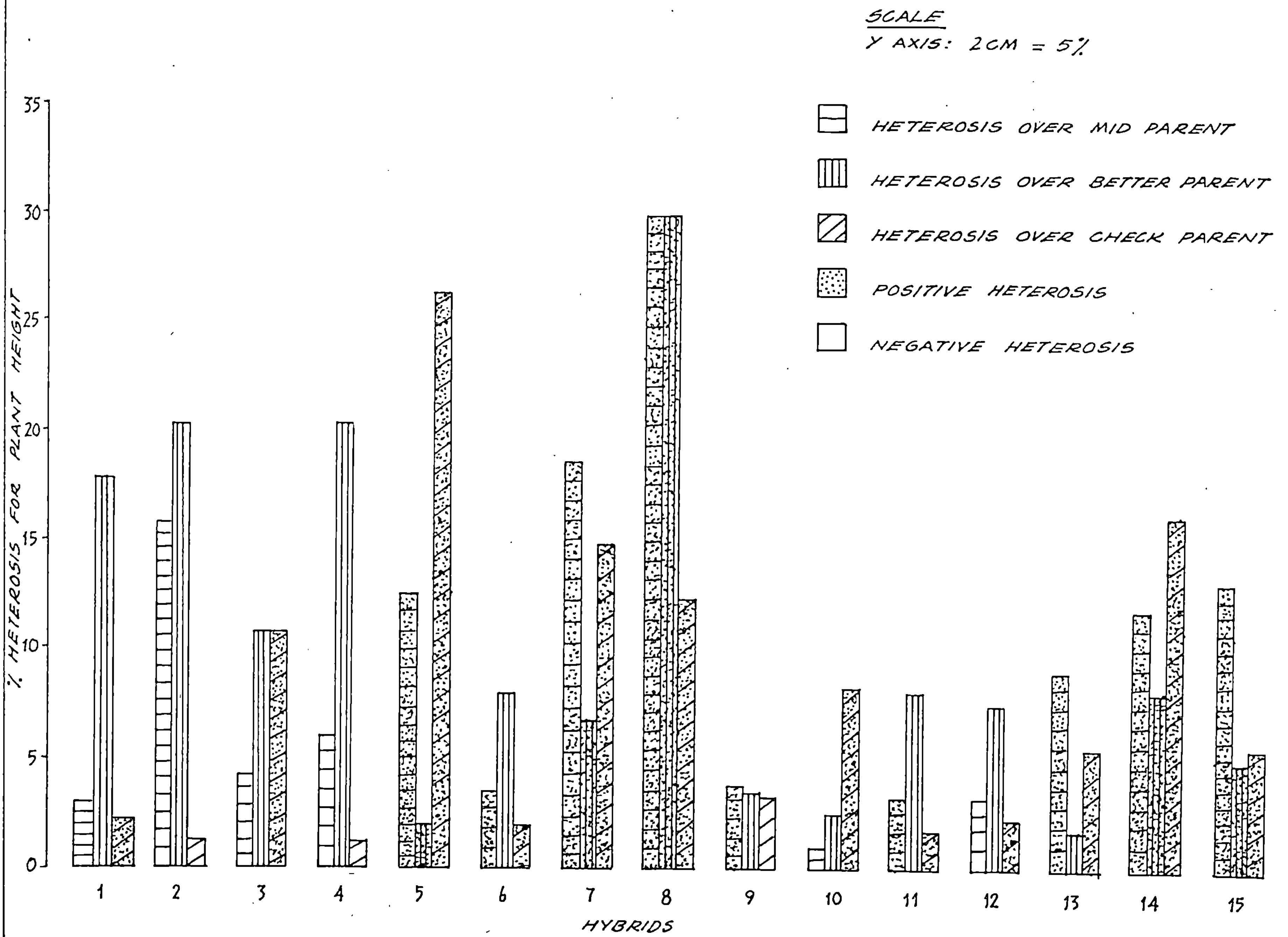
Table 9(i) shows the percentage of heterosis exhibited by the fifteen hybrids over their mid, better and check parental values, with respect to number of days to flower. The manifestation of heterosis was comparatively low for this character and late flowering varieties were taken as better parents.

Compared to mid-parental values, the percentage of heterosis ranged from -9.29 to 3.67. Positive heterosis was found only in one hybrid, viz. ACV.1 x CO.1 (3.67). Thirteen hybrids expressed negative heterosis and one cross did not exhibit any heterosis for this character. Maximum negative heterosis was shown by IC.284 x S.8 (-9.29) and was the only hybrid which showed significance.

Figure 2(a). Estimation of heterosis for plant height in a 6 x 6 diallel.

Treatment No.	Hybrid
1	ACV.1 x CO.1
2	ACV.1 x IC.284
3	ACV.1 x S.8
4	ACV.1 x VS.27
5	ACV.1 x K.1
6	CO.1 x IC.284
7	CO.1 x S.8
8	CO.1 x VS.27
9	CO.1 x K.1
10	IC.284 x S.8
11	IC.284 x VS.27
12	IC.284 x K.1
13	S.8 x VS.27
14	S.8 x K.1
15	VS.27 x K.1

FIG. 2(a)


SCALE
Y AXIS: 2CM = 5%
HETEROSIS OVER MID PARENT
HETEROSIS OVER BETTER PARENT
HETEROSIS OVER CHECK PARENT
POSITIVE HETEROSIS
NEGATIVE HETEROSIS
% HETEROSIS FOR PLANT HEIGHT
0
5
10
15
20
25
30
35
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
HYBRIDS

Compared to the better parent (late flowering parent), the percentage of heterosis ranged from -9.29 to 3.67, fourteen hybrids exhibited negative heterosis, the maximum being shown by IC.284 x S.8 (-9.29) which was statistically significant too. Positive heterosis was recorded by one hybrid only, ACV.1 x CO.1 (3.67).

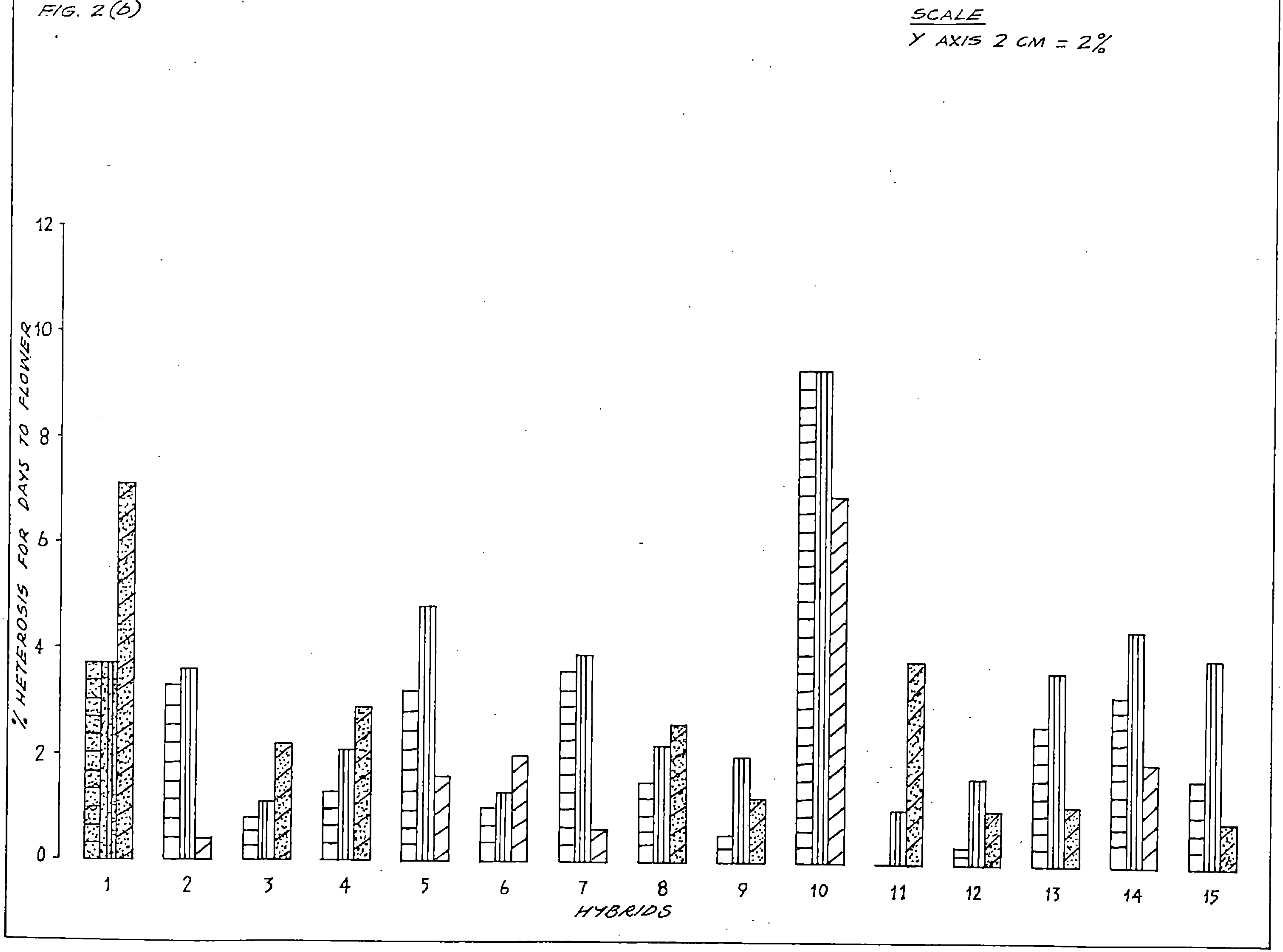
Compared to the check parent, K.1, heterosis percentage ranged from -6.86 exhibited by IC.284 x S.8 to 7.14 exhibited by ACV.1 x CO.1. Positive heterosis was shown by nine hybrids, of which ACV.1 x CO.1 (7.14) was statistically significant. Six hybrids expressed negative heterosis of which only IC.284 x S.8 (-6.86) was significant. This was followed by CO.1 x IC.284 (-1.94) and S.8 x K.1 (-1.86).

The best combination for early flowering was found to be IC.284 x S.8 followed by S.8 x K.1 and ACV.1 x K.1. The heterosis percentage exhibited by the fifteen hybrids over their mid, better and check parental values is represented in Figure 2(b).

4.3.3. <u>Days to mature</u>

The percentage of heterosis manifested by the fifteen hybrids over their mid-parent, better parent and the check parent in respect of days to mature is presented in Table 9(i).

FIG. 2(b)


SCALE
Y AXIS 2 CM = 2%
% HETEROSIS FOR DAYS TO FLOWER
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
HYBRIDS

Compared to the mid-parental value, the percentage of heterosis ranged from -1.39 to 1.63. Positive heterosis was recorded by eight hybrids. Seven hybrids showed negative heterosis, viz. IC.284 x S.8 (-1.39), VS.27 x K.1 (-1.27), CO.1 x IC.284 (-1.15), CO.1 x K.1 (-0.98), IC.284 x VS.27 (-0.84), CO.1 x VS.27 (-0.79), and S.8 x VS.27 (-0.18). The positive heterosis exhibited by IC.284 x K.1 (1.63) was alone statistically significant.

Compared to the better parent (late maturing parent), the percentage of heterosis ranged from -2.39 to 0.85. Four hybrids exhibited positive heterosis but none was statistically significant. Eleven hybrids showed negative heterosis. Maximum negative heterosis was recorded by the crosses, viz. IC.284 x S.8 (-2.39), CO.1 x IC.284 (-2.39), VS.27 x K.1 (-2.16) and CO.1 x VS.27 (-1.92) but none were statistically significant.

Compared to the check parent, K.1, the percentage of heterosis ranged from -1.22 to 2.68. Positive heterosis was manifested by eight hybrids, the maximum being shown by IC.284 x K.1 (2.68), ACV.1 x VS.27 (1.71), ACV.1 x IC.284 (1.22) and IC.284 x VS.27 (1.10). Seven hybrids exhibited negative heterosis, viz. CO.1 x K.1 (-1.22), CO.1 x IC.284 (-0.37), IC.284 x S.8 (-0.37), VS.27 x K.1 (-0.37), ACV.1 x CO.1 (-0.12), CO.1 x VS.27 (-0.12) and ACV.1 x S.8 (-0.12).

None of the hybrids were statistically significant.

The best hybrid for early maturity was IC.284 x S.8 followed by VS.27 x K.1 and CO.1 x IC.284. The heterosis percentage over mid, better and check parental values for days to mature is represented in Figure 2(c).

4.3.4. <u>Number of branches per plant</u>

Table 9(ii) shows the percentage of heterosis manifested by the fifteen hybrids over their mid, better and check parental values for the character number of branches per plant.

The percentage of heterosis ranged from -27.69 in ACV.1 x IC.284 to 34.75 in VS.27 x K.1, when compared to their mid-parental values. Six hybrids recorded negative heterosis and seven hybrids exhibited positive heterosis. Maximum percentage of positive heterosis was exhibited by VS.27 x K.1 (34.75) followed by CO.1 x K.1 (24.80), IC.284 x K.1 (20.00), CO.1 x VS.27 (18.92), CO.1 x IC.284 (12.41), ACV.1 x CO.1 (2.40) and S.8 x K.1 (0.71). But only one hybrid viz. VS.27 x K.1 showed statistical significance. Two hybrids, ACV.1 x K.1 and CO.1 x S.8 showed no heterosis for this character.

Compared to the better parent, the percentage of heterosis ranged from -34.15 in ACV.1 x S.8 to 18.18 in

Table:9 Contd.

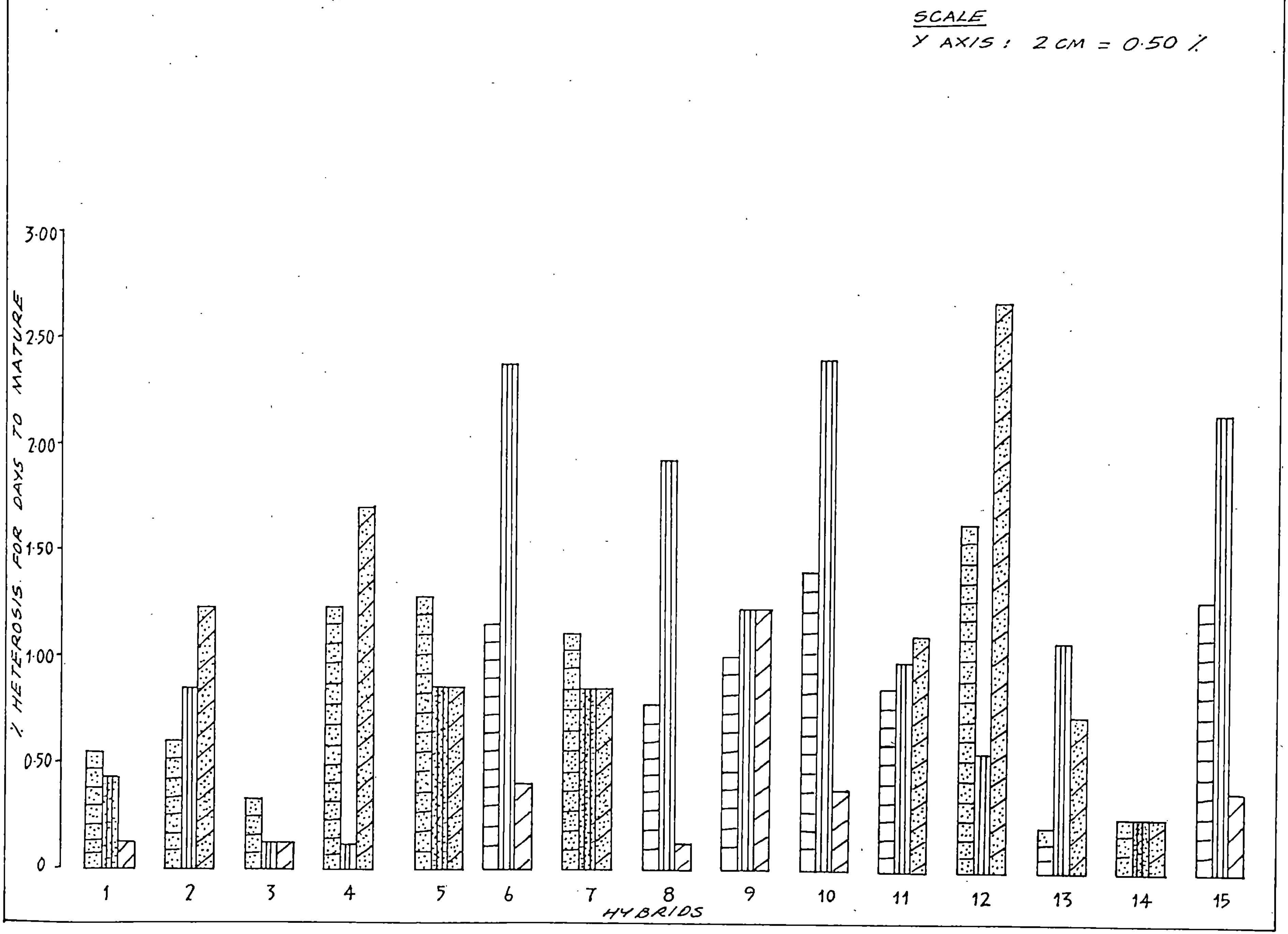
(ii)Heterosis percentage for number of branches per plant, number of capsules per plant and length of capsule

