CYTOMORPHOLOGICAL AND CHEMICAL STUDIES ON INTERVARIETAL CROSSES OF *Capsicum annuum, L.*

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REG. NO. 13

THESIS

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE (AGRICULTURE) IN AGRICULTURAL BOTANY (CYTOGENETICS AND PLANT BREEDING) OF THE UNIVERSITY OF KERALA

DIVISION OF AGRICULTURAL BOTANY

AGRICULTURAL COLLEGE & RESEARCH INSTITUTE

VELLAYANI, TRIVANDRUM

1970

CERTIFICATE

This is to certify that the thesis herewith submitted contains the results of bonafide research work carried out by Shri. P.Manikantan Nair, under my supervision. No part of the work embodied in this thesis has been submitted earlier for the award of any degree.

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September 1970.

ACKNOWLEDGEMENT

The author owes deep debt of gratitude and sincere thanks to:

Dr.(Mrs.) Mary K.George, Professor of Agricultural Botany for suggesting the problem, supervision and guidance, constant encouragement and help throughout the course of present investigation.

Dr. J. Sam Raj, Principal of this institution for the timely sanctioning of the estimates, and providing necessary facilities for the study.

Dr. K.M.Narayanan Namboodiri and Sri. K.Gopakumar, Lecturers of this Division for their constructive and helpful suggestions.

Sri. E.J.Thomas, Professor of Agricultural Statistics for his assistance in statistically analysing the data.

Sri.N.Chitharanjan Nair, Research Officer, Pesticide Testing Laboratory and Mrs. Alice Abraham for the valuable help rendered in the chemical analysis.

Kumari. D.Chandramoni, Research Assistant, Botany Division for her unstinted cooperation and helpful criticisms, and suggestions throughout the course of study.

Sri. P.Sukumaran Nair, Technical Assistant of Botany Division for his help rendered in taking photomicrographs.

All colleagues of the Division for the cooperation and help rendered during the execution of this work.

The author is also grateful to the Government of Kerala for having deputed him for the postgraduate course.

P.MANIKANTAN NAIR

C O N T E N T S

LIST OF FIGURES

LIST OF PLATES

Plate 6. a) Photomicrograph of the metaphase I chromosomes showing 12 bivalents in Local blue

b) Photomicrograph of metaphase I chromosomes showing 12 bivalents in Chinese giant

Plate 7. a) Photomicrograph showing the ring IVs in the F_1 hybrid of Local blue x Russian

b) Photomicrograph showing the ring IVs in the microsporocytes of F_1 hybrid of Local blue x Indian long red

Plate 8. a) Photomicrograph showing the chain quadrivalents in the microsporocytes of F_1 hybrid of Local blue x Chinese giant

b) Photomicrograph showing the bridge at anaphase I in the microsporocytes of F_1 hybrid of Local blue x Indian long red

Plate 9. a) Photomicrograph showing the unequal distribution during meiosis in the F_1 hybrid of Local blue x Chinese giant

b) Photomicrograph showing the fragments in the microsporocytes of F_1 hybrid of Local blue x Chinese giant

c) Photomicrograph showing pycnosis in F_1 hybrid of Local blue x Chinese giant.

Plate 10. a) Photomicrograph showing high percentage of fertile pollen grains in the common seed parent Local blue

b) Photomicrograph showing low percentage of fertile pollen grains in the hybrid of Local blue x Chinese giant

Plate 11. Photograph showing the size, shape and pigmentation of immature and mature fruits of parents and hybrids of Local blue x Russian

Plate 12. Photograph showing the size, shape and pigmentation of immature and mature fruits of parents and hybrids of Local blue x Indian long red

Plate 13. Photograph showing the size, shape and pigmentation of immature and mature fruits of parents and hybrids of Local blue x Chinese giant

Plate 14. Photograph showing the size, shape and pigmentation of immature and mature fruits of parents and hybrids of Local blue x Oskosh

INTRODUCTION

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Chilli (*Capsicum* sp), an important spice crop of India, is an exotic one (Decandolle 1904) having attained a great diversity under domestication.

Chilli, otherwise known as red pepper or cayenne pepper in other parts of the world, is an important condiment of everyday use in Indian home and forms an indispensable and common ingredient in the South Indian foods. It is consumed in a variety of ways and is used either in the green condition as a vegetable or in the dried form as chilli powder. Chilli preparations are also used as counter irritants in lumbago, neuralgia and rheumatic disorders. It has a carminative action and is useful in atonic dyspepsia.

This crop was introduced in India from tropical South American in the 17th century. Chilli occupies the major cultivated areas of Andhra Pradesh, Maharashtra, Mysore and Madras. In Kerala this important spice crop is grown in 3200 hectares.

About ninety species in the genus *Capsicum* have been reported so far. Chilli fruit contains

carbohydrates, proteins, fats, fibre, mineral matter and vitamins especially Vitamin C. In fact Capsicum is one of the richest sources of vitamin C (Ascorbic acid). The pungency of chilli is due to the active principle 'Capsaicin' which is mostly contained in the skin and septa of fruits.

Like other solanaceous crops chilli is also not free from the clutches of the dreadful disease mosaic, which often prevents the large scale cultivation of this paramount spice crop. Resistance to diseases have been known to be a heritable character which is mostly under monogenic control.

The myriads of genetic variations already existing and being multiplied by nature have opened vast vistas in combining desirable economic attributes.

Breeding for nutritionally rich products is a new branch in Plant Breeding and is assuming unprecedented importance in almost all crops. Production of protein rich cereals at the Indian Agricultural Research Institute is an elegant example to this line of modern research.

In this investigation it was observed that 'Local blue; a variety of Capsicum annuum received from the Agricultural College and Research Institute, Coimbatore,

was endowed with the important economic attributes of prolific bearing habit, mosaic resistance, long life span, and high pungency. Many of the commercial varieties like Russian, Indian long red, Chinese giant, and Oshosh lack the aforementioned qualities, but they provide an excellent source for ascorbic acid and sucrose. Moreover the latter varieties have larger fruits too.

As a part of the long term breeding programme, to transfer the mosaic resistance, prolific bearing nature and long life span of the Local blue variety in other commercial varieties which possess larger fruit size, higher ascorbic acid and sucrose content, the present investigation has been undertaken in the Agricultural Botany Division, Agricultural College and Research Institute, Vellayani. The F_1 hybrids of all combinations of crosses between the Local blue and the varieties viz. Russian, Indian long red, Chinese giant and Oshosh were raised and the various economic aspects like yield potential, mosaic resistance, ascorbic acid, sucrose, and capsaicin content and cytology of these F_1 hybrids were studied and compared with those of the parents in order to trace the economic possibilities of genetic variation.

The work appears to be the first of its kind and the results of the studies point towards the possibility of selecting mosaic resistent, nutritionally rich and high yielding capsicum varieties combined with long life span, from the segregating generations of backcrosses.

REVIEW OF LITERATURE

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Origin of Capsicum

Historians agree on the new world origin of *Capsicum*. Dried pods recovered from burial tombs in Peru are believed to be more than 2000 years old (Safford 1926). De Candolle (1886) concluded from lack of reference to this genus in ancient languages that "no Capsicum is indigenous to the old world".

The centre of diversity of common cultivated pepper, *Capsicum annuum* is Mexico, with a secondary centre in Guatemala. *C. frutescens* is widely distributed throughout the tropical and subtropical Americas, both in wild and cultivated forms, and was domesticated in Central American. The other cultivated and wild forms also have their origin in Central and South American and the genus quite clearly is South American in origin. (Bukasov 1930, Smith and Heiser 1957).

The Portuguese brought Capsicum to India from Brazil prior to 1585.

Taxonomy

The genus *Capsicum* is a member of the Solanaceae or Nightshade family. Early taxonomic

treatment of the genus, resulted in descriptions of nearly 100 supposedly good species and botanical varieties (Fingerhuth 1832, Irish 1898). Modern taxonomists recognising the extent of genetic variability, have consolidated the cultivated Capsicums into five species. C. annuum L., C.frutescens L., C.pendulum Willd., C. pubescens R & P., and C. chinense jacq. (Heiser and Smith 1948, Erwin 1949).

The genus Capsicum is placed along with the genera Solanum, Physalis, Atropa, Lycium and Lycopersicon in the tribe Solanae of the family Solanaceae on the basis of the curved embryo, five equal stamens and bilocular ovary by Willis (1955).

Shaw and Khan (1929) described the genus Capsicum L. to be characterised by flowers pedicelled, axillary, solitary or 2-3 together, calyx companulate, sub-entire or minutely five lobbed much shorter than the fruit; corolla rotate, lobes five, valvate in bud; stamens five, attached near the base of the corolla, anthers not longer than the filament, dehisce longitudinally; ovary 2 or rarely 3 celled, style linear and stigma sub-capitate.

De Candolle (1904) cited the fact that there is no name for chillies in Sanskrit and Chinese as an evidence to point out that the plant was not known to Asia till modern times.

The classification of genus Capsicum was carried out by Roxburgh (1832), Hooker (1879), Irish (1898) Prain (1902) and Shrivatsava (1916). In 1771 when the binomial system was usually adopted, Mitter enumerated ten species under Capsicum.

Linnaeus recorded 2 species in his "species plantarum" (1753) and in his Montissa edition (1767) enumerated two additional ones. Romer and Schultzes added eighteen more species in the "Systema Vegetabilium" (1819). Sendtner (1846) recognised 10 species and numerous varieties as occurring in Brazil alone, he having named seven of the species.

Roxburgh (1832) enumerated six species as occurring in India but this was reduced by Hooker (1879) to three, namely,

1. Capsicum frutescens
2. Capsicum minimum, and
3. Capsicum grossum

Both Irish (1898) and Prain (1902) stated that only two species C. annuum and C. frutescens are

found in India. The latter species has peduncle in pairs and is synonymous with Capsicum minimum of Roxburgh (1832) and Hooker (1879). Capsicum annuum and C. frutescens were differentiated more clearly by Smith and Heiser (1951) with the common cultivated pepper being placed under C. annuum without varietal sub-divisions. By current rules of botanical nomenclature the terminology C. annuum L. is incorrect (Shinners, 1956).

The species C. annuum is divided into number of varieties which include all the other forms C. purpureum, C. grossum and C. cernsiforme of earlier workers.

Different authors have attached different degree of importance to the morphological characters on which the taxonomical division of the genus were based. Generally the shape of the fruit, and the nature of the calyx are taken as the most reliable differentiating characters.

Shaw and Khan (1929) used the following morphological characters to differentiate types and species found in India.

1. Number of pedicels in the axil
2. Flower colour

3. Shape of the fruit
4. Nature of calyx
5. Shape of transverse section of fruit
6. Position of the fruit
7. Colour of the fruit
8. Size of the fruit
9. Surface of the fruit
10. Apex of the fruit
11. Flesh of the fruit
12. Maturity
13. Colour of the foliage
14. Height of the plant and
15. Character of the stem

Capsicum annuum, L. was described by Baily as follows.

Erect, much branching and glabrous. Leaves ovate, elliptic to narrow lanceolate, simple and entire. Flowers white (purple in some varieties), pedicelled, solitary, decline, calyx stout, somewhat enlarging near the base of fruit, corolla, rotate or nearly so, usually five lobbed; stamens commonly five, not closely connivent, bluish anthers, opening longitudinally; ovary 2-3 celled but cells often multiplying under domestication; style simple; stigma capitate; fruit a pod-like, indehiscent, many seeded berry with thick integuments, widely varies

in size, shape and colour, pungent to taste.

Development of flower bud in Capsicum annuum

The development of flower bud in C. annuum was studied by Shaw and Khan (1929) and Gopalarathnam (1933). Both observed that the bud took two to three days for the formation of pedicel. The calyx remained closed till the bud attained fifth day. In another two or three days the corolla pushed out of calyx and took about a week for opening of the flowers.

The relative position of anthers and stigma varied in the buds. In the young buds both of them were at the same height but the style grew more rapidly than the stamens. By the time the flower opened the style was found 1 to 2 mm longer than the stamens. However varying lengths of styles were noted on the same plant by Gopalarathnam (1933).

The pedicels were erect when the buds were young and as the buds became old they bent; when the flowers opened they were completely inverted. In those varieties which had erect fruits however the bending was only at the tip and flower remained horizontal; they took about 8 to 19 days to attain erect pose after fertilization.

Anthesis and Pollination

Shrivatsava (1916) working on chillies in Central Province stated that on clear days the flowers opened between 4 A.M. and 7 A.M. and opening prolonged on cloudy days up to 9 A.M. In a few cases they opened as early as 1 A.M. and as late as 12 Noon. The percentage of cross pollination varied from 2 to 5.

Erwin (1932) working in Iowa stated that the period of anthesis in chillies was comparatively short and in most cases less than a full day. The flowers according to him from his one day observation, opened from 5.15 A.M. to 10 A.M.

Shaw and Khan (1929) noted that chilli flowers opened earlier on warm and dewless days than on cold and dew days.

During November the flowers opened from 7.30 A.M. to 1 P.M. and the peak was between 8 A.M. and 10 A.M. The anthers burst from about half an hour later to flower opening to 4 P.M. The flowers remained opening for 2 or 3 days unlike what Shrivastava (1916) described ie. closing of the flowers in the evening and reopening on the next day, in Central Province. The fertilized flower took 2½ months to mature into ripe fruit.

Gopalaratnam (1933) working in Guntur observed that chilli flowers opened as early as 2 A.M. and continued upto 4 A.M. The majority opened before 6 A.M. He also observed that on cloudy and dew days it was delayed. The dehiscence of anthers was found to follow flower opening. The receptivity of stigma and viability of pollen grain were found to extend upto 24 hours. The percentage of setting was observed to be six. Percentage of cross pollination was upto seven. The time taken for the fertilized flower to mature into a ripe fruit was 44 to 77 days.

CROSSABILITY STUDIES

A. Intergeneric

Miwa et al (1958) conducted intergeneric crosses involving solanum and capsicum.

(i) Capsicum annuum x S.melongena

(ii) C. annuum x S.integrifolium

As different incompatability mechanisms operate for the isolation of different genera, these crosses were made possible only by hormonal treatments.

In all the cases the F_1s were sterile. Krishnappa and Channaveeraiah (1964) attempted one intergeneric cross involving S.pseudocapsicum and C.annuum but it was not successful.

B. Interspecific

Interspecific hybridization of Capsicum have been reported to be unsuccessful owing to various incompatability systems operated among alleles. Malhova (1966) made possible to overcome the incompatability between the two species of Capsicum (C.annuum and C.pubescens) by the use of tetraploid forms of C.annuum as the female parent.

C. Intervarietal

Shankaranarayana Pillai (1967) noticed significant difference in yield, plant height, number of branches, number of fruits per individual plant, percentage of fruit setting, weight of seeds per rod, and duration of maturity among the ten divergent varieties he studied for the selection indices for yield.

Angeli (1957) observed that hybrid peppers were suited for early cropping both in glass house and outdoors; being earlier and more productive, more resistant to disease and better adapted to consumer requirements than the parental varieties.

Many interesting phenomena were noticed by Hristov (1965) in the hybridization of sweet peppers. Crossing without emasculation proved difficult as

self-pollination was appreciable. Pollen from freshly dehisced anthers germinated more freely than that from unopened anthers and the percentage of germination and fertilization was highest at 10 A.M. The addition of other pollens like tomato and egg plant had no obvious effect on germination and fertilization, but tomato pollen increased earliness by 19.73 per cent and total yield by 10.51 per cent. The highest germination percentage of 34.1 was obtained when emasculation was carried out without clipping the petals and pollination was performed immediately thereafter. Repeated pollination increased earliness and total yield.

The influence of productivity factors on the total yield of the fruit was reported by Betlach (1965). The F_1 results showed that number of fruits/plant and the average weight of fruit were the most important factors determining yield. Heterosis was more marked in the number of fruits.

Gikalo (1967) reported that best yield of hybrid seed obtained when pollination was carried out immediately after emasculation, though no loss of viability occurred when dried pollen was stored for 24 hours at 30-35^{0}C.

Heterosis

Knight (1779) described hybrid vigour as a natural sequence of crossing varieties of a species. Mendel (1866) observed hybrid vigour in his pea crosses. East (1908), Shull (1908, 1911) and Jones (1918, 1945) have reported superiority of hybrids in corn. Odland and Noll (1948) experimented with 16 hybrid types and recorded that in every case the hybrids outyielded their respective parents, besides being earlier, the percentage of increase ranged from 11 to 153. The mean percentage of increase of all the 16 hybrids over the mean of all the parents was 62.1. They also observed that the two parental lines with the lowest mean yields were able to combine to produce hybrids of excellent productivity. Babu Rao (1965) reported heterosis in certain characters like number of branches, number of flowers, percentage of fruit set and number of fruits/plant in certain interspecific hybrids of solanum.

From a detailed study of F1 hybrids of 8 crosses involving 5 parental varieties of Brinjal, Viswanath (1967) reported hybrid vigour in plant height, number of branches, number of leaves, spread, earliness, number of flowers, number of fruits, size and weight of fruits, weight and number of seeds and pollen diameter.

Based on intervarietal hybridization of Capsicum Popova (1965) observed that the F_1 progenies were intermediate between the parents and uniform in habit and fruit form. Subsequent generation showed much variation.

Lippert et al (1966) reported a list of genes controlling the characters including quantitative ones and disease resistance. F_1 hybrids had shown heterosis for vigour and productivity over the mean value of the superior parent.

Height of plants

Bailya (1918) was probably the first to report the superiority of f_1 hybrids in height over their parents, based on his studies of a cross between a native and a foreign variety of brinjal.

Pal and Singh (1946) in their studies of six crosses of brinjal found that all except two crosses showed increase in height over the taller parent.

Mishra (1961) found that the hybrids were invariably superior to both parents except in a few cases showing intermediate plant height.

Choudhary and Mishra (1966) found that 11 out of 15 f_1s studied, showed an increase in height of 15 day

old seedlings. Viswanathan (1967) has reported that out of eight hybrids studied six in comparison with mid parental value and three as compared to better parental mean showed significant increase in height.

Malinowski et al (1960) studied crosses between inbreds in maize and found that the f_1 surpassed the taller parent in mean height in all crosses. Mitra (1962) reported that hybrid vigour was found to persist in the crosses of winter varieties of rice with summer varieties. Mean height of f_2 in every case exceeded that of the taller parent.

Number of branches

Nagai and Kaida (1926) and Kakizaki (1930-31) had reported hybrid superiority with respect to the number of branches in brinjal hybrids. Pal and Singh (1946) found an increase in the number of branches in five out of eight hybrids, this increase ranging from 9 to 54 per cent over the better parent. Mishra (1961) observed that a large number of hybrids of brinjal showed their superiority in average number of branches but one hybrid had decreased number of branches when compared to both the parents.

Viswanathan (1967) has recorded that 2 out of

8 combinations, in brinjal, showed their superiority statistically over the parental mean.

Joshy et al (1958) in their studies in bhindi have recorded that the hybrids in general were, significantly better than the parents regarding the number of branches produced, the range of increase being 1.2 to 25.3 per cent. In eight crosses the f_1s were intermediate, most of them having a tendency towards the superior parent. Decrease in number of branches compared to the inferior parent was recorded in five hybrids. Two out of nine hybrids of bhindi, studied by Raman and Ramu (1962) showed significant increase in number of branches.

Mathews (1966) in his studies in bhindi hybrids has reported that with respect to number of branches, the increase recorded in one cross in f_1 was not maintained in the later generations.

Number of leaves

Bailye (1918) in his studies in brinjal found that the f_1 hybrids produced more number of leaves than the parents. The intermediate nature of f_1 hybrids as compared to the parents in respect of number of leaves was recorded by Venkatarammani (1946).

Swarup and Pal (1966) in their studies regarding gene effect in cauliflower, observed that the

F_1 hybrids had higher number of leaves and larger leaf size. They concluded that heterosis in leaf number was mainly due to dominance while in leaf size it was due to additive x dominance gene effects. Issac (1965) in bhindi reported that out of 12 F_1s studied by him none showed their superiority with respect to number of leaves. According to Mathews (1966) in bhindi, hybrid vigour observed in F_1 was not retained in the subsequent F_2 and F_3 generations.

Spread of plants

Balya (1918), Nagai and Kaida (1926) and Kakizaki (1930-31) have recorded hybrid superiority in respect of spread of plants. Based on their studies in the manifestation of hybrid vigour in brinjal and bitter gourd, Pal and Singh (1940, 41) reported that the average values of F_2 progenies were lower than those of the F_1s and parents in all the six crosses. Venkataramani (1946) recorded a marked increase in F_1 hybrids as compared to parents with respect to this character.

Choudhary and Mishra (1966) concluded that 13 out of 15 F_1 hybrids were significantly superior to their respective better parents in spread along and across the rows, the maximum increase in spread being 33.63 per cent and 25.61 per cent respectively over

their better parents.

Gopimony (1968) obtained hybrids which showed their superiority statistically with respect to spread of plants compared with the mean of hybrids and parents in brinjal.

Time of flowering and number of flowers

Venkataramani reported that the F_1 hybrids of brinjal flowered 18 days earlier than the earlier parent. Such earliness of flowering of hybrids was also reported by Pal and Singh (1949) and Mishra (1961).

According to Rajabhandary (1966) significant difference was noticed between hybrids and parents in the number of days from sowing to flowering.

Choudhary and Mishra (1966) recorded intermediate nature of F_1 hybrids with respect to flowering durations.

Swarup and Pal (1966) reported that six hybrids of egg plants showed significant heterosis in terms of earliness over the better parent, whereas one exhibited the same over the mid parent.

Mathews (1966) observed that larger number of flowers were produced by F_1 and F_2 generations of 3 out of eight crosses over the mid parental values, in bhindi.

Number of fruits

Considerable increase in the number of fruits has been recorded by Nagai and Kaida (1926) and Tetesi (1927) in brinjal. Pal and Singh (1940, 41) based on their studies on the manifestation of hybrid vigour in brinjal and bitter gourd reported an increase over better parent in 50 per cent of their crosses.

Venkataramani (1940) reported intermediate nature of F_1 hybrids (brinjal) the hybrid plants producing eight fruits while the female and male parents producing ten and seven respectively. Mishra (1961) obtained F_1 plants having significantly higher number of fruits than their respective parents.

Samarov (1965) studied 60 hybrids of tomatoes grown under varied conditions. In all cases the hybrid surpassed the standard in yield and a number of other characters. The maximum increase in yield were often noticed in hybrids between varieties differing in origin and morphological characters.

Issac (1965) in bhindi reported that one hybrid registered a significant increase in the number of fruits over the better parent.

Legg and Lippert (1966) estimated the genetic and environmental variability in the inter-varietal hybrids of Capsicum. They found that the large portion of phenotypic variation was genic. Estimation of genetic and phenotypic correlation coefficients showed that number of mature fruits was positively correlated with the dry weight, yield and the average fruit weight was highly correlated with fruit length, width and carotenoid level.

Viswanathan (1967) reported from the 8 crosses he studied that there was an increase in the number of fruits per plant and this increase was significant in five out of eight cases when the comparison was made with the parental mean.

Gopimony (1968) found that all the three F_1 hybrids of brinjal studied by him showed a significant increase in the number of fruits produced per plant when compared to their respective parental means.

Betlach (1967) reported transgression in total yield in F_1 progeny. Heterosis was expressed as increased number of fruits per plant alone or in interaction with an increase in the average weight of a single fruit.

