STUDIES ON HETEROSIS, GENE ACTION AND PROTEIN PROFILES IN BITTERGOURD (*Momordica charantia* L.)

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Dedicated
to
someone who sacrificed
his present for my better future
'My husband Mukesh'

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CERTIFICATE

This is to certify that the thesis entitled **"STUDIES ON HETEROSIS, GENE ACTION AND PROTEIN PROFILE IN BITTERGOURD (*Momordica charantia* L.)"**, submitted in partial fulfilment of the requirements for the degree of **DOCTOR OF PHILOSOPHY** with major in **VEGETABLE SCIENCE** and Minor in **GENETICS & PLANT BREEDING** of the College of Post Graduate Studies, G. B. Pant University of Agriculture and Technology, Pantnagar, is a record of *bona fide* research carried out by **MS. DEEPALI TEWARI,** Id.No. 19327, under my supervision and no part of the thesis has been submitted for any other degree or diploma.

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

(Hari Har Ram)
Chairman
Advisory Committee

CERTIFICATE

We, the undersigned, members of the Advisory Committee of **MS. DEEPALI TEWARI,** Id.No. 19327, a candidate for the degree of **DOCTOR OF PHILOSOPHY** with major in **VEGETABLE SCIENCE** and minor in **GENETICS & PLANT BREEDING** agree that the thesis entitled **"STUDIES ON HETEROSIS, GENE ACTION AND PROTEIN PROFILE IN BITTERGOURD (*Momordica charantia* L.)",** may be submitted in partial fulfilment of the requirements for the degree.

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INTRODUCTION

Chapter 1

INTRODUCTION

Bittergourd (*Momordica charantia* L. 2n = 2x = 22) known for its high pharmacological value is cultivated on a large scale in India. A native of the world tropics, bittergourd was iong ago introduced into Brazil, and from there it fanned out into the rest of new world. Although its native country is uncertain, the regions of eastern India and southern China are suggested as possible centres of domestication (Mini Raj *et al.*, 1993). In India, many species of the genus *Momordica* are found (Chadha and Lal, 1993). These include *M. charantia,* the familiar common bittergourd, *M cochinchinensis,* the sweetgourd of Assam and north-eastern states and *M. dioica,* the Kakrol of the tribal regions of Bengal, Bihar and Orissa. Bittergourd is a monoecious crop, with the higher proportion of male flowers than the female ones. It ranks first among the cucurbits so far as its nutritive value is concerned (Aykroyd, 1963). It is rich in vitamin C, Iron and Phosphorus. Besides the nutritional superiority, it is known for its medicinal importance. The most important medicinal value of the bittergourd is its hypoglycaemic activity which was first observed by Rivera in 1941. For this reason it has been patented in USA.

The major emphasis on the improvement of bittergourd in India was initiated in 1970s and now the improvement work is in progress at several State Agricultural Universities and ICAR Institutes

F_1 hybrid breeding is prominent among the methods used in the improvement of vegetable crops, especially in out breeding species. Pearson (1983) cited a report by Hays and Jones (1916) on first-generation crosses in cucumber as probably the first suggestion that hybrid vigour can be exploited in vegetable breeding. Pearson himself, in 1932,proposed field scale production of hybrid seed in cabbage using the natural self incompatibility system and Jones and Clarke (1943) described practical methods for the commercial production of F_1 hybrid onion varieties using cytoplasmic genetic male sterility.

Modern horticulture is influenced by rising cost of labour and energy, increasing international competition and changing demands of consumers and processing industries. New varieties must be superior in reliability of yield and quality, and for some crops in their adaptability to mechanical harvesting. Hybrids offer opportunities for improvements in productivity, earliness, uniformity and quality and for the rapid deployment of dominant genes for resistance to diseases and pests (Riggs, 1988). Hybrid breeding exploits heterosis and is a way for private breeders to have control on their products without the necessity for legal patents or plant breeders' right (Janick, 1998). The vegetable crops where hybrids are dominating the market include asparagus, broccoli, brussels sprout, cabbage, carrot, collards, cucumber, eggplant, muskmelon, onion, pumpkin, spinach, summer squash, sweet corn/pop corn, tomato and water melon (Janick, 1998).

Various techniques to produce hybrids have been developed depending on the crop including hand emasculation, rouging of staminate plants in dioecious lines, use of gynoecious or highly female lines, cytoplasmic genetic male sterility, genic male sterility, protogyny and self incompatibility.

Cucurbits form a distinct group in respect of methods of improvement. They have wide ranging sex forms and sex expression, which favour outbreeding. Another characteristic of this group is that they do not suffer much from inbreeding depression. So pureline selection can be used as method of improvement (Verma, 1998). Hybrid breeding is assuming importance in recent years after the enforcement of new seed policy and involvement of private sector in vegetable hybrid development on a wider scale. Various methods are applied to develop hybrids in cucurbits. Use of gynoecious and monoecious inbreds is common in cucumber and muskmelon. In pumpkin and squashes, hybrids are produced by regulating sex expression with the help of growth regulators (ethephon). Production of hybrid is much easier, in bittergourd as it involves removal of male flowers from female parent.

The analysis of combining ability helps in selecting suitable genotypes as parents. A speedy improvement can be brought about by assembling the genetical variability, locating the best combiners and exploiting the heterosis. Combining ability analysis (Sprague and Tatum, 1942) is one of the powerful tools available which gives the estimates of combining ability effect and aids in selecting desirable parents and crosses for further exploitation (Munshi and

Verma, 1999). Diallel analysis is widely used to estimate combining ability effects of the parents and the crosses (Griffing, 1956). It further helps in estimating the genetic components of variation, the degree of dominance, the proportion of dominant and recessive genes, the distribution of genes with positive and negative effects and the block of genes/the effective factors governing the expression of a particular trait. Further, the Vr/Wr graphical analysis indicates the degree of dominance and distribution of the dominant and recessive genes among the parents (Hayman, 1954b). This overall information reflects what is broadly known as gene action and plays a decisive role in pursuing an appropriate breeding procedure applicable to both inbreeder as well as outbreeder crops. Bittergourd is ideally suitable for adoption of breeding procedures as applicable to inbreeders and outbreeders because it does not respond to inbreeding, usually manifests heterosis and morphologically suits for hybrid seed production.

Along with carrying an appropriate breeding strategy in bittergourd, characterization of cultivars using seed protein electrophoresis is important. Electrophoresis of seed or seedling extracts followed by appropriate protein or activity stains has been suggested a possible method for distinguishing cultivars These techniques are all based on the concept that each cultivar is distinct and relatively homogenous at the genetic level. Thus, by screening enough loci one should be able to uniquely define each cultivar (Weeden, 1984). Seed protein

(Gepts, 1990) and isozyme variants (Wendel and Weeden, 1989) that migrate at different rates under electrophoresis have been extensively used for characterization of species during last quarter century (Bretting and Widrlechner, 1995). Electrophoresis is also of significant use in testing purity of a hybrid seed lot. Generally the profiles of the storage proteins or total soluble proteins extracted from seed are stable, least influenced by the environment and are reproducible. These profiles are examined for the purpose of variety identification as well as genetic purity testing (Dadlani, 1998).

Keeping the above considerations in view the present investigation entitled "Studies on heterosis, gene action and protein profiles in bittergourd (*Momordica charantia* L.) was undertaken with the following objectives :

1. To estimate better parent heterosis or heterobeltiosis and standard heterosis.
2. To determine general and specific combining ability variances and effects.
3. To find out the genetic components of variation and to carry out Vr/Wr graphical analysis.
4. To characterize the parental cultivars by performing sodium dodecyl sulphate poly acrylamide gel electrophoresis (SDS-PAGE) of total proteins of seeds.