Sl. No.	Parents and hybrids	No. of branches per plant: Mean	No. of branches per plant: Percentage of heterosis over Mid Parent	Better Parent	Check Parent	No. of capsules per plant: Mean	No. of capsules per plant: Percentage of heterosis over Mid Parent	Better Parent	Check Parent	Length of the capsule: Mean (cm)	Length of the capsule: Percentage of heterosis over Mid Parent	Better Parent	Check Parent
1.	ACV.1	1.97				35.07				2.22			
2.	ACV.1xCO.1	2.13	2.40	-3.03	-8.12	16.53	-34.95**	-52.85**	-49.14**	2.27	4.85	2.10	5.09
3.	ACV.1xIC.284	1.57	-27.69	-33.80*	-20.30	16.33	-44.22**	-53.42**	-49.75**	2.18	2.26	-1.80	0.93
4.	ACV.1xS.8	1.80	-23.40	-34.15*	-8.63	20.87	-47.68**	-53.32**	-35.78**	2.27	1.26	0.44	5.09
5.	ACV.1xVS.27	2.03	-13.48	-25.61	3.05	31.27	12.94*	-10.84*	-3.78	2.27	3.33	2.25	5.09
6.	ACV.1xK.1	1.97	0.00	-9.76	0.00	26.40	-21.86**	-24.72**	-18.77**	2.33	6.46*	4.95	7.87*
7.	CO.1	2.20				15.77				2.11			
8.	CO.1xIC.284	2.57	12.41	8.45	30.45	23.63	20.37*	0.57	-27.29**	2.24	8.03**	6.49*	3.70
9.	CO.1xS.8	2.47	0.00	-9.76	25.38	41.03	35.72**	-8.20*	26.25**	2.45	12.21**	8.41**	13.43**
10.	CO.1xVS.27	2.93	18.92	7.32	48.73*	49.20	172.83**	142.37**	51.38**	2.32	8.17**	6.43*	7.41*
11.	CO.1xK.1	2.60	24.80	18.18	31.98	23.17	-4.01	-28.72**	-28.70**	2.06	-3.44	-4.63	-4.63
12.	IC.284	2.37				23.50				2.05			
13.	IC.284xS.8	2.17	-15.03	-20.73	10.15	26.00	-23.75**	-41.83**	-20.00**	2.29	6.50*	1.48	6.02*
14.	IC.284xVS.27	2.20	-13.73	-19.51	11.68	27.77	26.79**	18.16*	14.55*	2.24	6.08*	2.91	3.70
15.	IC.284xK.1	2.60	20.00	9.86	31.98	48.03	71.55**	47.80**	47.78**	2.21	5.07	2.32	2.32
16.	S.8	2.73				44.70				2.26			
17.	S.8xVS.27	2.37	-13.42	-13.42	20.30	40.90	25.85**	-8.50*	25.85**	2.21	-0.53	-2.36	2.32
18.	S.8xK.1	2.37	0.71	-13.42	20.30	38.83	0.60	-13.13**	19.48**	2.30	4.07	1.77	6.48*
19.	VS.27	2.73				20.30				2.18			
20.	VS.27xK.1	3.17	34.75*	15.85	60.91**	46.40	75.79**	42.77**	42.77**	2.18	0.69	0.31	0.93
21.	K.1	1.97				32.50				2.16			
CD	CD(0.05)		0.69	0.80	0.80		3.10	3.58	3.58		0.114	0.132	0.132
	CD (0.01)		0.93	1.07	1.07		4.15	4.79	4.79		0.153	0.177	0.177

Figure 2(c). Estimation of heterosis for days to mature in a 6 x 6 diallel.

Treatment No.	Hybrid
1	ACV.1 x CO.1
2	ACV.1 x IC.284
3	ACV.1 x S.8
4	ACV.1 x VS.27
5	ACV.1 x K.1
6	CO.1 x IC.284
7	CO.1 x S.8
8	CO.1 x VS.27
9	CO.1 x K.1
10	IC.284 x S.8
11	IC.284 x VS.27
12	IC.284 x K.1
13	S.8 x VS.27
14	S.8 x K.1
15	VS.27 x K.1

FIG. 2(C)


SCALE
Y AXIS : 2 CM = 0·50 %
% HETEROSIS FOR DAYS TO MATURE
3·00
2·50
2·00
1·50
1·00
0·50
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
HYBRIDS

CO.1 x K.1. Out of the fifteen hybrids, ten showed negative heterosis of which the crosses, viz. ACV.1 x IC.284 (-33.80) and ACV.1 x S.8 (-34.15) were statistically significant. Maximum positive heterosis was recorded by the hybrid CO.1 x K.1 (18.18) followed by VS.27 x K.1 (15.85), IC.284 x K.1 (9.86), CO.1 x IC.284 (8.45) and CO.1 x VS.27 (7.32) but none were statistically significant.

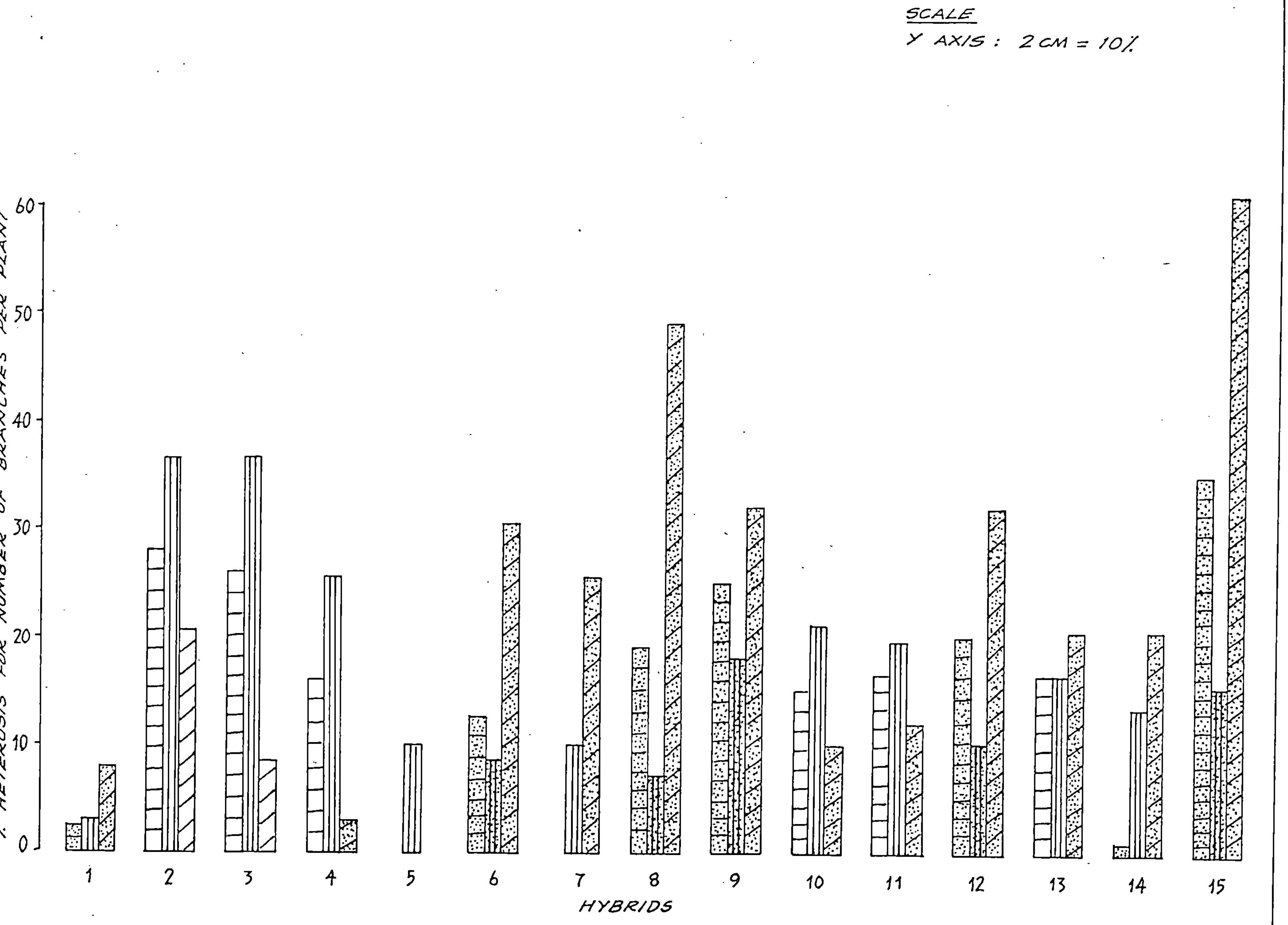
Compared to the check parent, K.1, the percentage of heterosis ranged from -20.30 to 60.91. Only two hybrids, viz. ACV.1 x S.8 (-8.63) and ACV.1 x IC.284 (-20.30) showed negative heterosis. All the other hybrids exhibited positive heterosis except ACV.1 x K.1 which did not show any heterosis for this character. The maximum positive heterosis was recorded by VS.27 x K.1 (60.91) followed by CO.1 x VS.27 (48.73), CO.1 x K.1 (31.98), IC.284 x K.1 (31.98), CO.1 x IC.284 (30.45), CO.1 x S.8 (25.38), S.8 x VS.27 (20.30), S.8 x K.1 (20.30), IC.284 x VS.27 (11.68), IC.284 x S.8 (10.15), ACV.1 x CO.1 (8.12) and ACV.1 x VS.27 (3.05). Only two hybrids were statistically significant, viz. VS.27 x K.1 and CO.1 x VS.27.

The best hybrids for maximum number of branches were VS.27 x K.1 followed by CO.1 x K.1 and CO.1 x VS.27. The percentage heterosis over mid, better and check parent for this character is represented in Figure 2(d).

Figure 2(d). Estimation of heterosis for number of branches per plant in a 6 x 6 diallel.

Treatment No.	Hybrid
1	ACV.1 x CO.1
2	ACV.1 x IC.284
3	ACV.1 x S.8
4	ACV.1 x VS.27
5	ACV.1 x K.1
6	CO.1 x IC.284
7	CO.1 x S.8
8	CO.1 x VS.27
9	CO.1 x K.1
10	IC.284 x S.8
11	IC.284 x VS.27
12	IC.284 x K.1
13	S.8 x VS.27
14	S.8 x K.1
15	VS.27 x K.1

FIG. 2(d)


SCALE
Y AXIS : 2 CM = 10%
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
HYBRIDS

4.3.5. Number of capsules per plant

The percentage of heterosis manifested by the fifteen hybrids over their mid parent, better parent and the check parent with regard to the number of capsules per plant is given in Table 9(ii).

Compared to the mid-parent, the percentage of heterosis ranged from -47.68 in ACV.1 x S.8 to 172.83 recorded in CO.1 x VS.27. Six hybrids exhibited negative heterosis, of which the crosses, viz. ACV.1 x K.1 (-21.86), IC.284 x S.8 (-23.75), ACV.1 x CO.1 (-34.95), ACV.1 x IC.284 (-44.22) and ACV.1 x S.8 (-47.68) were statistically significant. Positive heterosis was shown by nine hybrids viz. CO.1 x VS.27 (172.83), VS.27 x K.1 (75.79), IC.284 x K.1 (71.55), CO.1 x S.8 (35.72), IC.284 x VS.27 (26.79), S.8 x VS.27 (25.85), CO.1 x IC.284 (20.37), ACV.1 x VS.27 (12.94) and S.8 x K.1 (0.60). But the heterosis exhibited by CO.1 x VS.27, VS.27 x K.1, IC.284 x K.1, IC.284 x VS.27, CO.1 x S.8, S.8 x VS.27, CO.1 x IC.284 and ACV.1 x VS.27 were statistically significant.

Compared to the better parent, the percentage of heterosis ranged from -53.42 in ACV.1 x IC.284 to 142.37 in CO.1 x VS.27. Ten hybrids exhibited negative heterosis and were statistically significant. They were CO.1 x S.8 (-8.20), S.8 x VS.27 (-8.50), ACV.1 x VS.27 (-10.84), S.8 x K.1 (-13.13), CO.1 x K.1 (-28.72), ACV.1 x K.1 (-24.72), IC.284 x S.8 (-41.83), ACV.1 x CO.1 (-52.85), ACV.1 x S.8 (-53.32) and ACV.1 x IC.284 (-53.42). Positive heterosis was recorded by five hybrids of which the crosses CO.1 x VS.27 (142.37), IC.284 x K.1 (47.80), VS.27 x K.1 (42.77) and IC.284 x VS.27 (18.16) were significant.

Compared to the check parent, K.1 the heterosis percentage ranged from -49.75 in ACV.1 x IC.284 to 51.38 in CO.1 x VS.27. Seven hybrids exhibited positive heterosis of which all were statistically significant. They were CO.1 x VS.27 (51.38), IC.284 x K.1 (47.78), VS.27 x K.1 (42.77), CO.1 x S.8 (26.25), S.8 x VS.27 (25.85), S.8 x K.1 (19.48) and IC.284 x VS.27 (14.55). Negative heterosis was shown by eight hybrids of which seven hybrids viz. ACV.1 x K.1 (-18.77), IC.284 x S.8 (-20.00), CO.1 x IC.284 (-27.29), CO.1 x K.1 (-28.70), ACV.1 x S.8 (-35.78), ACV.1 x CO.1 (-49.14) and ACV.1 x IC.284 (-49.75) showed statistical significance.

The best cross combination for this character was CO.1 x VS.27 followed by VS.27 x K.1 and IC.284 x K.1. The percentage heterosis over mid, better and check parental values for number of capsules per plant is represented in Figure 2(e).

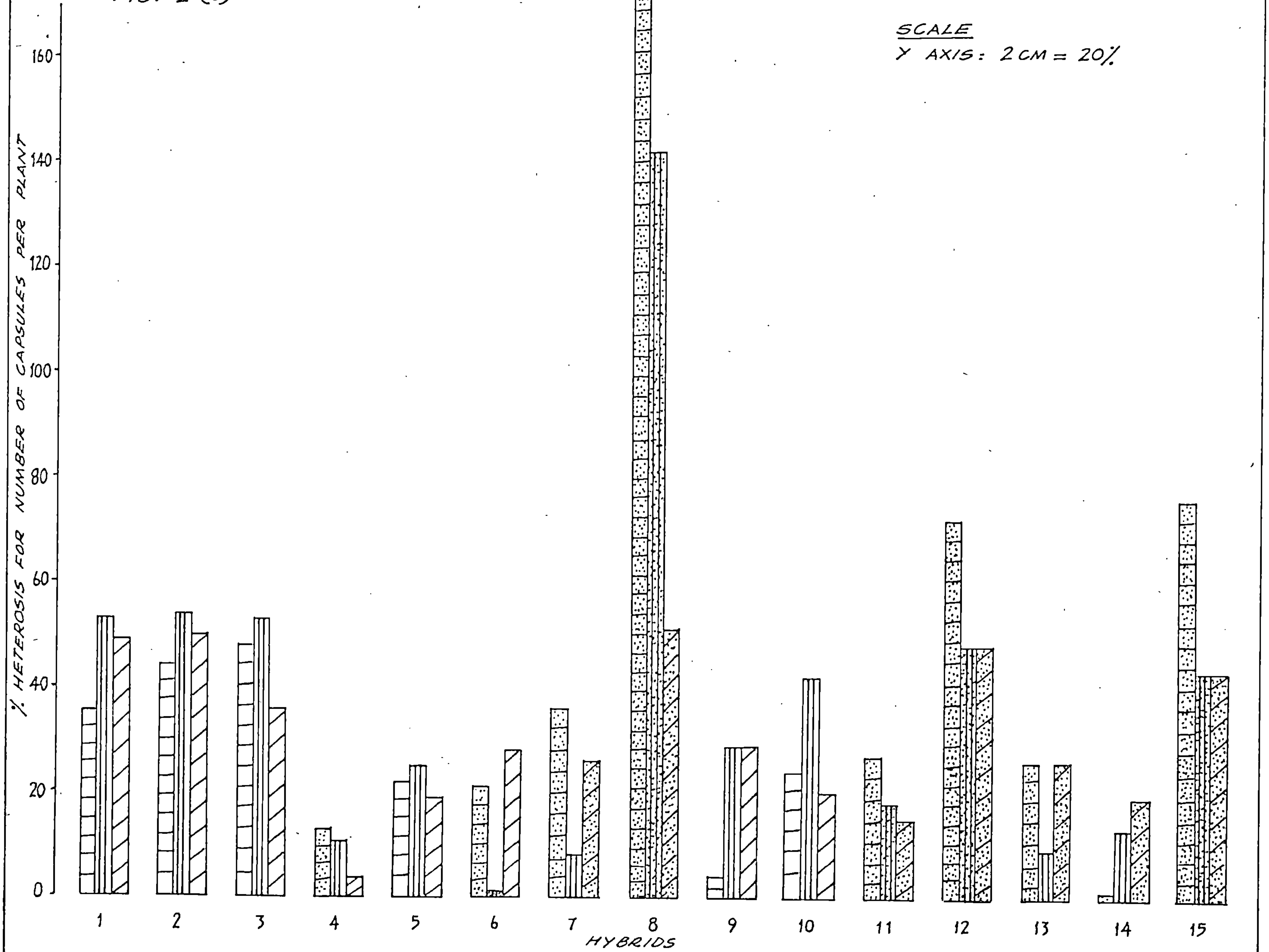
Figure 2(e). Estimation of heterosis for number of capsules per plant in a 6 x 6 diallel.