Percentage of fruit set

Rao (1965) reported that percentage of fruit set in the case of inter-specific f_1 hybrids of Solanum was greater than that of parents. Betlach (1966) observed average fruit sets of 39.7 per cent and 47.47 per cent in two hybrids of Capsicum.

Alpatev (1967) observed that when pollination was performed two days after emasculation, the f_1 plants were intermediate in most characters, pollination 4 days after emasculation gave 31.2 per cent of plants resembling the pollen parent and 6 days after gave 80.6 percent. Pollination 2 days after emasculation with pollen stored for 5 days at 20-22°C in a desiccator gave 97.3 per cent of plants resembling the seed parent. Similar deviations were observed in the f_2.

Weight of fruits

Nagai and Kaida (1926) obtained 10 crosses of brinjal plants all of which showed an increase over parental mean by one to 70 per cent in yield. Most of the hybrids yielded more than the better parent, the average increase of all the hybrids being 15 per cent.

Pal and Singh (1940, 42) in their studies in

six crosses of brinjal which was spread over two seasons, found that in respect of weight of fruits during both the years all crosses except one showed an increase upto 129.2 per cent.

While studying different japanese varieties of brinjal, Odland and Noll (1948) reported that the hybrid exceeded the mean yield of parents, the range of increase being 11 to 153 per cent. Choudhury and Mishra (1966) observed that out of the fifteen hybrids studied by them, thirteen exhibited significant increase in total yield over their better parents. Viswanathan (1967) concluded that six out of eight crosses studied by him showed an increased weight. Gopimony (1968) found that only two crosses MS x SI and MM x SI showed significant increase of fruit weight per plant.

Size and shape of fruits

Observations of Nagal and Kida (1929) revealed that in every case the crosses of brinjal showed an intermediate fruit shape.

Based on intervarietal hybridization of Capsicum Popova (1965) noticed that the F_1 progenies were intermediate between the parents and uniform in

habit and fruit form. Subsequent generation showed much variation. Andronicescu and Enachescu (1966) noticed that the fruit characteristics of size, shape and appearance in Capsicum tended to be intermediate between those of the parents. Tall habit was found to be dominant.

Mathews (1966) studied six intervarietal crosses of bhindi and recorded that with respect to length of fruits the F_1 and F_2 generations of one cross was superior to the better parent while another cross registered an increase over the mid parental value.

Number and weight of seeds

Kakizaki (1931) reported that the F_1 seeds showed an increase in weight over the selfed seeds of the mother parent, which was due to the increase in size of embryo by heterosis. Increase in number of seeds was noted in three out of eight crosses studied by Viswanathan (1967).

Inheritance of certain characters

In Solanum Bailey (1892) found that hybrids between green stemmed with white fruited varieties and purple stemmed and very dark purple fruited parents had purple tinged stem and fruits were usually purple

with lighter apex.

Tatebe (1936) reported that purple plant colour of egg plant was dominant over green of scarlet egg plant.

Fruit shape

Tatebe (1943) reported that in crosses between round and long fruited egg plants the F_1 produced fruits approximating to the geometric mean of the fruit of the two parents.

Khan and Ramzan (1953) estimated 5 pairs of genes to be governing the fruit shape in Solanum.

Genetic studies on fruit characters in Capsicum annuum by Sakai (1937) revealed the following.

1. Fruit weight per plant is heterotic in some crosses but not in all.
2. The smaller number of fruits per plant in a cross is usually completely dominant and
3. Small size of fruit is partially dominant

In Capsicum Miyazawa (1957) reported that the minimum number of genes controlling fruit weight is 52.24, fruit length is 0.79 and fruit width is 9.52.

Synder (1957) obtained the following results regarding the inheritance of seed weight in tomato.

1. Seed weight is quantitatively inherited
2. Large number of factors are involved in the expression of seed weight
3. The effect of these factors is additive, the only effect of heterosis being in early flowering of the hybrid and not in total yield. Small seeds of normally large seeded inbreds exhibited low percentage of germination.

Mosaic disease

Capsicum plants are not free from the clutches of the dreadful disease of mosaic which is assuming serious proportions and causing considerable concern among the growers of this paramount spice crop.

Tobacco mosaic virus and cucumber mosaic virus are the two important mosaic diseases to which sweet pepper is subjected to. Ajroldi (1939) reported that the disease was soil borne and the intensity is favoured by sudden changes of temperature during night, heavy application of nitrogenous mineral fertilizers especially at transplanting and frequent irrigation with cold water.

Dolivera (1940) observed 2 virus diseases in Capsicum and the same was due to tobacco mosaic virus and cucumber mosaic virus. The symptoms were given as follows.

T.M.V. Slight stunting, a large mosaic pattern on the leaves accompanied by a slight amount of rugosity in severe cases and heavy reduction in yield.

C.M.V. Present a rigid denuded aspect, the leaves being abnormally narrow and pointing downwards, with a profusion of axillary buds; here also the abscission of floral buds involves a drastic diminution of output; one grower reporting a decrease per plant from 120 to 20 or 25 grm of the dried product.

The mode of transmission of T.M.V being obscure, while insects are chiefly instrumental in the conveyance of cucumber mosaic virus from diseased to healthy plants. Inoculation experiments gave positive results.

Roque and Adusur (1941) narrated in detail the symptoms of the disease. A marked clearing of veins in younger leaves in about 10 to 12 days after inoculation followed by mottling usually ending in vein banding. In addition leaves become wrinkled and plant stunted especially if infected early. Fruit setting

will be reduced and the fruits that develop are undersized, mottled and badly distorted.

Zabala et al (1947) reported that the disease was not transmitted by seed but readily conveyed from diseased to healthy plants by juice inoculation, Myzus persicae was the only one of eight insects tested to give possible results in transmission experiments.

Solymosy (1958) reported that infections with C.M.V. during the 12 - 14 leaf stage and with T.M.V.+ C.M.V. during the 6 - 8 leaf stage were the most harmful, resulting in the reduction of average number of ripe fruits, and index number (average number x length of fruit per plant) and total yields.

Investigations on pepper varieties for resistance under field conditions to natural infection by virus disease was studied by Danko and Michalikova (1965). In four years replicated trials with 10 pepper varieties, considerable annual fluctuation in virus infection was noted depending on weather conditions which determined the occurrence of vectors. Virus infection ranged from 23.3 per cent to 43.9 per cent. Both diseases (T.M.V. and C.M.V) reduced the number and edible fruits per plant, the effect of C.M.V. being greater than that of T.M.V.

Ramanujam and Joshi (1965) reported that the mosaic resistance of Puri red is due to a single gene which is linked with the gene controlling erect fruit position, but independent of the loci governing leaf colour, petal colour and colour of immature and mature fruits. He could also observe that this resistance was dominant to the susceptibility of N P 46 A.

Ramakrishnan, Kandaswamy and Thankamony (1966) differentiated five types of reactions of the disease and numerous varieties were grouped according to the reaction type. Capsicum microcarpum and C.frutescens were found to be immune.

Cook (1966) observed that the resistance to potato disease was due to a simple recessive gene.

Pal uden (1967) reported that the degree of infection among 13 varieties inoculated with various viruses varied considerably.

Chemical constituents, with particular reference to Ascorbic acid, Capsaicin and sucrose content

Capsicum is one of the rich sources of Vitamin C or ascorbic acid ($C_6 H_8 O_6$). Ascorbic acid was first isolated by Gyorfii from paprika in Hungary and found to be similar in chemical and anti scorbutic properties with that obtained from adrenal glands.

But many cultivated varieties possess very little quantity of this essential vitamin.

Gyorffy (1949) reported that the inheritance of ascorbic acid content appeared to be multigenic with the F_1 mean value from crosses of low and high value parents corresponding closely to the geometric parental mean. Values in the F_2 were distributed between limits of parental lines.

Schutt (1958) studied the proportion of ascorbic acid in various parts of the fruit as well as at varying stages of ripening. In red and green Capsicum fruits the highest content of ascorbic acid was found at the tip of the fruit, and the lowest at the base. Maximum content of ascorbic acid was found in mature red fruits. After storage at room temperature or in cellars ascorbic acid content sometimes showed increase upto 100 per cent. Ascorbic acid content in dried fruits after nine months storage was similar to that in fresh tissue.

Souty and Andre (1965) determined the sugar, acid and vitamin C contents of both green and ripe fruits of 8 varieties. The vitamin C, total sugar and sucrose contents, were highest in the least acid fruits, and varietal differences in vitamin C content were

confirmed. The total acidity increased markedly with ripening in all cases.

Hristov et al (1965) found an increase in dry matter with greater reduction in sugars. Higher vitamin C content in tetraploid fruits were reported by Swaran Rampal (1965).

The superiority of hybrids in higher ascorbic content was reported by Chroboczek et al (1966).

Erwin (1932), Miller and Fineman (1937) (quoted by Lippert, Smith and Bergh) recognized the site of production of capsaicin as being in the secretory cells located along the placenta. Soil and climatic conditions are attributed to the varying levels of pungency from different places.

When classification is based on pungent and non pungent criteria only, irrespective of degrees of pungency, segregation indicate pungency of capsaicin resulting from the presence of a single dominant gene C (Webber 1911, Deepande 1935, Reminh and Pillai 1935, Odland 1948, Greenleaf 1952). Bruner (1962) attempted to relate degrees of pungency to a three member allelic series but exception to theoritical results were evident.

Sievers and Mic Intyre (1921) quoted by Paul have shown that as the fruit develops and reaches maturity the pungency was masked by the presence of sugar.

Webber (1911) and Despande (1937) quoted by Paul recorded that pungency is a heritable character, and they were agreed that it is a simple monogenic character dominant to non-pungency.

Miller and Fineman (1938) quoted by Paul reported that non-pungency was dominant over pungency, in the f_2 although the f_1 was pungent, being intermediate between both parents. They offered an explanation that under cool conditions pungency fails to develop in the heterozygous types, and non-pungency became dominant under such conditions.

The proportion of capsaicin secreting tissue and the amount in the tissue were studied in 12 varieties of Capsicum by Ramanujam and Thirumalachar (1966). Variation was large and independent in the two components, suggesting that genetic control of the total content is polygenic. Investigations on 15 varieties have shown that ascorbic acid and reducing sugar content increased with ripening (Michna 1966). The increased ascorbic acid content along with maturity

was also recorded by Butkevic (1967). The ascorbic acid content of 5 pepper varieties studied increased upto full maturity. Fruits maturing in the autumn contained considerably more ascorbic acid than those picked in July/August. The variability in the capsaicin content was studied by Thirumalachar (1967).

Csedo and Kisgyorgy (1967) reported that in variety longum higher contents of capsaicin tended to be associated with lower contents of ascorbic acid and vice versa. But he could observe no correlation between the amounts of these constituents and colouring matter.

Betlach (1967) could notice no marked difference between parents and F_1 progeny as regards to the content of ascorbic acid, dry matter and total sugar.

Cytology

Cytological studies in the genus Capsicum have been made by several workers. Kostoff (1926) determined the chromosome number of 4 varieties of Capsicum annuum and reported six as gametic number for the species. However this was contradicted by Devilmorin and Simonet (1927) Huskins and Lacour (1930) Dixit (1931) and Banerji (1933) all of whom reported

twelve and twenty four as gametic and somatic numbers respectively. Further, Pal and Ramanujam (1940) confirmed this.

Meiosis

Most of the workers found regular meiosis in this genus. Dixit (1931) reporting the details of meiosis stated that two divisions of meiosis occurred in rapid succession before any wall formation begun and four microspore nuclei were formed inside the microspore mother cell. The microspore arrangement was usually tetrahedral resulting from simultaneous mode of division of its nucleus, but cases were reported where the arrangement was bilateral due to successive division taking place during meiosis. The tendency of bivalents coming close to each other at poles after each division giving an impression that the haploid number of chromosomes to be six was also reported by the same author. Such meiotic stages, Dixit (1931) feels must have led Kostoff (1926) to the erroneous conclusion that the haploid number was six.

Sinha (1950) reporting the meiosis of C. frutescens and C. cordiforme stated that they were different in their cytological behaviour. C. cordiforme was found to behave normally resulting in normal tetrads.

At diakinesis 12 bivalents approximately of equal size were observed, majority of which were joined by one chiasma of which some had sub-terminal and other had terminal attachments. The presence of a small nucleolus was also noticed. The orientation of bivalents at metaphase plate was regular and in polar view twelve could be very easily counted.

The meiosis of C.frutescens on the other hand was found to be disorganised completely and there was no first or second division. The division started with prophase and ended with a second telophase with formation of varying number of supernumerary microspores.

Raman et al (1964) described the ornamental chilli plant (C.frutescens var. bnccatum) found especially in Mangalore. The haploid chromosome number was noted to be 12. They observed quadrivalent in meiosis and proposed that the origin of the species may be due to allopolyploidy. The stickiness of chromosomes in metaphase was explained to be due to complementary action of gene brought together in hybridization when the species was first formed as in the case of diploid hybrids between Arachis villosa x Arachis durmensis (Raman and Kesavan 1962).

Pal et al (1941) compared the meiosis of

diploid and colchicine induced tetraploid. The tetraploid plant formed 1-7, IV and the rest bivalents. The tetrasomics gave rise to trisomics, tetrasomics, and one diploid considered by them as an interchange heterozygote forming 1 IV + 10 II instead of the regular 12 II.

Asynapsis in Capsicum ie. non-pairing of chromosomes at diakinesis and metaphase was reported by Pal and Ramanujam (1940). This was already described in plants like maize, Oenothera, Pisum, Hordeum, Oryza, Datura and Nicotiana. Twenty four univalents were observed at diakinesis. Occasional bivalents and loose pairing were also noticed. The meiosis was highly irregular and restitution nuclei were formed and pollen sterility upto 90 per cent was observed. The progeny of asynaptic plants consisted of plants having 3n, 2n+1 and 2n.

Christens and Bamford (1943) reported haploids in G.annuum from twin seedlings. The range of chromosome association in meiosis was from 6 II to 12 univalents though 1-2 II were most frequent. Typical metaphase plate was absent in most of the cases and splitting of chromosome was also noticed. The lagging chromosomes ended as micronuclei.

Raman et al (1964) observed that the irregularity in meiotic division led to the chromosal deficiencies in the resulting gametes.

C.pendulum and C.microcarpum were found to have the same karyotype and form fertile hybrids (Eshbaugh 1965). They exhibited normal chromosome pairing also. He could also observe the existence of 2 distinct groups, based on the cytogenetic studies of 14 taxa.

Malhova (1965) recorded that complete or partial sterility in the F_1 and F_2 was caused by disturbed meiosis of p.m.c's and by structural and functional defects of the embryo sacs. He could also recognise that the mode of inheritance of hybrids was influenced by the degree of sterility and course of macrosporogenesis in the crosses.

Shopova (1966) noticed pycnotic degeneration and stickiness in the meiotic chromosomes of cultivated peppers, together with defective spindle, movement and cytokinesis. These irregularities were held to occur due to the genotypic unbalance which results from the inbreeding which has accompanied cultivation.

He also made cytological comparison of chromosome structure and behaviour in the genus Capsicum (Annuum, frutescens, pubescens). They differed in chiasma frequency, amount of heterochromatic material, and distribution of nucleolar-organising chromosomes with secondary constrictions, although they share a common chromosome number.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present study was undertaken in the Division of Botany, Agricultural College and Research Institute, Vellayani during the year 1969-70. The experiment relates to the two crops, one parental and the other hybrids.

Selection of parents

Nine varieties of Capsicum annuum were put to observation with regard to the major economic attributes. The following varieties were subjected to detailed study.

(1) Oskosh
(2) Chinese giant
(3) California wonder
(4) Local green
(5) Hungarian wax
(6) Eholer
(7) Indian long red
(8) Russian
(9) Local blue

Each variety was grown in separate plots. Thirty plants from each variety were studied for their economic characteristics.

The following main qualitative and quantitative characters were observed with a view to select the better parents.

(1) Height and spread
(2) Average number of fruits/plant
(3) Fruit size
(4) Mean weight of individual fruit
(5) Ascorbic acid content
(6) Sucrose content
(7) Nature of disease resistance
(8) Time taken for blooming
(9) Total life span

The parents for further investigation were selected on the basis of their performance.

A. MATERIALS

Materials involved in the present study constitute the following five different varieties of Capsicum annuum, L.

(1) Local blue
(2) Russian
(3) Indian long red
(4) Chinese giant
(5) Oshosh

The seeds of Local blue variety was obtained from the Agricultural College and Research Institute,

Coimbatore. The rest of the seeds were received from M/s. Pestonjee P. Pocha and Sons, Poona.

The variety Local blue is endowed with the paramount economic attributes of resistance to the common dreadful diseases of mosaic and wilt, long life span and profuse bearing nature. The other varieties possess little of the aforementioned qualities but, provided with high ascorbic acid and sucrose content.

B. METHODS

The time of flower opening and dehiscence of anthers under Vellayani conditions were found to be between 7.00 and 9.30 A.M.

The crossing work was done between 8.00 and 8.30 A.M.

The following method was adopted for hybridization. In the evening of the day previous to crossing the correct sized buds that appear bulged and which would open the next day were selected and with the help of a fine pointed needle a longitudinal split was made on the corolla. Then using a pointed forceps the anthers were removed one after another. Utmost care was taken not to injure any other floral parts including the removed anthers. After ensuring the stigma to be free from pollen the emasculated

flower buds were covered with a polythene bag and pinned the free end of the bag to prevent contamination with foreign pollen. Some matured flower buds which would open next day were selected from the pollen parent and bagged in the same evening as a safeguard against any admixture of pollen.

Next morning at about 7.30 A.M. the protected flower buds from the pollen parent were plucked and kept in a petridish in which a little of water was sprinkled to keep up the humidity. Then a few anthers were taken out and a longitudinal split was made on it using the needle and the outcoming white pollen grains were dusted gently over the stigma of the emasculated flower of seed parent, using a camel-hair brush. Dusting was done between 8 A.M. and 8.30 A.M. After pollination the flower buds were again bagged and labelled. The bags were removed only after 9 days.

In order to get selfed seeds of the parental varieties, in each case fifteen well developed flower buds which would open the next day were covered with polythene bags in the previous evening and labelled. The bag was allowed to remain for 4 to 4 days until all the flower parts except the ovary had fallen off. The bag was then removed after tying the label on the developing fruit.

The fruits of both selfed and crossed flowers were harvested when completely matured, the maturity being judged by the standard ripening colour of the variety concerned.

2. Field plot technique and the study of F_1 generation

The study of F_1 generation of plants along with their parents was conducted under the following major heads.

I. Morphological studies

II. Study on Mosaic resistance

III. Chemical studies

IV. Cytological studies

The methods adopted for each of the above studies are enumerated below.

I. Morphological studies

1. Lay out

The experiment was laid out in a randomised block design with five replications. In each replication there were nine small pits representing nine treatments. The hybrids and parents were randomised and grown in these plots.

2. Treatments

The nine treatments consisted of the four hybrids and five parental varieties were as follows.

Parents	Treatment No.	I	Local blue
	,,	II	Oskosh
	,,	III	Russian
	,,	IV	Indian long red
	,,	V	Chinese giant
F_1 hybrids	Treatments	VI	Local blue x Oskosh
	,,	VII	Local blue x Russian
	,,	VIII	Local blue x Indian long red
	,,	IX	Long blue x Chinese giant

For the sake of convenience the following notations are used for parents.

(1) Local blue - LB

(2) Russian - R

(3) Indian long red - ILR

(4) Oskosh - OS

3. Nursery

Well developed good seeds from the four crosses and the parents were sown in seed pans. The seed pans were filled with standard pot mixture and seeds were sown at the rate of 100 seeds per pan.

4. Transplanting

Thirty five days after sowing healthy seedlings of uniform growth were selected for transplanting in the main field. Prior to transplanting the main field was thoroughly prepared and levelled. Small pits were taken at 3/4 metre apart. Then the pits were burnt with dry leaves. Half basket full of farm yard manure was applied as basal dressing in each pit and mixed well with the soil. Two seedlings were planted in each pit.

Fifteen days after transplanting when the seedlings had established well, thinning was done leaving only one healthy seedling in each pit. The crop was regularly irrigated twice a day.

Observations on the following characteristics were recorded for both the F_1 hybrids and the parents.

A. QUANTITATIVE CHARACTERS

(1) Number and weight of F_1 and parental seeds
(2) Germination capacity of F_1 and parental seeds
(3) Height of seedlings
(4) Height of plant
(5) Number of branches
(6) Number of leaves

(7) Spread of plants

(8) Area of leaves

(9) Time of flowering

(10) Percentage of fruit set

(11) Number of total fruits

(12) Size and weight of fruits

The details of observations taken in each aspect are given below.

(1) Number and weight of F_1 and parental seeds

The number of seeds in the crossed and selfed fruits was counted. For finding the weight of seeds three samples of 100 seeds each was taken from each treatment and weighed in a chemical balance and weights recorded.

(2) Germination capacity

A random sample of 100 seeds from each treatment was placed in petridishes containing moist blotting paper. The number of seeds germinated was counted on every day.

(3) Height of seedlings

The height of seedlings was also taken on the 35th day of sowing.

(4) Height of plants

Height of plants were taken from the ground level to the top most bud leaf of all the plants by using a metre scale. The first observation was taken on the 10th day after transplanting and the subsequent ones at 10 days interval. The last one was taken on the 70th day. The mean of the plants was taken and recorded.

(5) Number of branches

Primary, secondary and tertiary branches were taken into account. The mean of the plants was taken and recorded.

(6) Number of leaves

The total number of leaves of all plants were counted at 10 days interval.

(7) Spread of plants

Observations were recorded after full maturity of the plant. Measurement was taken in the direction where there was maximum spread of plant.

(8) Area of leaves

Observations regarding the area of leaves was taken on the 60th day after transplanting. In each plant, the length and breadth of five matured leaves

were taken to find the area of the leaf. The length of the leaf was taken from the tip of the leaf to the base and the breadth as on the middle of the leaves having maximum width. The mean of the treatments were taken and recorded.

(9) Time of flowering

The number of days taken for the first flower to bloom was observed and recorded for each treatment.

(10) Percentage of fruit set

The total number of flowers bloomed and the total number of fruit set were observed in order to work out the percentage of fruit set.

(11) Number of total fruits

The total number of fruits set in each treatment was counted.

(12) Size and weight of fruits

Ten random fruits from each plant were selected and their length and maximum girth were measured.

B. QUALITATIVE CHARACTERS

The following qualitative characters were studied.

(1) Habit
(2) Colour of foliage
(3) Colour of stem
(4) Flower bearing habit
(5) Colour of corolla
(6) Colour of anthers
(7) Colour of style
(8) Colour of stigma
(9) Fruit shape and colour
(10) Fruit colour at maturity

II. Study on Mosaic and wilt resistance

Severely infected young leaves were collected. Added one cc of distilled water at the rate of one gram of leaf. The green leaves were ground well by using a glass mortar and pestle. The solution was filtered through muslin cloth. The filtered solution was centrifuged for half an hour (2000 r.p.m.).

35 days old seedlings were selected for inoculation. Carborundum powder was first sprinkled over the leaves and then the surface of the host leaves were gently rubbed with cotton wool dipped in the centrifuged suspension containing mosaic virus.

III. Chemical studies

1. Estimation of Ascorbic acid content

The following procedure was adopted for the estimation of ascorbic acid content. In the present investigation fully ripe fruits kept at the refrigerator for a week's time was used.