REVIEW OF LITERATURE

Chapter 2

REVIEW OF LITERATURE

Pertinent literature on bittergourd is reviewed under four sub heads. Since information available on bittergourd on these aspects is inadequate, related literature on few other cucurbits has also been included. The sub heads are :

2.1 Heterosis

2.2 Combining ability

2.3 Genetic components of variation and Vr - Wr graph.

2.4 Varietal identification through Sodium dodecyl sulphate poly acrylamide gel electrophoresis (SDS-PAGE)

2.1 Heterosis

The first suggestion, that hybrid vigour can be exploited in vegetables was given by Hays and Jones (1916) in cucumber. F_1 hybrid eggplants were commercially used in Japan before 1925 (Kakizaki, 1930). Practical application at field scale was first proposed in 1932, using the self incompatibility system in cabbage (Pearson, 1932) and in 1943 using the cytoplasmic male sterility mechanism in onion (Jones and Clarke, 1943). The first hybrid release in India in private sector was Karnataka (tomato) and Bharat (*Capsicum*) by Indo-American hybrid seeds company, Banglore and in public sector, Pusa Meghdoot and Pusa Manjari (bottlegourd) were the first releases. Since then heterosis is being exploited on large scale in vegetables by private as well as public sectors in India and abroad.

The term heterosis refers to the phenomenon in which the F_1 populations exhibit increased or decreased vigour over the better parent or over the midparental value. Shull (1914) coined this term and referred to this phenomenon as the stimulous of heterozygosis and in his words it has been the "interpretation of increased vigour, size, fruitfulness, speed of development, resistance to diseases and insect pests or to the climatic vigour of any kind manifested by the outbreeding organisms as compared with the corresponding inbreds as a specific results of the unlikeliness in the constitution of the uniting parental gametes".

The term heterobeltiosis has been proposed to describe the superiority in relation to better parent of the cross (Bitzer *et al.*, 1968).

There are at present two principal hypotheses concerning the genetical basis of heterosis. The one holds that heterosis is caused by bringing together the dominant favourable genes of both parents in the hybrid. The second theory holds that heterozygosity *per se* is responsible for heterosis (East and Hayes, 1912; East and Jones, 1919; Shull, 1948). East (1936) sought to explain heterosis in terms of the complementary action of alleles at the same locus, a phenomenon which has variously been described as "superdominance" (Fisher, Immer and Tedin, 1932) and "overdominance" (Hull, 1945).

The major point of differences lies in their basic assumption whereby in one it is assumed that heterosis results from the sheltering of deleterious effects of the recessive gene by dominant counterparts, while in other it is not the sheltering effect but the amount of cumulative support and complementation between the alleles which is responsible for the expression of heterosis.

Jinks (1983) revealed that heterosis would be dependent on heterozygosity if hybrid vigour were due to true overdominance or to tight linkae in the repulsion phase at some incompletely dominant loci. Much evidence suggested that apparent overdominance is, in fact, due to non-allelic interaction and linkage disequilibrium and that heterosis is principally a result of the bringing together of unidirectionally dominant alleles dispersed between the parental lines. If this simple additive-dominance explanation holds, with little contribution due to tight linkages or to true over dominance, then heterozygosity is not an essential prerequisite for high performance, uniformity and stability of performance (Jinks, 1983).

Some of the earliest and most persistent claims that over dominance is the cause of heterosis, came from analysis of diallels as did also the earliest evidence that such overdominance could be attributed to biases ariving from non-allelic interactions (Jinks, 1955). When non-allelic interactions are absent, the inbred lines are in linkage equilibrium and the gene frequencies are approximately equal, the diallel analysis of Jinks and Hayman (1953) provides estimates of D and H and hence of dominance ratio, that are as good as those from any alternative design for interpreting the genetical basis of heterosis.

2.1.1 Bittergourd (*Momordica charantia* Linn.)

In India, the first attempt of exploitation and utilization of hybrid vigour was carried out by Pal and Singh (1946) in bittergroud. They reported hybrid vigour as much as 191.30 per cent in terms of increase in the yield of the best hybrid combination. Heterosis was also found for length and girth of fruit, number of fruits per plant and number of female flower.

Aiyadurai (1953) evaluated 20 crosses in selected parents and found that some hybrids produced large sized fruits with thick flesh and showed hybrid vigour. It indicated the possibility of utilizing hybrid vigour to produce better quality fruits by careful selection and hybridization.

Agrawal *et al.* (1957) reported that F_1's derived from crosses between cultivated species of bittergourd were intermediate in fruit size, shape and flavour between the parental cultivars.

Lal *et al.* (1976) crossed four varieties i.e. Midget, Green Local, White Local and Bundelkhand Local in all combinations. All crosses of Midget failed to produce seeds and seeds of crosses Green Local x White Local and Green Local x Bundelkhand Local germinated. Heterosis was observed for number of primary branches, length of vine, leaf size, internode length, number of fruits per plant, fruit size, fruit weight and total yield over their respective parents.

Sirohi and Choudhury (1978) observed that range of F_1 hybrids were larger than that of parents in all the characters except for fruits per plant. Negative heterosis for days to first harvest was found. Range of heterosis was 0.30 to 128.41 per cent in the best heterotic crosses for all characters over their respective better parent. It varied from 1.66 to 23.37 per cent for vine length, 0.30 to 7.85 per cent for days to first harvest, 1.25 to 39.39 per cent for fruit length, 2.94 to 26.63 per cent for flesh thickness, 0.86 to 32.44 per cent for fruit weight and 0.08 to 128.41 per cent for total yield per plant. The F_1 hybrid (Pusa Do Mausami x S144) was found to be the best and gave 84 per cent higher yield than better parent.

Singh and Joshi (1980) studied heterosis in diallel set of five cultivars and observed that heterosis for yield was not high enough to be exploited at commercial scale.

Lawande and Patil (1989) studied eight yield components in eleven bittergourd inbred lines and their F_1 hybrids and reported that the highest yield (4.15 kg/plant) was obtained in Co 1 x Green Hissar selection. Lawande and Patil (1990) observed heterosis for fruit yield and other component characteristics of 55 F_1 hybrids and concluded that maximum and significant heterosis over better parent was observed for yield per vine (86.07%), fruit number (62.92%), fruit weight (20.79%) and fruits affected by fruitfly (-22.19%).

Chaudhari and Kale (1991) observed heterosis for 7 yield related characters of 55 F_1 hybrids. Eight hybrids were found superior to their better parent for yield. Highest heterosis was found for yield per plant (2.36%). Ranpise and Kale (1992) conducted a study on heterosis for the yield contributing characters in bittergourd involving eight parents in diallel analysis (excluding reciprocals). Maximum heterobeltiosis was reported for yield per plant (93.69%). Appreciable heterosis over better parent was observed for flesh thickness (43.18%), fruit weight (36.09%), number of fruits per plant (32.70%), fruit length (26.02%), number of internodes at which first female flower appeared (-24.72%) and vine length (50.00%). Singh *et al.* (1992) studied degree of heterobeltiosis in 30 F_1 hybrids of bittergourd involving 10 lines and 3 testers. Appreciable heterosis over better parent was observed for all the characters. Maximum heterosis (81.56%) was observed for yield per plant. The best F_1 hybrid, Faizabadi x Priya, which gave 64.47 per cent higher yield over better parent can be used for commercial growing.

Mishra *et al.* (1994) made a 9 x 9 diallel cross in bittergourd and range of heterobeltiosis for fruit yield was -28.69 to 139.95 per cent, followed by fruit weight (-63.00 to 124.39%), fruits per plant (-51.97% and 119.28%), fruit length (-61.62 to 35.24%) and fruit girth (-25.18 to 18.35%).

Khattra *et al.* (1994a) studied heterosis and interrelationships among economical traits in the parental and F_1 generations of eight parent diallel cross (excluding reciprocals) in bittergourd. The cross ACC-3 x ARU-4 showed maximum heterosis for total yield and marketable yield per plant. Pusa Do Mausami x Priya gave highest heterotic value for days to anthesis of first female flower, days to first harvest, fruit length and number of fruits per plant.