Treatment No.	Hybrid
1	ACV.1 x CO.1
2	ACV.1 x IC.284
3	ACV.1 x S.8
4	ACV.1 x VS.27
5	ACV.1 x K.1
6	CO.1 x IC.284
7	CO.1 x S.8
8	CO.1 x VS.27
9	CO.1 x K.1
10	IC.284 x S.8
11	IC.284 x VS.27
12	IC.284 x K.1
13	S.8 x VS.27
14	S.8 x K.1
15	VS.27 x K.1

Figure 2(b). Estimation of heterosis for days to flower in a 6 x 6 diallel.

Treatment No.	Hybrid
1	ACV.1 x CO.1
2	ACV.1 x IC.284
3	ACV.1 x S.8
4	ACV.1 x VS.27
5	ACV.1 x K.1
6	CO.1 x IC.284
7	CO.1 x S.8
8	CO.1 x VS.27
9	CO.1 x K.1
10	IC.284 x S.8
11	IC.284 x VS.27
12	IC.284 x K.1
13	S.8 x VS.27
14	S.8 x K.1
15	VS.27 x K.1

FIG. 2 (e)


SCALE
Y AXIS: 2 CM = 20%
% HETEROSIS FOR NUMBER OF CAPSULES PER PLANT
160
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
HYBRIDS

4.3.6. Length of the capsule

Table 9(ii) shows the percentage of heterosis manifested by the fifteen hybrids over their mid, better and check parent for the character, length of the capsule. The heterosis percentage was comparatively low for this character.

Compared to the mid parent, the percentage of heterosis ranged from -3.44 in CO.1 x K.1 to 12.21 in CO.1 x S.8. Only two hybrids, viz. S.8 x VS.27 (-0.53) and CO.1 x K.1 (-3.44) exhibited negative heterosis. Out of the thirteen hybrids which recorded positive heterosis, the statistically significant cross combinations were CO.1 x S.8 (12.21), CO.1 x VS.27 (8.17), CO.1 x IC.284 (8.03), IC.284 x S.8 (6.50), ACV.1 x K.1 (6.46) and IC.284 x VS.27 (6.08).

The percentage of heterosis ranged from -4.63 in CO.1 x K.1 to 8.41 in CO.1 x S.8 when compared to their better parental values. Negative heterosis were recorded by ACV.1 x IC.284 (-1.80), S.8 x VS.27 (-2.36) and CO.1 x K.1 (-4.63). Out of the twelve hybrids which exhibited positive heterosis, statistically significant cross combinations were CO.1 x S.8 (8.41), CO.1 x IC.284 (6.49) and CO.1 x VS.27 (6.43).

Compared to the check parent, K.1, the percentage of heterosis was found to range from -4.63 to 13.43. Only one hybrid, viz. CO.1 x K.1 (-4.63) exhibited negative heterosis. Positive heterosis was manifested by fourteen hybrids of which the cross combinations, viz. CO.1 x S.8 (13.43), ACV.1 x K.1 (7.87), CO.1 x VS.27 (7.41), S.8 x K.1 (6.48) and IC.284 x S.8 (6.02) were statistically significant.

The best cross combination for this character was CO.1 x S.8 followed by CO.1 x VS.27 and ACV.1 x K.1. The heterosis percentage over mid, better and check parental values for length of the capsule is represented in Figure 2(f).

4.3.7. Number of seeds per capsule

The percentage of heterosis manifested by the fifteen hybrids over their mid, better and check parental values with regard to the number of seeds per capsule is presented in Table 9(iii).

The percentage of heterosis over mid parental value ranged from -26.51 in ACV.1 x S.8 to 26.99 in CO.1 x S.8. Six hybrids recorded positive heterosis, the significant cross combinations being CO.1 x S.8 (26.99), VS.27 x K.1 (11.06), S.8 x K.1 (9.36) and S.8 x VS.27 (8.73). Negative heterosis was exhibited by nine hybrids of which the crosses, viz. IC.284 x S.8 (-10.22), IC.284 x VS.27 (-11.92), CO.1 x

Table:9 Contd.

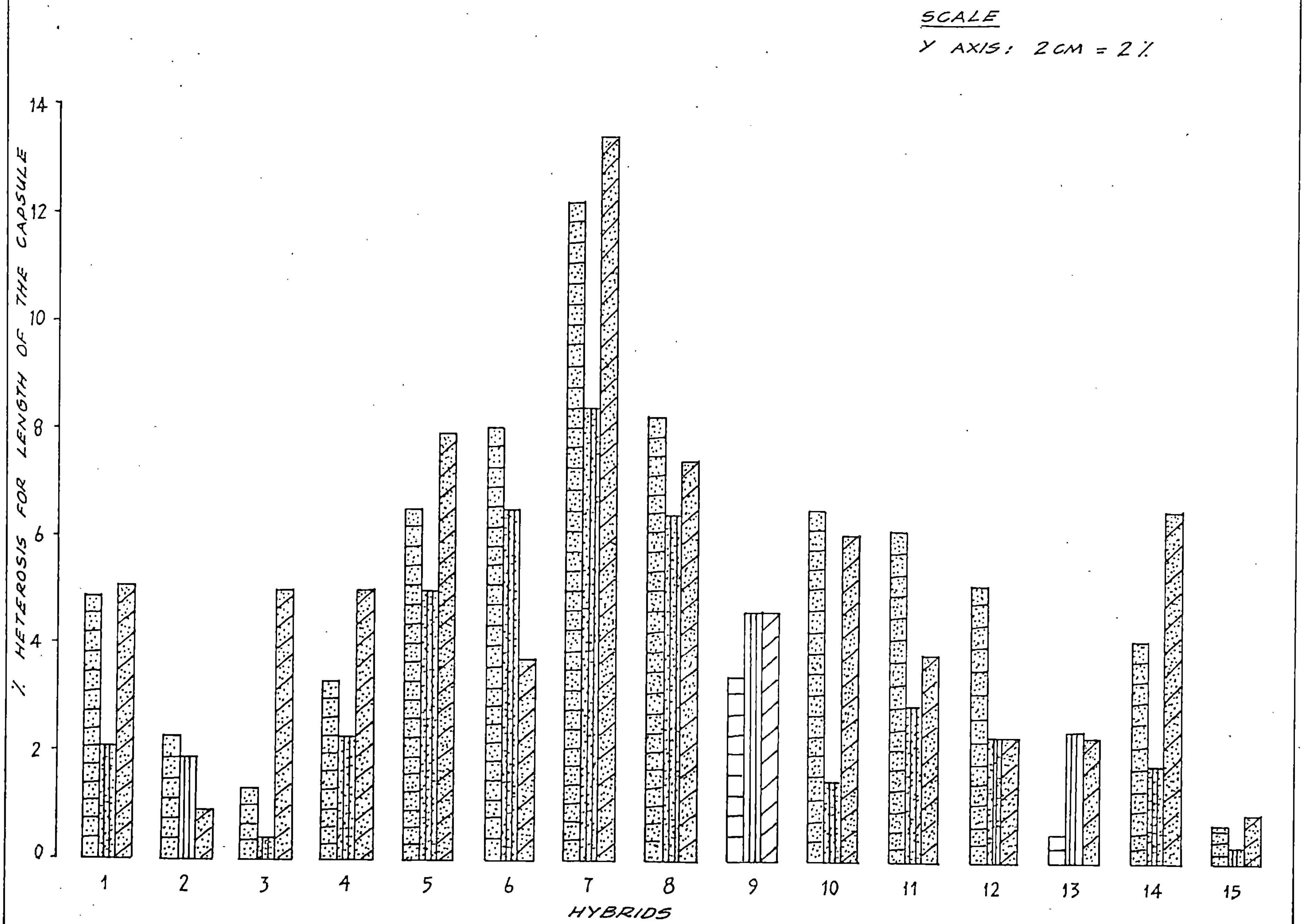
(iii)Heterosis percentage for number of seeds per capsule, weight of 1000 seeds and oil content.

Sl. No.	Parents and hybrids	Mean	No. of seeds per capsule Percentage of heterosis over			Mean (g)	Weight of 1000 seeds. Percentage of heterosis over			Oil content Mean	Percentage of heterosis over		
			Mid Parent	Better Parent	Check Parent		Mid Parent	Better Parent	Check Parent		Mid Parent	Better Parent	Check Parent
1.	ACV.1	100.87				3.29				53.57			
2.	ACV.1xCO.1	57.03	-26.25**	-43.46**	11.82*	2.16	-28.49**	-34.28**	-16.28**	36.33	-33.87**	-34.54**	-5.22
3.	ACV.1xIC.284	83.70	-5.08	-17.02**	64.12**	2.62	-4.76**	-20.30**	1.55**	36.50	-28.13**	-31.86**	-4.77
4.	ACV.1xS.8	58.00	-26.51**	-42.50**	13.73*	2.52	-16.33**	-23.32**	-2.33**	31.67	-39.14**	-40.88**	-17.38**
5.	ACV.1xVS.27	57.67	-26.32**	-42.83**	13.08*	2.67	-5.74**	-18.94**	3.49**	32.67	-26.85**	-39.02**	-14.77**
6.	ACV.1xK.1	57.70	-24.01**	-42.80**	13.14*	2.72	-7.30**	-17.24**	5.43**	26.87	-41.94**	-50.22**	-30.42**
7.	CO.1	53.80				2.76				55.50			
8.	CO.1xIC.284	56.57	-12.50**	-25.08**	10.92*	2.28	-8.36**	-17.35**	-11.63**	30.33	-41.39**	-45.35**	-20.87**
9.	CO.1xS.8	70.33	26.99**	23.46**	37.90**	2.66	-3.37**	-3.68**	3.10**	38.16	-27.99**	-31.23**	-0.44
10.	CO.1xVS.27	59.70	9.07	7.25	17.06**	2.65	3.43**	-3.87**	2.71**	36.33	-20.15**	-34.54**	-5.22
11.	CO.1xK.1	52.57	0.32	2.29	3.08	2.84	6.48**	-3.14**	10.08**	25.50	-45.65**	-54.05**	-33.47**
12.	IC.284	75.50				2.22				48.00			
13.	IC.284xS.8	59.47	-10.22**	-21.24**	16.61**	2.32	-6.45**	-15.39**	-10.08**	36.83	-25.21**	-27.06**	-3.91
14.	IC.284xVS.27	57.77	-11.92**	-23.49**	13.27*	2.13	-6.91**	-9.89**	-17.44**	45.83	9.78**	-4.51	19.57**
15.	IC.284xK.1	54.40	-13.99**	-27.95**	6.67	2.29	-4.71**	-11.50**	-11.24**	35.67	-17.38**	-25.69**	-6.94
16.	S.8	56.97				2.74				50.50			
17.	S.8xVS.27	61.23	8.73*	7.49	20.06**	2.57	0.54	-6.28**	-0.39	44.67	3.88	-11.55**	16.54**
18.	S.8xK.1	59.03	9.36*	3.63	15.75**	2.16	-18.79**	-21.10**	-16.28**	44.50	0.19	-11.88**	16.10**
19.	VS.27	55 67				2.37				35.50			
20.	VS.27xK.1	59.23	11.06*	6.41	16.14**	2.45	-1.19	-5.33**	-5.04**	40.17	8.80*	4.78	4.80
21.	K.1	51.00				2.58				38.33			
	CD (0.05)		4.78	5.52	5.52		0.03	0.03	0.03		2.43	2.81	2.81
	CD (0.01)		6.39	7.38	7.38		0.04	0.04	0.04		3.25	3.75	3.75

Figure 2(f). Estimation of heterosis for length of the capsule in a 6 x 6 diallel.

Treatment No.	Hybrid
1	ACV.1 x CO.1
2	ACV.1 x IC.284
3	ACV.1 x S.8
4	ACV.1 x VS.27
5	ACV.1 x K.1
6	CO.1 x IC.284
7	CO.1 x S.8
8	CO.1 x VS.27
9	CO.1 x K.1
10	IC.284 x S.8
11	IC.284 x VS.27
12	IC.284 x K.1
13	S.8 x VS.27
14	S.8 x K.1
15	VS.27 x K.1

FIG. 2(f)


SCALE
Y AXIS: 2CM = 2%
% HETEROSIS FOR LENGTH OF THE CAPSULE
0
2
4
6
8
10
12
14
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
HYBRIDS

IC.284 (-12.50), IC.284 x K.1 (-13.99), ACV.1 x K.1 (-24.01), ACV.1 x CO.1 (-26.25), ACV.1 x VS.27 (-26.32) and ACV.1 x S.8 (-26.51) were statistically significant.

Compared to the better parent, the heterosis percentage ranged from -43.46 in ACV.1 x CO.1 to 23.46 in CO.1 x S.8. Positive heterosis was noticed only in five cases of which statistical significance was recorded by CO.1 x S.8 (23.46) only. Ten hybrids recorded negative heterosis of which nine crosses, viz. ACV.1 x IC.284 (-17.02), IC.284 x S.8 (-21.24), IC.284 x VS.27 (-23.49), CO.1 x IC.284 (-25.08), IC.284 x K.1 (-27.95), ACV.1 x S.8 (-42.50), ACV.1 x K.1 (-42.80), ACV.1 x VS.27 (-42.83) and ACV.1 x CO.1 (-43.46) were statistically significant.

Compared to the check parent, K.1, the percentage of heterosis ranged from 3.08 to 64.12. All the fifteen hybrids exhibited positive heterosis of which thirteen were statistically significant. They were ACV.1 x IC.284 (64.12), CO.1 x S.8 (37.90), S.8 x VS.27 (20.06), CO.1 x VS.27 (17.06), IC.284 x S.8 (16.61), VS.27 x K.1 (16.14), S.8 x K.1 (15.75), ACV.1 x S.8 (13.73), IC.284 x VS.27 (13.27), ACV.1 x K.1 (13.14), ACV.1 x VS.27 (13.08), ACV.1 x CO.1 (11.82) and CO.1 x IC.284 (10.92).

The best combination for this character was CO.1 x S.8 followed by S.8 x VS.27 and VS.27 x K.1. The heterosis percentage over mid, better and check parental value for number of seeds per capsule is represented in Figure 2(g).

4.3.8. Weight of 1000 seeds

Table 9(iii) shows the percentage of heterosis manifested by the fifteen hybrids over their mid, better and check parental values for the character, weight of 1000 seeds.

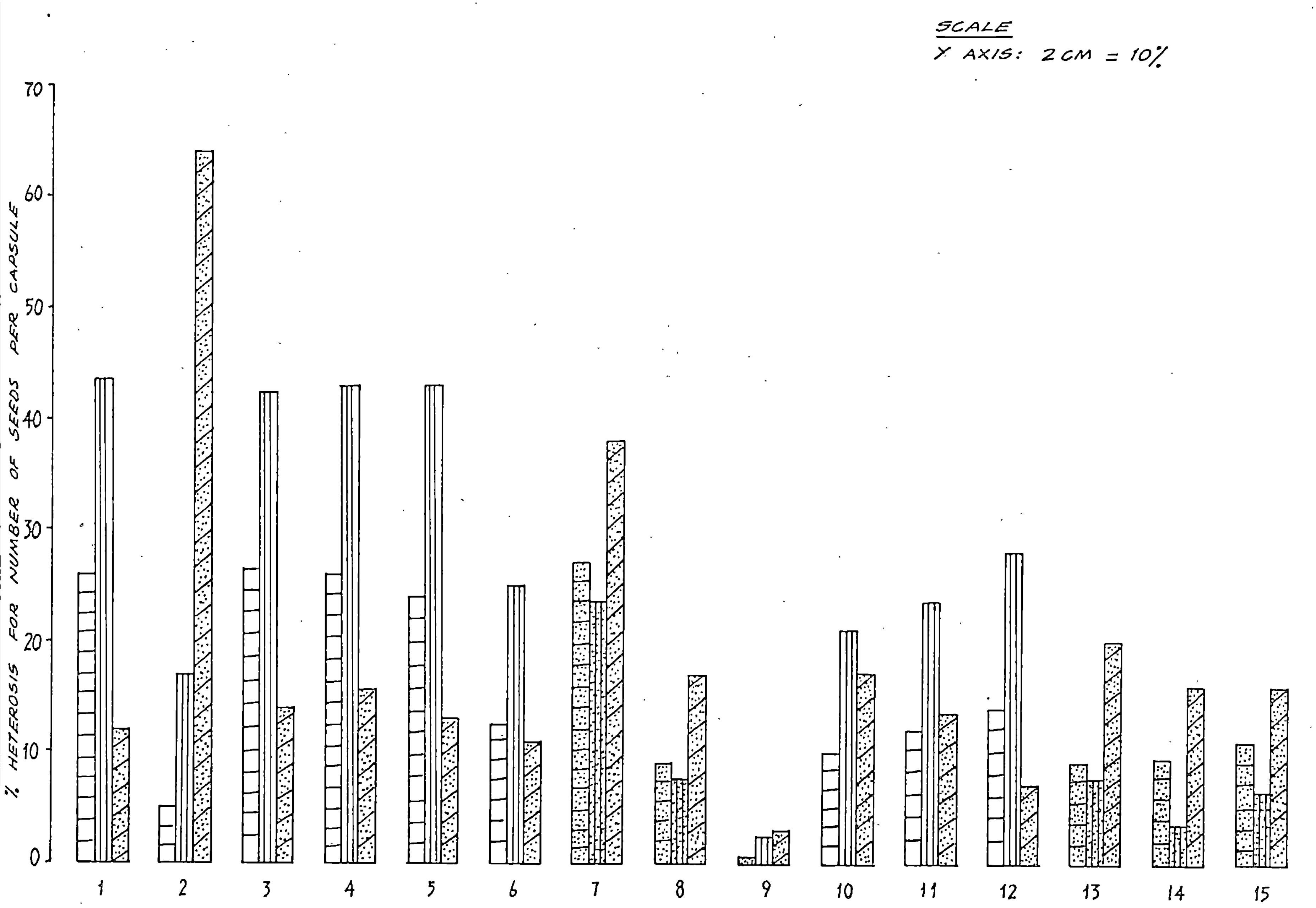
Compared to the mid-parent, the percentage of heterosis ranged from -28.49 in ACV.1 x CO.1 to 6.48 in CO.1 x K.1. Twelve hybrids recorded negative heterosis of which eleven were significant. They were CO.1 x S.8 (-3.37), IC.284 x K.1 (-4.71), ACV.1 x IC.284 (-4.76), ACV.1 x VS.27 (-5.74), IC.284 x S.8 (-6.45), IC.284 x VS.27 (-6.91), ACV.1 x K.1 (-7.30), CO.1 x IC.284 (-8.36), ACV.1 x S.8 (-16.33), S.8 x K.1 (-18.79) and ACV.1 x CO.1 (-28.49). Only three hybrids exhibited positive heterosis of which CO.1 x K.1 (6.48) and CO.1 x VS.27 (3.43) were statistically significant.