Procedure

After removing the seed fifty grams of the fruit was weighed. Extracted the fruit in 50 ml of 2 per cent oxalic acid in a beaker. Then the extract was transferred into a 250 ml volumetric flask and made upto volume. The solution was filtered.

Preparation of standard dye solution

The phenol Indo 2:6 dichlorophenol dye was standardised by taking 10 ml of the standard ascorbic acid solution and 5 ml of 2 per cent oxalic acid and titrating against the dye solution taken in a burette. The end point is indicated by the light but distinct rose pink colour.

Titration

Pipetted out 10 ml of the fruit extract in a conical flask and added 5 ml of 2 per cent oxalic acid. Titrated this against the standard dye solution in the burette.

2. Estimation of sucrose content

Procedure

Twenty five grams of the fruit after removing seeds were taken. Made an extract in 100 cc of lead acetate. The extract was then kept in a water bath at 80°C for 30 minutes. The solution was then filtered and made upto 250 cc.

100 cc of the solution was then taken and removed the lead by precipitation with potassium phosphate. This was filtered into a 250 cc volumetric flask and hydrolised with 5 cc of concentrated HCL for 8 minutes at 80°C. Cooled the solution. Neutralised the excess acid with sodium carbonate and again made upto 250 cc. Titrated with 10 cc of fehling solution.

Estimation of Capsaicin content

The Capsaicin in the dried fruits was extracted by the following method outlined by Spanyar and Blazovich (1969).

The dried sample is extracted with diethyl ether using a Soxhlet apparatus. The ether extract is distilled under vacuum in a water bath at 30-35°C. The residue is extracted by agitating with four successive portions each of 5 ml of 57 per cent ethanol (v/v) and the ethanolic extract is transferred into 100 ml

separating funnel. The residual pigment in the flask is dissolved in 30 ml of light petroleum (Bp 60-80°C), and the solution is added to the same separating funnel. About 1 gm NaCl is added to the mixture in the separating funnel, and shaken for 5 minutes. The lower ethanolic layer is transferred to a 100 ml fractionating flask. The light petroleum phase is extracted with a further 10 ml of 57 per cent ethanol and the lower ethanolic layer is added to the contents of the fractionating flask. 5 ml of 0.1 N. NaCl solution is added to the yellowish ethanolic solution in the flask and the alcohol is removed by distillation at 75-80° C in a water bath in a stream of Nitrogen. The solution left in the flask is cooled in a stream of nitrogen gas and transferred to a separating funnel, rinsing the flask with a few cc of distilled water. The capsaicin in the solution is extracted first with 30 ml and then with 20 ml of diethyl ether. The ether layer is filtered through anhydrous sodium sulphate into a 100 ml previously weighed round bottomed flask. The ether is removed by evaporation on water bath at 30-35°C. The flask is dried in vacuum desiccator and weighed and the difference in weight is taken as the weight of capsaicin. The capsaicin content is expressed as percentage on oven dry basis.

IV. Cytological studies

(a) Pollen size

One hundred counts were taken from each treatment in order to ascertain the mean size of pollen grains. The pollen grains were stained with acetocarmine before measurements were taken.

A Carlzeiss microscope with A 16X eye piece and objective 40/0.65 was employed in the estimation of pollen size.

(b) Pollen sterility

Pollen grains collected from matured flower buds were utilized for the study of pollen sterility. The pollen grains were kept in a solution containing 1:1 acetocarmine and glycerine for two hours in a slide, under a cover glass. Then counts were taken from thirty fields for every treatment. Well filled and well stained pollen grains were taken as the fertile and the rest as sterile.

(c) Studies on pollen mother cells

With a view to ascertaining the meiotic behaviour of parents and hybrids studies on pollen mother cells were undertaken. The best time of fixing flower buds under Vellayani condition was found to be

between 9.45 A.M. and 10.30 A.M. The flower buds of suitable size was fixed in acetic-alcohol (1:3). The fixed buds were kept in a refrigerator for 12 to 24 hours. After that the buds were washed in water and preserved in 70 per cent ethyl alcohol. Meiosis was studied from temporary acetocarmine smears of pollen mother cells. The anthers were cut into half on the slide with a blade in a drop of 1 per cent acetocarmine. Then the anthers were gently pressed to facilitate the release of the pollen mother cells and debris removed. After putting a cover glass the slide was slightly warmed and gently pressed between the folds of a blotting paper and sealed with paraffin. The preparations were made permanent by butyl alcohol method (Swaminathan 1954).

An olympus binocular research microscope was used throughout the study. Photomicrographs were taken with the aid of Olympus Camera (35 mm) with an eye piece of 15X in conjunction with an oil immersion objective 100/1.30. The figures were enalrged to 2 B size.

RESULTS

EXPERIMENTAL RESULTS

PART A

Selection of parents

A preliminary selection of parents were made with regard to their economic attributes. The table I reveals their relative performance.

The variety Local blue possesses long life span, profuse bearing nature, resistance to mosaic, and high capsaicin content although it has a very little ascorbic acid and sugar content.

The other parents, despite their short life span, non prolific bearing nature, susceptibility to mosaic disease and lower capsaicin content are endowed with the qualities of high ascorbic acid and sugar content.

The morphological description of selected parents are given in Table II.

TABLE I

Performance of different parents

Serial number	Name of variety	Time taken from seed to blooming	Height in cm	Spread in cm	Average fruits per plant	Size	Mean weight of individual fruit in grams	Ascorbic acid in mg/100 gm of ripe fruit	Percentage of sucrose	Nature of reaction to mosaic disease
1.	Oshosh	65 days	51	53.6	32	Big oblong	36.00	438.50	4.422	Susceptible
2.	Chinese giant	63 ..	62	53.6	24	..	65.00	321.80	3.957	do
3.	California wonder	64 ..	56.8	53.1	26	..	41.00	339.15	3.252	do
4.	Local green	66 ..	46.8	55.9	97	Medium	10.5	287.28	3.044	do
5.	Hungarian wax	66 ..	49.1	48.9	42	Medium long	22.8	385.70	2.827	do
6.	Kholar	69 ..	63.2	60.0	29	Medium	14.5	272.65	2.178	do
7.	Indian long red	69 ..	64.0	63.2	129	Long slender	6.08	385.7	1.187	do
8.	Russian	65 ..	32.0	28.4	15	Oblong	22.74	399.00	0.892	do
9.	Local blue	80 ..	71.0	88.0	419	Long slender	2.04	139.65	0.74	Resistant

TABLE II

Description	Local blue	Russian	Indian long red	Chinese giant	Oskosh
1. Habit	Tall with spreading top	Bushy	Bushy	Bushy	Bushy
2. Plant height (mean)	71 cm	32 cm	64 cm	62 cm	51 cm
3. Stem colour	Purple	Green	Green	Green	Green
4. Foliage colour	Light purple	Green	Green	Green	Green
5. Inflorescence	Solitary	Solitary	Solitary	Solitary	Solitary
6. Position of flower	Erect	Erect	Pendent	Erect	Erect
7. Colour of corolla	Light purple	White	White	White with greenish tinge	Dull white
8. Colour of anther	Ash grey with purple tinge	Ash grey	Purple tinge	Greenish purple	Slight purple
9. Colour of style	Purple	Slightly white	Slightly white	Greenish white	Cream yellow
10. Size of style	Long	Long	Medium	Short	Long
11. Colour of stigma	Purple	Cream yellow	Cream yellow	Greenish white	Greenish yellow
12. Colour of immature fruits	Deep purple	Cream yellow	Green	Green	Green
13. Colour of ripe fruits	Red	Brick red	Deep red	Brick red	Orange yellow
14. Fruit shape	Slender, medium, long	Medium sized oblong	Long with undulated margin	Big, oblong	Large oblong

The details of crosses effected are given in Table III.

TABLE III

Serial No.	Female parent	Male parent	No. of flowers crossed	No. of fruits obtained	Percentage of fruit set
1	Local blue	Russian	140	15	10.714
2	do	Indian long red	20	7	35.000
3	do	Chinese giant	80	8	10.000
4	do	Oskosh	85	16	18.823

Table III reveals that the maximum fruit set was observed in cross LB x ILR followed by LB x OS (18.823 per cent). The crosses LB x R and LB x CG displayed more or less the same rate of fruit set.

PART B

COMPARITIVE STUDY OF PARENTS AND HYBRIDS

I. Morphological studies

A. Quantitative characters

1. Number and weight of F_1 and parental seeds

The seeds collected from the selfed and crossed fruits were kept for 15 days in a cool dry place before sowing. The number of seeds per fruit and the weight of 100 seeds in each treatment are given in Table IV.

TABLE IV

Treatments	No. of seeds/ fruit			Weight of 100 seeds in milligrams		
		Percentage of deviation of F_1 mean from the			Percentage of deviation of F_1 mean from the	
	Mean	Better parent	Parental mean	Mean	Better parent	Parental mean
Local blue	87			365		
Local blue x Russian	69	28.12 (-)	24.59 (-)	759	26.71 (+)	57.46 (+)
Russian	171			539		
Local blue x Indian long red	48	50.00 (-)	47.54 (-)	630	5.17 (+)	30.70 (+)
Indian long red	96			599		
Local blue x Chinese giant	27	90.32 (-)	85.24 (-)	639	59.75 (+)	67.32 (+)
Chinese giant	279			400		
Local blue x Oskosh	52	63.88 (-)	54.97 (-)	940	22.07 (+)	65.64 (+)
Oskosh	144			770		

As regards the number of seeds per fruit, all the hybrids have shown a considerable reduction. They exhibited marked decrease from the better parent, which ranged from 28.12 to 90.32 per cent. The maximum decrease in seed number was observed in the cross LB x CG, the percentage of decrease being 90.32. LB x OS also recorded a marked decrease of 63.88 per cent. The minimum decrease in seed number was registered in the cross LB x R. All of them showed a considerable decrease with respect to their parental mean also.

When the weight of 100 seeds were taken into account all the hybrids exhibited an increase over their better parent as well as parental mean. Maximum increase in weight was recorded by the cross LB x CG, the increase being 59.75 per cent. Minimum increase in weight (5.17) was observed in the cross LB x LLR. All the hybrids showed marked increase in weight with respect to their respective parental means. The maximum increase being 67.32 registered by LB x CG and minimum 30.7 by LB x LLR.

2. Germination capacity of F_1 seeds and parental seeds

Table V shows the germination percentage of the F_1 seeds. Among the five parents, Local blue recorded the maximum germination percentage of 98 which is closely

TABLE V

Germination capacity of F_1 and parental seeds

Treatments	Number of seeds germinated out of 100												
	4th day	5th day	6th day	7th day	8th day	9th day	10th day	11th day	12th day	13th day	14th day	15th day	16th day
Local blue	5	16	33	60	65	71	77	82	84	87	89	90	98
Local blue x Russian	3	4	6	11	18	23	25	26	27	29	30	30	30
Russian	2	7	10	18	28	41	60	71	77	78	78	78	78
Local blue x Indian long red	1	2	9	12	15	17	19	25	30	33	33	33	33
Indian long red	1	7	12	20	29	33	60	68	71	77	83	83	83
Local blue x Chinese giant	2	3	5	8	11	14	15	16	17	17	17	17	17
Chinese giant	1	7	19	28	34	58	65	71	77	81	81	81	81
Local blue x Oskosh	1	4	6	10	18	21	25	27	28	28	28	28	28
Oskosh	2	5	10	19	28	35	49	57	63	77	82	85	85

followed by Oskosh, Indian long red and Chinese giant. The variety Russian showed the minimum germination, being 78 per cent.

As regards hybrids, all of them exhibited poor germination capacity. Of the hybrids, the maximum germination was observed in the cross of Local blue and Indian long red, being 33 per cent which is closely followed by the crosses of Local Blue x Russian (30 per cent and Local blue x Oskosh (28 per cent). The minimum germination was noticed in the cross between Local blue and Chinese giant being 17 per cent.

3. Height of seedlings

The results of analysis are given in Table VI.

TABLE VI (a)

Mean height of seedlings of F_1 hybrids and parents (in cm) of the 35th day of sowing

Analysis of variance table

Source	S.S	df	m.s	F
Total	268.00	44		
Block	2.88	4	0.72	2.48
Treatments	256.00	8	32.00	110.34**
Error	9.12	32	0.29	

**Significant at both 5% and 1% level of probability

The mean height of seedlings are ranked as follows

TABLE VI (b)

Sl.No.	Treatment	Height in cm	
1	Local blue x Russian	14.3	C.D. for comparison of better parental mean and hybrid mean = 2.18
2	Local blue x Indian long red	14.1	
3	Indian long red	9.5	
4	Oskosh	8.7	
5	Local blue x Oskosh	8.6	C.D. for comparison of parental mean and hybrid mean = 0.599
6	Local blue x Chinese giant	8.5	
7	Chinese giant	8.5	
8	Local blue	8.2	
9	Russian	8.0	

Among parents Indian long red showed maximum seedling height, although no significant difference was noticed from other parents.

As regards hybrids, Local blue x Russian manifested the maximum seedling height, the figure being 14.3 cm followed by Local blue x Indian long red (14.1 cm). These two crosses showed significant increase in height over their better parent and parental mean. On the other hand hybrids of LB x CG and LB x OS recorded

no significant difference over their respective parents.

Among hybrids, LB x R and LB x ILR showed significant increase over LB x CG and LB x OS.

4. Height of plants

The height of parents and hybrids were recorded at 10 days interval. The data pertaining to the growth pattern of parents and hybrids are graphically presented in fig. 1. The data relating to the final observations were analysed statistically and furnished in table VII.

TABLE VII (a)

Mean height of F_1 and parents (in cm) on the 70th day of transplanting

Source	S.S	df	m.s	F
Total	7545.2	44		
Block	368.3	4	92.08	1.77
Treatment	5515.2	8	689.4	13.27**
Error	1661.7	32	51.92	

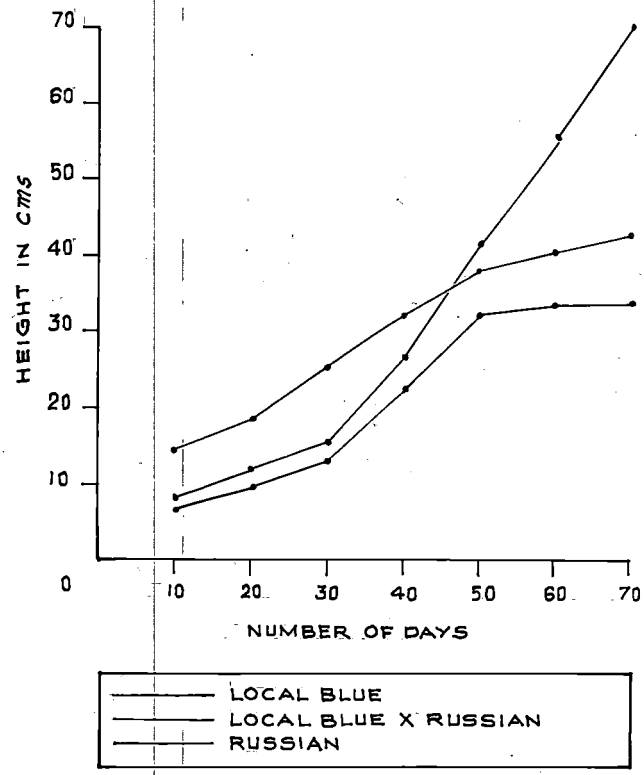
**Significant at both 5 and 1 per cent level of probability

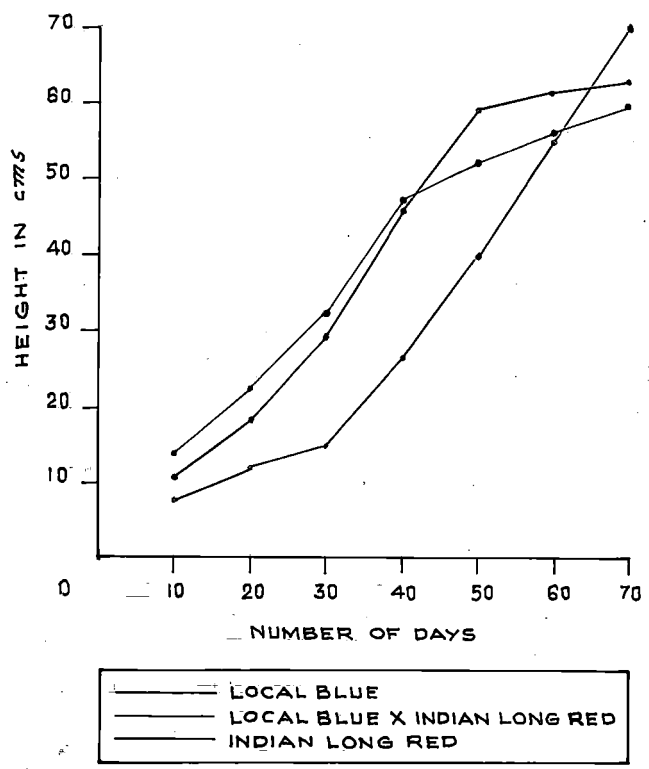
The heights are ranked as follows.

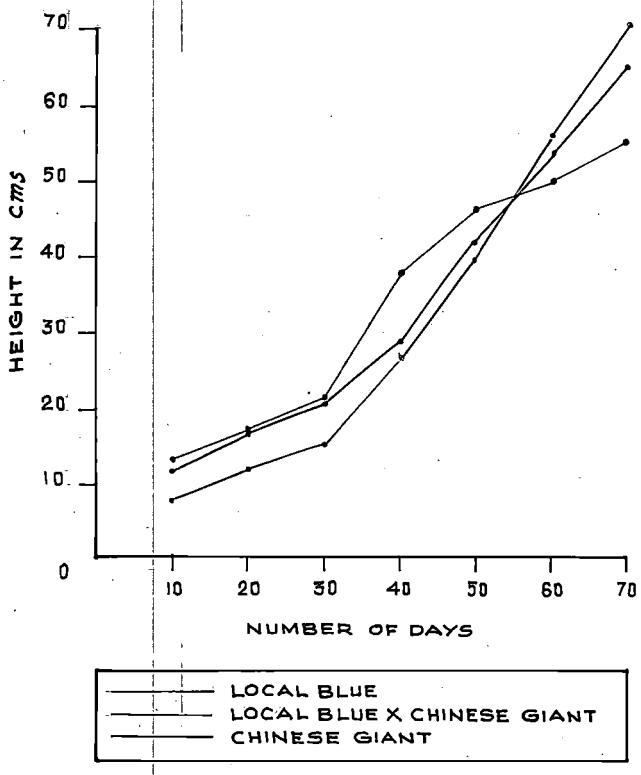
TABLE VII (b)

Sl.No.	Treatments	Height in cm	
1	LB	71	C.D. for comparison between hybrid mean and better parental mean = 9.27
2	ILR	64	
3	CG	62	
4	LB x ILR	57	
5	LB x CG	56	
6	LB x OS	55	C.D. for comparison between hybrid mean and parental mean = 8.02
7	OS	51	
8	LB x R	42	
9	R	32	

Among the parents maximum height was recorded in Local blue (71 cm) and minimum by Russian (32 cm). The crosses LB x R and LB x OS were intermediate between parents. They did not show superiority either over their better parent or parental mean. The heights of other hybrids were lower than that of the dwarf parents. As regards the hybrids LB x ILR, LB x CG, LB x OS were significantly superior over LB x R while no significant difference was observed among the former 3 hybrids.


HEIGHT IN CMS
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
NUMBER OF DAYS
LOCAL BLUE
LOCAL BLUE X RUSSIAN
RUSSIAN


HEIGHT IN CMS
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
NUMBER OF DAYS
LOCAL BLUE
LOCAL BLUE X INDIAN LONG RED
INDIAN LONG RED


HEIGHT IN CMS
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
NUMBER OF DAYS
LOCAL BLUE
LOCAL BLUE X CHINESE GIANT
CHINESE GIANT

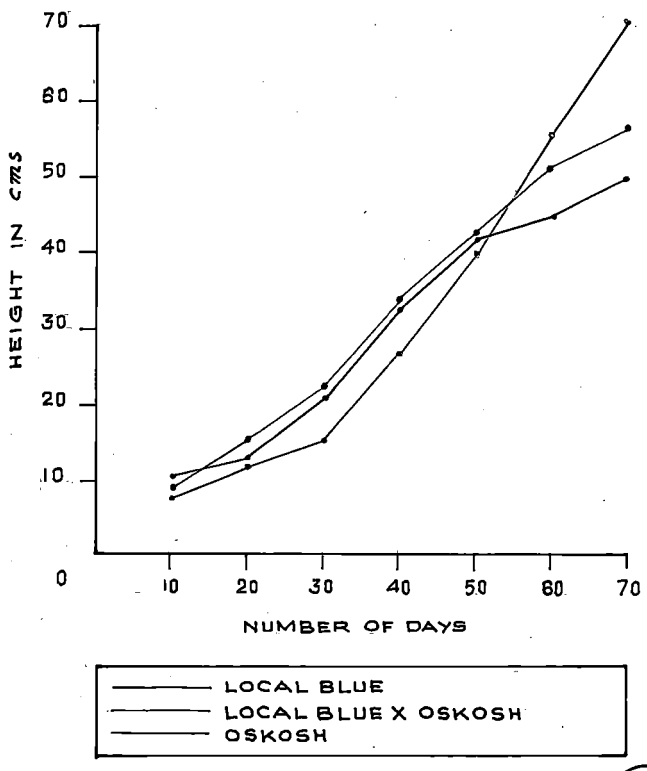

HEIGHT IN CMS
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
NUMBER OF DAYS
LOCAL BLUE
LOCAL BLUE X OSKOSH
OSKOSH

FIG 1

5. Number of branches

The results of analysis are shown in Table VIII.

TABLE VIII (a)

Mean number of branches of parents and hybrids on the 70th day of transplanting

Source	S.S	df	m.s	F
Total	128486.45	44		
Block	928.22	4	232.05	0.38
Treatment	108238.85	8	13529.85	22.41**
Error	19319.38	32	603.73	

** Significant at both 5 and 1 per cent level of probability

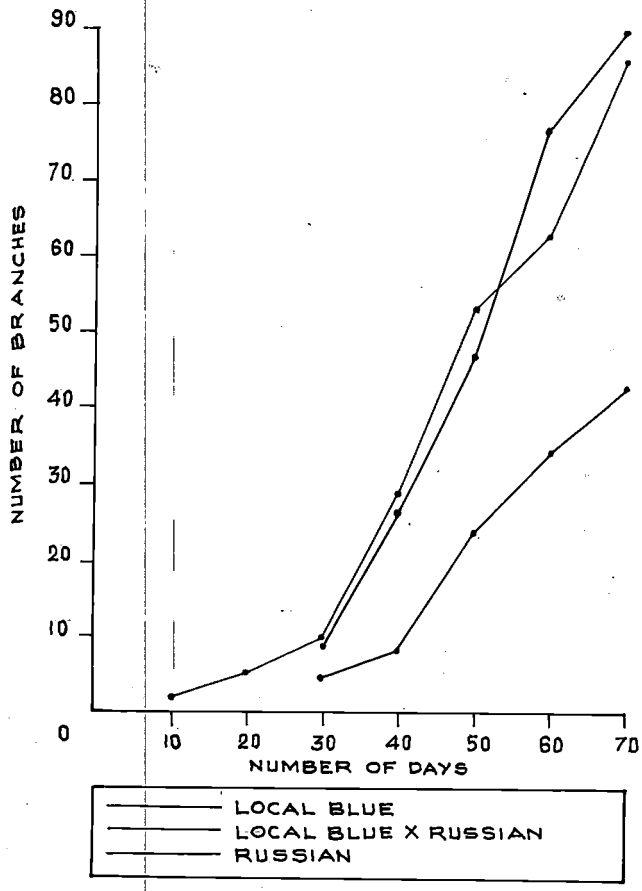
The mean number of branches of parents and hybrids are tabulated below according to their order of difference.