Kennedy *et al.* (1995) crossed four lines with 15 testers and resulting 60 F_1 hybrids were evaluated for heterosis for 12 fruit yield components. The best hybrid, Pusa Vishesh x MC-13 recorded 65.7 per cent heterosis over the standard variety (MC 84) and 49 per cent heterosis over the better parent (MC-13) for yield.

Celine and Sirohi (1996) studied the extent of heterosis for yield and associated characters in bittergourd using 10 F_1 hybrid combinations from 10 promising genotypes. Remarkable heterosis for yield and yield attributes was observed over better parent, top parent and local check. Arka Harit x BG 14, Pusa Do Mausami x Kalyanpur Sona, MC 84 x Pusa Do Mausami showed 54.00, 38.59 and 36.24 per cent heterosis respectively for yield.

Ram *et al.* (1997) conducted an experiment with 11 parents and 24 F_1's to study heterosis in bittergourd. Negative heterosis, which is desirable for days to male flower anthesis and female flower anthesis and plant height was common in most of the crosses. Fruits per plant and yield per plant were found to be most heterotic characters. High positive heterosis over better parent was observed in the cross IC-50516 x VRBT-77 for number of fruits per plant and in crosses, Narendra x VRBT-46 and IC-50516 x VRBT -77 for yield per plant. These hybrids can be exploited for development of hybrids in bittergourd.

Tiwari and Ram (1999) studied heterosis for yield and other associated characters in bittergourd using 3 F_1 hybrids from 3 promising genotypes of diverse nature maintained at Pantnagar. Ample amount of heterosis was found for yield over local check and better parent. The best performing hybrid was PBIG-1 x PBIG-2 which showed 25.75 per cent heterosis over better parent.

2.1.2 Bottlegourd

Rajendran (1961) observed hybrid vigour as much as 266.51 per cent increase in the yield of the best hybrid combination of bottlegourd over better parent.

Roy (1964) reported 81.42 and 78.60 per cent heterosis over their respective better parent in yield in best two F_1 hybrids of bottlegourd.

Choudhury and Singh (1971) developed two high yielding bottlegourd hybrids namely, Pusa Meghdut and Pusa Manjari. These two were very first two hybrids of Public sector. Pusa Meghdut, a F_1 cross between Pusa Summer Prolific Long x Selection-2, recorded 16 per cent higher early yield as compared to the best parent in long type. Increase in total yield was recorded 75 per cent with estimated yield of 258 q/ha.

Pusa Manjari, F_1 of Pusa Summer Prolific Round x Selection-11, showed 36 per cent higher early yield than better parent. Total increase in F_1 hybrid was 106 per cent and average estimated yield was 253 q/ha.

Kolhe (1972) evaluated 91 F_1's obtained from 25 parents in bottlegourd. He found that only one combination in bottlegourd (Kalyanpur-9 x Malkapur-20) showed 145.55 per cent heterosis over better parent.

Sharma *et al.* (1983) observed heterosis for number of fruits, fruit weight and total yield in the two F_1's of bottlegourd evaluated by them. Pal *et al.* (1984) reported heterosis in four F_1 crosses of bottlegourd and their reciprocals with regard to germination of seeds by 2-7 days. The hybrids gave 20 per cent higher yield and had a longer harvesting period.

Sirohi *et al.* (1987) recorded significant heterosis over respective parents for vine length, fruit number and yield. For yield, the hybrids S-36-1-H x NC 5912, S-39-1-3 x S-13-6, S-55-8-5 x 49-2-1 proved to be the best and manifested 48.01, 34.61 and 29.03 per cent heterosis, respectively over best check.

Janakiram and Sirohi (1989) studied heterosis for 9 yield components in 45 F_1 hybrids namely S-46 x S-54, S-10 x S-52-7 and S-54 x S-52-7 which showed 84.5, 80.0 and 80.0 per cent heterosis respectively for yield over the best parent line S-41.

Maurya *et al.* (1993) studied the performance of 36 F_1 hybrids under low temperature during winter season. Highest yielding cross took only 83.33 days for first picking compared to 111.33 days by commercially adopted cultivar Pusa Summer Prolific Long. Heterosis of highest yielding cross over the better parent for yield per plant was 80.51 per cent.

Sharma *et al.* (1993a) studied heterosis of F_1 hybrids from 11 line x 3 testers crosses. F_1 cross Summer Long Green Selection-2 x Faizabadi Long showed highest heterosis over control cultivar Pusa Summer Prolific Long for number of fruits (106.63%) and total yield per plant (110.33%). Hissar Local 2 Sel. x Pusa Summer Prolific Long had the highest heterosis (22.93%) over the control cultivar for fruit length.

Pitchaimuthu and Sirohi (1994) reported appreciable amount of heterosis for all the characters except days to first fruit harvest. The F_1 hybrids Pusa Naveen x S-10, Pusa Naveen x Pusa Summer Prolific Long and Pusa Summer Prolific Long x S-10 were observed to be the best performing for yield and they showed 64.62, 60.38 and 63.20 per cent heterosis for yield over top parent S-10.

Singh *et al.* (1996) conducted an experiment to evaluate heterosis in long fruited bottlegourd and results revealed that BTG-1 x PSPL was the best hybrid with 22.45 per cent heterobeltiosis and 16.85 per cent standard heterosis for yield. This hybrid was also early maturing so could be used to exploit heterosis on commercial scale.

Singh *et al.* (1998) evaluated twenty eight F_1 hybrid alongwith eight parents for heterosis. The crosses showing significant heterosis over the better parent were ARBGH-7 x Pusa Naveen for yield per vine per hectare and number of fruits per vine, ARBGH-7 x LC_2-1 for fruit weight and days to first female flowering, PBDG-61 x NDBG-56 for fruit length, girth and vine length and Pusa Summer Prolific Long x ARBGH-7 for days to first fruit harvest. The cross ARBGH-7 x LC2-1 was considered fit for commercial exploitation of hybrid vigour.

Kumar *et al.* (1998) computed 'Line x Tester analysis' in bottlegourd. The highest heterobeltiosis for yield was recorded in cross Pusa Summer Prolific Long x NDBG-1 (106.85%), while the yield per plant of F_1 hybrids BTG-1 x NDBG-56 (27.07%) and NDBG-104 x NDBG-1 (20.68%) manifested heterosis over the standard parent (Pusa Naveen).

Kumar *et al.* (1999) studied twenty F_1 hybrids developed from ten lines and two testers and observed appropriate quantum of heterosis for yield per plant, fruit weight and number of fruits per plant in bottlegourd. Significant and positive heterotic effects over better parent and standard check was observed for fruit yield per plant in hybrids PBOG-22 x Punjab Komal, PBOG-62 x Punjab Komal, followed by Pusa Summer Prolific Long x Punjab Komal and PBOG-62 x BGL 2-1.

2.1.3 Cucumber

Hybrid combinations are frequently developed using proven inbred testers in cucumber. These inbreds may be either gynoecious or monoecious or they may be developed exclusively from new lines (Lower and Edward, 1986). The cultivated species of cucumber have a sex pattern that can be manipulated, to produce F_1 hybrids economically. The use of the genetic control of sex in cucumber has been described by Galun (1973).

Heterosis in cucumber is principally expressed as an increase in the number of fruits and in earliness. A review of work in field of hybrid breeding is as follows :

In 1916, Hays and Jones reported heterosis in cucumbers for the first time. They recorded 29.39 per cent increase in yield over higher yielding parent.

Hutchius (1939) while crossing the early pickling variety Mincu by several slicing types, showed heterosis for increased number of fruits and earliness.

Singh *et al.* (1970) observed hybrid vigour for early and total yield and number of fruits per plants in cucumber. Japanese Long Green was taken as well adapted cultivar and range of increase in early and total yield was found 70.31 to 153.68 per cent and 47.74 to 78.78 per cent.