Compared to the better parent, the percentage of heterosis ranged from -34.28 in ACV.1 x CO.1 to 3.14 in CO.1 x K.1. Fourteen hybrids exhibited negative heterosis and only one hybrid, viz. CO.1 x K.1 (3.14) recorded positive heterosis. All the fifteen hybrids were statistically significant.

Figure 2(g). Estimation of heterosis for number of seeds per capsule in a 6 x 6 diallel.

Treatment No.	Hybrid
1	ACV.1 x CO.1
2	ACV.1 x IC.284
3	ACV.1 x S.8
4	ACV.1 x VS.27
5	ACV.1 x K.1
6	CO.1 x IC.284
7	CO.1 x S.8
8	CO.1 x VS.27
9	CO.1 x K.1
10	IC.284 x S.8
11	IC.284 x VS.27
12	IC.284 x K.1
13	S.8 x VS.27
14	S.8 x K.1
15	VS.27 x K.1

FIG. 2(9)


SCALE
Y AXIS: 2 CM = 10%
% HETEROSIS FOR NUMBER OF SEEDS PER CAPSULE
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

Compared to the check parent, K.1, the percentage of heterosis ranged from -17.44 to 10.08. Six hybrids recorded positive heterosis and were statistically significant. They were CO.1 x K.1 (10.08), ACV.1 x K.1 (5.43), ACV.1 x VS.27 (3.49), CO.1 x S.8 (3.10), CO.1 x VS.27 (2.71) and ACV.1 x IC.284 (1.55). Negative heterosis was exhibited by nine hybrids of which eight crosses, viz. ACV.1 x S.8 (-2.33), VS.27 x K.1 (-5.04), IC.284 x S.8 (-10.08), IC.284 x K.1 (-11.24), CO.1 x IC.284 (-11.63), ACV.1 x CO.1 (-16.28), S.8 x K.1 (-16.28) and IC.284 x VS.27 (-17.44) were statistically significant.

Maximum heterosis percentage for this character was exhibited by CO.1 x K.1. The percentage of heterosis over mid, better and check parental values for 1000 seed weight is represented in Figure 2(h).

4.3.9. Oil content

The percentage of heterosis manifested by the fifteen hybrids over their mid-parent, better parent and check parent for oil content is presented in Table 9(iii). The hybrids were generally inferior to their parents with regard to oil content.

The percentage of heterosis ranged from -45.65 in CO.1 x K.1 to 9.78 in IC.284 x VS.27, when compared to

Figure 2(h). Estimation of heterosis for 1000 seed weight in a 6 x 6 diallel.

Treatment No.	Hybrid
1	ACV.1 x CO.1
2	ACV.1 x IC.284
3	ACV.1 x S.8
4	ACV.1 x VS.27
5	ACV.1 x K.1
6	CO.1 x IC.284
7	CO.1 x S.8
8	CO.1 x VS.27
9	CO.1 x K.1
10	IC.284 x S.8
11	IC.284 x VS.27
12	IC.284 x K.1
13	S.8 x VS.27
14	S.8 x K.1
15	VS.27 x K.1

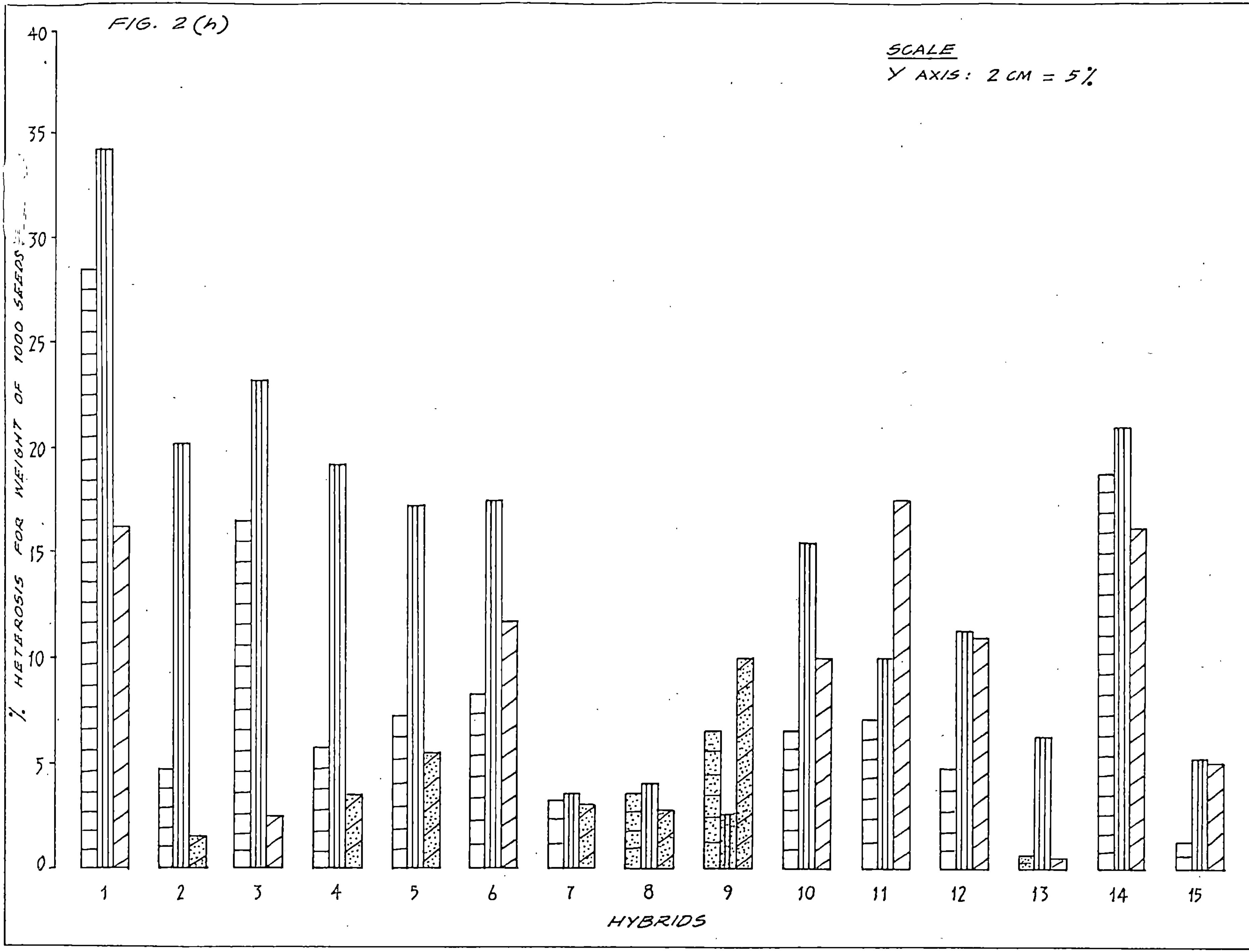


FIG. 2 (h)
SCALE
Y AXIS: 2 CM = 5%
% HETEROSIS FOR WEIGHT OF 1000 SEEDS
0
5
10
15
20
25
30
35
40
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
HYBRIDS

their mid-parental values. Eleven hybrids recorded negative heterosis which were statistically significant. They were IC.284 x K.1 (-17.38), CO.1 x VS.27 (-20.15), IC.284 x S.8 (-25.21), ACV.1 x VS.27 (-26.65), CO.1 x S.8 (-27.99), ACV.1 x IC.284 (-28.13), ACV.1 x CO.1 (-33.87), ACV.1 x S.8 (-39.14), CO.1 x IC.284 (-41.39), ACV.1 x K.1 (-41.94) and CO.1 x K.1 (-45.65). Only four hybrids exhibited positive heterosis, viz. IC.284 x VS.27 (9.78), VS.27 x K.1 (8.80), S.8 x VS.27 (3.88) and S.8 x K.1 (0.19) of which only IC.284 x VS.27 and VS.27 x K.1 were significant.

Compared to the better parent, the percentage of heterosis ranged from -54.05 recorded in CO.1 x K.1 to 4.78 in VS.27 x K.1. Positive heterosis was recorded by one cross only, viz. VS.27 x K.1 (4.78) but was not significant. Fourteen hybrids exhibited negative heterosis of which thirteen were statistically significant. They were S.8 x VS.27 (-11.55), S.8 x K.1 (-11.88), IC.284 x K.1 (-25.69), IC.284 x S.8 (-27.06), CO.1 x S.8 (-31.23), ACV.1 x IC.284 (-31.86), CO.1 x VS.27 (-34.54), ACV.1 x CO.1 (-34.54), ACV.1 x VS.27 (-39.02), ACV.1 x S.8 (-40.88), CO.1 x IC.284 (-45.35), ACV.1 x K.1 (-50.22) and CO.1 x K.1 (-54.05).

Compared to the check parent, K.1, the heterosis percentage ranged from -33.47 to 19.57. Only four hybrids expressed positive heterosis of which three crosses were significant. They were IC.284 x VS.27 (19.57), S.8 x VS.27 (16.54) and S.8 x K.1 (16.10). Negative heterosis was exhibited by eleven hybrids of which the statistically significant crosses were ACV.1 x VS.27 (-14.77), ACV.1 x S.8 (-17.38), CO.1 x IC.284 (-20.87), ACV.1 x K.1 (-30.42) and CO.1 x K.1 (-33.47).

The best combination for this character was IC.284 x VS.27. The percentage of heterosis over mid, better and check parental values for oil content is represented in Figurs 2(i).

4.3.10. <u>Seed yield per plant</u>

Table 9(iv) shows the percentage of heterosis manifested over mid, better and check parental values for seed yield per plant.

The percentage of heterosis ranged from -51.11 in ACV.1 x S.8 to 105.78 in CO.1 x VS.27 when compared to their mid-parental values. Eight hybrids recorded negative heterosis of which six were statistically significant. They were ACV.1 x VS.27 (-15.31), IC.284 x S.8 (-24.65), ACV.1 x K.1 (-33.33), ACV.1 x IC.284 (-34.48), ACV.1 x CO.1 (-46.83) and ACV.1 x S.8 (-51.11). Positive heterosis was exhibited by six hybrids of which five crosses viz.

Table:9 Contd.

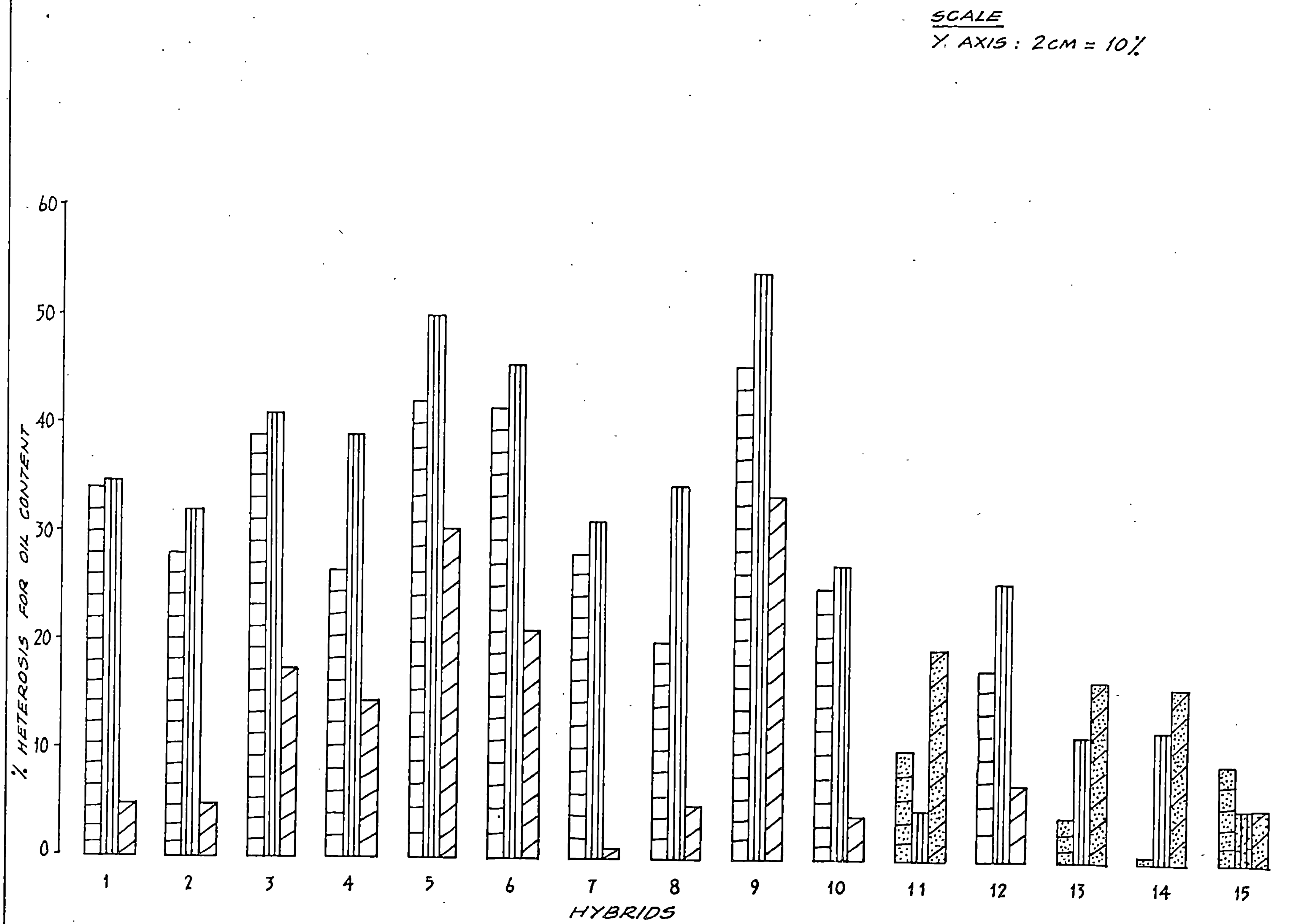
(iv)Heterosis percentage for seed yield per plant and seed yield per plot.

Sl. No.	Parents & Hybrids	Seed yield per plant. Mean (g)	Percentage of heterosis over Mid Parent	Better Parent	Check Parent	Seed yield per plot Mean (g)	Percentage of heterosis over Mid Parent	Better Parent	Check Parent.
1.	ACV.1	5.82				205.13			
2.	ACV.1xCO.1	2.13	-46.83**	-63.44**	-30.84**	61.22	-55.14**	-70.16**	-39.07**
3.	ACV.1xIC.284	2.91	-34.48**	-49.97**	-5.52	92.57	-40.38**	-54.88**	-7.86
4.	ACV.1xS.8	2.57	-51.11**	-55.87**	-16.56	78.67	-57.54**	-61.65**	-21.70*
5.	ACV.1xS.27	3.49	-15.31*	-39.94**	13.57	124.82	-10.41	-39.15**	24.24**
6.	ACV.1xK.1	2.97	-33.33**	-48.99**	-3.70	100.70	-34.10**	-50.91**	0.23
7.	CO.1	2.18				67.78			
8.	CO.1xIC.284	2.35	-10.48	-23.37*	-23.70*	74.50	-13.95	-29.30**	-25.85**
9.	CO.1xS.8	4.93	43.50**	5.20	60.06**	181.84	55.92**	9.90	80.99**
10.	CO.1xVS.27	4.75	105.78**	95.21**	54.22**	172.87	144.65**	135.09**	72.06**
11.	CO.1xK.1	2.58	-2.15	-16.43	-16.23	84.33	0.25	-16.06	-16.06
12.	IC.284	3.07				105.37			
13.	IC.284xS.8	2.92	-24.65**	-37.65**	-5.19	90.73	-33.00**	-45.17**	-9.69
14.	IC.284xVS.27	2.88	4.61	-6.20	-6.49	86.97	-2.78	-17.47**	-13.44
15.	IC.284xK.1	4.13	34.42**	34.05**	34.09**	156.43	52.00**	48.46**	55.70**
16.	S.8	4.68				165.47			
17.	S.8xVS.27	4.58	28.81**	-2.14	48.70**	162.53	36.01**	-1.77	61.77**
18.	S.8xK.1	3.88	0.00	-17.09**	25.97**	132.83	-0.10	-19.72**	32.21**
19.	VS.27	2.43				73.53			
20.	VS.27xK.1	4.38	58.91**	42.16**	42.21**	167.93	93.03**	67.15**	67.14**
21.	K.1	3.08				100.47			
	CD (0.05)		0.495	0.572	0.572		15.74	18.17	18.17
	CD (0.01)		0.662	0.765	0.762		21.06	24.31	24.31

Figure 2(i). Estimation of heterosis for oil content in a 6 x 6 diallel.