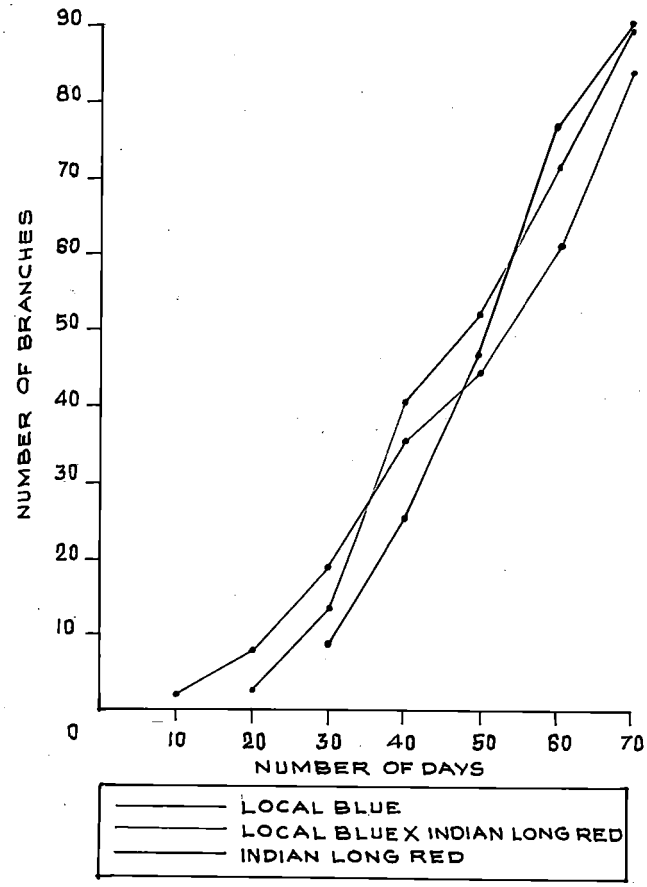
TABLE VIII (b)

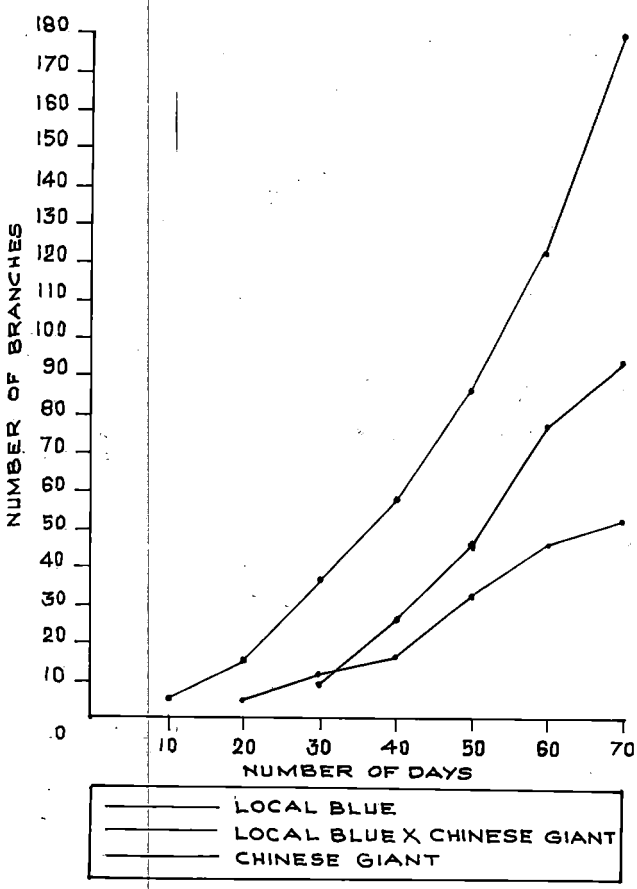
Sl.No.	Treatments	Branches in numbers	
1	LB x OS	187.8	C.D. for comparison between hybrid mean and better parental mean = 31.65
2	LB x CG	180.8	
3	LB	91.2	
4	ILR	90.8	
5	LB x R	86.4	C.D. for comparison between hybrid mean and parental mean = 27.41
6	LB x ILR	86.0	
7	OS	62.8	
8	CG	51.6	
9	R	43.6	

As regards parents, both LB and ILR showed significant difference over R and CG.

Among hybrids, LB x R was intermediate between their parents with respect to the number of branches. One cross LB x ILR showed a slight decrease in the number of branches from both the parents. While the other two hybrids LB x CG and LB x OS not only showed statistically significant superiority over other hybrids and parents, but also recorded a 100 per cent increase over their common seed parent LB. The growth pattern of the number of branches produced by parents and hybrids are graphically represented


NUMBER OF BRANCHES
NUMBER OF DAYS
LOCAL BLUE
LOCAL BLUE X RUSSIAN
RUSSIAN


NUMBER OF BRANCHES
NUMBER OF DAYS
LOCAL BLUE
LOCAL BLUE X INDIAN LONG RED
INDIAN LONG RED


NUMBER OF BRANCHES
NUMBER OF DAYS
LOCAL BLUE
LOCAL BLUE X CHINESE GIANT
CHINESE GIANT

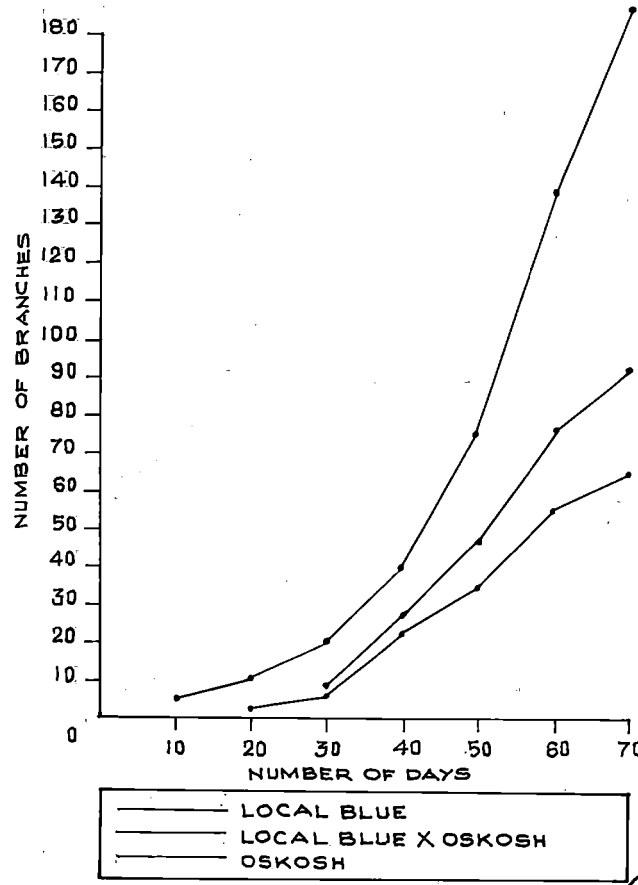

NUMBER OF BRANCHES
NUMBER OF DAYS
LOCAL BLUE
LOCAL BLUE X OSKOSH
OSKOSH

FIG 2

in fig.2.

6. Number of leaves

Statistical analysis of the mean number of leaves produced by parents and offsprings are presented in Table IX.

TABLE IX (a)

Analysis of mean number of leaves produced by parents and F_1 on the 70th day of transplanting

Source	S.S.	df	m.s	F
Total	516868.00	44		
Block	6350.75	4	1587.68	<1
Treatments	350798.00	8	43849.75	8.78**
Error	159719.25	32	4991.23	

**Significant at both 5 and 1 per cent level of probability

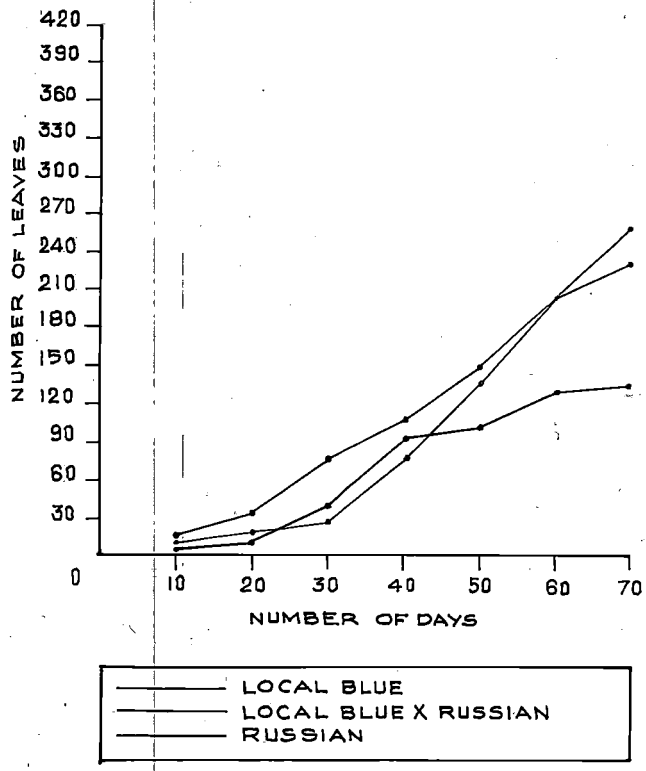
The mean number of leaves produced by the parents and hybrids are shown below according to their order of difference.

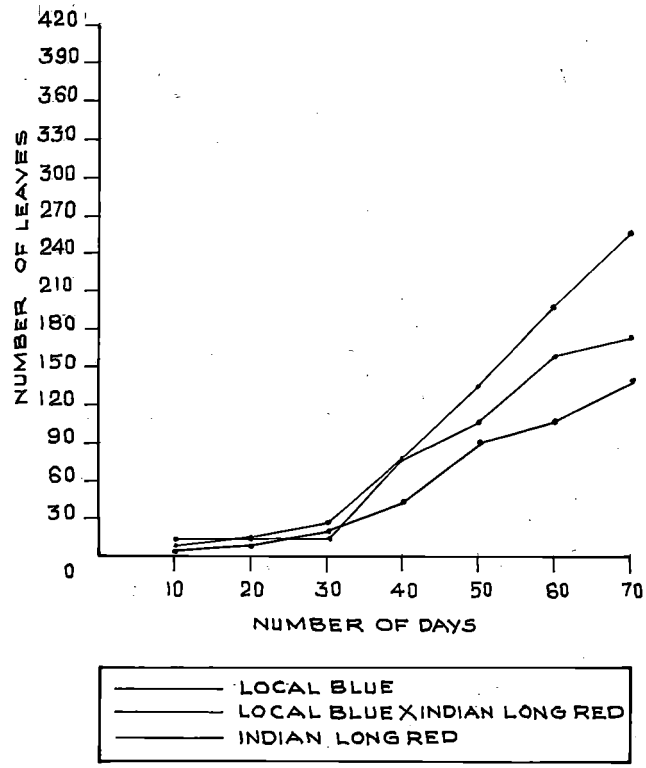
TABLE IX (b)

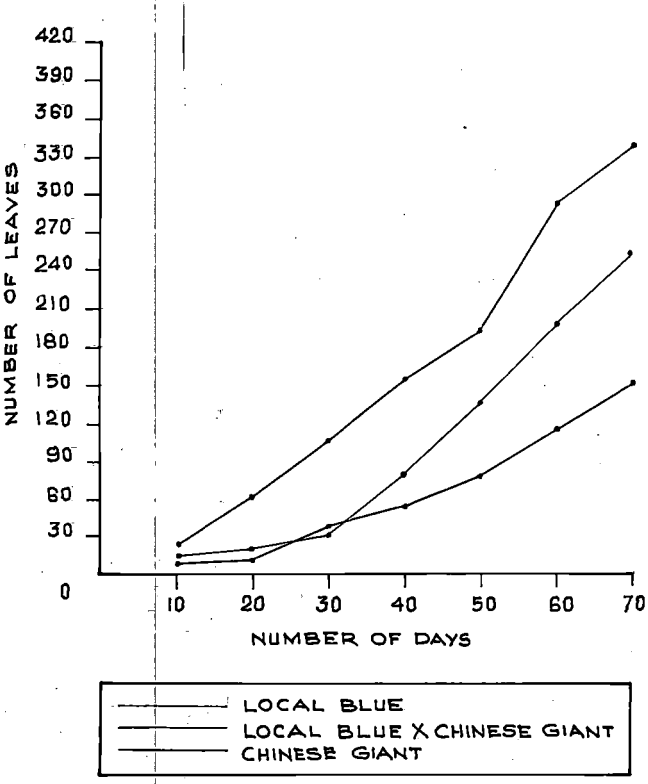
Sl.No.	Treatments	Mean number of leaves	
1	LB x OS	379	C.D. for comparison of hybrid mean and better parental mean = 90.85
2	LB x CG	338	
3	LB	256	
4	LB x R	228	
5	LB x MLR	175	C.D. for comparison of hybrid mean and parental mean = 78.66
6	CG	154	
7	MLR	140	
8	R	130	
9	OS	125	

Among parents Local Blue (LB) recorded maximum number of leaves and the same was statistically superior over other parents. Only two hybrids (LB x R and LB x MLR) were intermediate between their parents with respect to the number of leaves produced while the other two hybrids LB x CG and LB x OS produced significantly superior number of leaves over the parents and hybrids.

The crosses LB x OS and LB x CG registered 32.45 per cent and 24.26 per cent increase respectively over the common seed parent LB. The number of leaves produced by parents and hybrids are graphically represented in fig.3.


NUMBER OF LEAVES
420
390
360
330
300
270
240
210
180
150
120
90
60
30
0
10
20
30
40
50
60
70
NUMBER OF DAYS
LOCAL BLUE
LOCAL BLUE X RUSSIAN
RUSSIAN


NUMBER OF LEAVES
420
390
360
330
300
270
240
210
180
150
120
90
60
30
0
10
20
30
40
50
60
70
NUMBER OF DAYS
LOCAL BLUE
LOCAL BLUE X INDIAN LONG RED
INDIAN LONG RED


NUMBER OF LEAVES
420
390
360
330
300
270
240
210
180
150
120
90
60
30
0
10
20
30
40
50
60
70
NUMBER OF DAYS
LOCAL BLUE
LOCAL BLUE X CHINESE GIANT
CHINESE GIANT

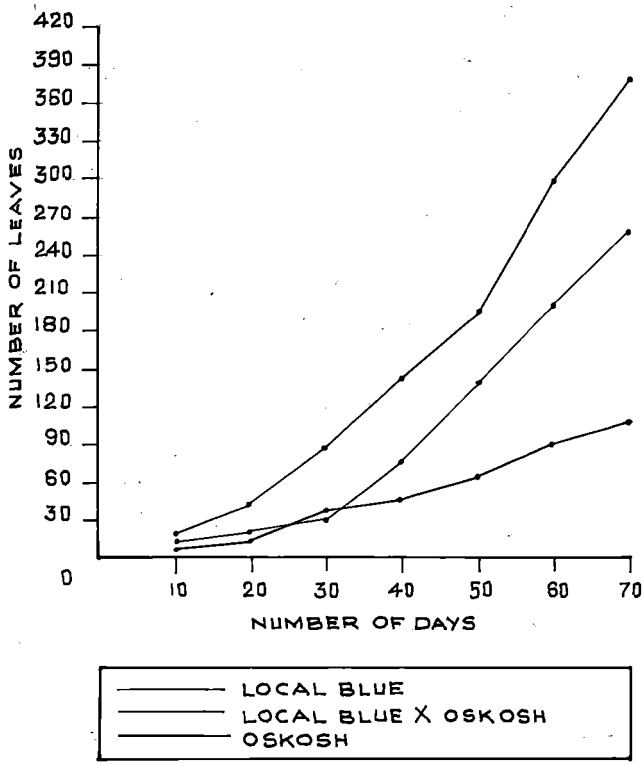

NUMBER OF LEAVES
420
390
360
330
300
270
240
210
180
150
120
90
60
30
0
10
20
30
40
50
60
70
NUMBER OF DAYS
LOCAL BLUE
LOCAL BLUE X OSKOSH
OSKOSH

FIG 3

7. Spread of the plants

Table X(a) represents the analysis of the mean spread of both the parents and F_1 plants.

TABLE X (a)

Results of the statistical analysis of the mean spread of parents and hybrids (in cm) on the 70th day of transplanting

Source	S.S	df	m.s	F
Total	13529.25	44		
Block	191.25	4	47.81	0.56
Treatments	10626.45	8	1328.30	15.67**
Error	2711.55	32	84.73	

**Significant at both 5 and 1 per cent level of probability

The mean spread of parents and F_1 hybrids are as follows according to their order of difference

TABLE X (b)

Sl.No.	Treatments	Mean spread of plants in cm	
1	LB	88	C.D. for comparison of hybrid mean and better parental mean = 11.86
2	ILR	63.2	
3	LB x OS	62.2	
4	LB x CG	57.6	
5	CG	53.6	C.D. for comparison of hybrid mean and parental mean = 10.27
6	OS	53.6	
7	LB x ILR	48.6	
8	LB x R	42.4	
9	R	28.4	

The common parent Local blue recorded a statistically superior spread over the other parents and hybrids as well. LLR showed significant difference over one parent i.e. Russian.

All the hybrids (except LB x LLR) were intermediate between their respective parents with regard to the spread of the plant. The hybrid LB x OS recorded a significant increase over LB x R and LB x LLR while the hybrid LB x CO showed significance in difference of spread over LB x R only.

8. Area of leaves

The results of analysis are tabulated in Table XI.

TABLE XI (a)

Results of the analysis of the mean leaf area (in sq.cm) of the parents and hybrids

Source	S.S	df	m.s	F
Total	6592.16			
Block	15.395	4	3.848	0.549
Treatments	6352.786	8	794.098	113.60**
Error	223.98	32	6.99	

**Significant at both 5 and 1 per cent level of probability

The mean area of leaves of parents and hybrids are tabulated below according to their order of variation.

TABLE XI (b)

Sl.No.	Treatments	Mean area of leaves in sq.cm	
1	LB x CC	62.36	C.D. for comparison of hybrid mean and better parental mean = 3.4036
2	LB x OS	61.08	
3	CC	44.82	
4	R	39.25	
5	LB x R	34.08	C.D. for comparison of hybrid mean and parental mean = 2.93
6	OS	33.70	
7	LB x ILR	33.59	
8	ILR	30.91	
9	LB	29.31	

Among parents CC showed significant increase over other parents. The variety R also exhibited increase over ILR, OS and LB. The common seed parent LB possessed the lowest leaf area.

As regards hybrids, only one hybrid LB x R was intermediate between their parents. All the other 3 hybrids surpassed their better parents remarkably with respect to leaf area.

The maximum leaf area was observed in the

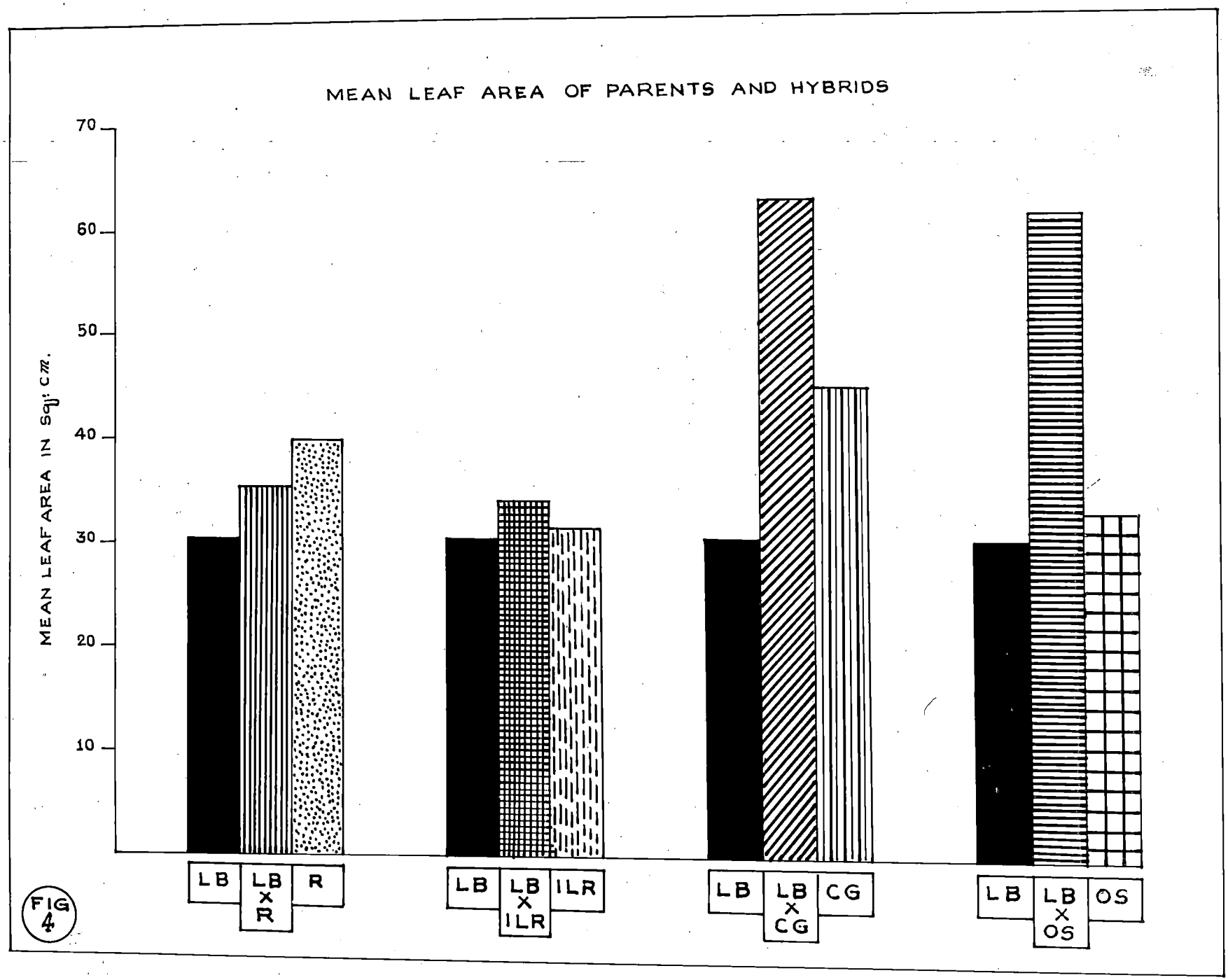

MEAN LEAF AREA OF PARENTS AND HYBRIDS
MEAN LEAF AREA IN Sq. Cm.
70
60
50
40
30
20
10
LB
LB X R
R
LB
LB X ILR
ILR
LB
LB X CG
CG
LB
LB X OS
OS

FIG 4

cross LB x CG (62.36 sq.cm) which is closely followed by LB x OS (61.08 sq.cm).

The mean leaf area of parents and hybrids are represented in the bar diagram (fig.4).

9. Time of flowering

The results are tabulated and presented in Table XII.