Gill *et al.* (1973) recommended hybrid 'Pusa Sanyog' a cross between a gynoecious line derived from a Japanese variety "Kaga Amoga Fushinari" and "Green Long Naples". It out yielded the standard cultivar Japanese Long Green by 23.05 to 128.78 per cent and it was also found 10 days earlier.

Galun (1973) gave genetics of sex expression in the cucumber and described different forms of hybrid production.

Om *et al.* (1978) observed heterosis in a half diallel cross of seven varieties of cucumber. The crosses were heterotic for fruit yield, total yield and number of fruits per plant. Significant negative heterosis for the ratio of female : male flowers and number of female flowers.

Gharderi and Lower (1978) observed that hybrids showed greater growth than the parents and in 30 comparisons, 29 hybrids plant produced more top and root fresh weight than the better parents. The hybrids also showed greater phenotypic stability under varying environments than the parents.

Airyapetyan (1981) observed in a study of 9 F_1 hybrids of cucumber derived from 6 varieties, that 77.8 per cent of hybrids exhibited heterosis for number of fruits per plant over the better parent. Solanki *et al.* (1982) analysed data of parents and F_1 generations of nine crosses of 8 varieties and revealed that heterosis over better parent was the highest for primary branches per vine (25.26%), number of female flowers (50.95%) and average fruit weight (33.33%) in Nindeka x Balamkhira, while it was highest for harvested fruit number per plant (83.81%) in Furkin Riesenschel x Solan Local.

Seshadri and Chatterjee (1983) studied various factors contributing to low productivity and recommended varieties for various environments. They also gave information about exploitation of heterosis in various crops including cucumber.

Musmade and Kale (1986) studied the extent of heterosis in cucumber in seven parent diallel crosses involving diverse monoecious cucumber cultivars originated from tropical and temperate regions. Considering the overall performance they concluded that the hybrids Poona Khira x Japanese Long Green, White Long Cucumber x Poinsette and Kalyanpur Ageti x Pamul were the most promising since these hybrids showed the highest sca effects and recorded 135.47, 56.52 and 54.72 per cent higher yield per vine over better parent in order of merit.

Hormuzdi and More (1989) evaluated 24 F_1 hybrids alongwith their 11 parents during rainy season and 32 hybrids along with 12 parents during summer season. They reported heterosis over better parent for earliness, yield and its components. Hybrid WI 2757 x PKS 295 and Poinsett x PKS-300 for the rainy season and SR 551 F x Balam khira, SR 551F x Japanese Long Green and SR551F x Poona khira for the summer season emerged promising for commercial cultivation.

Vijaykumari *et al.* (1991) studied 15 F_1 hybrids developed by crossing three female parents with five monoecious varieties according to line x tester mating design. Hybrids 304 x EC 142412 and Gyn. JPL x EC 129110 in summer and 322-11 x Balam Khira and 304 D x RK 5295 in rainy season were promising for both the component of earliness.

In Europe, most of the existing varieties are hybrids. In Germany, for instance, 24 of the 28 listed pickling cucumber and 21 of the 39 listed slicing cucumber varieties are hybrids. The proportion of hybrid varieties is increasing continuously. Thus, the main task of most cucumber breeder is extraction of inbreds and determination of the best hybrid combination (Tatliglu, 1973).

Li-Jianveru *et al.* (1995) derived information on heterosis from data on 9 yield components in 4 inbred cucumber lines and their 6 F_1 hybrids. Total yield, early yield, fruit number, average fruit weight, leaf area, fruit ratio and fruit shape index had positive heterosis. Vine length had negative heterosis.

Dagra *et al.* (1997) produced diallel of 5 cucumber lines (excluding reciprocals). Their 10 F_1's and a standard were evaluated. The cross K 75 x Gy-1 recorded the highest heterobeltiosis (51.35%) for yield per plant.

2.1.4 Pumpkin and Squash

Curtis (1941) showed heterosis in early fruit harvest of 114 per cent over the parental mean and 87 per cent over the better parent as the average production at 2 locations in summer squash.

Hutchins and Craston (1941) compared crosses of 8 varieties of winter squash with a common parent, an inbred of Green Gold. They found that heterosis averaged 68 per cent for total yield per plant, 78 per cent for yield of mature fruits per plant, 24 per cent for average fruit weight and 30 per cent for number of fruits per plant. The hybrids were 2-3 days earlier in opening the first pistillate flower.

Gill *et al.* (1971) observed considerable heterosis in early and total yield in summer squash. They reported increase in total yield from 24.77 to 100.22

per cent while no conspicuous heterosis was found in fruit length.

Doijode and Sulladmath (1981) while studying genetic architecture of yield and its components in pumpkin, reported that heterosis over better parent ranged from 11 per cent for earliness to 203.30 per cent for cavity size. The combinations CMR 12 x Arka Chandan and CMR 12 x IHR 8 gave significant positive heterosis over better parents for fruit weight.

Doijode and Sulladmath (1982) studied heterosis of 9 yield related traits in 21 F_1's derived from 7 x 7 half diallel in pumpkin. Fruit weight, fruit size, cavity size and flesh thickness exhibited the highest positive heterosis. CM-12 in combination with Arka Chandan or IHR 8 gave significant positive heterosis over the better parent for fruit weight.

Dhillon and Sharma (1987) reported the crosses 15-4-1 x 15-2-6 and 1-1-1 x 15 -2-6 exhibiting the highest heterosis over the better parent for days to anthesis and days to maturity respectively in summer squash.

Sirohi (1994) studied 3 F_1 crosses of pumpkin in diallel set involving 9 parents for yield and yield related traits. Appreciable heterosis was reocrded over best parental lines for all the characters except number of fruits per plant. The three best performing F_1 hybrids Pusa Vishwas x S 122, Pusa Vishwas x VS -93 and S 93 x S 122 showed 36.9, 25.8 and 24.6 per cent heterosis, respectively for yield over 'Pusa Vishwas', the best parental line.

Mohanty and Mishra (1998) evaluated 28 non- reciprocal F_1 hybrids of pumpkin and their 8 parents at two locations. The pooled analysis revealed that heterosis to the extent of 29.0, 23.6, 73.8, 145.6, 82.0, 41.5 and 188.2 per cent over better parent for vine length, number of branches, female flowers and fruits per plant, fruit weight, flesh thickness and yield per plant respectively. The cross Ambili x BBS-10 was the best performing hybrid which showed 134.5 and 165.6 per cent heterosis over better and check parent respectively.

2.1.5 Muskmelon

Yield, quality (generally high TSS) and resistance to diseases are important traits to be considered in F_1 hybrids in muskmelon. Earliness is important to catch better market price (Kalloo, 1988). In certain cases, there was improvement in the fruit quality in addition to an increase in yield and also hybrid combined crown blight resistance alongwith good shipping quality of fruits (Foster, 1968). A brief review in field of hybrid in muskmelon is as follows :

Scott (1933) observed that there was no inbreeding depression after 4-7 generations of selfing, and no heterosis in average fruit weight or yield of muskmelon.

Kubicki (1962) compared the F_1 and F_2 of the cross of *C. melo agrestis* by *C. melo vulgaris* cultivar Gribowski with the parental types. Gribowski is an early, commercial type, *C. melo agrestis* is a small fruited type not used in commerce. Thus, there were many contrasting characters to be compared. He found a great deal of heterosis over the larger parent in the vegetative character of number and length of stems, leaf size and number of male and female flowers formed (which would follow from the increase in stem length), and yield per plant, but essentially the same as the parental mean for days to first flower, days for fruit development, and total days for first ripe fruits. He considered that heterosis is due to the interaction of particular genes so that Gribowski (low branching, high growth rate) combined with agrestis (high branching, low growth rate) produced a plant that was high branching with high growth rate.

Rowe (1969) reported that sex pattern of muskmelon resembles that of cucumber, but is controlled some what differently as follows :

Aagg	Gynomonoecious	-	All female flowers
aagg	Hermaphrodite	-	All perfect flowers
aaGG	Andromonoecious	-	Perfect and male flowers
AAGG	Monoecious	-	Female and male flowers

All of the standard round fruited varieties are andromonoecious. Introduction of monoecious or gynomonoecious factors increases elongation of the ovary resulting an oval fruit, which may be due to a closely linked gene rather than pleitropy.