Treatment No.	Hybrid
1	ACV.1 x CO.1
2	ACV.1 x IC.284
3	ACV.1 x S.8
4	ACV.1 x VS.27
5	ACV.1 x K.1
6	CO.1 x IC.284
7	CO.1 x S.8
8	CO.1 x VS.27
9	CO.1 x K.1
10	IC.284 x S.8
11	IC.284 x VS.27
12	IC.284 x K.1
13	S.8 x VS.27
14	S.8 x K.1
15	VS.27 x K.1

FIG. 2 (i)


SCALE
Y AXIS : 2CM = 10%
60
50
40
30
20
10
0
% HETEROSIS FOR OIL CONTENT
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
HYBRIDS

CO.1 x VS.27 (105.78), VS.27 x K.1 (58.91), CO.1 x S.8 (43.50), IC.284 x K.1 (34.42), and S.8 x VS.27 (28.81) were statistically significant. One hybrid, viz. S.8 x K.1 showed no heterosis for this character.

Compared to the better parent, the percentage of heterosis ranged from -63.44 in ACV.1 x CO.1 to 95.21 in CO.1 x VS.27. Negative heterosis was shown by eleven hybrids, of which eight, viz. S.8 x K.1 (-17.09), CO.1 x IC.284 (-23.37), IC.284 x S.8 (-37.65), ACV.1 x VS.27 (-39.94), ACV.1 x K.1 (-48.99), ACV.1 x IC.284 (-49.97), ACV.1 x S.8 (-55.87) and ACV.1 x CO.1 (-63.44) were statistically significant. Four crosses recorded positive heterosis, of which the hybrids, CO.1 x VS.27 (95.21), VS.27 x K.1 (42.16) and IC.284 x K.1 (34.05) were significant.

Compared to the check parent, K.1, the heterosis percentage ranged from -30.84 to 60.06. Seven hybrids exhibited positive heterosis of which six crosses, viz. CO.1 x S.8 (60.06), CO.1 x VS.27 (54.22), S.8 x VS.27 (48.70), VS.27 x K.1 (42.21), IC.284 x K.1 (34.09) and S.8 x K.1 (25.97) were statistically significant. Negative heterosis was exhibited by eight hybrids of which two crosses were significant. They were CO.1 x IC.284 (-23.70) and ACV.1 x CO.1 (-30.84).

The best combination for seed yield per plant was CO.1 x VS.27 followed by VS.27 x K.1 and CO.1 x S.8. The percentage heterosis over mid, better and check parental values for this character is represented in Figure 2(j).

4.3.11. Seed yield per plot

The percentage of heterosis manifested by the fifteen hybrids over their mid, better and check parental values for seed yield per plot is presented in Table 9 (iv).

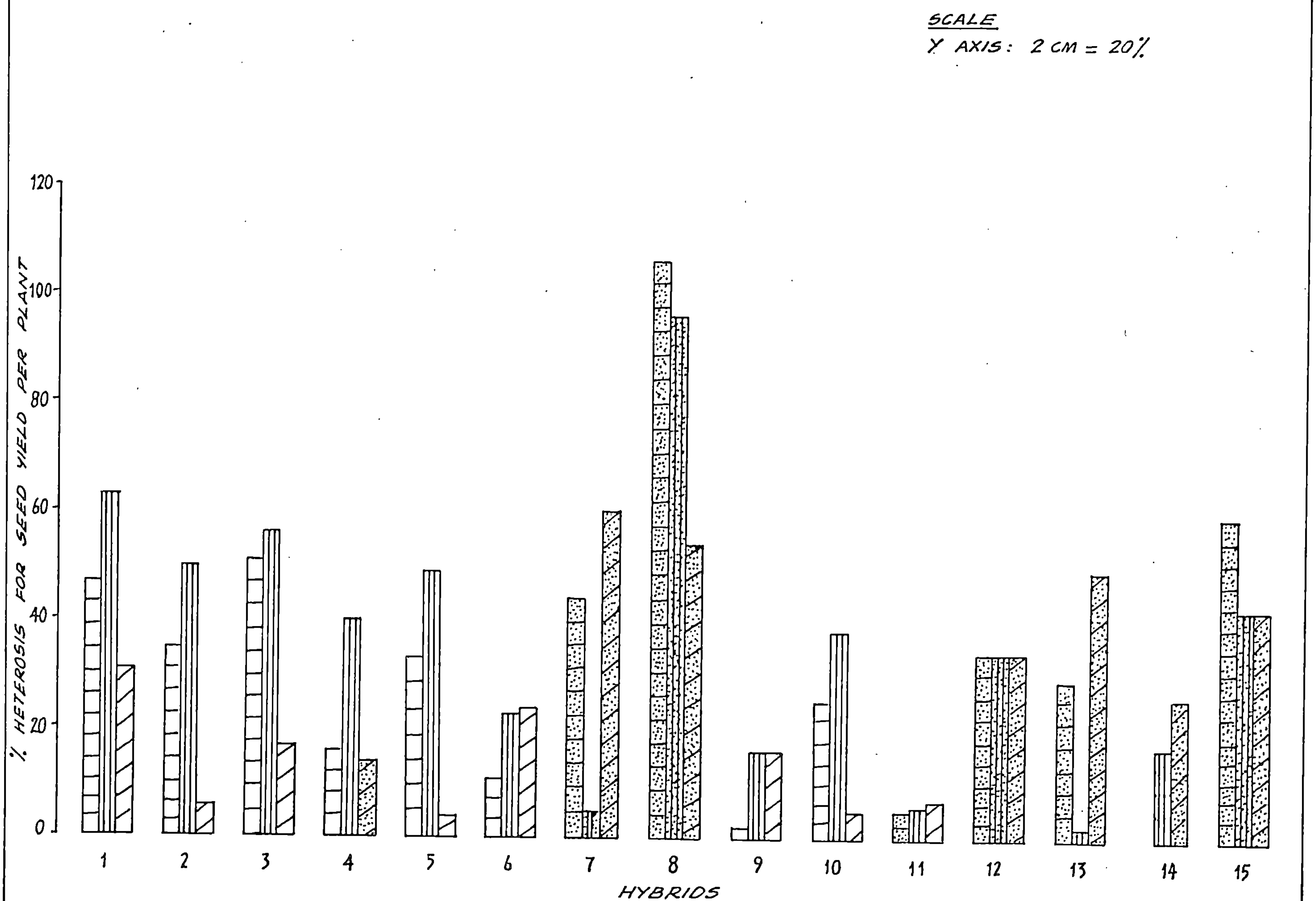
Compared to the mid-parent, the percentage of heterosis ranged from -57.54 in ACV.1 x S.8 to 144.65 in CO.1 x VS.27. Nine hybrids exhibited negative heterosis of which five hybrids viz. IC.284 x S.8 (-33.00), ACV.1 x K.1 (-34.10), ACV.1 x IC.284 (-40.38), ACV.1 x CO.1 (-55.14) and ACV.1 x S.8 (-57.54) were statistically significant. Six hybridsrecorded positive heterosis. The significant hybrids were CO.1 x VS.27 (144.65), VS.27 x K.1 (93.03), CO.1 x S.8 (55.92), IC.284 x K.1 (52.00) and S.8 x VS.27 (36.01).

Compared to the better parent, the percentage of heterosis ranged from -70.16 in ACV.1 x CO.1 to 135.09 in CO.1 x VS.27. Four hybrids recorded positive heterosis of which the three crosses, viz. CO.1 x VS.27 (135.09), VS.27 x K.1 (67.15) and IC.284 x K.1 (48.46) were significant. Eleven hybrids recorded negative heterosis of which

Figure 2(j). Estimation of heterosis for seed yield per plant in a 6 x 6 diallel.

Treatment No.	Hybrid
1	ACV.1 x CO.1
2	ACV.1 x IC.284
3	ACV.1 x S.8
4	ACV.1 x VS.27
5	ACV.1 x K.1
6	CO.1 x IC.284
7	CO.1 x S.8
8	CO.1 x VS.27
9	CO.1 x K.1
10	IC.284 x S.8
11	IC.284 x VS.27
12	IC.284 x K.1
13	S.8 x VS.27
14	S.8 x K.1
15	VS.27 x K.1

FIG. 2(j)


SCALE
Y AXIS: 2 CM = 20%
120
100
80
60
40
20
0
% HETEROSIS FOR SEED YIELD PER PLANT
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
HYBRIDS

nine were significant. They were IC.284 x VS.27 (-17.47), S.8 x K.1 (-19.72), CO.1 x IC.284 (-29.30), ACV.1 x VS.27 (-39.15), IC.284 x S.8 (-45.17), ACV.1 x K.1 (-50.91), ACV.1 x IC.284 (-54.88), ACV.1 x S.8 (-61.65) and ACV.1 x CO.1 (-70.16).

Compared to the check parent, K.1, the heterosis percentage ranged from -39.07 to 80.99. Positive heterosis was exhibited by eight hybrids of which seven crosses were statistically significant. They were CO.1 x S.8 (80.99), CO.1 x VS.27 (72.06), VS.27 x K.1 (67.14), S.8 x VS.27 (61.77), IC.284 x K.1 (55.70), S.8 x K.1 (32.21), and ACV.1 x VS.27 (24.24). Seven hybrids recorded negative heterosis of which the significant crosses were ACV.1 x S.8 (-21.70), CO.1 x IC.284 (-25.85) and ACV.1 x CO.1 (-39.07).

Maximum heterosis for this character was exhibited by the cross, CO.1 x VS.27 followed by VS.27 x K.1 and CO.1 x S.8. The heterosis percentage over mid, better and check parental values for seed yield per plot is represented in Figure 2(k).

It was seen that the varieties S.8, VS.27 and ACV.1 were the best general combiners for yield and important yield attributes and the best specific combinations for these characters were CO.1 x VS.27, CO.1 x S.8 and VS.27 x

Figure 2(k). Estimation of heterosis for seed yield per plot in a 6 x 6 diallel.

Treatment No.	Hybrid
1	ACV.1 x CO.1
2	ACV.1 x IC.284
3	ACV.1 x S.8
4	ACV.1 x VS.27
5	ACV.1 x K.1
6	CO.1 x IC.284
7	CO.1 x S.8
8	CO.1 x VS.27
9	CO.1 x K.1
10	IC.284 x S.8
11	IC.284 x VS.27
12	IC.284 x K.1
13	S.8 x VS.27
14	S.8 x K.1
15	VS.27 x K.1

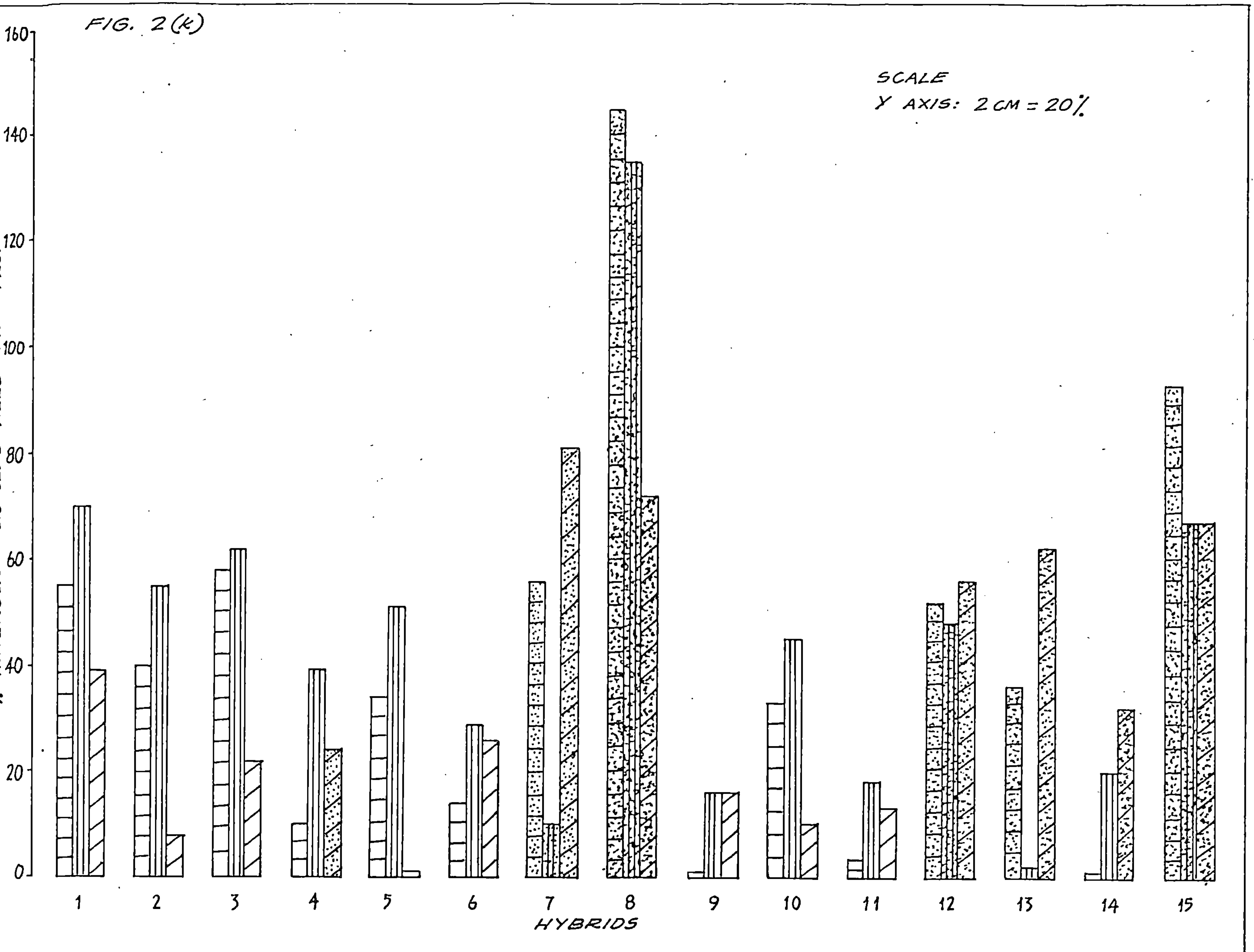
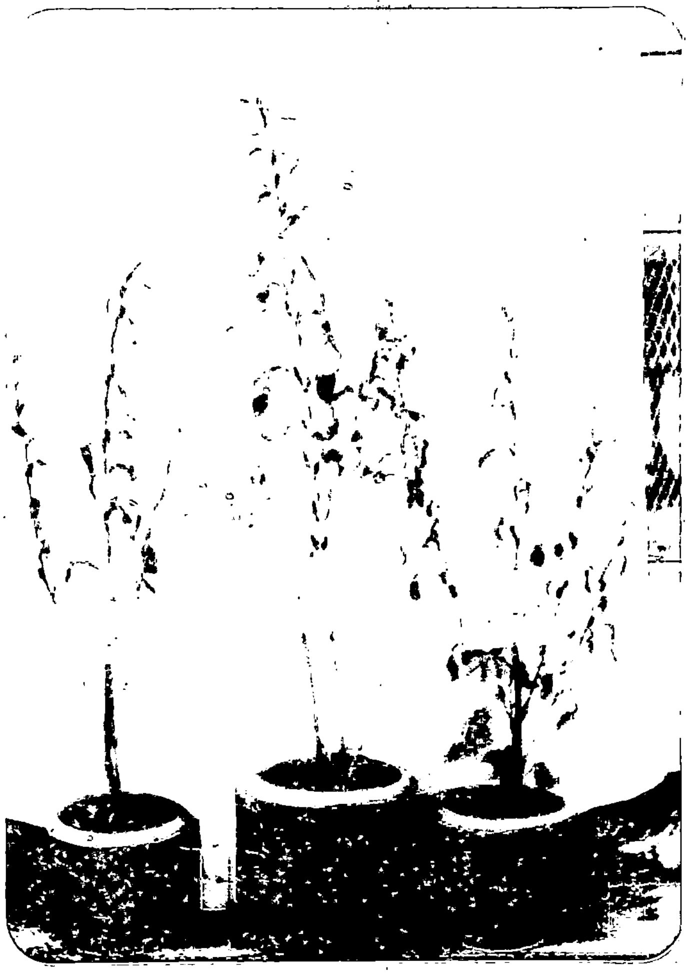


FIG. 2(k)
SCALE
Y AXIS: 2 CM = 20%
160
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
HYBRIDS

K.1. (Fig.3). The cross combinations with high s.c.a effects also exhibited the maximum heterosis for the character under study. The most important character, yield and its attributes were influenced by additive and non-additive gene action although non-additive gene action predominated.

Figure 5. Best specific combinations among 6 x 6 diallel.




CO-1
F1
S-8


VS-27
F1
K-1

DISCUSSION

DISCUSSION

The breeder of a self-pollinated crop is in general faced with the problem of choice of parents for hybridization and the selection of the best lines from hybrid progenies. The diallel cross technique which involves the crossing of a group of lines in all possible combinations is an efficient method for the study of combining ability and the nature and type of genetic parameters operating in the expression of various characters. This enables the choice of appropriate parental material for employing the most suitable breeding methodology. Further, the average productivity of sesame in Kerala is comparatively low and the scope for exploitation of hybrid vigour in this crop needs investigation. The present experiment was undertaken to study the combining ability, gene action and heterosis in sesame. Six varieties and the fifteen hybrids obtained by crossing them in all possible combinations, excluding reciprocals, were subjected to diallel analysis. The results obtained are discussed in the ensuing sections.