TABLE XII

Mean number of days taken from sowing to flowering by F_1 hybrids and parents

Treatments	Mean number of days	Percentage of devintion of F_1 mean from the	
		Earlier parent	Parental mean
LB	75		
LB x R	57	18.571(-)	21.37(-)
R	70		
LB x ILR	59	15.714(-)	18.62(-)
ILR	70		
LB x CG	62	1.587(-)	10.14(-)
CG	63		
LB x OS	61	7.575(-)	13.47(-)
OS	66		

It can be observed from the Table XII that all the hybrids showed earliness in flowering compared

their respective earlier parents and the parental means as well. Maximum earliness of 18.57 per cent was observed in the cross between LB x R which is followed by the cross LB x ILR, the figure being 15.714 per cent. The minimum amount of earliness was expressed by the cross LB x CG.

10. Percentage of fruit set

The results are tabulated and presented in Table XIII.

TABLE XIII

Percentage of fruit set in F_1 hybrids and parents

Treatments	Mean	Percentage of deviation of F_1 mean from the	
		Better parent	Parental mean
LB	74.5		
LB x R	44.82	39.83(-)	21.16(-)
R	39.21		
LB x ILR	63.15	15.23(-)	3.05(-)
ILR	55.78		
LB x CG	46.27	37.89(-)	23.37(-)
CG	40.18		
LB x OS	76.49	2.67(+)	34.95(+)
OS	38.87		

Out of the four crosses, three showed marked decrease in fruit set when compared to better parent as

well as parental mean. The maximum decrease in fruit set was exhibited by LB x R (39.83 per cent), the decrease from the parental mean being 21.16 per cent. This is closely followed by another hybrid LB x CC. The percentage of decrease over the better parent (LB) was 37.89 and the decrease from parental mean 23.37.

One cross LB x OS registered conspicuous increase in fruit set over its respective parents and parental mean. The increase over better parent and parental mean were 2.67 per cent and 34.95 per cent respectively. All the other hybrids were intermediary to their parents.

11. Number of total fruits per plant

The results are tabulated and presented in Table XIV.

TABLE XIV (a)

Analysis of the mean number of fruits produced in F_1 hybrids and parents

Source	S.S	df	m.s	F
Total	667554.00	44		
Block	5318.00	4	1329.5	2.58
Treatment	645752.8	8	80719.1	156.70**
Error	16483.2	32	515.1	

**Significant at both 5 and 1 per cent level of probability

The mean number of fruits produced by parents and F_1 hybrids are shown below according to their order of difference.

TABLE XIV (b)

Sl.No.	Treatments	Mean number of fruits	
1	LB	419	C.D. for comparison of hybrid mean and better parental mean = 29.25
2	LB x R	77	
3	R	15	
4	LB x ILR	108	
5	ILR	129	
6	LB x CG	143	C.D. for comparison of hybrid mean and parental mean = 25.27
7	CG	24	
8	LB x OS	217	
9	OS	32	

The number of fruits produced by the hybrids remained intermediate between the parents. Among parents, the common seed parent Local blue produced maximum number of fruits which is superior over other parents and hybrids as well. The hybrid LB x OS manifested significant superiority over other 3 hybrids. The cross LB x CG also showed significant superiority over LB x R and LB x ILR. The cross LB x ILR showed statistically significant increase over LB x R only.

12. Size and weight of fruits

(a) Length of fruits

The results are tabulated and presented in Table XV.

TABLE XV (a)

Analysis of the mean length of fruits of parents and F_1 hybrids

Source	S.S	df	m.s	f
Total	199.24	44		
Block	0.99	4	0.247	0.86
Treatment	190.122	8	23.752	83.34**
Error	9.12	32	0.285	

**Significant at both 5 and 1 per cent level of probability

The mean fruit lengths are given below according to their order of variation.

TABLE XV (b)

Sl.No.	Treatments	Mean length of fruits in cm	
1	LLR	11.9	C.D. for comparison
2	LB x LLR	9.48	of hybrids and better
3	OS	8.2	parents = 0.674
4	LB x R	8.16	C.D. for comparison
5	LB x CG	7.68	of hybrids and parental
6	CG	7.66	mean = 0.591
7	LB	5.7	
8	R	5.66	
9	LB x OS	4.82	

Only the cross LB x R showed significant increase of fruit length over the better parent. The fruit length of other hybrids remained intermediate between their respective parents except LB x OS. Among parents the variety Indian long red showed significant increase over other parents and hybrids as well.

(b) Girth of fruits

The results are tabulated and presented in Table XVI.

TABLE XVI (a)

Analysis of the girth of fruits of parents and hybrids

Source	S.S	df	m.s	F
Total	1186.31	44		
Block	3.08	4	0.77	<1
Treatment	1122.15	8	140.26	73.43**
Error	61.08	32	1.91	

**Significant at both 5 and 1 per cent level of probability

The mean girth of fruits of parents and F_1 hybrids are tabulated below according to their order of variation.

TABLE XVI (b)

Sl.No.	Treatments	Mean girth of fruits in cm	
1	CG	20.5	C.D. for comparison of hybrids and better parents = 1.77
2	R	11.68	
3	OS	10.66	
4	LB x OS	9.8	
5	LB x CG	7.38	C.D. for comparison of hybrids and parental mean = 1.528
6	LB x R	6.26	
7	LB x ILR	5.18	
8	ILR	3.52	
9	LB	3.1	

Among parents the variety Chinese giant (CG) exhibited maximum girth being 20.5 cm.

As regards hybrids, only LB x ILR recorded slight increase in girth over the better parent, but the same was not statistically significant. However the difference was significant when the parental means were taken into account. All the other hybrids remained intermediate between their respective parents with regard to the girth of fruits. Fruit size index (taken as length x girth) was compared and tabulated below.

TABLE XVII

Fruit size index of F_1 hybrids and parents

Crosses	F_1 fruit size	Arithmetic mean of fruit size of parents	Geometric mean of the fruit size of parents
LB x R	51.08	41.88	34.178
LB x ILR	49.106	29.78	27.205
LB x CG	56.68	87.35	52.674
LB x OS	47.236	52.541	39.301

The results of the comparison of the fruit size index (taken as length x girth) of the parents and hybrids revealed that the F_1 mean of one cross (LB x CG) was more approximating to the geometric mean of the parents than to the arithmetic mean.

The other three hybrids LB x R, LB x ILR and LB x OS illustrated that their means were nearing more towards the arithmetic mean than towards the geometric mean of the parents.

(c) Weight of fruits

The results of analysis are shown in Table XVIII.

TABLE XVIII (a)

Results of analysis of mean weight of fruits of parents and F_1 hybrids

Source	S.S	df	m.s	F
Total	20209.948	44		
Block	265.011	4	66.252	0.74
Treatments	17096.540	8	2137.067	24.00**
Error	2848.397	32	89.012	

**Significant at both 5 and 1 per cent level of probability.

Mean weight of fruits of parents and F_1 hybrids are tabulated hereunder according to their order of variation.

TABLE XVIII (b)

Sl.No.	Treatments	Mean weight of fruits in gms	
1	CG	65.0	C.D. for comparison of hybrids and better parents = 12.14
2	OS	36.0	
3	R	22.74	
4	LB x OS	9.2	
5	LB x CG	7.76	C.D. for comparison of hybrids and parental mean = 10.51
6	LB x R	6.26	
7	ILR	6.08	
8	LB x ILR	5.96	
9	LB	2.04	

Of the parents, Chinese giant recorded the maximum weight which is followed by Oskosh. The common parent Local blue had the minimum weight of 2.04 grams. The variety Chinese giant showed significant increase in weight over all other parents and hybrids. Oskosh exhibited significant difference in weight over other parents and hybrids except Chinese giant, and the variety Russian recorded significant superiority of weight over other parents and hybrids except Chinese giant and Oskosh. All the hybrids remained intermediate between their respective parents, as regards the individual weight of fruits.

13. Number of seeds per fruit

The results of analysis are presented in Table XIX.

TABLE XIX (a)

Analysis of mean number of seeds in parents and F_1 hybrids

Source	S.S	df	m.s	F
Total	218077.25	44		
Block	2811.25	4	702.81	2.22
Treatment	205150.05	6	25643.75	81.31**
Error	10115.95	32	316.12	

**Significant at both 5 and 1 per cent level of probability

The mean number of seeds in the parents and hybrids are shown below, as per the order of their variation.

TABLE XIX (b)

Sl.No.	Treatments	Mean number of seeds	
1	CG	279	C.D. for comparison of hybrids and better parents = 22.907
2	R	171	
3	OS	144	
4	ILR	96	
5	LB x ILR	89	C.D. for comparison of hybrid and parental mean = 19.76
6	LB	87	
7	LB x R	79	
8	LB x OS	59	
9	LB x CG	53	

Among parents the variety Chinese giant recorded maximum number of seeds per fruit and significant superiority over other parents and hybrids. The Russian variety exhibited significant superiority over other parents (except Chinese giant) and hybrids. The variety Oskosh also showed statistically significant superiority over other parents (except Chinese giant and Russian) and hybrids.

As regards the hybrids LB x ILR and LB x OS were intermediate between their parents with respect to the

number of seeds. The other two hybrids showed a decrease for the parents which possessed lesser number of seeds. The hybrids LB x LLR showed significant superiority over the two hybrids LB x CG and LB x OS. The hybrid LB x R recorded significant superiority over LB x CG and LB x OS.

B. Qualitative characters

The observations pertaining to the qualitative characters are furnished in Table XX.

Colour of stem

In two crosses, LB x R and LB x LLR the nodes had the purple colour ie. the stem colour of the common seed parent LB. The other two hybrids LB x CG and LB x OS however had no change with regard to their stem or nodal colour.

Colour of foliage

No transmission of the purple colour was obtained to the hybrids from the common seed parent.

Colour of corolla

The purple corolla colour of the common seed parent was seen transmitted to the three hybrids LB x R, LB x LLR, LB x CG. The apex of the corolla of these hybrids were purple. The hybrid LB x OS had no colour change in corolla.

Colour of anther

No marked difference was noticed between parents and hybrids.

Colour of style

The purple colour of the common seed parent LB was transmitted in 3 crosses LB x R, LB x ILR and LB x CG, while the cross LB x OS had shown little affinity towards LB.

Position of flower

Solitary flowers were seen in all the parents. LB x CG produced two flowers in the axils of many branches and the same were fertile to develop into fruits.

Fruit shape and colour

Conspicuous difference was manifested in both shape and colour of hybrid fruits.

The hybrid LB x R had longer fruits than the parents. The apex of the hybrid fruits had abrupt ending as it is in the pollen parent R.

The hybrids LB x ILR and LB x OS were intermediate in shape with respect to their parents while the hybrid LB x OS was small and roundish than their respective parents.

TABLE XX

Treatments	Colour of stem	Colour of foliage	Position of flower	Colour of corolla	Colour of anther
Local blue	Purple tinge	Purple tinge	Erect	Purple	Ash grey with pink tinge
Local blue x Russian	Green with purple nodes	Green	Semi erect	White with purple apex	Pale purple
Russian	Green	Green	Erect	White	Ash grey
Local blue x Indian long red	Green with purple nodes	Green	Semi erect	White with purple apex	Light
Indian long red	Green	Green	Pendent	White	Light violet
Local blue x Chinese giant	Green	Green	Pendent	White with purple margin	Ash grey
Chinese giant	Green	Green	Semi	White with greenish tinge	Greenish pink
Local blue x Oskosh	Green	Green	Pendent	White	Pale ash grey
Oskosh	Green	Green	Erect	Dirty white	Slight violet

Colour of style	Length of style	Colour of stigma	Fruit shape and colour at maturity	Fruit pigmentation and colour at ripeness
Light pink	Two types long and medium	Purple	Slender, medium, deep purple	Deep red at maturity
Purple	Long	Dirty white	Medium	Purple spots in the young fruits coalesce at maturity, vanishes gradually and at ripeness thef fruit colour is brick red
Slightly white	Long	Cream yellow	Oblong cream yellow	Red
Purple	Medium	Dirty white	Medium	As in the cross of Local blue x Russian
Slightly white	Medium	Dirty yellow	Long, with undulated margin green colour	Deep red
Light purple	Medium	Dirty white	Undulated margin	As in the cross of Local blue x Russian
Greenish white	Short	Greenish white	Oblong with green colour	Deep red
White	Long	Cream	Small, oblong with green colour	Red. No purple pigmentation
Slight yellow	Long	Greenish white	Oblong with green colour	Orange yellow

Marked difference in pigmentation was noticed in hybrids. The young hybrid fruits of LB x R, LB x ILR, LB x CO had small patches of purple colour of the common seed parent LB. The patches increased in number and size, as the fruit matured and they eventually coalesced together to give a uniform purple colour. The purple colour subsequently disappeared at maturity. The ripe fruit colour was deep brick red.

On the contrary no purple pigmentation was observed in the fruits of LB x OS at any stage. The colour of ripe fruit was deep red.

Abnormalities

Abnormalities in corolla and fruits were noticed in the crosses of LB x ILR and LB x R. Two fruits were seen in the same pedicel in a few branches in the cross LB x ILR. Furthermore petalloid stamens were noticed abundantly in both the crosses LB x ILR and LB x R.

About half of the anthers were transformed into petalloid structures and only the remaining half portion was functional.

II. Study on mosaic resistance

The 35 days old seedlings of parents and hybrids were inoculated with virus containing leaf juice. Clear symptoms of the disease was manifested from the 19th day of inoculation. Among parents the common seed parent Local blue showed little symptoms of the disease while the four pollen parents namely Russian, Indian long red, Chinese giant and Oskosh succumbed to the disease.

With regard to hybrids none of them showed any clear symptoms of the disease.

III. Chemical studies

(1) Ascorbic acid (Vitamin C) content of ripe fruits of parents and hybrids.

The results are tabulated and presented in Table XXI.

TABLE XXI

Ascorbic acid content in ripe fruits of parents and hybrids

Treatments	Ascorbic acid in milligrams per 100 grams of ripe fruit	Percentage of deviation of F_1 mean from the	
		Better parent	Parental mean
LB	139.65		
LB x R	445.50	11.65(+)	65.4(+)
R	399.00		
LB x ILR	370.20	4.01(-)	40.89(+)
ILR	385.70		
LB x CG	382.75	18.94(+)	65.89(+)
CG	321.80		
LB x OS	414.15	5.55(-)	43.2(+)
OS	438.5		

Among parents, Oshkosh exhibited maximum amount of ascorbic acid (438.5 mg/100 gram) and the common seed parent Local blue, the minimum (139.65 mg/100 grams).

Two hybrids LB x R, and LB x CG registered a marked increase over their better parents and parental means as well. In the latter hybrid the percentage of increase over better parent and parental mean were 18.94 and 65.89 respectively. The two remaining hybrids LB x ILR and LB x OS exhibited a decrease over

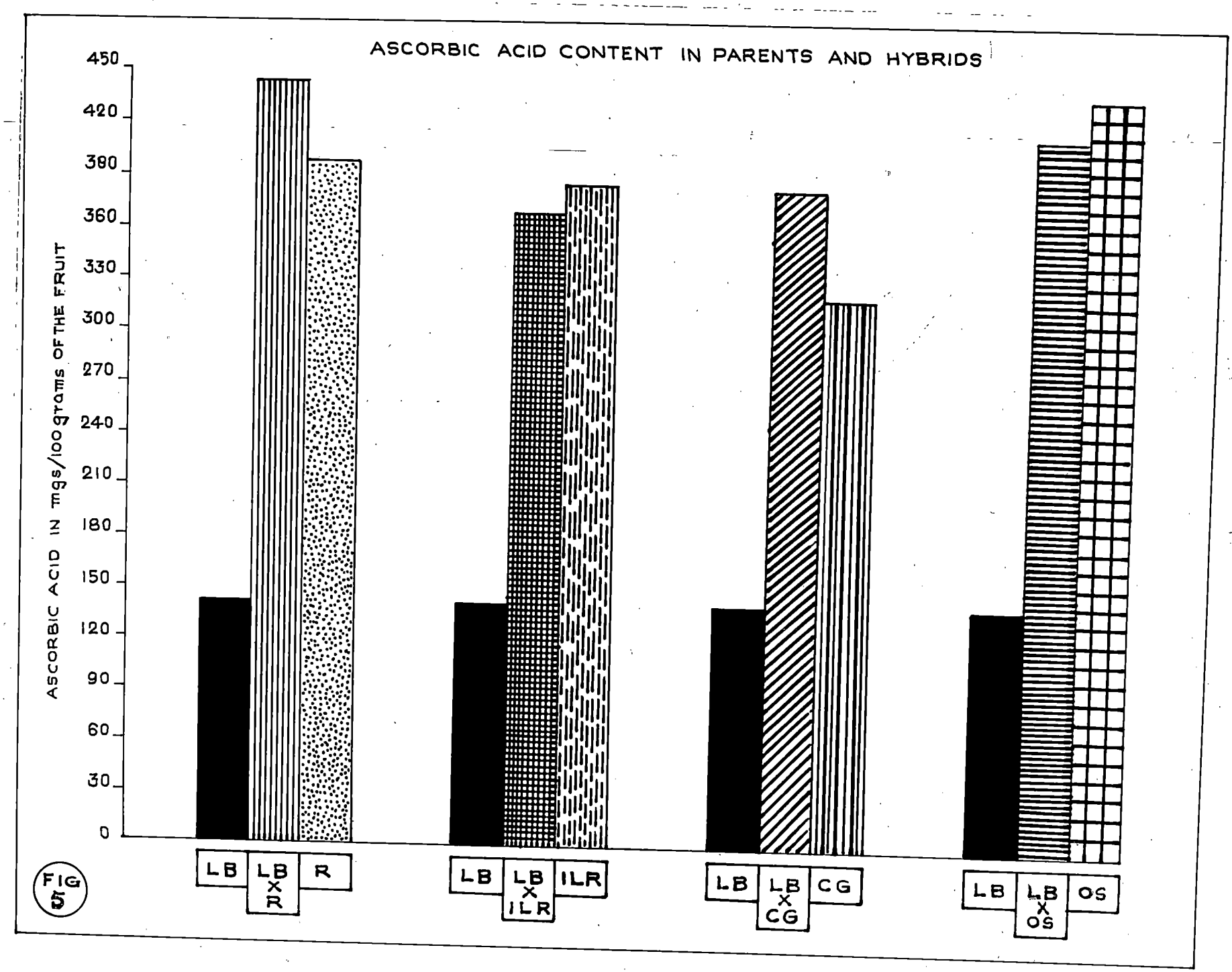

ASCORBIC ACID CONTENT IN PARENTS AND HYBRIDS
ASCORBIC ACID IN mgs/100 grams OF THE FRUIT
450
420
390
360
330
300
270
240
210
180
150
120
90
60
30
0
LB
LB X R
R
LB
LB X ILR
ILR
LB
LB X CG
CG
LB
LB X OS
OS

FIG 5

their respective better parents, the percentage being 4.01 and 5.55 respectively. But these two hybrids had an increased percentage of ascorbic acid when the parental mean were taken into consideration. All the hybrids manifested a spectacular increase over their parental mean. The maximum increase was observed in LB x CC (65.89) which is closely followed by LB x R (65.4). The minimum increase was 40.89 shown by LB x ILR.

In all cases the percentage of ascorbic acid in green fruits was found to be less than that in ripe fruits, the range of variation being 48.5 to 52 per cent. Ascorbic acid content in parents and hybrids are graphically represented in fig. 5.

(ii) Estimation of sucrose content in ripe fruits

The results are tabulated and presented in Table XXII.

TABLE XXII

Chemical analysis of ripe fruits for the estimation of sucrose content

Treatments	Percentage of sucrose content	Percentage of deviation of F_1 mean from the	
		Better parent	Parental mean
LB	0.74		
LB x R	4.157	366.03(+)	409.43(+)
R	0.892		
LB x ILR	5.301	346.58(+)	450.46(+)
ILR	1.187		
LB x CG	3.757	5.05(-)	60.008(+)
CG	3.957		
LB x OS	4.301	2.73(-)	66.64(+)
OS	4.422		

Among parents the variety Oshkosh exhibited maximum percentage of sucrose (4.422) which is closely followed by Chinese giant (3.957). The common seed parent Local blue possessed the minimum amount of sucrose (0.74 per cent).