Nandpuri *et al.* (1974b) studied 16 F_1's of muskmelon and observed heterotic effect for yield per vine, ratio of yield per vine to vine length, weight per fruit, distance of first ripe fruit from the vine base and vine length. The overall quality of the progeny of Edisto x Hara Madhu was the best.

More and Seshadri (1980) recorded heterosis over better parent in muskmelon for earliness, yield and quality.

Dixit and Kalloo (1983) observed the highest amount of heterosis over the better parent for number of fruits per plant (54.3%) in the cross combination Punjab Sunehri x Sel. 1. In respect of fruit yield, heterosis to an extent of 46.70 per cent and 38.10 per cent was noticed in the F_1 hybrids Pusa Sharbati x Sarda Melon and Pusa Sharbati x Punjab Sunehari, respectively. Heterotic hybrids (Arka Jeet x Durgapura Madhu and Arka Jeet x Sarda Melon) for fruit quality (TSS content) were also identified.

Mishra and Seshadri (1985) observed the greatest heterosis over the better parent for early yield (433.2%) in muskmelon. Hybrids heterotic for earliness of first harvest were also heterotic for early yield.

Swamy (1986) detected 111.4 per cent heterosis over better parent in F_1 of Arkajeet x UFG 515. The range of heterosis was found to be low for quality characters in muskmelon.

Om *et al.* (1987) reported heterosis for total soluble solid (6.38%) and flesh firmness (8.53%) in a diallel cross of 6 varieties of muskmelon. In 1990, a very promising hybrid Pusa Rasraj was released by Project Directorate of Vegetable Research for commercial cultivation in Delhi, U.P., Punjab, Haryana Bihar and Rajasthan.

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Randhawa and Singh (1990) reported hybrid vigour in muskmelon over mid parent for fruit yield, fruit number, fruit weight and number of node of first female flower.

Munshi and Verma (1997) studied six parental lines and 15 F_1 hybrids of muskmelon obtained from half diallel cross to investigate the extent of heterosis for yield and its contributing characters. Appreciable heterosis was recorded over better parent and top parent for days to first harvest, number of fruits per plant, average fruit weight, flesh thickness, and yield per plant. In order of merit, F_1 hybrids Pusa Madhuras x Ravi, Pusa Sharbati x Pusa Madhuras and Pusa Madhuras x Hara Madhu were observed to be three best performing F_1 hybrids for yield per plant. The best performing F_1 hybrid, Pusa Madhuras x Ravi which recorded 28.15 per cent higher yield over best commercial check. Pusa Madhuras may be exploited for commercial cultivation.

2.1.6 Watermelon

A considerable degree of heterosis was observed in watermelon for yield, number of fruits, size of fruit, weight of fruit, female flower, earliness, TSS and number of seeds. Heterosis for fruit yield and number of fruits was extensively studied (Kalloo, 1988).

Triploid watermelon hybrids are almost seedless and of excellent quality. Kihara (1951) obtained seedless watermelon from the cross of tetraploid x diploid forms. However, its reciprocal are never successful.

Nath and Dutta (1970) obtained a maximum of 58 and 75 per cent increased yield over the better parent in hybrid watermelon IHR 20 x Crimson Sweet and IHR 20 x Charlston Grey, respectively.

Brar and Sidhu (1977) studied 7 x 7 diallel analysis for four characters of watermelon. Maximum heterosis for days to maturity (earliness) was 4.88 per cent over the earlier parent, no hybrid was significantly earlier than the earliest variety. Shipper x 10-6-5 had significant heterosis for length of harvest, total soluble solids and number of seeds per kg flesh.

Dhaliwal *et al.* (1983) reported heterosis for various traits in cross combination of Shipper x Durgapur Meetha in watermelon.

Reddy *et al.* (1987) studied six cultivars of watermelon in a diallel cross along with their 15 F_1's (excluding reciprocals). The hybrid DM x AM showed significant heterosis for yield per plant by weight and TSS content. Significant heterosis was observed in SB x T4 for total number of fruits per plant, DM x T4 for average fruit weight and Ay x SB for edible flesh content.

Gill and Kumar (1988) identified superior hybrid combinations like Sugar Baby x Durgapur Meetha for yield and number of fruits per plant and also good performer for earliness.

Chadha and Lal (1993) described heterosis in watermelon and other cucurbits for yield and quality attributes.

2.2 Combining ability

Genetically superior parents are the most important prerequisite for development of high yielding and promising hybrids. Combining ability concept has been an important and effective tool for selecting desirable parents for superior hybrids. This concept of combining ability as a measurement of type of gene action was proposed by Sprague and Tatum (1942) while investigating relative importance of general combining ability in corn. They defined term general combining ability (gca) as average performance of a line in hybrid combination whereas specific combining ability (sca) was referred to those cases in which certain combinations do relatively better or worse than would be expected on the basis of the average performance of the lines involved. Animal breeder used the term 'nicking' for the same thing. They concluded that in single cross involving previously tested lines, gene conditioning specific combining ability have effect in determining differences, whereas in previously untested material, gene affecting general combining ability are of most importance. They also concluded that gca was mainly due to additive cffccts whereas sca was largely dependent on genes with dominance and epistatic effects. Magnitude of the general and specific component estimate is influenced by the choice of lines comprising a set. With general lines the estimates have some general utility. With selected lines, the utility of approach depends largely upon the questions posed by plant breeder (Sprague, 1966).

There are two schools of thought relative to the exact meaning and utility of estimates of general and specific combining ability (Robertson, 1963). The statistical geneticist may argue that the present lines should represent derivatives from a random mating populations. In this case gca and sca are considered as estimates of population parameters. The second view is more related to gene action within a given set of selected inbred lines. The interests of the plant breeder is in second group. If he is interested in improved varietal performance, his interest will be with sets of relatively highly selected material. Interest will be centered on types of gene action within each sets. Such information may be helpful in suggesting testing procedures, or in choice of best combinations.

Several technique, worthful for estimation of combining ability are polycross progeny testing, diallel cross analysis, line x tester analysis, partial diallel cross and triallel crosses (Sharma, 1998).

Some work, done on combining ablity on bittergourd and other cucurbitaceous vegetables is reviewed as follows :

2.2.1 Bittergourd

Sirohi and Choudhury (1977) studied combining ability in bittergourd in a 8 x 8 diallel cross excluding reciprocals. They concluded that out of 8 parents, Pusa Do Mausami, S 63 and S144 were observed to be the best combiners as they contributed significantly for as many as 8 out of 10 characters.

Singh and Joshi (1980) studied the extent of heterosis and combining ability in a diallel set of five cultures in bittergourd. They indicated that parental line BWL 1 was the good general combiner for yield and its components.

Pal *et al.* (1983) studied yield and yield related characters in a 5 line (female) x 2 tester cross. The gca was high for days to female flower initiation and fruits per plant. Mausoon Miracle was the best general combiner for yield, fruit weight and fruit size.

Srivastava and Nath (1983) studied gca and sca effects for days to flowering, fruits per plants, fruit weight per plant and total yield per plant in the parental and F_1 generations of a 10 x 10 diallel in bittergourd. For each of the four traits, several parental breeding lines showed significant gca effects.

Lawande and Patil (1989) studied combining ability for fruit yield and other component characters of 55 F_1 hybrids of bittergourd in a diallel cross without reciprocals. They concluded that in addition to sca and gca effects, *per* *se* performance of parents and crosses also played an important role in displaying heterosis for fruit yield per vine.

Lawande and Patil (1990) derived information on combining ability from data on 5 yield components in 55 F_1 hybrids from 11 lines of *Momordica charantia*, grown during 1985-86. Co Long Green, Green Long, Hissar Selection, Delhi Local and Co 2 White Long were the best combiners.