5.1 Combining ability

The estimate of g.c.a and s.c.a effects will be of great value in sorting out elite parents and desirable cross combinations. Results of combining ability analysis of the chosen six parents and the fifteen hybrids obtained by crossing them are discussed below.

The analysis of variance due to combining ability revealed that both g.c.a and s.c.a variances were significant for the characters, plant height, number of capsules per plant, number of seeds per capsule, weight of 1000 seeds, oil content, seed yield per plant and seed yield per plot. Similar results were reported for plant height by Rathnaswamy (1984). Fatteh et al. (1982) also reported significant g.c.a and s.c.a variances for the characters, plant height, total number of capsules per plant, thousand seed weight and seed yield. In the present investigation, a preponderance of s.c.a variance was observed for all the characters studied. This is in accordance with the reports of Dora and Kamala (1987).

The high s.c.a variance observed for plant height is in confirmity with the reports of Murty and Hashim (1974), Krishnadoss et al. (1987) and Dora and Kamala (1987). However the significant g.c.a variance for this character in the present study is in agreement with the findings of Murty (1975), Kotecha and Yermanos (1978), Shrivas and Singh (1981) and Rathnaswamy (1984). The g.c.a effects were significant in five parents and s.c.a effects significant in twelve hybrids. Maximum positive g.c.a effect (for tallness) was expressed by ACV.1 followed by S.8 and K.1. Negative g.c.a effects (for dwarfness) was recorded by VS.27, CO.1 and IC 284. Among the different cross combinations, maximum positive s.c.a effect was shown by CO.1 x VS.27 which was a combination involving poor general combiners for plant height. The next best combinations were ACV.1 x K.1 followed by CO.1 x S.8. The cross ACV.1 x K.1 involved both the parents which were good general combiners for height whereas in CO.1 x S.8 the female parent (CO.1) was a poor combiner and S.8, a good combiner. Moreover ACV.1 and S.8 the best general combiners did not produce hybrids with positive s.c.a effect. High s.c.a effects were manifested in all the three combinations involving poor x poor, good x good and good x poor general combiners. Similar results were also noticed by Sharma and Chauhan (1985) whereas Fatteh et al. (1982) reported that the best general combiners were involved in best specific combinations. The g.c.a of the parents were in general, directly related to their per se performance ie, the parents with high means showed high g.c.a effects. The g.c.a of the parents in general had no bearing on the s.c.a effects of the crosses ie, the crosses involving the high general combiners were not necessarily having high s.c.a effects. The g.c.a and s.c.a effects were significant for this character suggesting the importance of both g.c.a and s.c.a variances as was also evidenced in the present study. Out of the eight cross combinations with positive s.c.a effects, three were between poor x good, three between poor x poor and two between good x good general combiners.

For the character days to flower, the variance due to s.c.a alone was significant, suggesting the importance of specific combining ability for this trait. This is in accordance with the reports of Murty and Hashim (1974), Godawat and Gupta (1985) and Dora and Kamala (1987). However, contradictory to this, Murty (1975), Veena et al. (1983) and Sharma and Chauhan (1985) reported higher g.c.a variance for days to flower. Negative g.c.a effects were shown by the parents S.8, K.1 and IC.284 and the maximum significant negative s.c.a effect by IC.284 x S.8. The parents with negative g.c.a effects were involved in IC.284 x S.8. The other best combinations for earliness to flower were ACV.1 x K.1 and ACV.1 x IC.284 where ACV.1 was with positive g.c.a and IC.284 and K.1 were with negative g.c.a effects. The best specific combinations for earliness therefore involved early x early and late x early parents. It was also seen that the g.c.a of the parents were generally related to their <u>per se</u> performance. Correspondence between the s.c.a effect and <u>per se</u> performance of the F_1's were seen in most of the crosses. Out of the ten best combinations for earliness, six involved parents which were late x early, two late x late and two early x early general combiners. All the three possible types of combinations between parents of high and low g.c.a effects were also reported by Sharma and Chauhan (1985). On the contrary, Fatteh et al. (1982) from a diallel set of six sesame strains revealed that the best general combiners were involved in the best specific combinations.

The treatments did not differ significantly for the character days to mature and hence g.c.a and s.c.a variances was not significant. Contrary to this, Fatteh et al. (1982), Chaudhari et al. (1984) and Sharma and Chauhan (1985) revealed that g.c.a was higher for the character, whereas, Dora and Kamala (1987) reported significant s.c.a for days to mature.

The variance due to s.c.a alone was significant for the character number of branches per plant. This is in line with the results reported by Murty and Hashim (1974), Fatteh et al. (1982) and Dora and Kamala (1987). On the contrary, g.c.a was reported to be high by Gupta (1981) and Rathnaswamy (1984). Maximum positive g.c.a effect for this character was recorded by the parent VS.27 followed by CO.1, K.1 and S.8. Negative g.c.a effects were shown by IC.284 and ACV.1. Among the different cross combinations, maximum s.c.a effects were shown by the cross VS.27 x K.1 followed by IC.284 x K.1 and CO.1 x IC.284. In the cross VS.27 x K.1, both the parents were good general combiners for the character, whereas in the crosses IC.284 x K.1 and CO.1 x IC.284, the poor combiner involved was IC.284. CO.1 and K.1 were with positive g.c.a effects. The best combinations involved parents which were good x good and poor x good general combiners for the character. In general, the crosses involving the high general combiners were not necessarily having high s.c.a effects. The g.c.a of the parents and their *per se* performance and the s.c.a of the crosses and *per se* performance of the F_1's were not related, for this character. Out of the five cross combinations with positive s.c.a effects, three involved parents which were poor x good and two good x good general combiners. Combining ability studies by Sharma and Chauhan (1985) revealed that for the character, number of branches, the superior combinations involved all the three possible combinations between parents of high and low g.c.a effects. On the contrary, Fatteh et al. (1982) reported that the best general combiners were involved in best specific combinations.

Significant g.c.a and s.c.a variances were recorded for the character number of capsules per plant but s.c.a variance was three times higher in magnitude than the g.c.a variance. Preponderance of s.c.a variance was also reported by Murty and Hashim (1974), Sengupta (1980) and Dora et al. (1987). But contrary to this, Gupta (1981), Fatteh et al. (1982) and Rathnaswamy (1984) reported higher g.c.a variance for this character. The best general combiner for number of capsules per plant was S.8 followed by K.1 and VS.27. Negative g.c.a effects were recorded by ACV.1, CO.1 and IC.284. The maximum s.c.a effect for this character was recorded by CO.1 x VS.27 followed by IC.284 x K.1. In both these crosses, one of the parents was with positive g.c.a and the other with negative g.c.a effects. In the next best cross VS.27 x K.1, both the parents were with positive g.c.a effect. Out of the seven cross combinations with positive s.c.a effects, four were combinations between parents which were poor x good combiners, two good x good combiners and one was a cross between two poor general combiners. This is in accordance with the results obtained by Sharma and Chauhan (1985) where all the three possible combinations viz. between high x high, high x low and low x low general combiners were involved to produce superior combinations. On the contrary, combining ability studies by Fatteh et al. (1982) revealed that the superior combinations were between best general combiners for the character. The g.c.a of the parents were not generally related to their _per se_ performance. But a relation was detected between the *per se* performance of the F_1's and the best specific combinations.

For the character, capsule length, s.c.a variance was found to be significant. Similar results were also reported by Dora and Kamala (1987). However Kotecha and Yermanos (1978) and Rathnaswamy (1984) suggested the significance of g.c.a for this character. The g.c.a effects were significant for two parents and s.c.a effects for five cross combinations. The best positive g.c.a effect was recorded by S.8 followed by ACV.1. Negative g.c.a effects were exhibited by the parents K.1, CO.1, IC.284 and VS.27. Among the different cross combinations maximum positive s.c.a effects were recorded by CO.1 x S.8, followed by ACV.1 x K.1 and CO.1 x VS.27. The crosses, CO.1 x S.8 and ACV.1 x K.1 involved parents with positive and negative g.c.a effects, whereas, CO.1 x VS.27 cross involved parents with negative g.c.a effects. Out of the ten cross combinations with positive g.c.a effects, six were combinations between parents which were good x poor and four between poor x poor general combiners. This indicates the significance of s.c.a for this character. The g.c.a of the parents and their *per se* performance were generally related and the *per se* performance of some of the best F_1's were related to their s.c.a effects.

The variances due to g.c.a and s.c.a were significant for the character number of seeds per capsule but the s.c.a variance was twice the g.c.a variance, suggesting the importance of s.c.a for this character. This is in accordance with the results obtained by Chavan et al. (1981), Veena et al. (1983), Chaudhari et al. (1984), Shivaprakash (1986) and Dora and Kamala (1987). On the contrary, g.c.a was reported to be predominant by Fatteh et al. (1982). The g.c.a effects were significant in all the six parental varieties and the s.c.a effects in fourteen hybrids. The maximum positive g.c.a effects were exhibited by ACV.1 and IC.284. Negative g.c.a effects were shown by the parents S.8, VS.27, CO.1 and K.1. Among the different cross combinations, the maximum positive s.c.a effect was recorded by the cross CO.1 x S.8 which involved parents with negative g.c.a effects for the character. The next best cross combinations were ACV.1 x IC.284 where both the parents involved were with positive g.c.a effects followed by the cross VS.27 x K.1 where both the parents were with negative g.c.a effects. Here also the best specific combinations did not necessarily involve good general combiners for the character. Out of the seven cross combinations with positive s.c.a effects, only one was between good general combiners and the other six were between poor combiners. All these suggest the importance of both g.c.a and s.c.a and the predominance of s.c.a for this character. The g.c.a of the parents were generally related to their *per se* performance. The *per se* performance of the F_1's were not directly related to the s.c.a effects of the cross combinations.

The character thousand seed weight had significant g.c.a and s.c.a variances. Sharma and Chauhan (1985) also obtained similar results. In the present study, the variance due to s.c.a was predominant, suggesting the importance of s.c.a for this character. This is in line with the reports of Tyagi and Singh (1981) and Dora and Kamala (1987). On the contrary, Veena et al. (1983) reported that the g.c.a variance was higher for this character. The g.c.a effects were significant for four parental varieties and s.c.a effects for eleven cross combinations. The maximum positive g.c.a effect for this character was recorded by the variety ACV.1 followed by CO.1 and S.8. Negative g.c.a effects were shown by K.1, IC.284 and VS.27. Among the different cross combinations, maximum positive s.c.a effect was recorded by CO.1 x K.1 followed by CO.1 x VS.27, ACV.1 x IC.284 and S.8 x VS.27. All these crosses involved atleast one parent which was a poor general combiner. The g.c.a effects of the parents were related to their *per se* performance. Out of the seven cross combinations with positive s.c.a effects, only one cross involved parents which were good general combiners. All the other six crosses were between good and poor general combiners. Similar results were also observed by Sharma and Chauhan (1985) in a set of 10 x 10 diallel where the superior combinations involved all the three possible combinations between parents of high and low g.c.a effects. On the contrary, Fatteh et al. (1982), from a diallel set of six strains of sesame reported that the best specific combinations involved the best general combiners. All these suggest the importance of both g.c.a and s.c.a and the predominance of s.c.a for controlling this character.

The combining ability analysis for oil content showed that both g.c.a and s.c.a variances were significant for the character oil content, but the s.c.a variance was predominant. Similar results were also reported by Murty (1975), Fatteh et al. (1982), Veena et al. (1983), Chaudhari et al. (1984) and Dora et al. (1987). But contrary to this, Sharma and Chauhan (1985) reported higher g.c.a for this character. The g.c.a effects were significant for three parental varieties and s.c.a effects for fourteen hybrids. The maximum positive g.c.a effect for this character was recorded by S.8 followed by IC.284 and CO.1. Negative g.c.a effects were shown by ACV.1, VS.27 and K.1. Among the different cross combinations, the maximum positive s.c.a effect was recorded by IC.284 x VS.27 followed by S.8 x K.1 and VS.27 x K.1. The first two crosses viz. IC.284 x VS.27 and S.8 x K.1 involved parents with positive and negative g.c.a effects and the third cross viz. VS.27 x K.1 involved parents with negative g.c.a effects. Out of the four cross combinations with positive s.c.a effects, three involved parents which were good x poor combiners and one, poor x poor general combiners. This is in accordance with the results observed by Sharma and Chauhan (1985). Reddy et al. (1986) studied genetic architecture of seed and oil yield in sesame and reported that the promising crosses were governed by positive g.c.a of one or both the parents. On the contrary, Fatteh et al. (1982) revealed that the best general combiners were involved in best specific combinations. All these indicated the importance of g.c.a and s.c.a but the predominance of s.c.a for this character. The g.c.a effects of the parents were not related to their per se performance. The per se performance of the F_1's were related to the s.c.a effects in some crosses.

The variances due to g.c.a and s.c.a were significant for the character seed yield (both per plant and per plot), but the s.c.a variance was higher in magnitude than g.c.a. This is in line with the reports of Murty (1975);

Shrivas and Singh (1981), Veena et al. (1983), Sharma and Chauhan (1985), Krishnadoss et al. (1987) and Kumar and Sreerangaswamy (1987) in sesame. At the same time, g.c.a was reported to be pronounced for this character by Kotecha and Yermanos (1978), Gupta (1981) and Rathnaswamy (1984).

The g.c.a effects of the parents for seed yield per plant was significant in four parental varieties and s.c.a effect significant in thirteen crosses. The parent, S.8, recorded the maximum g.c.a effect for the character followed by ACV.1 and VS.27. Negative g.c.a effects were expressed by CO.1, IC.284 and K.1. Among the fifteen cross combinations, the maximum s.c.a effect was recorded by the hybrid CO.1 x VS.27 followed by CO.1 x S.8 and IC.284 x K.1. Here the crosses CO.1 x VS.27 and CO.1 x S.8 involved parents with positive and negative g.c.a effects whereas the cross IC.284 x K.1 involved both the parents with negative g.c.a effects. Out of the five cross combinations with positive s.c.a effects, three crosses involved parents which were poor x good, one good x good and one poor x poor general combiners. The g.c.a effects of the parents were not related to their <u>per se</u> performance. The <u>per se</u> performance of the F_1'S also did not correspond to the s.c.a effects of the cross combinations.

For seed yield per plot, the g.c.a effects were significant for five parental varieties and thirteen crosses exhibited significant s.c.a effects. The best general combiners for this character were S.8 followed by ACV.1, VS.27 and K.1. Negative g.c.a effects were recorded by CO.1 and IC.284. The cross combination which expressed the maximum s.c.a effect was CO.1 x VS.27 where the female parent (CO.1) had negative g.c.a effect and the male parent (VS.27) with positive, g.c.a effect. The other best crosses were CO.1 x S.8 and IC.284 x K.1 which involved parents which were poor x good general combiners. Out of the five cross combinations which exhibited positive s.c.a effects, three crosses were between poor x good, one between poor x poor and one between good x good general combiners. This is in accordance with the results obtained by Sharma and Chauhan (1985) from a set of 10 x 10 diallel. Based on F_1 diallel, Reddy et al. (1986) identified promising crosses where seed yield was governed by positive g.c.a of one or both the parents. On the contrary, combining ability studies by Fatteh et al. (1982) revealed that the best general combiners were involved in best specific combinations. All these suggest the importance of both g.c.a and s.c.a but the predominance of s.c.a for this character. The g.c.a effects of the parents were not related to their per se performance.

In general, the general combining ability of the parents were not related to their per se performance.

Although the *per se* performance of the F_1 in general corresponded with their s.c.a effects, a perfect relation was not obtained for all the crosses. The best general combiner for seed yield per plant was S.8 which was also a good combiner for most of the other yield contributing traits. The ranking of the parental lines for their g.c.a effects with respect to various characters are given in Table 10. VS.27, the other good combiner for seed yield was also a good general combiner for number of capsules per plant, branches per plant and dwarfness. In the light of the combining ability analysis, the varieties S.8, VS.27 and ACV.1 should be given due consideration while framing future breeding programmes. Crosses involving these parents viz. CO.1 x VS.27 (Maximum plant height, maximum number of capsules per plant, seed yield per plant and seed yield per plot), VS.27 x K.1 (maximum number of branches per plant), CO.1 x S.8 (maximum capsule length and number of seeds per capsule), CO.1 x K.1 (maximum 1000 seed weight) and IC.284 x VS.27 (maximum oil content) were the best specific combinations for the different characters.

The crosses involving parents with high general combining ability were not necessarily having the high s.c.a effect. The high x high combinations giving high s.c.a effect stressed the role of additive or additive x

Table 10. Ranking of parental lines for their g.c.a effects with respect to the ten characters in a 6 x 6 diallel.