Two hybrids LB x R and LB x ILR surpassed their respective better parents in their sucrose content, the increase being 366.03 per cent and 346.58 per cent respectively. The other two hybrids

SUCROSE CONTENT IN PARENTS AND HYBRIDS

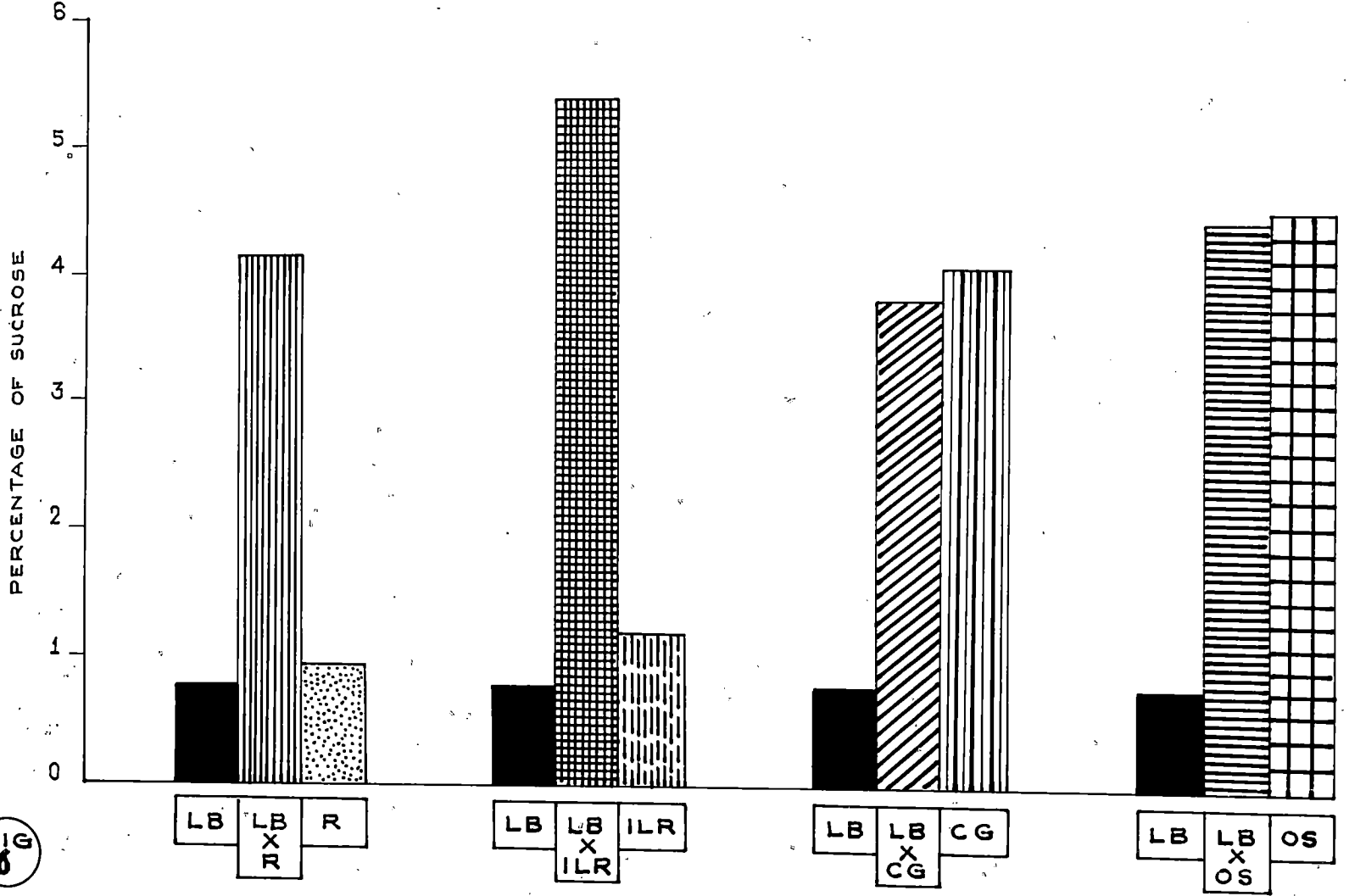


FIG 6

LB x CG and LB x OS showed a decrease in sucrose content from their respective better parents, the percentage being 5.05 and 2.73 respectively. However all the four hybrids showed a marked increase over their respective parental means. The maximum increase over parental mean was manifested by LB x ILR, the increase being 450.46. The minimum amount of increase over parental mean was exhibited by LB x CG (60.008 per cent). Sucrose content in parents and hybrids are graphically represented in fig. 6.

iii) Estimation of capsaicin content in parents and hybrids

The results are displayed in table XXIII

TABLE XXIII

Capsaicin content (in per cent) in parents and hybrids

Treatments	Mean	Percentage of deviation of F_1 mean from the	
		Better parent	Parental mean
LB	0.71		
LB x R	0.35	50.70(-)	16.66(-)
R	0.14		
LB x ILR	0.4	43.66(-)	39.39(-)
ILR	0.62		
LB x CG	0.37	47.88(-)	19.56(-)
CG	0.21		
LB x OS	0.89	25.35(+)	61.81(+)
OS	0.39		

CAPSAICIN CONTENT OF PARENTS AND HYBRIDS

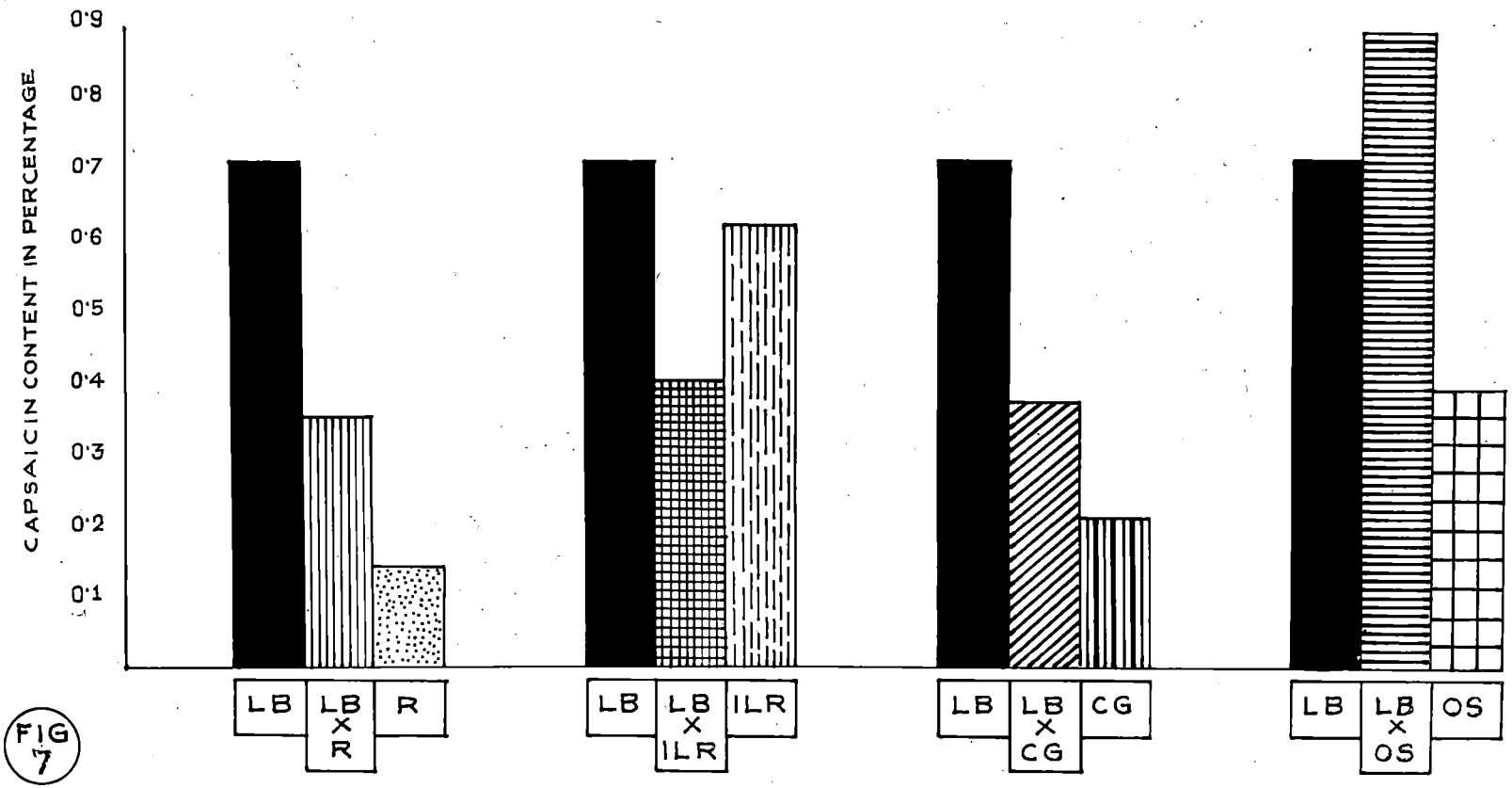


FIG 7

The table above reveals that, out of the parents the common seed parent LB exhibited maximum percentage of capsaicin content being 0.71 and the minimum was recorded in the variety Russian (0.14).

Of the hybrids, all except LB x OS, displayed a marked decrease in capsaicin content when compared to their better parent. While the cross LB x OS registered a positive heterosis. The increase over better parent was 24.35 per cent.

When the parental mean was taken into account the same results were obtained. All the 3 hybrids except LB x OS manifested pronounced decrease while the cross LB x OS registered an increase of 61.81 per cent. Capsaicin content in parents and hybrids are illustrated graphically in fig.7.

IV. Cytological studies

(a) Pollen size

The results are presented in Table XXIV.

TABLE XXIV

The mean pollen diameter of parents and F_1 hybrids (in μ)

Treatments	Mean	Percentage of deviation of F_1 mean from the	
		Better parent	Parental mean
LB	26.335		
LB x R	30.59	3.27(-)	5.55(+)
R	31.625		
LB x ILR	34.155	20.24(+)	24.78(+)
ILR	28.405		
LB x CG	28.175	2.77(-)	1.87(+)
CG	28.98		
LB x OS	28.175	2.03(-)	2.29(+)
OS	28.75		

Among the parents, the variety Russian had the largest sized pollen grains and the common seed parent Local blue, the smallest. The mean pollen diameters of the aforementioned varieties were 31.625 μ and 26.335 μ respectively.

The hybrid LB x ILR exhibited a marked increase of 20.24 per cent over its better parent, while the hybrids LB x R, LB x CG and LB x OS recorded a decrease over their respective better parents, the

figures being 3.27, 2.77 and 2.03 per cent respectively.

As regards parental mean, all the four hybrids showed a marked percentage of increase on the pollen size, over their respective parental means. The maximum increase was observed in LB x ILR and the minimum increase in LB x CG.

(b) Pollen sterility

The results are tabulated and presented in Table XXV.

TABLE XXV

Percentage of pollen sterility in parents and hybrids

Treatments	Mean	Percentage of devintion of F_1 from the	
		Better parent (more sterile)	Parental mean
LB	13.513		
LB x R	32.432	140.006(+)	51.47(+)
R	29.31		
LB x ILR	31.934	136.32(+)	79.50(+)
ILR	22.068		
LB x CG	78.5	481.04(+)	290.74(+)
CG	26.67		
LB x OS	47.887	254.38(+)	208.21(+)
OS	17.561		

The common seed parent Local blue exhibited the minimum pollen sterility. The maximum pollen sterility, among parents was observed in the variety Russian (29.31 per cent).

A high degree of pollen sterility was manifested by all the four hybrids. The hybrid pollen sterility varied from 31.934 per cent to 78.5 per cent. All the hybrids showed spectacular increase in pollen sterility from their respective better parent. The maximum amount of increase was registered by LB x CG the increase over the better parent being 481.05 per cent. This is closely followed by LB x OS, the increase over better parent was 254.38 per cent. The minimum increase was observed in LB x R.

Moreover, all the four hybrids manifested marked increase of pollen sterility over their respective parental means. The maximum being 290.74 per cent exhibited in LB x CG which is closely accompanied by LB x OS (208.21 per cent). The minimum increase over parental mean was noticed in LB x R (51.47 per cent). The pollen sterility of parents and hybrids are shown graphically in fig.8.

(c) Studies on pollen mother cells

(1) Chiasma frequency

The chiasma frequency of all the five parents

POLLEN STERILITY IN PARENTS AND HYBRIDS

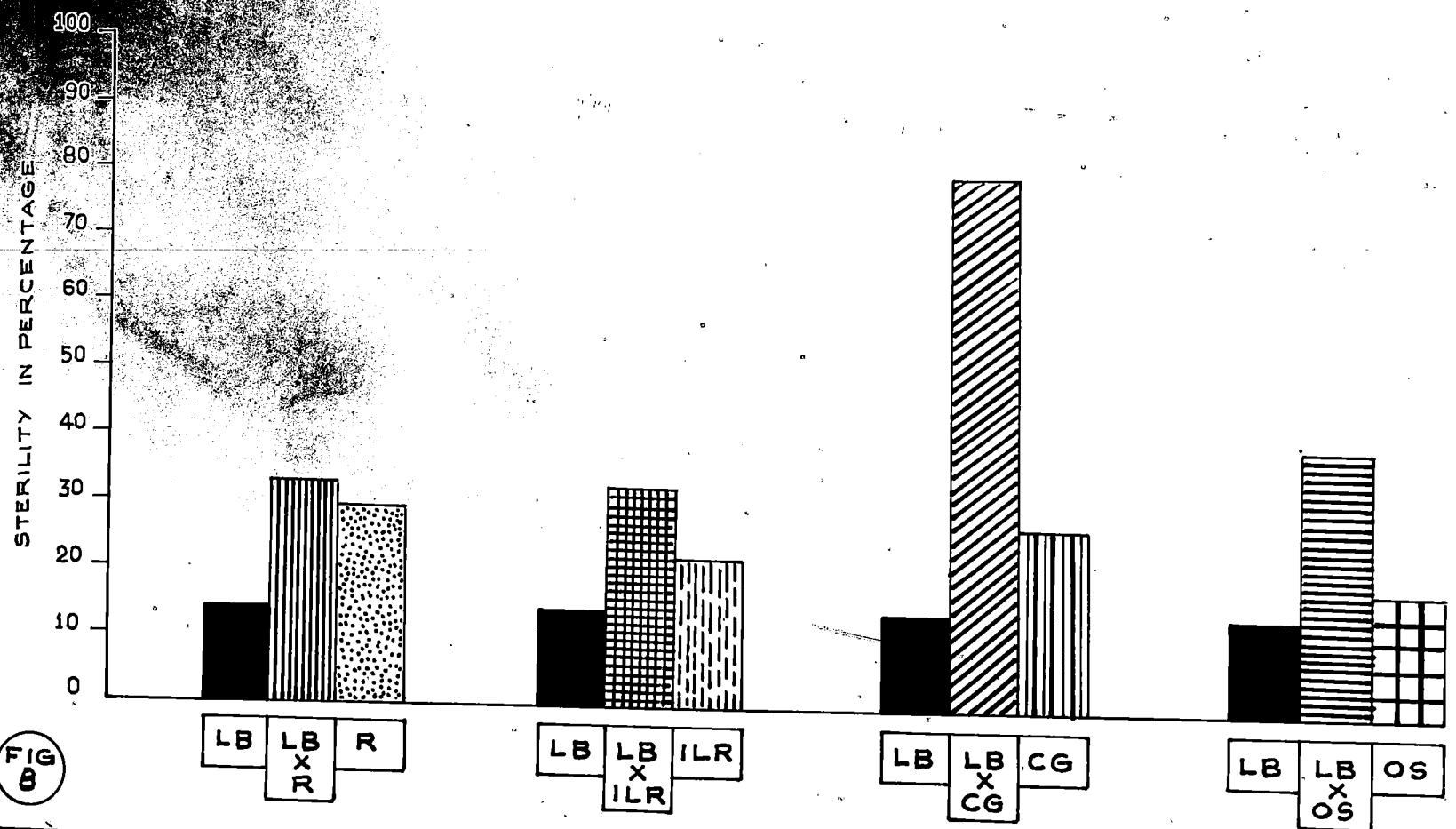


FIG 8

and four hybrids have been worked out. They are presented in the following tables.

TABLE XXVI

Chiasma frequency in the common seed parent Local blue

Serial number of cells studied	Rod II	Ring II	♀	Chiasma frequency	Total chiasmata
1	1	11	-	1+23	24
2	2	10	-	2+20	22
3	-	12	-	24	24
4	1	11	-	1+22	23
5	2	10	-	2+20	22
6	2	10	-	2+20	22
7	1	11	-	1+22	23
8	-	12	-	24	24
9	1	11	-	1+23	24
10	1	11	-	1+22	23
11	2	10	-	2+21	23
12	2	10	-	2+20	22
13	1	11	-	1+22	23
14	-	12	-	24	24
15	1	11	-	1+22	23
16	1	11	-	1+23	24
17	2	10	-	2+20	22
18	1	11	-	1+22	23
19	-	12	-	24	24
20	-	12	-	24	24
Total	21	219	-		463

Mean number of chiasmata/cell = 22.8705
Mean number of chiasmata/bivalent = 1.9058

TABLE XVII

The chiasma frequency of the variety Russian is given below

Serial number of cells studied	Rod TT	Ring TT	T	Chiasma frequency	Total chiasmata
1	5	6	2	5+12	17
2	4	7	2	4+14	18
3	2	8	4	2+16	18
4	3	8	2	3+16	19
5	2	9	2	2+18	20
6	2	8	4	2+16	18
7	2	9	2	2+18	20
8	5	6	2	5+12	17
9	4	7	2	4+14	18
10	2	8	4	2+16	18
11	3	8	2	3+16	19
12	2	9	2	3+16	19
13	5	6	2	5+12	17
14	2	8	4	2+16	18
15	4	7	2	4+14	18
16	2	9	2	2+18	20
17	2	8	4	2+16	18
18	2	9	2	2+18	20
19	2	9	2	2+18	20
20	4	7	2	4+14	18
Total	59	156	50		371

Mean number of chiasmata/cell = 18.225

Mean number of chiasmata/bivalent = 1.518

TABLE XXVIII

The chiasma frequency of variety Indian long red is given below

Serial number of cells studied	Rod TT	Ring TT	T	Chiasma frequency	Total no. of chiasmata
1	1	11	-	1+22	23
2	1	11	-	1+22	23
3	1	10	2	1+20	21
4	2	10	-	2+20	22
5	1	11	-	1+22	23
6	1	11	-	1+23	24
7	2	10	-	2+20	22
8	1	11	-	1+22	23
9	1	10	2	1+20	21
10	1	11	-	1+22	23
11	2	10	-	2+20	22
12	1	11	-	1+23	24
13	1	11	-	1+22	23
14	1	11	-	1+23	24
15	2	10	-	2+20	22
16	2	10	-	2+20	22
17	1	11	-	1+22	23
18	1	11	-	1+22	23
19	1	10	2	1+20	21
20	2	10	-	2+20	22
Total	26	211	6		451

Mean number of chiasmata/cell = 22.937
Mean number of chiasmata/bivalent = 1.911

TABLE XXIX

The chiasma frequency of variety Chinese giant is tabulated below

Serial number of cells studied	Rod ⊤⊤	Ring ⊤⊤	T	Chiasma frequency	Total no. of chiasmata
1	5	7	-	5+14	19
2	6	6	-	6+12	18
3	4	8	-	4+16	20
4	3	9	-	3+18	21
5	2	9	2	2+18	20
6	6	6	-	6+12	18
7	5	7	-	5+14	19
8	5	7	-	5+14	19
9	3	9	-	3+18	21
10	2	9	2	2+18	20
11	6	6	-	6+12	18
12	6	6	-	6+12	18
13	4	8	-	4+16	20
14	5	7	-	5+14	19
15	6	6	-	6+12	18
16	2	9	2	2+18	20
17	4	8	-	4+16	20
18	3	9	-	3+18	21
19	6	6	-	6+12	18
20	5	7	-	5+14	19
Total	88	149	6		386

Mean number of chiasmata/cell = 19.7
Mean number of chiasmata/bivalent = 1.64

TABLE XXX

Chiasma frequency of the variety Oskosh is presented below

Serial number of cells studied	Rod II	Ring II	I	Chiasma frequency	Total no. of chiasmata
1	6	6	-	6+12	18
2	4	8	-	4+16	20
3	2	10	-	2+20	22
4	2	10	-	2+20	22
5	2	10	-	2+22	24
6	2	10	-	2+20	22
7	4	8	-	4+16	20
8	1	11	-	1+23	24
9	5	7	-	5+16	21
10	7	5	-	7+12	19
11	5	7	-	5+16	21
12	3	9	-	3+19	22
13	2	9	2	2+18	20
14	3	8	2	3+17	20
15	5	7	-	5+14	19
16	2	10	-	2+20	22
17	5	7	-	5+16	21
18	4	8	-	4+16	20
19	2	10	-	2+20	22
20	2	10	-	2+20	22
Total	68	170	4		421

Mean number of chiasmata/cell = 21.33
Mean number of chiasmata/bivalent = 1.77

The chiasma frequency in hybrids are tabulated and presented in the following tables.

TABLE XXXI

Chiasma frequency in the cross between Local blue x Indian long red

Serial number of cells studied	Ring IV	Chain IV	III	Rod II	Ring II	Chiasma frequency	Total no. of chiasmata
1	1	-	-	1	9	4+1+18	23
2	1	1	-	-	8	4+3+16	23
3	1	-	2	-	7	4+4+14	22
4	1	-	-	1	9	4+1+18	23
5	1	-	-	2	8	4+2+16	22
6	1	-	-	2	8	4+2+16	22
7	2	-	-	1	7	8+1+14	23
8	1	-	-	1	9	4+1+18	23
9	1	1	-	-	8	4+3+16	23
10	1	-	-	2	8	4+2+16	22
11	1	-	2	-	7	4+4+14	22
12	1	-	2	-	7	4+4+14	22
13	1	-	-	1	9	4+1+18	23
14	1	1	-	-	8	4+3+16	23
15	1	-	-	2	8	4+2+16	22
16	1	-	-	1	9	4+1+18	23
17	1	1	-	-	8	4+3+16	23
18	1	-	-	2	8	4+2+16	22
19	1	-	-	1	9	4+1+18	23
20	1	-	-	1	9	4+1+18	23
Total	21	4	6	18	163		452

Mean number of chiasmata/cell = 22.805
Mean number of chiasmata/bivalent = 1.900

Chiasma frequency in the cross between Local blue x Russian are tabulated below.

TABLE XXXII

Serial number of cells studied	Ring IV	Chain IV	III	Rod II	Ring II	Chiasma frequency	Total no.of chiasmata
1	1	-	-	2	8	4+2+16	22
2	1	-	-	-	10	4+20	24
3	-	2	-	-	8	6+16	22
4	-	2	2	-	5	6+4+10	20
5	-	2	-	-	7	6+1+14	21
6	1	-	-	2	8	4+2+16	22
7	-	-	-	1	11	1+22	23
8	1	-	-	-	10	4+20	24
9	-	2	-	1	7	6+1+14	21
10	-	2	-	1	7	6+1+14	21
11	1	-	-	2	8	4+2+16	22
12	-	2	-	-	8	6+16	22
13	-	2	-	1	7	6+1+14	21
14	1	-	-	2	8	4+2+16	22
15	-	2	-	1	7	6+1+14	21
16	-	2	-	1	7	6+1+14	21
17	-	2	-	-	8	6+16	22
18	1	-	-	2	8	4+2+16	22
19	-	2	-	-	8	6+16	22
20	1	-	-	-	10	4+20	24
Total	8	22	2	17	160		439

Mean chiasmata per cell = 22.025
Mean chiasmata per bivalent = 1.835

TABLE XXXIII

Chiasma frequency in the hybrids of Local blue x Chinese giant

Serial number of cells studied	Ring IV	Chain IV	Chain III	Rod II	Ring II	Ring I	Chiasma frequency	Total no. of chiasmata
1	1	-	-	-	10	-	4+20	24
2	1	-	-	-	8	4	4+16	20
3	1	-	2	-	7	-	4+4+14	22
4	1	1	-	1	6	2	4+3+1+12	20
5	1	-	1	-	7	-	4+2+14	20
6	-	1	-	2	7	2	3+2+14	19
7	-	2	-	1	7	-	6+1+14	21
8	-	1	-	1	9	-	3+1+18	22
9	1	-	2	-	7	-	4+4+14	22
10	1	-	1	-	7	-	4+2+14	20
11	-	2	-	1	7	-	6+1+14	21
12	-	1	-	2	7	-	3+2+14	19
13	-	1	-	1	9	-	3+1+18	22
14	1	-	-	-	10	-	4+20	24
15	-	2	-	1	7	-	6+1+14	21
16	1	-	1	-	7	3	4+2+14	20
17	-	2	-	1	7	-	6+1+14	21
18	1	-	-	-	8	4	4+16	20
19	-	1	-	2	7	2	3+2+14	19
20	1	-	-	-	10	-	4+20	24
Total	11	14	7	13	157	25		421

Mean number of chiasmata/cell = 20.70
Mean number of chiasmata/bivalent = 1.725

TABLE XXXIV

Chiasma frequency in the cross between Local blue x Oskosh

Serial number of cells studied.	Ring IV	Chain IV	Rod III	Rod II	Ring II	I	Chiasma frequency	Total no. of chiasmata
1	1	-	-	-	10	-	4+20	24
2	1	1	-	-	8	-	4+3+16	23
3	1	-	-	1	9	-	4+1+18	23
4	1	-	2	-	7	-	4+4+14	22
5	1	-	-	1	8	2	4+1+16	21
6	-	2	-	1	7	-	6+1+14	21
7	1	-	1	-	7	3	4+2+14	20
8	-	2	-	-	8	-	6+16	22
9	1	-	-	-	10	-	4+20	24
10	1	1	-	-	8	-	4+3+16	23
11	1	-	-	1	9	-	4+1+18	23
12	1	-	-	-	10	-	4+20	24
13	1	-	-	2	8	-	4+2+16	22
14	1	-	-	1	9	-	4+1+18	23
15	1	-	-	-	10	-	4+20	24
16	1	1	-	-	8	-	4+3+16	23
17	1	-	-	1	9	-	4+1+18	23
18	1	-	-	2	8	-	4+2+16	22
19	1	1	-	-	8	-	4+3+16	23
20	1	-	-	-	10	-	4+20	24
Total	18	8	3	10	171	5		454

Mean number of chiasmata/cell = 23.10
Mean number of chiasmata/bivalent = 1.92

TABLE XXXV

Analysis of the mean number of chiasmata/ cell of parents and hybrids

Treatments	Range	Mean	Standard error	Coefficient of variation
LB	22-24	22.8705	0.088	1.73
LB x R	20-24	22.025	0.18	2.42
R	17-20	18.225	0.12	2.93
LB x ILR	22-23	22.805	0.029	0.53
ILR	21-24	22.937	0.102	2.006
LB x CC	10-24	20.70	0.14	3.14
CC	18-21	19.7	0.11	2.64
LBxOS	20-24	23.10	0.123	2.38
OS	18-24	27.33	0.15	3.18

TABLE XXXVI

The chiasma frequency (per cell) of parents and hybrids

Sl.No.	Treatments	Mean	Percentage of deviation of F_1 mean over	
			Better parent	Parental mean
1	LB	22.87		
2	LB x R	22.03	3.67(-)	7.201(+)
3	R	18.23		
4	LB x ILR	22.81	0.56(-)	0.39(-)
5	ILR	22.94		
6	LB x CG	20.70	9.48(-)	2.72(-)
7	CG	19.7		
8	LB x OS	23.10	1.01(+)	4.52(+)
9	OS	21.33		

Table XXXVI reveals that among parents maximum number of chiasmata per cell was exhibited by ILR and common seed parent LB the figures being 22.94 and 22.87 respectively. The minimum number of chiasmata was observed in the variety Russian (18.23).