Devadas and Ramdas (1993) estimated combining ability for yield components among parents and their 132 F_1 hybrids in a full diallel experiment in two seasons. The gca effects of parents and sca of direct and reciprocal crosses were significant with a higher magnitude of gca variance. Among the parents Coimbatore Local, Priya and Co 1 were good general combiners for yield and most of the yield components.

Khattra *et al.* (1994b) studied general and specific combining ability in parental and F_1 generations respectively, of 8 parental diallel cross (excluding reciprocals) of bittergourd. Pusa Do Mausami was the best general combiner for fruit length, average fruit weight and total yield. ACC 32 had maximum gca effects for fruit diameter, fruit number, anthesis of first female flower and marketable yield. Pusa Do Mausami x Priya was the best specific combiner for anthesis of first female flower, days to first harvest and fruit length. Cross BG 14 x ACC 32 was the best for fruit number and total yield.

Mishra *et al.* (1994) reported that cultivar Coimbatore Long was the best general combiner for all 5 characters. At least one parent with high gca was involved in most of the hybrids showing high sca effects.

Munshi and Sirohi (1994) carried out combining ability analysis in a 10 x 10 diallel cross of bittergourd excluding reciprocals. The parents Pusa Do Mausami, Pusa Vishesh, Arka Harit, Kalyanpur Sona and Priya were observed to be good general combiner for a number of characters including yield per plant. The crosses Pusa Vishesh x Arka Harit, Pusa Do Mausami x Pusa Vishesh, Pusa Do Mausami x Kalyanpur Sona, Pusa Do Mausami x Priya and BG 14 x NDBT-1 were observed to be the most promising combinations for earliness and other desirable characters including yield per plant.

Devadas and Ramdas (1993) studied combining ability derived from data on 6 yield components in 12 parental genotypes and their 132 F_1 hybrids. Cultivar MC 13 was a good general combiners for seeds/fruits and 100-seed weight and MC 84 was a good general combiner for field emergence, seedling length and seedling dry weight.

Ram *et al.* (1999) conducted a study during 1995 on combining ability in 8 line x 3 tester crosses for 13 component characters in bittergourd 'Narendra' and 'VRBT 46' were good general combiners for marketable fruit yield. 'VRBT-46' was good combiner for leaf length, fruit length, fruit girth and number of seeds/fruit. The crosses 'Faislabad x VRBT 46', 'IC 44410 B' x 'VRBT 46', 'MC 48' x 'VRBT 78' and 'Narendra' x 'VRBT 78' combined well for earliness. For marketable yield, the good cross combinations were 'Narendra' x 'VRBT 46', 'Arka Harit' x 'VRBT 78' , 'MC 63' x 'VRBT 77' and 'IC 50516' x 'VRBT 77'.

2.2.2 Bottlegourd

Sivakami *et al.* (1987) studied the combining ability for yield per plant and 8 component characters in a diallel cross of 10 bottlegourd lines. The gca and sca effects were significant for all 9 characters. The gca effects were predominant over sca effects for all these characters.

Janakiram and Sirohi (1988) studied an incomplete diallel cross of 10 bottlegourd lines. The estimated component of variance of gca were larger than those for sca for all the characters studied except days to opening of first male and female flowers and fruit polar diameter. S-52 and S-54 were the best combiners for a number of characters including yield per plant. S-46 x S-54 was the best specific combination for fruit weight and yield per plant.

Maurya *et al.* (1993) observed that out of 9 parents, NDBG-60 was the best general combiner as it showed high general combining ability effects in desirable direction for most of the traits. They also observed that the crosses having high sca effects and *per se* performance were not necessarily the products of parents having high gca effects and high *per se* performance, respectively.

Sharma *et al.* (1993b) studied combining ability in 33 crosses derived from 11 lines x 3 testers. The cross combinations showing highest sca effects for number of fruits and yield per plant involved one of the parents having high gca effects. The cross Hisar Local 2 Sel x Pusa Summer Prolific Long involving former as the best general combiner for number of fruits and yield per plant did not show significant sca effects for these characters. It was concluded that the crosses Summer Long Green Sel 2 x Faizabadi Long and Pusa Summer Prolific Long Sel 1 (Pocha Seeds) x Pusa Summer Prolific Long could be exploited for hybrid vigour both for number of fruits and yield per plant in bottlegourd.

Kushwaha and Ram (1997) in a study of 6 inbred half diallel crosses, analysed combining ability in bottlegourd and concluded that additive gene action was involved in days to anthesis, days to first female flower, node number to first female flower, fruit diameter, fruit length, fruit weight and primary branches per plant. For fruit diameter and fruit length both additive and non additive gene action were predominant. Most of gca and sca effects were non-significant. BOG-22, BOG-7, BOG 40 and NDBG-1 were identified as good general combiners for fruit length and BOG-68 and BOG-13 for fruit diameter.

Kumar and Singh (1997) observed that variance due to sca was highly significant for node bearing first female flower, days to first harvest, average weight of edible fruit, number of fruits per plant, vine length, number of primary branches per plant and yield per plant. L_{13} (Pusa Summer Prolific Long) had high gca effects for the average weight of edible fruit, number of fruits per plant, number of primary branches per plant and yield per plant. Estimate of sca showed that the best cross combination for yield per plant was L_3 (NDBG-10) x T_3 (Pusa Naveen) followed by L_3 (NDBG-10) x T_1 (NDBG-1C).

Kumar *et al.* (1998) observed highly significant variance due to sca. The highest gca effects were detected in L_{13} (PSPL) for average weight of edible fruit, number of fruits per plant, number of primary branches per plant and yield per plant.

2.2.3 Cucumber

Wang and Wang (1980) reported that in 36 combinations involving 16 parents of autumn cucumber, general and specific combining ability effects were significant for yield and maturity characters. Lines 3-6-11-13-3-9, 24-3-22-2 and 3-11-2-1 had good gca for yield.

Musmade and Kale (1986) studied combining ability in several cultivars of cucumber crossed in all possible combinations (excluding reciprocals). It was observed that both gca and sca variances were significant for all characters studied. The earliest hybrid Poona Khira x Turkish Long Green had highest sca effects and the parents, Poona Khira involved in this cross was a good general combiner, while the other parent, Turkish Long Green recorded poor gca effects for this trait. The hybrids, Poona Khira x Japanese Long Green, White Long Cucumber x Poinsette and Kalyanpur Ageti x Pannel were the most promising since these hybrids showed the highest sca effects in respect of important economic characters.

Frederick and Staub (1989) studied combining ability in 9 processing cucumber lines. They revealed that sca mean squares were significant for days to anthesis. WI 2963 (male) and 4H261 (female) had the highest gca for total yield and number of primary lateral branches.

Prasad and Singh (1992) studied combining ability for yield and its components following line x tester analysis in cucumber in 24 cross combinations. The female parent CH-8-2-3-1 was a good general combiner for yield, fruit number, node number and number of branches. The powdery mildew tolerant male line CH-20-3-2-1 was a good general combiner for all the vegetative characters such as node number, number of branches and vine length.

Wu *et al.* (1995) derived information on heterosis and combining ability from data on 9 yield components in 4 inbred cucumber lines and their 8 F_1 hybrids. Line 112 had the greatest gca for average fruit weight and fruit ratio. Hybrid 111 x 112 had the greatest sca for fruit number, average fruit weight, vine length, fruit length diameter ratio and leaf area.

El-Hafez *et al.* (1997) studied combining ability for yield and its component in cucumber involving 5 x 5 diallel. Estimates of gca effect revealed that the inbred line 78 NC AIOL had the highest positive value for all studied characters. The cross 78 NC AIOL x Biet Alpha had the highest sca values for marketable and total yield on weight and number basis.