Sl. No.	Characters	Parents					
		ACV.1	CO.1	IC.284	S.8	VS.27	K.1
1.	Plant height	G (T)	G (D)	MG (D)	G (T)	G (D)	MG (T)
2.	Days to flower	G (L)	G (L)	G (E)	G (E)	G (L)	G (E)
3.	Number of branches per plant	G (N.B)	G (B)	MG (N.B)	MG (B)	G (B)	MG (B)
4.	Number of capsules per plant	P	P	P	G	M.G.	G
5.	Length of the capsule	M.G	P	P	G	P	P
6.	Number of seeds per capsule	G	P	M.G	P	P	P
7.	Weight of 1000 seeds	G	G	P	MG	P	P
8.	Oil content	P	M.G	M.G	G	P	P
9.	Seed yield per plant	G	P	P	G	G	P
10.	Seed yield per plot	M.G	P	P	G	M.G	M.G

G = Good M.G = Medium Good P = Poor

T = Tall D = Dwarf L = Late E = Early

B = Branching N.B = Non-Branching

additive type of gene action. Such an explanation was also given by Hosfield et al. (1977) in onion. The high x low combinations giving higher s.c.a effects is due to dominance and epistasis (Jinks, 1956), whereas, the high x low combinations giving negative s.c.a effects is due to mutual cancellation of the components of heterosis (Hayman, 1958). The high x high combinations resulting in lower s.c.a estimates and the low x low combinations giving higher s.c.a estimates is due to complementary gene action (Basak and Dana, 1971; in Jute and Singh and Dhaliwal, 1971 in wheat). The high x high combinations expressing high s.c.a effects is expected to yield transgressive segregants in later generations. The high x low or high x average combinations with high s.c.a will throw good segregants only if the allelic genetic systems are present in good combination and epistatic effects present in the crosses act in the same direction so as to maximise the desirable characters. For efficient utilization of these cross combinations, it is suggested to make <u>inter se</u> crossing of these combinations (involving high x low g.c.a effects) of the F_1 generations in all possible combinations so as to have multiple parents input in a central gene pool which will supplement faster genetic recombinations and break genetic blocks, if present.

5.2 Gene action

Griffing (1956) pointed out that high g.c.a contains not only the additive genetic variance but also a portion of the epistatic variance (additive x additive) and the s.c.a includes all of the dominance and the remaining epistatic variance. The analysis of variance in the present study for combining ability revealed the preponderance of s.c.a variance for all the characters studied. The ratio of g.c.a variance to s.c.a variance is also used to interpret the relative significance of additive and non-additive gene effects.

For the character plant height, the variance due to g.c.a and s.c.a were significant. This implied the importance of additive and non-additive gene action in governing this character. But s.c.a variance was more than twice that due to g.c.a and ratio of g.c.a to s.c.a variance was 0.044:1 revealing the predominant role of non-additive gene action for plant height. This is in line with the reports of Chavan et al. (1981), Shrivas and Singh (1981), Chaudhari et al. (1984), Shivaprakash (1986) and Dora and Kamala (1987). On the contrary, additive gene action was found to be important by the works of Murty (1975), Kotecha and Yermanos (1978), Fatteh et al. (1982), Veena et al. (1983) and Rathnaswamy (1984). Moreover, the cross combinations with high s.c.a effects mainly involved good x poor and poor x poor combinations emphasising the preponderance of non-additive gene action for the character.

For the character days to flower, only the variance due to s.c.a was significant indicating that non-additive gene action exerted control over its inheritance. The g.c.a to s.c.a variance ratio of 0.034:1 also established this fact. This was in conformity with the results reported by Godawat and Gupta (1985) and Sharma and Chauhan (1985). On the contrary, Murty (1975) and Fatteh et al. (1982) reported additive gene effects for this character. The cross combinations which were early to flower mostly involved parents which were late x early and late x late general combiners suggesting the predominance of non-additive gene action for this character.

The variance due to g.c.a and s.c.a was not significant for the character days to mature, but s.c.a variance was higher in magnitude. According to the reports of Fatteh et al. (1982), Chaudhari et al. (1984) and Sharma and Chauhan (1985) additive gene effects were predominant for this character, whereas, Dora and Kamala (1987) opined that non-additive gene effects were important for days to mature.

The character number of branches per plant was characterised by significant s.c.a variance which was twice the g.c.a variance. Moreover g.c.a to s.c.a ratio was 0.052:1 suggesting the predominant role of non-additive gene action for this character. This is in line with the reports of Dixit (1976), Shrivas and Singh (1981), Sharma and Chauhan (1985), Shivaprakash (1986) and Dora and Kamala (1987). But contrary to this, Murty (1975), Rathnaswamy (1984) and Chandramony and Nayar (1985) revealed that additive gene effects were more important for this character. Most of the best specific combinations were between parents which were poor x good general combiners indicating that non-additive gene action was more important for this character.

The variances due to g.c.a and s.c.a were significant for number of capsules per plant suggesting the importance of both additive and non-additive gene action for this character. The s.c.a variance was four times higher in magnitude than g.c.a variance and g.c.a to s.c.a variance ratio was 0.033:1 establishing the predominant role of non-additive genic control for capsule number per plant. This is in conformity with the reports of Murty and Hashim (1974), Shrivas and Singh (1981), Chavan et al. (1981), Chaudhari et al. (1984), Shivaprakash (1986) and Dora and

Kamala (1987), whereas, additive gene action was reported to exert control over capsule number per plant by Kotecha and Yermanos (1978), Janardhanam et al. (1981), Fatteh et al. (1982) and Chandramony and Nayar (1985). Most of the best combinations with positive s.c.a effect for this character involved parents with negative x positive g.c.a effects or negative x negative g.c.a effects, indicating that non-additive gene action is predominant for capsule number per plant.

The length of the capsule was characterised by significant s.c.a variance which was four times higher in magnitude than the g.c.a variance. The g.c.a to s.c.a variance ratio was 0.023:1 revealing that this character was also under non-additive genic control. Similar results were also reported by Dora and Kamala (1987) whereas, Fatteh et al. (1982) and Rathnaswamy (1984) observed that additive gene effects were more important for this character. All the combinations with positive s.c.a effects were between parents which were good x poor and poor x poor general combiners suggesting the importance of non-additive gene action.

The variances due to g.c.a and s.c.a were significant for number of seeds per capsule indicating the importance of both additive and non-additive gene action for the expression of this character. Similar results were also obtained by Janardhanam et al. (1981). The s.c.a variance was twice the g.c.a variance and g.c.a to s.c.a variance ratio was 0.06:1 indicating the predominance of non-additive gene action in governing this character. This was in agreement with the reports of Chavan et al. (1981), Chaudhari et al. (1984), Shivaprakash (1986) and Dora and Kamala (1987). But contrary to this, Fatteh et al. (1982) observed additive gene action for this character. Out of the seven combinations with high s.c.a effects, six crosses involved both parents with negative g.c.a effects and one cross was between parents with positive g.c.a effects. All these suggested the importance of non-additive gene action in controlling the number of seeds per capsule.

Thousand seed weight was characterised by significant g.c.a and s.c.a variances indicating the importance of both additive and non-additive gene effects in the control of this character. Sharma and Chauhan (1985) also obtained similar results in sesame. The s.c.a variance was more than twice the g.c.a variance and the g.c.a:s.c.a variance ratio was 0.048:1 indicating the predominant role of non-additive gene action in governing this character. This was in confirmity with the reports of Chaudhari et al. (1984), Veena et al. (1983) and Dora and Kamala (1987).

On the contrary, Dixit (1976) and Fatteh et al. (1982) observed the preponderance of additive gene effects in controlling thousand seed weight. Most of the cross combinations with positive s.c.a effects were between parents with positive and negative g.c.a effects rather than between positive general combiners. This also pointed to the importance of non-additive gene action for this character.

For the character, oil content, both the variances due to g.c.a and s.c.a were significant suggesting the significance of additive and non-additive gene action for this trait. Similar results were also obtained by Culp (1959), Sharma and Chauhan (1985) and Reddy et al. (1986). The s.c.a variance was ten times higher in magnitude than the corresponding g.c.a variance and the g.c.a to s.c.a variance ratio was 0.011:1 supporting the predominance of non-additive gene action governing this character. This was in agreement with the reports of Murty (1975), Fatteh et al. (1982), Veena et al. (1983), Chandramony and Nayar (1985) and Dora and Kamala (1987). The best cross combinations with positive s.c.a effects were between parents with positive x negative g.c.a effects or negative x negative g.c.a effects, indicating the significance of non-additive gene action in the expression of this character.

Both seed yield per plant and seed yield per plot were characterised by significant variances for g.c.a and s.c.a. This was in conformity with the findings of Dixit (1976), Chavan et al. (1981) and Sharma and Chauhan (1985). In both cases, the s.c.a variance was more than six times the g.c.a variance and the g.c.a to s.c.a variance ratio was 0.02:1 and 0.017:1 for seed yield per plant and seed yield per plot respectively indicating that this character was under non-additive gene action. Similar results were also reported by Murty (1975); Kotecha and Yermanos (1978), Rathnaswamy (1984), Godawat and Gupta (1985) and Dora and Kamala (1987). But contrary to this, Fatteh et al. (1982) reported predominance of additive gene action for seed yield. The best cross combinations with positive s.c.a effects involved parents with negative x positive or negative x negative g.c.a effects, for both seed yield per plant and seed yield per plot. All these indicated that seed yield was under non-additive gene action.

In general, it was seen that non-additive gene action predominated although additive gene action was also significant for the important yield components like plant height, number of capsules per plant, number of seeds per capsule, thousand seed weight, oil content and seed yield. Conventional breeding methods exploit only that portion of genetic variability which is due to additive x additive type of gene interaction. The predominance of non-additive gene action, which is non-fixable for yield and its components would require maintenance of heterozygosity in the population.

5.3 Heterosis

During the course of the present investigation, marked heterotic effect was observed in various hybrids for some of the characters studied.

A maximum of 29.73 percent, 29.67 percent and 26.16 percent heterosis over mid, better and check parent respectively was observed for the character plant height. Positive heterosis was recorded by nine hybrids over the mid parent, five hybrids over the better parent and twelve hybrids over the check parent. Of these, the heterosis exhibited by seven, four and eight hybrids over their mid, better and check parental values respectively were significant. Pal (1945) reported that heterosis was not manifested for this character in the various sesame crosses studied. Positive heterosis over better parental value was reported for this character by Kotecha and Yermanos (1978), Chavan et al. (1982), Paramasivam et al. (1982) and over mid parent by Shrivas and Singh (1978) and Rathnaswamy (1984). On the contrary, Murty (1975) observed that the overall heterosis percentage for plant height was low and ranged from 4.69 to 8.81 percent only, while Chaudhari et al. (1979) reported that none of the hybrids gave significant increase in height over their mid and better parental values. In the present study, the hybrid CO.1 x VS.27 expressed the maximum heterosis over mid parental value followed by CO.1 x S.8 and VS.27 x K.1. The hybrids which excelled the better parental value were CO.1 x VS.27, S.8 x K.1 and CO.1 x S.8. The hybrids ACV.1 x K.1, S.8 x K.1 and CO.1 x S.8 performed better than the check parental value. The combining ability analysis revealed that the crosses which exhibited maximum heterosis had the highest s.c.a effects.

For the character days to flower, negative heterosis was desirable for earliness to flower. Maximum negative heterosis of -9.29 percent over mid and better parental value and -6.86 percent over check parental value were recorded for this character. Thirteen hybrids expressed negative heterosis over mid-parent, fourteen hybrids over better and six hybrids over the check parent. But only one hybrid over mid and better parent and two hybrids over the check parent were statistically significant. The cross combination IC.284 x S.8 expressed the maximum negative heterosis in all the three heterosis estimates, followed by ACV.1 x K.1 and S.8 x K.1. Pal (1945) reported that positive heterosis was not manifested in this crop for days to flower. In the present study also, only one hybrid, ACV.1 x CO.1 expressed positive heterosis over mid, better and check parental values, but was significant over the check parental value only. Sharma and Chauhan (1983) reported negative heterosis upto a maximum of -19.63 percent for this character. High degree of heterosis for days to flower was observed by Dixit (1976) and Kotecha and Yermanos (1978). Moreover, in the combining ability analysis, these hybrids which expressed the maximum negative heterosis recorded the highest s.c.a effects too.

The heterotic effect was generally low for the character days to mature. The maximum percentage of heterosis was 1.63 percent, 0.85 percent and 2.68 percent over mid, better and check parent respectively. Negative heterosis was an indication of earliness to mature and the hybrids recorded -1.39 percent, -2.39 percent and -1.22 percent negative heterosis over their mid, better and check parental values. Seven hybrids exhibited negative heterosis over mid-parent, eleven hybrids over better parent and seven hybrids over the check parental values. But none of the hybrids except IC.284 x K.1 over mid-parent was statistically significant. Here heterosis for late maturity was exhibited. Negative heterosis for this character has been reported by Kotecha and Yermanos (1978) and Tyagi and Singh (1981), whereas, on the contrary, positive heterosis or heterosis for late maturity was observed by Sarafi (1976) and Chavan et al. (1982). The g.c.a and s.c.a variances were also not significant for this character.

As regards the number of branches per plant, maximum heterosis of 34.75 percent, 18.18 percent and 60.91 percent over mid, better and check parent was observed. Seven hybrids exhibited positive heterosis over mid-parent, five hybrids over better parent and twelve hybrids over the check parent. But only one hybrid over the mid-parental value and two hybrids over better and check parental values were statistically significant. The cross VS.27 x K.1 followed by CO.1 x K.1 and CO.1 x VS.27 exhibited maximum heterosis. Maximum negative heterosis favouring non-branching nature was expressed in ACV.1 x IC.284. Pal (1945) evaluated the number of branches in sesame crosses for heterotic effect and reported that heterosis was not manifested for this character. But positive heterosis was observed for branch number in sesame by Tyagi and Singh (1981), Chaudhari et al. (1979), Gupta (1980), Rathnaswamy (1984) and Dora and Kamala (1986). On the contrary, Murty (1975) found that for this character, the overall heterosis was low. In the combining ability analysis also the cross combinations which expressed the maximum heterosis exhibited high s.c.a effects.

A very high degree of heterosis for number of capsules per plant was manifested among the fifteen hybrids.

A maximum positive heterosis of 172.83 percent, 142.37 percent and 51.38 percent over mid, better and check parental values were recorded for this character. Nine hybrids exhibited positive heterosis over mid-parent, five hybrids over better parent and seven hybrids over the check parental values. The hybrids which dominated in all three heterosis estimates were CO.1 x VS.27, IC.284 x K.1 and VS.27 x K.1. The maximum heterosis was manifested over mid-parental value. Similar results were also obtained by Dora and Kamala (1986). Pronounced heterosis for this character was also reported by Sarathe and Dabral (1969); Dixit (1976), Tyagi and Singh (1981). Appadurai and Krishnaswamy (1984) and Godawat and Gupta (1985). On the contrary, Murty (1975) reported that only a maximum of 16 percent heterosis was observed for capsule number per plant. The cross combinations which expressed the maximum heterosis also recorded the highest values of s.c.a effects in the combining ability analysis too.

The heterotic effect was comparatively less marked for the character, length of the capsule. A maximum heterosis of 12.21 percent, 8.41 percent and 13.43 percent over the mid-parent, better parent and check parental values were recorded for this character. Thirteen hybrids exhibited positive heterosis over mid-parent, twelve over better parent and fourteen over the check parental values. The hybrids which dominated over mid-parent, better parent and check parent were CO.1 x S.8, CO.1 x VS.27 and ACV.1 x K.1. Tyagi and Singh (1981) also reported that hybrid vigour was less marked for capsule length. Positive heterosis for this character was observed by Srivastava and Prakash (1977), Kotecha and Yermanos (1978) and Rathnaswamy (1984). Combining ability analysis also revealed that these cross combinations with maximum heterosis exhibited the highest s.c.a effects also.

As regards the number of seeds per capsule, heterosis was limited in the fifteen cross combinations. The percentage of heterosis over mid-parent extended upto a maximum of 26.99 percent with six hybrids exhibiting positive heterosis. Five hybrids recorded positive heterosis over better parent, the maximum being 23.46 percent. Positive heterosis predominated for this character over the check parental value, the maximum recorded, being 64.12 percent. All the fifteen hybrids showed positive standard heterosis of which thirteen crosses were significant. The hybrids which dominated in all the three heterosis estimates were CO.1 x S.8, VS.27 x K.1 and CO.1 x VS.27. Heterosis was found to be less marked for this character as reported by Sarathe and Dabral (1969) and Tyagi and Singh (1981) as was also evidenced in the present study. Dora and Kamala (1986) revealed that heterosis over mid parental value was the most pronounced for this trait. On the contrary, Paramasivan et al. (1982) reported high degree of heterosis over the better parent for number of seeds per capsule. The best hybrids also recorded the maximum s.c.a effects in the combining ability analysis too.

The heterosis exhibited for 1000 seed weight in the fifteen hybrids were very limited. Negative heterosis was manifested in a large number of hybrids. Positive heterosis over mid-parent was exhibited only by three hybrids, the maximum being 6.48 percent. Only one hybrid recorded positive heterosis of 3.14 percent over the better parental value. Six hybrids expressed positive, heterosis over check parental value, the maximum recorded being 10.08 percent. The hybrid vigour was reported to be less marked for this character by Sarathe and Dabral (1969) and Tyagi and Singh (1981). On the contrary, marked heterosis was observed by Srivastava and Singh (1968) over mid parental value and Paramasivan et al. (1982) over the better parental value. The cross-combinations which recorded maximum heterosis in all the three estimates were CO.1 x K.1 and CO.1 x VS.27 which also exhibited the highest s.c.a effects in combining ability analysis.

Heterosis was limited in the case of oil content in the hybrids. The maximum heterosis of 9.78 percent over mid-parent, 4.78 percent over better parent and 19.57 percent over the check parent was expressed for this character. Negative heterosis was manifested in a majority of the crosses. Only four hybrids recorded positive heterosis over mid-parent, one over better parent and four over the check parent. The hybrids which dominated in the three heterosis estimates were IC.284 x VS.27, VS.27 x K.1, S.8 x VS.27 and S.8 x K.1. The s.c.a effects of these cross combinations were found to be positive in combining ability analysis. Sarathe and Dabral (1969), Tyagi and Singh (1981) and Reddy et al. (1986) observed that hybrid vigour was less marked for this character. On the contrary, positive heterosis was reported by Sharma and Chauhan (1983).