When the hybrids were taken into account all of them except LB x OS registered a decrease in the number of chiasmata from their better parent.

The maximum decrease was shown by LB x CG (9.48 per cent) and the minimum decrease by LB x ILR (0.56 per cent). However, the cross LB x OS recorded a slight increase over its better parent by 1.01 per cent.

When the hybrid mean was compared with parental mean crosses LB x R and LB x OS showed an increase, by 7.201 per cent and 4.52 per cent respectively, while the other crosses exhibited slight decrease.

Comparison with the parental mean revealed that only one hybrid LB x ILR showed a decrease in the number of chiasmata/cell while the other three hybrids exhibited a slight increase.

(2) Abnormalities of chromosomes

The table XXXVII presents the abnormal behaviour of meiotic chromosomes at diakinesis, anaphase I and telophase I. Out of the 1200 chromosomes studied in each case abnormal behaviour of chromosomes was noticed maximum in the cross LB x ILR (in 315 chromosomes). This is closely followed by LB x R (311), LB x CG (302) and LB x OS (287).

All the hybrids showed the presence of ring and chain quadrivalents and trivalents while the cross

LB x ILR exhibited univalents, pycnotic behaviour, unequal distribution and anaphase bridge. In the hybrids LB x ILR and LB x CG there were a few fragments.

The cross LB x ILR had the maximum percentage of chromosomal abnormalities (26.258) which was closely followed by LB x R (25.916), LB x CG (25.166) and LB x OS (23.916).

TABLE XXXVII

Details of aberrant cells in the hybrids (out of 50 cells studied from each of the hybrids)

Hybrids	Ring quadrivalent (IV)	Chain quadrivalent (IV)	Trivalent (III)	Univalents (I)	Fragments	Pycnotic regions	Unequal distribution	Anaphase bridge	Number of chromosomes which behaved abnormally	Number of chromosomes which behaved normally	Percentage of abnormal chromosomes.
LB x R	22	52	5	-	-	-	-	-	311	889	25.916
LB x ILR	53	10	15	18	21	13	20	5	315	885	26.25
LB x CG	27	35	18	-	69	-	-	-	302	898	25.166
LB x OS	45	20	9	-	-	-	-	-	287	913	23.916

DISCUSSION

DISCUSSION

The present study of inter-varietal hybridization of Capsicum annuum was undertaken with a view of transferring the economic attributes, such as mosaic resistance, profuse bearing habit, and long life span, present in the variety 'Local blue' to other varieties like Russian, Indian long red, Chinese giant and Oskosh, which are endowed with a larger fruit size and higher ascorbic acid and sucrose content. In this programme the variety 'Local blue' was taken as the common seed parent.

Biometric observations relating to growth characters, yield attributes, yield and quality of chilli were statistically analysed and presented in this programme of study. Now it remains to discuss briefly the interpretations of the data so as to draw valid conclusions regarding the performance and behaviour of F_1 hybrids compared to the parents. The results are discussed hereunder.

I. QUANTITATIVE CHARACTERS

The results of the present investigation point towards the fact that the extent or degree of expression of heterosis in Capsicum, varies with

different parental combinations. This difference between the crosses may, perhaps, be due to the different degrees of genetic diversity between the parents. Similar results of varying degrees of heterosis with respect to several characters were recorded by Nagai and Kida (1926), Kakizaki (1928, 30, 31), Pal and Singh (1946) Venkataramani (1946) and Odland and Noll (1948) in crosses of Brinjal.

Vigour of the hybrids can be expressed in various ways. Although the number of seeds produced by the F_1 showed a decrease yet an increase was observed in the weight of seeds. As it is referred by Kakizaki (1931) the increased weight of F_1 seeds can be attributed to the large size of the embryo, due to heterotic effect.

Plant size is mainly constituted by height, spread and number of branches. In the present investigation two crosses Local blue x Russian and Local blue x Indian long red exhibited positive heterosis in seedling height. This observation of enhanced seedling height is in conformity with the results of Choudhary and Mishra (1966) and Viswanathan (1967) in Solanum who have attributed such vigour due to heterotic effect.

Observations regarding the ultimate plant height of hybrids revealed intermediate position between parents, which is quite in accordance with the Nilson Ehle's hypothesis of quantitative inheritance. But this finding is in agreement with the results of Pal and Singh (1946) and Mishra (1961) and contrary to that of Viswanathan (1967).

The number of branches is another equally important economic character. The more the number of branches the greater will be the number of leaves and as the fruits are borne on leaf axils, this will ultimately results in the production of increased number of fruits. Thus increased number of branches have an indirect bearing on the total crop yield. In the present study two hybrids Local blue x Chinese giant, and Local blue x Oskosh surpassed their respective parents in the production of branches registering an increase of 100 per cent. The diverse behaviour of pollen parents again points towards the varied response of the common seed parent. Similar heterotic effects in the production of branches have been recorded by Kalda (1926) and Kakizaki (1930, 31) in brinjal hybrids and Joshy et al (1958) in bhindi hybrids.

Increase in the number of leaves and leaf area will remarkably enhance the photosynthetic activity which will have a direct bearing in promoting the yield potential. In the present investigation the hybrids from the two crosses Local blue x Chinese giant and Local blue x Oskosh showed statistically significant superiority over their parents and hybrids, thus confirming the positive heterotic effect.

Considering the spread of the plant, the present study indicates that the character follows the typical pattern of quantitative inheritance; the hybrids being intermediary to the parents. However, this observation is contradictory to that of Kalya (1918) and Venkataramani (1946) in brinjal hybrids.

Earliness in blooming is also an important economic attribute. In the present investigation all the hybrids displayed pronounced earliness. Similar heterotic effects in earliness were recorded by Pal and Singh (1949) and Mishra (1961) in brinjal hybrids.

Semisterile hybrids between individuals of the same species have long been known in Oenothera Campanula (Darlington and Gairdner 1937), Galeopsis (Muntzing 1930, d, 1938) and many other genera.

As regards percentage of fruit set one cross Local blue x Oskosh out yielded their respective parents, while the other hybrids registered a reduction. Betlach (1966) recorded average fruit set of 39.7 per cent and 47.47 per cent in two hybrids of Capsicum. In the present investigation the fruit set in hybrids ranged from 44.82 per cent to 76.49 per cent. The increased fruit set may be attributed to the heterotic effect, while its decrease, to the pollen sterility possibly resulted from meiotic abnormalities of pollen mother cells.

The number of fruits produced by the hybrids remained intermediate between that produced by the parents, agreeing with the principles of the inheritance of quantitative characters. Similar results have been obtained by Venkataramani (1940) in brinjal hybrids.

All the hybrid fruits were intermediate in size when compared with the fruits of their parents. This observation is in full conformity with the findings of Popovova (1965) based on his studies on the inter-varietal hybrids of Capsicum. In the case of fruit size, taken as length x girth, the F_1 mean of one cross was approximating to the geometric mean of the parents. This is in agreement with the findings of Fatehe (1943) and Rao (1966) in brinjal hybrids.

No significant increase in fruit weight was noticed in the present study which is in conformity with the observations of Viswanathan (1967) and Gopimony (1968) in brinjal.

All the four hybrids in the present investigation, displayed the intermediate condition in the number of seeds per fruit. The decrease in the seed set can be attributed to cytological reasons. The high frequency of multivalent associations exhibited by the metaphase chromosomes might have disrupted the normal meiotic behaviour which in turn might have resulted in the production of inviable microsporangia. The high degree of reduction in pollen stainability appears to bear a correlation with this phenomenon.

II. QUALITATIVE CHARACTERS

The colour of the mature and ripe fruits, has a pronounced commercial significance.

The dominance of purple colour over non-purple colour was reported by many workers. Ramanujam et al observed that purple colour of immature fruits and flower petals in Puri red variety of Capsicum was monogenically dominant over non pigmented condition of NP 46 A. The dominance of purple colour was also reported by Tatebe (1936) in egg plants.

The observations in the present hybridization work, regarding three crosses Local blue x Russian, Local blue x Indian long red and Local blue x Chinese giant point towards the aforesaid conclusions, although the development of purple colour in fruits was in conjunction with the maturity of fruits. The same phenomenon holds good in corolla colour also.

The non expression of the purple colour in either fruits or corolla in one cross Local blue x Oshosh, apparently suggests the presence of some inhibitory genes which prevents the development of purple colour in corolla and fruits. Similar results were obtained by Ramanujam et al in his inter-varietal crosses of Capsicum. Furthermore the dominance of non-pigmented condition in rice juncture was reported by Dhulappanvar (1963).

The constant association of petal and immature fruit colour would appear to be a case of pleiotropy, in the case of the common seed parent Local blue as suggested by Ramanujam et al.

In all the crosses the leaf colour of the hybrids remained green in contrast to the purple leaf colour of the common seed parent Local blue. Based on

the crosses of Puri red and NP 46-A Ramanujam et al concluded that the purple leaf colour of Puri red was due to two complementary genes while NP 46-A carried in addition to the recessive alleles at these two loci, an inhibitory factor, in the presence of which the leaf lamina remained green. It is also interesting to note that the inhibitory factor which masks the purple leaf colour is non functional so far as the colour in the immature fruits and petal is concerned. One possible reason for the more complex control of leaf colour might be that green leaves may be more efficient, photosynthetically than purple coloured leaves (Ramanujam et al 1965).

The erect fruit position manifested no dominance over pendent nature. This observation is in agreement with the findings of Ramanujam et al in his crosses between Puri red and NP 46-A.

As opposed to the findings of Sakai (1937), in the present study, three crosses showed intermediate condition in fruit size. But the small size of the fruits of the common seed parent Local blue, was completely dominant in the cross Local blue x Oshosh, which is again contrary to the partial dominance proposed by Sakai (1937) in crosses of Capsicum.

MOSAIC RESISTANCE

The most important economic objective of this study has been to transfer the mosaic resistance from the Local blue variety to the other four varieties. Ramanujam and Joshi (1965) based on their works on inter-varietal hybridization of Capsicum, postulated that the mosaic resistance of Puri red was under monogenic control.

Sinclair and Walker (1955) in a study of inheritance of virus in cow pea have reported that the resistance is due to a single dominant gene.

In the present investigation the disease resistance of the common seed parent Local blue could be incorporated in all the four hybrids. Further, the results of the studies indicate the dominant nature of disease resistance over susceptibility. The nature of control of disease resistance is to be confirmed by the study on subsequent segregating progenies.

The linkage association of mosaic resistance and erect fruit position was reported by Ramanujam et al (1965). This appears to be the case in the mosaic resistant variety of Local blue.

CHEMICAL STUDIES

Capsicum provides one of the richest sources of Vitamin C (ascorbic acid). Different varieties

exhibit varied range of this nutrient content. The same is the case with sucrose. Incorporation of these two characters provides another important objective of the present investigation.

As opposed to the findings of Betlach (1967) and as in agreement with Chroboczek et al (1966) all the hybrids of the present study manifested hybrid vigour in the ascorbic acid content. Moreover in accordance with the results of Michna (1966) and Butkevic (1967) the increase in the ascorbic acid content was observed along with the ripening of fruits.

The heterotic effect of ascorbic acid content was recorded by Lal (1968) in Dolichos lab lab. He reported that two hybrids registered an increase over their better parents. In the present hybridization work also the Vitamin C content of two hybrids displayed positive heterosis. This apparently suggests that the pollen parents have different genetic constitution for the expression of this trait.

Capsaicin is the active alkaloid ingredient responsible for the pungency of chillies. Webber (1911) and Deshpande (1935) recorded that pungency is a heritable character controlled by a single dominant gene.

Out of the four crosses, only Local blue x Oskosh provided a positive heterosis in the expression of this trait. The analysis of Capsaicin in parents and other hybrids does not seem to be in agreement with the observations of Webber (1911) and Deshpande (1935). On the other hand it leans more towards the conclusion of Ramanujam and Thirumalachar (1966) who suggested that the genetic control of capsaicin production is under polygenic system. It appears more reasonable to conclude that the reduction in the capsaicin content in the above hybrids may be due to the presence of high sucrose content. This view is supported by the results of Sievers and MicIntyre (1921) who suggested that the presence of sugar masks the expression of pungency.

The sucrose content in all the four hybrids exhibited heterosis. Two hybrids Local blue x Russian and Local blue x Indian long red surpassed their better parents, again indicating the diverse genetic architecture of the male parents.

CYTOLOGICAL STUDIES

The cytological studies of the parents and hybrids unveiled many interesting phenomena.

All the four crosses provided, pronounced hybrid vigour as regards the size of pollen grains which is in conformity with the findings of Viswanathan (1967) in brinjal.

The hybrid fertility is correlated with the number of bivalents and regular separation during the meiosis of the hybrids. Thus the degree of synapsis is a measure of the degree of hybrid fertility as postulated by Clausen.

The cytological observations conducted in the microsporocytes of hybrids in the present study reveals a definite correlation of meiotic abnormalities with the hybrid fertility. The percentage of pollen sterility was obviously higher in all the hybrids which had a direct bearing on the fruit set and number of seeds per capsule.

Meiotic disturbances like, formation of multivalents at diakinesis and bridges and fragments at anaphase I, reflected readily on the pollen sterility and percentage of fruit set. Chiasma frequency is seen related to the number of univalents, rod bivalents, trivalents and chain quadrivalents at diakinesis indicating a direct relationship of the degree of synapsis and hybrid fertility as postulated by Clausen.

Meiosis of microsporocytes in the present hybrids was characterised by the high frequency of occurrence of ring and chain-quadrivalents, hetero-pycnotic behaviour, univalents and fragments.

The presence of multivalent configurations of the meiotic chromosomes point towards the homology of the participant chromosomes.

A plausible explanation to the development of homology between three or more chromosomes can reasonably be offered to the rearrangement of chromosomes following breaks. The multivalent association including ring and chain quadrivalents suggests a possibility of the presence of translocations. The structural variations are manifested in anaphase bridges in one cross, which can be ascribed to the formation of dicentric chromosomes and univalents. The high frequency of fragments in one cross Local blue x Chinese giant presents a positive correlation to the pollen sterility and affects the ultimate fruit set.

Molhova (1965) recorded complete or partial sterility in the F_1 and F_2 owing to the disturbed meiotic behaviour of microsporocytes.

The reduction in pollen stainability and number of seed set per capsule in hybrids are generally correlated to the formation of quadrivalents at metaphase I as noticed by Yermanos and Gill (1967). This observation is in full agreement with the findings of the present study.

ECONOMIC SIGNIFICANCE

The economic attributes of Capsicum annuum are scattered in different varieties. But they are often accompanied by other undesirable qualities. For example, the pollen parents used in the study have large fruit size, high ascorbic acid and sucrose content, but are poor yielders and prone to mosaic disease. Mosaic is the most dreadful disease of Capsicum which forms the important impediment in the way of large scale cultivation of this paramount spice crop. The common seed parent Local blue possessed mosaic resistance and prolific bearing nature along with good capsaicin content. The wealth of variability among the varieties presented sufficient scope for the recombination of these economic traits.

All the F_1 hybrids, like the common seed parent was immune to mosaic disease. Further, ascorbic acid and sucrose content also have been brought in the

hybrids along with capsaicin. It is also worth mentioning that the prolific nature of the common mother plant could be incorporated partly. The same can be enhanced by subsequent backcrossing.

The results of the present investigation reveal enough economic proposition.

It deserves mention that the results are promising and point towards the possibility of selecting desirable types combining the economic attributes of both the parents namely mosaic resistance, prolific bearing, long life span, higher ascorbic acid and sugar content coupled with capsaicin, from the segregating generations of subsequent backcrosses.

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

1. The cytomorphological and chemical aspects of four F_1 hybrids of crosses involving five varieties of *Capsicum annuum*, L. were studied. The variety 'Local blue' which possessed mosaic resistance, prolific bearing habit, long life span and high pungency was selected as the common seed parent. The selected pollen parents were, Russian, Indian long red, Chinese giant and Oskosh which were gifted with a higher content of ascorbic acid and sucrose and larger fruit size, but lacking the qualities of the common seed parent.

2. All the four F_1 hybrids manifested a marked degree of heterosis in many economically important attributes like, earliness in blooming, number of leaves, number of branches, leaf area and chemical constituents like ascorbic acid and sucrose.

3. An intermediate condition was observed with regard to height, spread, number of fruits, fruit size and number of F_2 seeds.

4. The fruit size of F_1 hybrids was more approximating towards the arithmetic mean than towards the geometric mean except in one cross (Local blue x Chinese giant).

5. The deep purple colour of the common seed parent 'Local blue' was found to be dominant in three crosses. However, this colour failed to develop in one cross namely Local blue x Oskosh which apparently suggests the presence of some inhibitory factors in the variety Oskosh which prevented the expression of purple colour.

6. In all the crosses the fruit size was tending towards the small fruit size of the seed parent, Local blue and the bigger size of the fruits as such was not found to be dominant in any of the crosses.

7. The occurrence of double fruits (in Local blue x Indian long red) and petalloid stamens (in Local blue x Russian and Local blue x Indian long red) might be due to some developmental variations.

8. All the F_1s, like the common seed parent Local blue, exhibited resistance against mosaic disease.

9. The chemical studies recorded pronounced heterosis in the ascorbic acid and sucrose content in all hybrids. But the capsaicin content of the hybrids remained intermediate to that of the parents. The absence of increase in capsaicin content in hybrid fruits may be attributed to the presence of high sucrose

content which presumably should have masked the expression of pungency.

10. The pollen grains of all hybrids displayed an increase in size, probably due to heterosis. The hybrids exhibited a lesser chiasma frequency per cell and per bivalent and higher pollen sterility when compared to their parents indicating the linear relationship of homology in pairing and the production of fertile microspores. Thus the degree of synapsis of homologous chromosomes is found to have a bearing on the fertility of progenies.

11. Pollen sterility was more pronounced in hybrids which had a direct bearing on the percentage of fruit set. Cytological observations of meiotic chromosomes unveiled many interesting phenomena. The multivalent configurations at metaphase I, chromosome bridge and fragments at anaphase I and unequal distributions might have disrupted the production of normal viable microspores.

12. It deserves mention that the results on the whole are promising and point towards the possibility of selecting a mosaic resistant variety of Capsicum which combines all the economic characters of both parents (high productivity, long life span,

higher content of ascorbic acid and sucrose combined with capsaicin) from the segregating backcross generations and provide ample scope for the future line of work in this crop.

The promising results of this study indicate the better possibilities of evolving a mosaic resistant variety of Capsicum combining all the other economic attributes of the parents (high productivity, long life span, higher content of ascorbic acid, sucrose and Capsaicin), through repeated backcrosses. It deserves mentioning in this context that this study which reserves ample scope for the future line of work may be carried out to the full extent to make it a boon to the cultivator and consumer as well.