Dogra *et al.* (1997) developed diallel (excluding reciprocals) involving five cucumber lines (4 monoecious and 1 gynoecious) and analysed the lines and their F_1's for combining ability. K 75 x Gyn 1 recorded highest sca for yield per plant and LC 11 x K 75 showed highest sca for TSS and flesh to seed cavity. K 75 was regarded as the best general combiner and should be exploited for hybridization programme.

Ananthan and Pappiah (1997) observed that general combining ability and specific combining ability were significant for days to first male flowering, days to first female flowering, sex ratio, fruit number per vine, fruit length, fruit girth, seed number per fruit, tender fruit weight per vine and ripe fruit weight per vine.

Qiang *et al.* (1998) studied combining abillity of parthenocarpic yield in a diallel cross involving 5 varieties of cucumber (*Cucumis sativum*). Analysis of combining ability variances indicated that gca variances were predominant in controlling the inheritance of parthenocarpic yield.

2.2.4 Pumpkin and Squash

Bhagchandani *et al.* (1980) studied combining ability in a 5 x 5 diallel cross (excluding reciprocals) in summer squash for length of vine, number of branches, number of fruits and yield per plant. Vegetable Marrow x Early Yellow Prolific exhibited high sca effect followed by Vegetable Marrow x Sel -1P1-8 for most of the characters.

Chattopadhyay *et al.* (1986) studied a 5 x 5 half diallel cross in pumpkin and concluded that Arka Chandan was the best general combiner for fruit weight and total soluble solids, EC 121166 and Brazil were the best for earliness and CM 12 for ovary size. Sirohi *et al.* (1986) studied combining ability in pumpkin in a 10 x 10 diallel cross for 9 important characters. The estimated components of variance for sca were larger than those for gca in all characters except in vine length. The F_1 hybrids S-93 x CM-12 was the best specific combiner for total yield per plant and second best combiner for number of fruits per plant and fruit weight.

Dhillon and Sharma (1987) studied days to marketable maturity and days to anthesis of first female flower in 10 inbred of *Cucurbita pepo* and their F_1 hybrids and revealed highly significant sca and gca variances for both traits.

The parents 14-6-7 and 6-5-3-1-5 were good general combiners for both characters. Specific combining ability was highest in 15-4-1 x 1-1-1-2-5 for days to anthesis and in 10-1-2-4 x 14-6-7 for days to maturity.

Sirohi and Ghorui (1992) studied combining ability on nine inbred and cultivars for pumpkin. The parental lines S-122, Pusa Vishwas and S-93 were good combiners for yield, number of fruits per plant and fruit weight. The F_1 hybrid Pusa Vishwas x S-124 was the best specific combiner for total yield per plant.

2.2.5 Muskmelon

In a study involving two Japanese varieties and two male sterile lines of muskmelon, Bhattacharya *et al.* (1970) observed that gca variance was more than that of sca for plant height, male flower initiation and fruit maturity while both gca and sca variance were non-significant for fruit weight and sugar content.

Nandpuri *et al.* (1974a) studied combining ability in muskmelon and concluded that gca effects were more important for the male than the female parents. Arka Rajhans and Hara Madhu and the male sterile lines were good combiners for a large number of economic characters.

More and Seshadri (1980) studied the combining ability effects in muskmelon using a line x tester analysis. It was observed that Top Mark, Lucknow Safeda, Yanco Treat, Punjab Sunehari, Pusa Sharbati and Golden Perfection showed significant gca effects for maximum characters. The

The parents 14-6-7 and 6-5-3-1-5 were good general combiners for both characters. Specific combining ability was highest in 15-4-1 x 1-1-1-2-5 for days to anthesis and in 10-1-2-4 x 14-6-7 for days to maturity.

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Kalb and Devis (1984) reported that the variance of general combining ability was greater than that of specific combining ability for all the traits. Minnesota showed good general combining ability for those traits associated with earliness.

Swamy (1986) observed that the parents Arka Rajhans, Hara Madhu and Arka Jeet were good combiners for most of the characters of muskmelon.

Om *et al.* (1987) studied combining ability for several major characters in oriental melon. General combining ability was important for fruit weight, soluble solids content, flesh firmness, days to maturity and yield per plant.

Randhawa and Singh (1990) evaluated 6 parents and 15 F_1 hybrids for 8 yield related traits in muskmelon. They reported that the best general combiners were Durgapur Madhu for fruit yield, Punjab Sunehari for traits associated with earliness and WMR 29 for vine length.

Singh and Randhawa (1990) studied combining ability of 6 fruit traits in six muskmelon genotypes and their 15 F_1 hybrids. The local varieties Hara Madhu and Punjab Sunehari were the best general combiners for a combination of traits.

Kesavan and More (1991) studied the combining ability of six fruit traits in 56 F_1 hybrids (4 monoecious females x 14 males) of muskmelon. Among the four monoecious female, M 4 combines well for number of fruits, total yield, TSS (%) and flesh :cavity ratio. Two hybrids namely, FM 2 x G 515 (for number of fruits, average fruit weight and total yield) emerged as the best specific combiners.

Swamy and Dutta (1993) reported that UFG 15 was the best combiner for dry matter content followed by Hara Madhu.

Epinat and Pitrat (1994) detected highly significant gca effects for resistance to downy mildew in a study of half diallel of 8 inbred lines. The sca effects had low impact on total variation and therefore heterosis for resistance did not occur.

Lianjie *et al.* (1995) derived information on heterosis combining ability from data on 5 yield components in 3 thin-skinned and 4 thick skinned melow genotypes and their 12 F_1 hybrids. Thin skinned parent L 1 had the greatest gca for soluble solids content and hybrid L1 x Wangwenhuangdanzhi had the greatest sca.

Moon Soo *et al.* (1996) estimated combining ability for yield (fruit weight) and other agronomic traits in muskmelon through diallel crosses of 5 lines. The line West was the best general combiner as both female and male parent, and 713 x West was the best specific combination for fruit yield. The gca effects were high for leaf length, fruit length, fruit width, sugar content, fruit set ratio, days to flowering and days to maturity. Sca effects were notable for leaf width, fruit set ratio, days to flowering and days to maturity.

Dhaliwal and Lal (1996) produced 60 F_1 hybrids involving 3 females, viz., M 221, M 225 and W 321, and 20 males in a line tester design. Eight economic characters contributing to earliness, fruit yield and sweetness were studied. W 321 among lines and H 172 among testers were found good general combiner for most of the studied characters. Among the crosses M 221 x M 231, M 225 x A 102, M 225 x M 224, M 225 x F 143, W 321 x M 222 and W 321 x M 233 combined well to produce significant desirable sca effects for days to harvest and yield per plant.

Munshi and Verma (1999) conducted a study on the combining ability analysis and detected highly significant mean square due to gca and sca. Pusa Madhuras, T 96 and Ravi were observed to be good combiners for number of characters including yield per plant. The crosses Harela x Hara Madhu, Pusa Sharbati x Pusa Madhuras, Pusa Madhuras x Ravi and Pusa Sharbati x T 96 were most promising combinations for earliness and other desirable characters including yield per plant.

2.2.6 Watermelon

Sachan and Nath (1976) crossed ten varieties in a diallel and data were recorded on number of days to first female flower, number of fruits, fruit weight, total soluble solids and total yield. General combining ability variance was highly significant for all characters while significant specific combining ability was also observed for all the characters except total soluble solids.

Brar and Sukhija (1977) performed line x tester analysis of combining ability in watermelon. They reported that T_1 showed greater gca for yield, fruit weight, and total soluble solids than did T_2, where as T_2 was good combiner for fruit number. Brar and Sidhu (1977) reported that gca estimates were significant for all characters and sca estimates were significant for all characters except TSS.

Dhaliwal *et al.* (1983) reported significant gca and sca effects for all 8 yield and quality characters studied in 10 parental diallel crosses of watermelon. The variety H 23 and Durgapura Meetha were the best general combiners.