As regards seed yield, high heterosis was shown by the hybrids. For seed yield per plant, the maximum heterosis of 105.78 percent, 95.21 percent and 60.06 percent over mid, better and check parental values were recorded. Six hybrids exhibited positive heterosis over mid-parent, four over the better parent and seven over the check parent. Increased vigour for seed yield was also reported by Sarathe and Dabral (1969), Rathnaswamy (1984) and Krishnadoss et al. (1987). On the contrary, Shrivas and Singh (1981) reported a maximum of 7.52 percent heterosis over its superior parent for this character. The best cross combination for seed yield per plant were CO.1 x VS.27, VS.27 x K.1 and CO.1 x S.8 which also recorded the highest s.c.a effects in combining ability analysis.

A maximum heterosis of 144.65 percent, 135.09 percent and 80.99 percent over mid, better and check parental values were reported for the character seed yield per plot. Six hybrids exhibited positive heterosis over mid-parent, four hybrids over better parent and eight hybrids over the check parent. Similar results were also reported by Sarathe and Dabral (1969), Gupta (1980), Chaudhari et al. (1979), Reddy et al. (1986) and Krishnadoss et al. (1987). The superior cross combinations also recorded high s.c.a effects in combining ability analysis.

The details of the expression of heterosis for various characters in this investigation have presented valuable information. The heterozygosity in the hybrids had distinct advantage for boosting up character expression in sesame. In the present study, maximum heterosis was recorded for capsules per plant, seed yield per plot, seed yield per plant, branches per plant, plant height and number of seeds per capsule. Heterosis in seed yield was reflected through heterosis in the above yield components. This may be due to favourable action and interaction of genes for these traits. The difference in heterosis might be due to several reasons such as

(1) genetic diversity of the parents used

(2) agronomic conditions in the experiment

(3) non-allelic interaction which could either increase or decrease the expression of heterosis.

Genetic divergence as a function of s.c.a has frequently been related to the expression of heterosis in different crop plants (Govil and Murty, 1973 and Das and Borthakur, 1973). In the present study, a near perfect positive correspondence was observed between s.c.a and extent of heterosis. These findings have important bearing in planning future breeding programmes. It is apparent that hybrid vigour was manifested by the hybrids for most of the important traits in general and the two important traits, capsule number and seed yield in particular. An important approach for improvement in this crop would be to develop hybrid strains. This may be discouraging unless a genetic system which can ensure fair amount of cross pollination or male sterility is identified. In commercial practice, the expression of heterosis in a given hybrid will have no real meaning unless it is significantly superior than the standard check available. Heterosis was seen to be significant for most of the traits over the check parental value in the present investigation. The maximum seed production in sesame may be attainable only with a system which can exploit both additive and non-additive genetic variances. The important yield components in sesame was seen to be under additive and non-additive gene action. Hence an important approach in this crop will be population improvement by recurrent selection technique which will facilitate accumulation of desirable genes and breaking of linkages as suggested by Frey (1975) and Rachie and Gardner (1975) in self pollinated crops.

SUMMARY

SUMMARY

The present investigation was carried out in the Department of Plant Breeding, College of Agriculture, Vellayani. Initially twenty three sesame varieties were selfed for one generation and based on the superior performance and yield, six distinct varieties were chosen. They were crossed in all possible combinations, excluding reciprocals, in Experiment I, so as to get fifteen hybrids. The main experiment consisted of evaluation of the parents and hybrids for combining ability, gene action and heterosis. The characters studied were plant height, days to flower, days to mature, number of branches per plant, number of capsules per plant, length of the capsule, number of seeds per capsule, weight of 1000 seeds, oil content, seed yield per plant and seed yield per plot. The data collected were subjected to statistical analysis and the combining ability analysis was carried out as per the Method 2 under Model 1 suggested by Griffing (1956). The salient points reflected from the results are summarised below.

The analysis of variance study conclusively proved that in sesame, the twenty one treatments differed significantly among themselves for all the characters studied,

except for days to mature. The significant characters were then subjected to combining ability analysis.

The analysis of variance for combining ability revealed that the variance due to g.c.a and s.c.a were significant for the characters, plant height, number of capsules per plant, number of seeds per capsule, weight of 1000 seeds, oil content, seed yield per plant and seed yield per plot. The s.c.a variance was predominant for all the characters suggesting the importance of specific combining ability. Based on the g.c.a effects, the parent ACV.1 was found to be the best general combiner for plant height, seeds per capsule and 1000 seed weight, the parent S.8 for days to flower, number of capsules per plant, capsule length, oil content, seed yield per plant and seed yield per plot and the parent VS.27 for number of branches per plant. The best specific combinations, based on s.c.a effects, were CO.1 x VS.27 for maximum plant height, number of capsules per plant, seed yield per plant and seed yield per plot, VS.27 x K.1 for maximum number of branches per plant, CO.1 x S.8 for capsule length and number of seeds per capsule, CO.1 x K.1 for maximum 1000 seed weight and IC.284 x VS.27 for maximum oil content. The cross IC.284 x S.8 was the earliest to flower. Most of the superior specific combinations for a character involved parents with good and average or poor general combining ability for the character.

The significance of g.c.a and s.c.a variances for plant height, number of capsules per plant, number of seeds per capsule, 1000 seed weight, oil content, seed yield per plant and seed yield per plot indicated that these characters were under both additive and non-additive gene action. The higher magnitude of s.c.a variance and the ratio of g.c.a : s.c.a variance being less than unity for all the characters studied, suggested the predominance of non-additive gene action in controlling their inheritance.

The heterosis percent was calculated over mid, better and check parental values. Positive heterosis was observed for all the characters studied. The maximum heterosis of 172.83 percent was observed for number of capsules per plant, followed by seed yield per plot (144.65 percent) and seed yield per plant (105.78 percent). Heterosis was the most pronounced over mid and check parental values followed by better parental values.

In the present study, a near perfect positive relationship was detected between the s.c.a effects and the expression of heterosis for a character, ie, the specific combinations with highest s.c.a effects for a character also exhibited the maximum heterosis for that character. The varieties VS.27, S.8 and ACV.1 can be given due consideration while formulating future breeding programmes and the best combinations for yield and its attributes viz. CO.1 x VS.27 and CO.1 x S.8 can be further exploited through pedigree or heterosis breeding. The best approach in this crop would be to exploit both the additive and non-additive genetic variance through population improvement by recurrent selection.

REFERENCE

REFERENCES

Anonymous. (1986). Package of Practices recommendations, K.A.U., pp. 54.

Anonymous. (1987). Directorate of economics and statistics, Government of India.

Appadurai, R. and Krishnaswamy, S. (1984). A preliminary study on heterotic potential in sesame. Madras Agric. J., 71(2): 81-84.

Basak, S.L. and Dana, S. (1971). Gene effects and heterosis in jute. Indian J. Genet. Pl. Breed., 31: 480-485.

Bhandari, M.M. (1974). Practicals in Plant Breeding. A manual cum practical record. Oxford and IBH Publishing Co., pp. 158.

Briggle, L.M. (1963). Heterosis in wheat - A review. Crop Sci., 3: 407-412.

Chandramony, D. and Nayar, N.K. (1985). Genetic variability in sesamum. Indian J. Agric. Sci., 55(12): 769-770.

Chaudhari, P.N., Zope, R.E., Deokar, A.B. and Patil, N.Y. (1979). Heterosis in sesame. J. Maharashtra Agric. Univ., 4(1): 125-126.

Chaudhari, P.N., Zope, R.E. and Patel, D.M. (1984). Combining ability in sesame. J. Maharashtra Agric. Univ., 9(3): 270-271.

Chavan, A.A., Makhne, V.G. and Chopde, P.R. (1981). Gene action in sesame. Indian J. Genet., 41: 419-422.

Chavan, A.A., Makhne, V.G. and Chopde, P.R. (1982). Components of heterosis and inbreeding depression studies in sesame (*Sesamum indicum* L.). J. Maharashtra Agric. Univ., 7(1): 15-16.

Culp, T.W. (1959). Inheritance and association of oil protein content and seed coat type in sesame (Sesamum indicum L.). Genetics, 44: 897-909.

Das, D.R. and Borthakur, D.N. (1973). Genetic divergence in rice. Indian J. Genet., 33: 436-444.

Dixit, R.K. (1976). Inheritance of yield and its components in sesame (Sesamum orientale L.). Indian J. Agric. Sci., 46(4): 187-191.

Dixit, R.K. (1978). Combining ability analysis for protein content and test weight in sesame (Sesamum orientale L.) Indian J. Agric. Sci., 48(6): 362-364.

Dora, K.B. and Kamala, T. (1986). Heterosis and gene action in sesame. Indian J. Agric. Sci., 56(10): 690-694.

Dora, K.B. and Kamala, T. (1987). Combining ability in sesame. Indian J. Agric. Sci., 57(11): 774-778.

Fatteh, U.G., Shah, R.M. and Bodar, D.G. (1982). Studies on combining ability in sesame. Madras Agric. J., 69(3): 145-150.

Frey, K.J. (1975). Breeding concepts and techniques for self pollinated crops. International Workshop on Grain Legumes, Jan. 13-16, ICRISAT, Hyderabad, India, 1-24.

Godawat, S.L. and Gupta, S.C. (1985). Inheritance of grain yield and its components in sesame. J. Oil Seeds Res., 2: 260-267.

Govil, J.N. and Murty, B.R. (1973). Genetic divergence and nature of heterosis in grain sorghum. Indian J. Genet., 33: 252-260.

Griffing, B. (1956). Concepts of general and specific combining ability in relation to diallel crossing systems. Aust. J. Biol. Sci., 9: 463-93.

Gupta, T.R. (1980). A study on heterosis in sesamum (Sesamum indicum L.). Madras Agric. J., 67(5): 295-299.

Gupta, T.R. (1981). Combining ability analysis of yield components in sesamum. Madras Agric. J., 68: 281-288.

Hayes, H.K., Immer, F.A. and Smith, D.C. (1955). Methods of Plant Breeding. Mc Graw Hill Book Company, pp. 52-60.

Hayman, B.I. (1958). Separation of epistasis from additive and dominance variation in generation means. Heredity., 12: 371-390.

Hosfield, G.L., Vest, G. and Peterson, C.E. (1977). A seven parent diallel cross in Onions to evaluate general and specific combining ability and their interaction with genes and locations. J. Amer. Soc. Hort. Sci., 102: 56-61.

Janardhanam, V.B., Ratnakar, N., Sreerama Reddy, G., Satyanarayana and Subramanyam, D. (1981). Genotypic, phenotypic, environmental variability, heritability estimates and genetic advance in sesamum. Andhra Agric. J., 28: 105-108.

Jinks, J.L. (1956). The F_2 and back cross generations from a set of diallel crosses. Heredity., 10: 10-18.

John, S. (1980). Genetic analysis of pod characters in sesamum (Sesamum indicum L.). M.Sc. (Ag.) Thesis, K.A.U., College of Agriculture, Vellayani.

Kotecha, A. and Yermanos, D.M. (1978). Combining ability of four traits in sesame (Sesamum indicum L.). Agron. Abst. 68.

Krishnadoss, D. and Kadambavanasundarum (1987). Heterosis for yield in sesamum. Andhra Agric. J., 34(2): 151-154.

Krishnadoss, D., Kadambavanasundarum, M., Ramalingam, R.S. and Rajasekharan, S. (1987). Combining ability in sesame. Indian J. Agric. Sci., 57(2): 85-88.

Kumar, A.C.R. and Sreerangaswamy, S.R. (1987). Combining ability for yield in sesame. J. Oil Seeds Res., 4: 238-241.

*Morinaga, T.E., Fukushima, E., Kano, T. and Yamasaki, Y. (1929). Chromosome numbers of cultivated plants. II. Bot. Mag., 43: 589.

Murty, D.S. and Hashim, M. (1974). Diallel analysis in sesame. Indian J. Genet., 34: 703-712.

Murty, D.S. (1975). Heterosis, combining ability and reciprocal effects for agronomic and chemical characters in sesame. Theor. Appl. Genet., 45: 294-299.

Nayar, N.M. and Mehra, K.L. (1970). Sesame. Its uses, botany, cytogenetics and origin. Econ. Bot., 24: 20-31.

Pal, B.P. (1945). Studies in hybrid vigour. I. Notes on the manifestation of hybrid vigour in grain and sesamum, chillies and maize. Indian J. Genet., 5: 106-121.

Paramasivan, K.S., Varadharajan, S., Soundarapandian, G. and Venkataraman, N. (1982). Study on heterosis in hybrids of sesamum. Madras Agric. J., 69(1): 51-55.

Paroda, R.S. and Joshi, A.B. (1970). Genetic architecture of yield and components of yield in wheat. Indian J. Genet., 30: 298-314.

Rachie, K.O. and Gardner, C.O. (1975). Increasing efficiency in breeding partially out-crossing grain legumes. International Workshop on Grain Legumes. Jan. 13-16, ICRISAT, Hyderabad, India, pp. 285-297.

Rathnaswamy, R. (1984). Genetic analysis in sesamum (Sesamum indicum L.). Ph.D. Thesis, T.N.A.U., Coimbatore.

Reddy, M.B., Reddi, M.V. and Rana, B.S. (1984). Combining ability studies in sesame. Indian J. Genet., 44(2): 314-318.

Reddy, M.B., Reddi, M.V. and Rana, B.S. (1986). Genetic architecture of seed and oil yield in sesame. Indian J. Agric. Res., 20(3): 163-166.

*Sarafi, A. (1976). The study of heterosis for some agronomic characters in F_1 hybrids of four sesame varieties. Agron. Abst., 61.

Sarathe, M.L. and Dabral, K.C. (1969). Heterosis studies in *Sesamum orientale* L. Sci. Cult., 35: 572-573.

Sengupta, K. (1980). Combining ability in sesame (*Sesamum indicum* L.). Indian Agric., 24: 95-100.

Sharma, R.L. and Chauhan, B.P.S. (1983). Heterosis and inbreeding depression in sesame. Madras Agric. J., 70(9): 561-566.

Sharma, R.L. and Chauhan, B.P.S. (1985). Combining ability in sesame. Indian J. Genet. Pl. Breed., 45(1): 45-47.

Shivaprakash, B. (1986). Genetic analysis of yield and yield components in sesame. Mysore J. Agric. Sci., 20(2): 156.

Shrivas, S.R. and Singh, S.P. (1981). Heterosis and combining ability in sesamum. Indian J. Genet. Pl. Breed., 41(1): 1-4.

Singh, R.K. and Chaudhary, B.D. (1985). Biometrical methods in quantitative genetic analysis. Kaliyani Publishers, New Delhi, pp. 140-146

Singh, K.B. and Dhaliwal, H.S. (1971). Combining ability of graphical analysis for yield and its components in F_2 generation of wheat (*Triticum aestivum* L.). Indian J. Agric. Sci., 41: 1039-1046.

Sprague, G.F. (1966). Quantitative genetics in plant improvement. Quantitative Genetics and Plant Breeding, pp. 315-354.

Srivastava, S.C. and Prakash, R. (1977). Heterosis in sesame. Curr. Res., 6(3): 49-51.

Srivastava, D.P. and Singh, S.N. (1968). Heterosis in sesame. J. Indian Bot. Soci., 47(1): 79-88.

Tyagi, B.P. and Singh, H.G. (1981). Heterosis in sesame. Indian J. Agric. Sci., 51(12): 849-852.

Veena, K.S., Singh, H.G. and Chauhan, Y.S. (1983). Combining ability in sesame. Indian J. Agric. Sci., 53(5): 305-310.

*Yermanos, D.M., Edwards, R.T. and Hemstreet, S.C. (1964). Sesame. California Agric., 18: 2-4.

* Original not seen

COMBINING ABILITY, GENE ACTION AND HETEROSIS IN SESAME

BY

ELIZABETH GEORGE

ABSTRACT OF THE THESIS
submitted in partial fulfilment of the requirement
for the degree of
MASTER OF SCIENCE IN AGRICULTURE
Faculty of Agriculture
Kerala Agricultural University

Department of Plant Breeding
COLLEGE OF AGRICULTURE
Vellayani, Trivandrum

1989

ABSTRACT

Evaluation of six parents and fifteen hybrids of sesame were undertaken in the uplands of Vellayani for combining ability, gene action and heterosis. The six parents were chosen from twentythree sesame varieties based on their general performance, which were then crossed in all possible combinations, excluding reciprocals, to get fifteen hybrids.

Eleven characters, which included yield and yield attributes were studied. Significant differences were observed among the twentyone treatments for all the characters studied, except for days to mature. Combining ability analysis was carried out based on Method 2 under Model I as suggested by Griffing (1956).

The variance due to specific combining ability was significant and higher in magnitude than general combining ability variance for all the characters. It was seen that the varieties S.8 and VS.27 were the best general combiners and the cross combinations CO.1 x VS.27, VS.27 x K.1 and CO.1 x S.8 were the best specific combinations for yield and yield attributes.

The important yield attributes and yield were conditioned by significant g.c.a and s.c.a variances suggesting

the importance of additive and non-additive gene action in controlling the inheritance of these characters. Non-additive gene action was found to be predominant for all the characters studied.

Heterosis percentage was calculated over mid, better and check parental values. Positive heterosis was noticed for all the characters in general and maximum vigour was manifested for the characters capsule number per plant and seed yield. Heterosis in seed yield was reflected through heterosis in the yield components. In the present study, a near perfect positive correspondence was observed between s.c.a and the extent of heterosis.

The varieties S.8 and VS.27 and the cross combinations CO.1 x VS.27, VS.27 x K.1 and CO.1 x S.8 can be further exploited while framing future breeding programmes.