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*Original not seen

PLATES

PLATE No;

Local blue

x

Russian

F_1 hybrid plant of
Local blue x Russian

Local blue

Indian long red

F_1 hybrid plant of Local blue x Indian long red

PLATE NO: 3

Local blue

Chinese giant

F_1 hybrid plant of Local blue x Chinese giant

PLATE NO: 4

Local blue

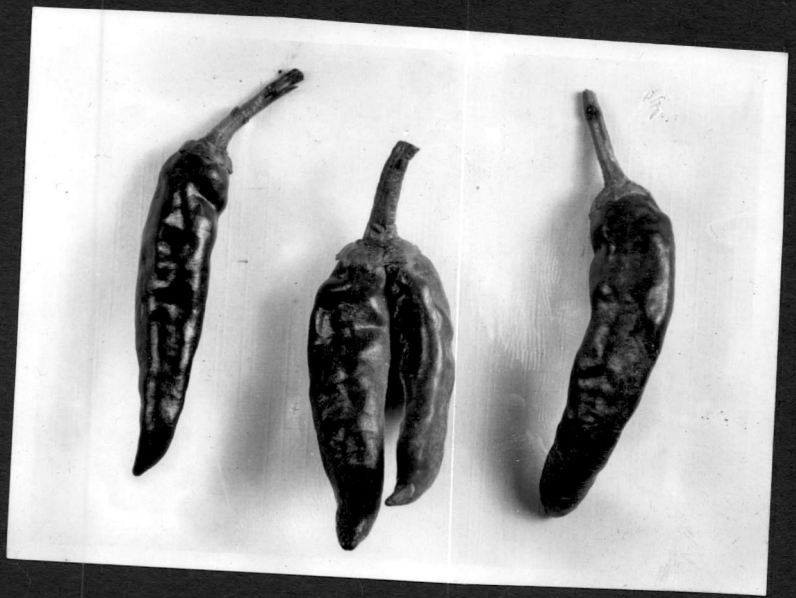
Oskosh

F_1 hybrid plant of Local blue x Oskosh

PLATE NO: 5

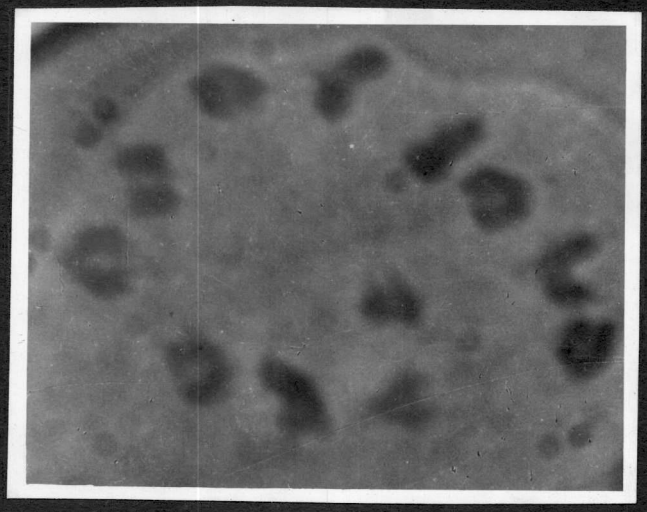
Two fruits in the same axil of the hybrid plant of Local blue x Chinese giant

Petalloid anthers in the hybrid plant of Localblue x Russian

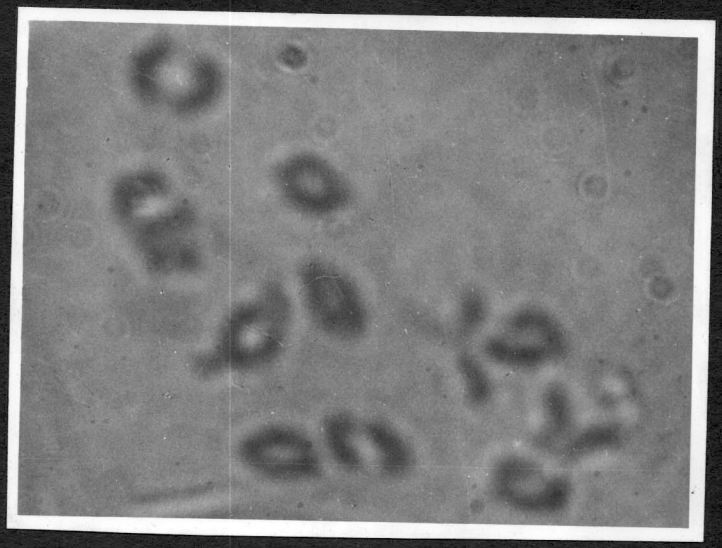


Double fruits in the same calyx of the hybrid plant of Local blue x Indian long red

PLATE NO: 6

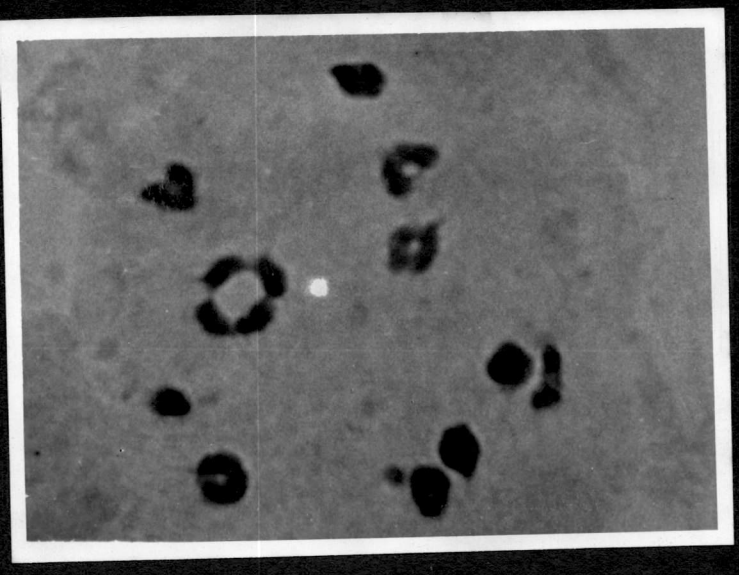


Metaphase I showing 12 bivalents in Local blue



Metaphase I showing 12 bivalents in Chinese giant

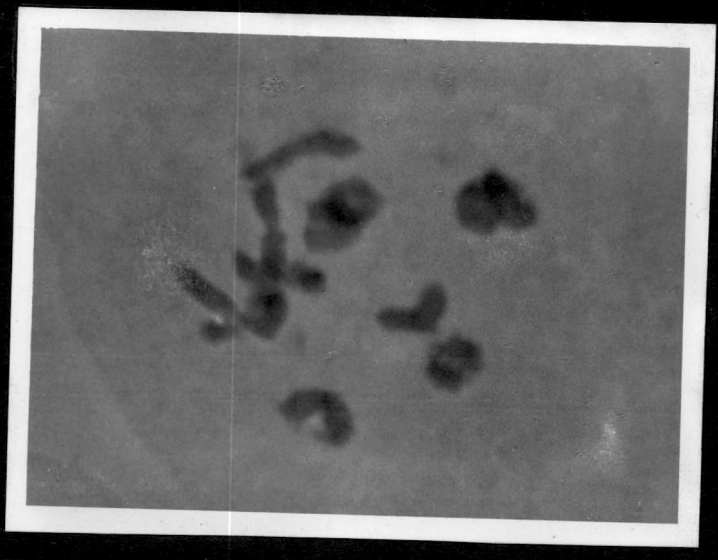
PLATE NO: 7



Metaphase I showing ring IVs in the F_1 hybrid of Local blue x Russian

Metaphase I showing the ring IVs in the F_1 hybrid of Local blue x Indian long red

PLATE NO:8

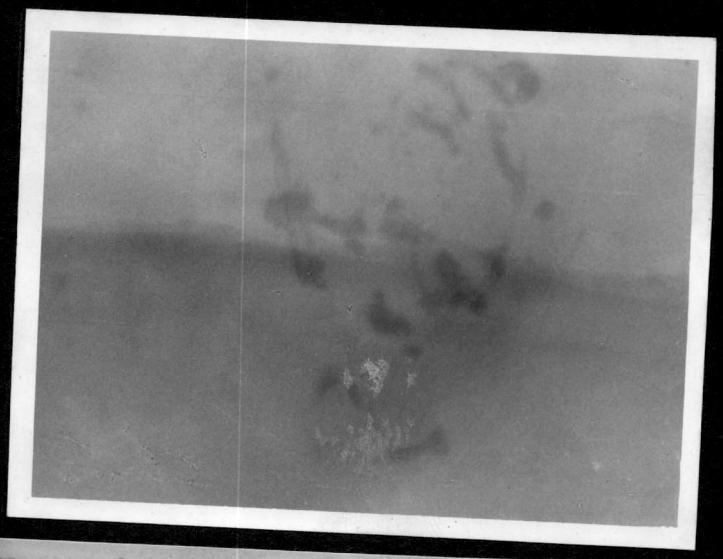


Metaphase I showing the chain IVs in the F_1 hybrid of Local blue x chinese giant

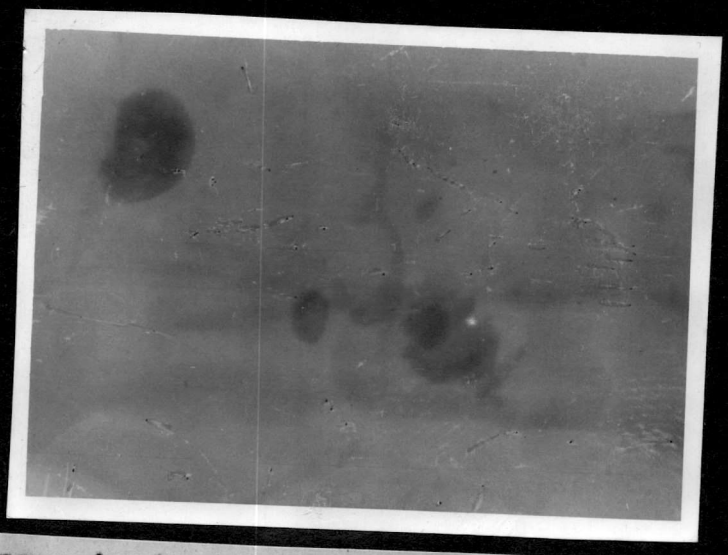
naphase I showing the bridge in the $_1$ hybrid of Local blue x Indian long red

PLATE NO: 9

Unequal distribution in the microsporocytes of F_1 of Local blue x Chinese giant

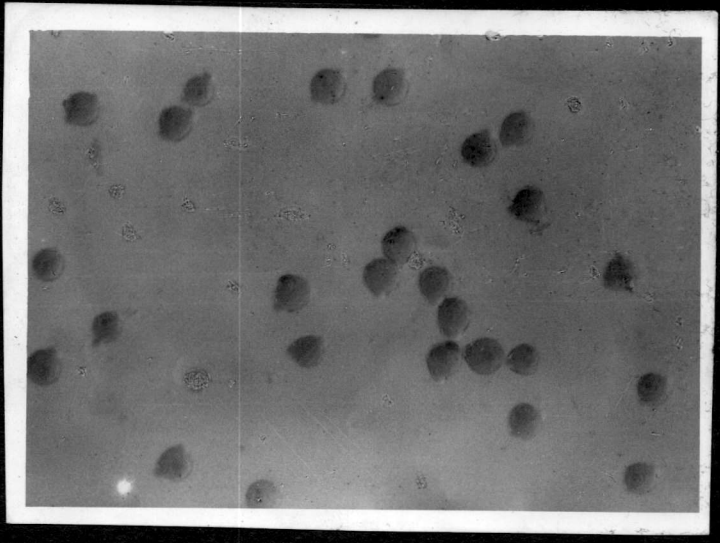


Fragments in the microsporocytes of F_1 hybrid of Local blue x Chinese giant

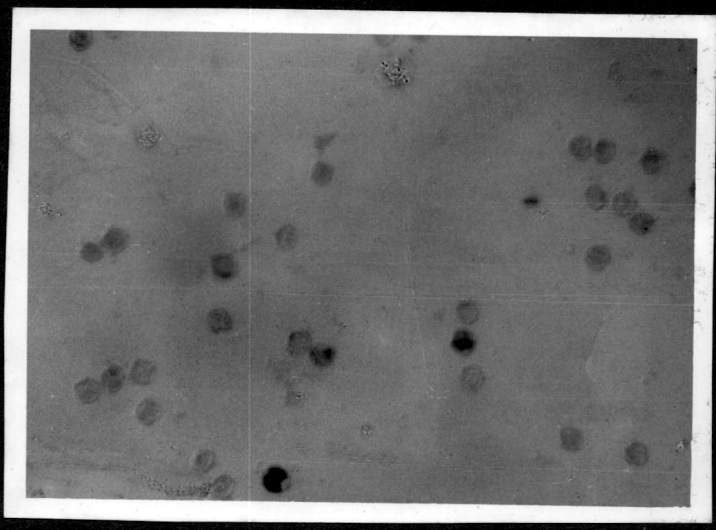


Pycnosis in the microsporocytes of F_1 hybrid of Local blue x Chinese giant

PLATE NO: 10

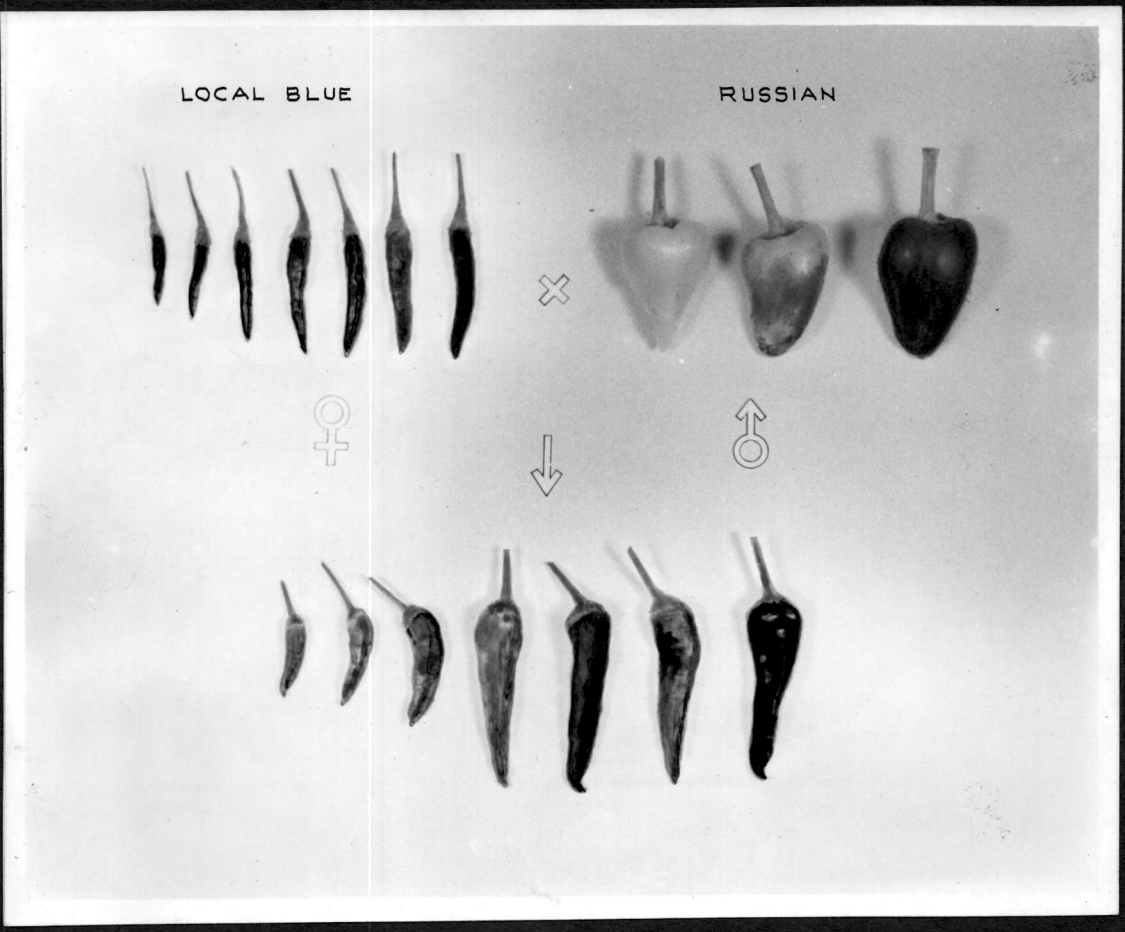


Higher percentage of fertile pollen grains in the common seed parent Local blue



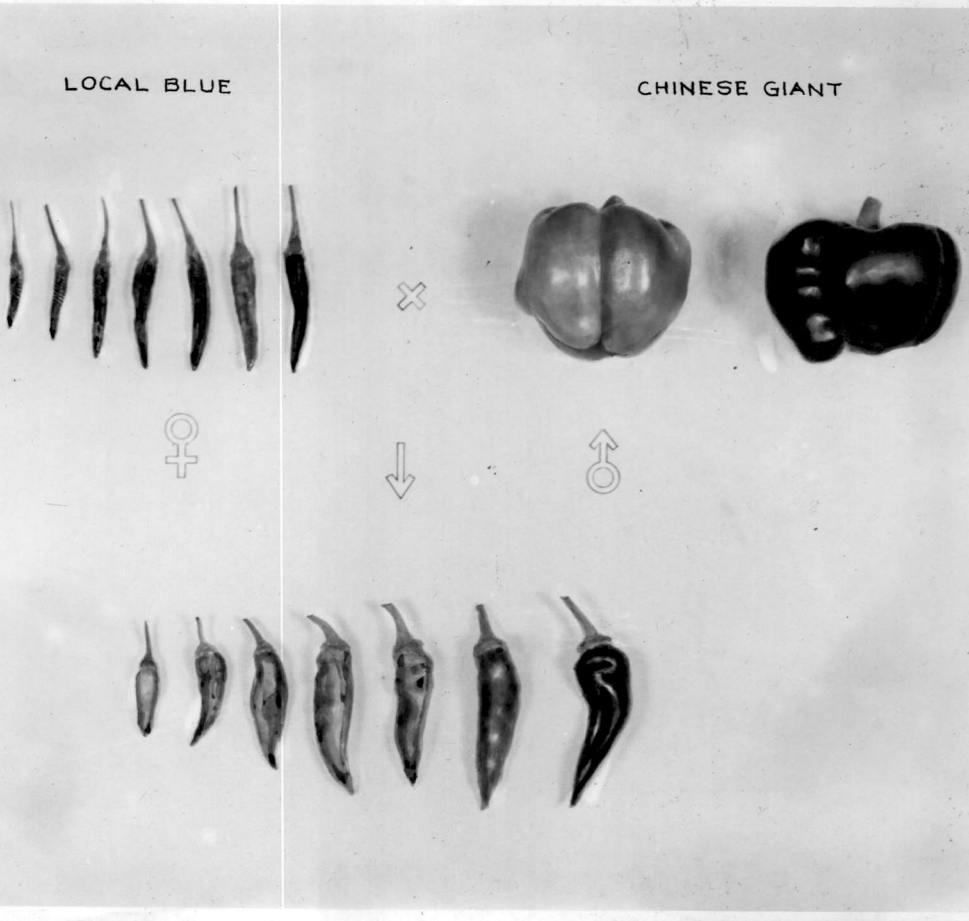
Lower percentage of fertile pollen grains in the F_1 hybrid of Local blue x Chinese giant

PLATE NO: 11



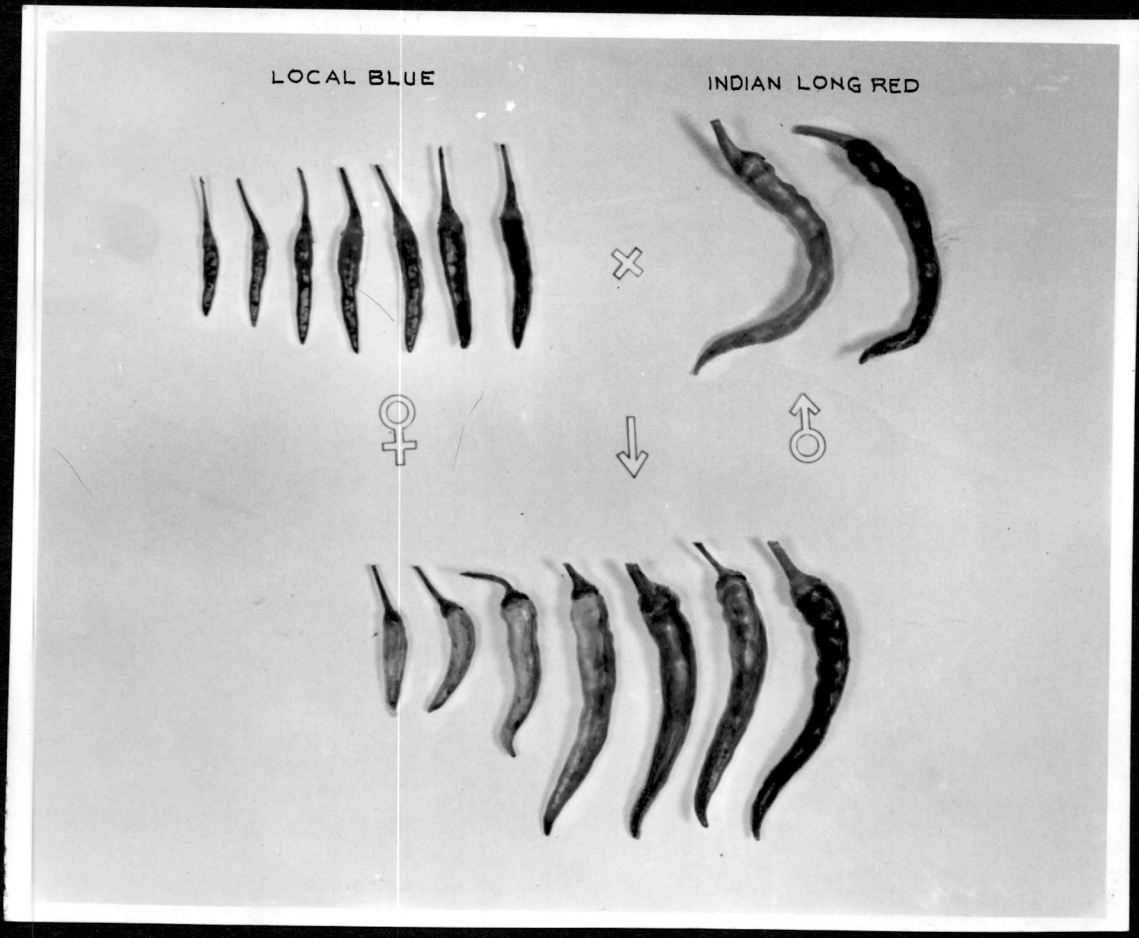
Mature and immature fruits of parents and hybrids showing size, shape and development of pigmentation

PLATE NO: 12



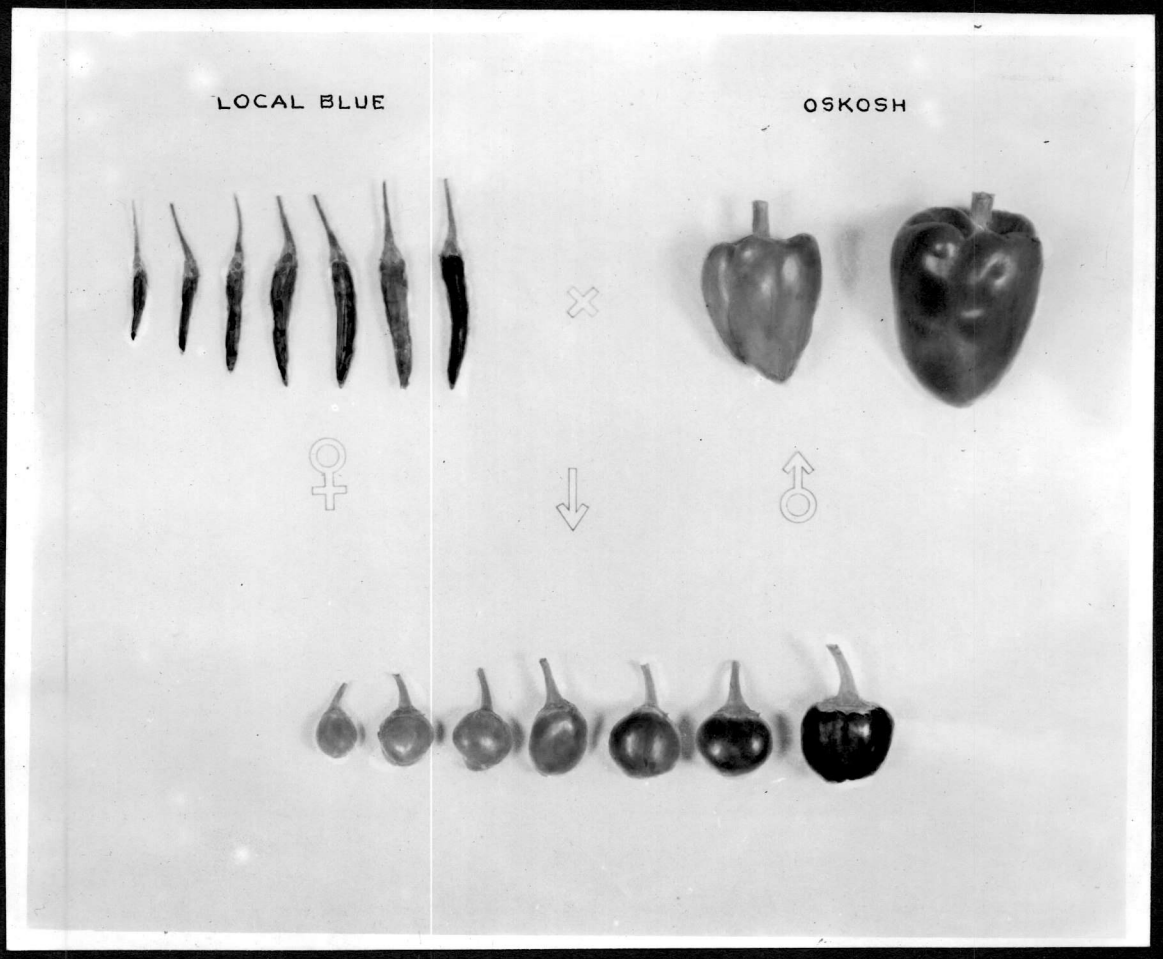
Mature and immature fruits of parents and hybrids showing size, shape and development of pigmentation

PLATE NO: 13



Mature and immature fruits of parents and hybrids showing size, shape and development of pigmentation

PLATE NO: 14



Mature and immature fruits of parents and hybrids showing size, shape and development of pigmentation