Kale and Seshadri (1988) studied combining ability of 7 yield and quality characters in six genotypes and their 15 F_1 hybrids. The best combiners identified were Asahi Yamato, Sugar Baby, Pusa Rasal and Russina. The best specific combination for all the traits studied was Pusa Russal x Ashai-Yamato.

Gill and Kumar (1989) studied the data from crosses between 4 female and 10 male varieties. They reported that among females Sugar Baby was the best combiner for TSS, total water soluble sugar and vitamin C whereas Shipper and Sel-3-1 were good general combiners for flesh thickness. Among male parents, Durgapura Meetha was a good general combiner for most of the characters.

Gopal *et al.* (1996) estimated combining ability of 10 quantitative characters from parents and F_1 data of a diallel set of 6 watermelon cultivars.

Sugar Baby and Bangalore Local were excellent general combiners for earliness and fruits per vine. Ashai Yamato was the best combiner for length of vine while Durgapur Meetha was superior for female flowers per vine. Crosses of Sugar Baby x Bangalore Local was good specific combiner for yield.

2.3 Components of genetic variation and Vr/Wr graph

Assessment of potential of different crosses in F_1 and F_2 generation is must to know the genetic system governing the inheritance of attributes to be improved. The term 'diallel' was given by Schmidt (1919) which implies all possible crosses among a collection of male and female animals. The analysis of such crosses is known as diallel analysis and provides information on nature and amount of genetic parameters. There are certain genetic assumptions on which the diallel analysis operates and these are :

(1) Parents involved must be diploid (2n) and homozygous

(2) Reciprocal differences should be absent

(3) Epistasis should be absent

(4) No multiple allelism is involved and

(5) Genes must be distributed independently between the two parents involved in a cross.

Diallel analysis is most worthwhile for highly heritable traits and very balanced and systematic experimental design to examine continuous variation. It is useful as it provides genetic information related to parental population quite in early generation (F_1 itself) so breeding strategy can be planned without losing much time (Sharma, 1998). Based on parental variance (Vr) and parental offspring covariance (Wr) relationship in diallel cross progenies, a two way representation or distribution of parental arrays along a regression line of Wr or Vr was first suggested by Jinks and Hayman (1953) and later refined by Hayman (1954). This two directional depiction is widely known as Wr-Vr graph and analysis as 'graphical approach'.

Initially Fisher (1918) divided the genotypic variance into three components : (1) additive (2) dominance and (3) interaction components.

Hayman and Mather (1955) partitioned the epistatic component into three types of interactions viz, additive x additive, additive x dominance and dominance x dominance. The digenic interactions can be further classified into complementary and duplicate type of interaction. To detect complementary or duplicate epistasis, the signs associated with D and DD are compared. When both D (=h) and DD(=l) component show positive signs, it is complementary epistasis otherwise it is duplicate.

2.3.1 Bittergourd

Singh and Joshi (1980) found that yield, stem length, number of primary branches per plant, fruit length, number and weight of fruits per plant in bittergourd are governed mainly by additive gene action.

Singh and Choudhury (1983) studied yield and seven yield characters in an eight parent diallel, without reciprocals, indicated additive gene action with partial dominance for stem length, days to first harvest, fruit length and diameter, fruit flesh thickness, fruits per plant and fruit weight.

Lawande and Patil (1989) studied 55 F_1 hybrids of bittergourd in a diallel set involving 11 parents (excluding reciprocals) to investigate the gene action for five important characters viz., fruit weight, fruit length, fruit diameter, fruit number per vine. The length of fruit was more influenced by additive effects. Presence of overdominance for yield was observed.

Mishra *et al.* (1994) crossed 9 cultivars in a 9 x 9 diallel. Parents and 36 F_1 hybrids were grown during 1989-90. Both additive and non-additive gene action were involved in the expression of fruits per plant, fruit length, fruit width, fruit weight and fruit yield.

Mishra *et al.* (1998) detected frequent occurrence of dominant allel for inheritance of the character studied. Both additive and non-additive gene action were involved in the character expression. Presence of dominance and complementary type of gene action along with low narrow-sense heritability for yield indicates that heterosis breeding would be more advantageous to get higher fruit yield in bittergourd.

2.3.2 Bottlegourd

Janakiram and Sirohi (1987) studied gene action in round fruited bottlegourd and reported that overdominance was present for vine length, days to open first male flower, days to first harvest, fruit equatorial diameter, fruits per plant, fruit weight and yield per plant, dominance for days to open first female flower and partial dominance for fruit polar diameter. Epistasis was pronounce for all the traits whereas dominant allels were more frequent for all the characters except for fruit polar diameter.

Sivakami *et al.* (1987) studied yield and its components in long-fruited bottlegourd in a set of 10 x 10 diallel cross. The ratio of components of genetic variance indicated preponderance of additive gene action over non-additiveness for vine length, days to open first male flower, days to open first female flower, days to first harvest, fruit length, fruit girth, number of fruits per plant, fruit weight and total yield per plant.

Sirohi *et al.* (1988) studied F_1 hybrid of bottlegourd from a diallel cross involving 12 parents (excluding reciprocals) showed overdominance for vine length, days to opening of first male flower, days to opening of first female flower, days to first harvest, fruit diameter, number of fruits per plant, fruit weight and yield per plant. Additive gene action was thought to be involved in the inheritance of fruit length only.

Maurya and Singh (1994) observed preponderance of non-additive gene action for all the characters including yield, number of fruits, average weight of edible fruits, days to anthesis at first male and female flowers, days to first harvest, number of branches and vine length.

Kushwaha and Ram (1996) studied 15 hybrids and 6 parents to investigate gene action through Vr, Wr graphical analysis. This analysis indicated involvement of a major recessive gene responsible for round fruit shape and major dominant gene for long fruit shape, the degree of dominance for fruit length being partial. The position of regression line passing through origin showed complete dominance for node to first female flower (summer season), fruit diameter (rainy season) and fruit weight (rainy season). Position of regression line intersecting Wr axis well above the origin demonstrated partial dominance for fruit diameter (summer season), fruit length (rainy season) and fruit length (summer season).

2.3.3 Cucumber

Om *et al.* (1978) observed that both additive and non-additive effects were important for early yield per plant.

Solanki *et al.* (1982) reported that the loss of vigour in F_2 was less than the extent of heterosis, thus indicating additive x additive interaction in the manifestation of heterosis.

El-Shawaf and Baker (1984) observed that the additive genetic variance was greater and more important than dominance variance for fruit shape.

Prasad and Singh (1992) revealed that the variances to gca were higher than sca for all the characters indicating importance of additive gene action.

Stankovic *et al.* (1997) observed that additive gene effects play a more significant role in inheritance of yield than non-additive gene effects.

Qiang *et al.* (1998) studied genetic effects of parthenocarpic yield in a diallel cross involving 5 varieties of cucumber and observed additive effect was a major component of the genetic effects. Additive variance was 96.78%

of total variance. The analysis of combining abilities and Wr/Vr graph showed that EP and Yaugzhou Xiaugua are comparatively ideal breeding materials.

2.3.4 Pumpkin and Squash

Doijode and Sulladmath (1981) studied genetic architecture of yield and its component in pumpkin and additive, non-additive and epistasis effects were observed for all the characters studied.

Doijode and Sulladmath (1982) studied genetics of fruit maturity in pumpkin and reported that inheritance of days to first maturity is governed by additive, dominance and epistatic gene action with the magnitude of the additive general, additive x additive gene interaction was prominent for this trait.

Sirohi *et al.* (1986a) studied yield per plant and 8 yield related traits from a 10 x 10 complete dialllel cross and revealed the importance of over-dominance for stem length, days to opening of the first male, and female flower, fruit number per plant, and yield per plant and dominance for days to first harvest, fruit weight, fruit index and fruit thickness. Epistasis was pronounced for all traits.

Sirohi and Ghorui (1992) studied combining ability of quantitative characters in pumpkin. Both additive and non-additive type of gene action were observed to be operative for most of the characters.

2.3.5 Muskmelon

Singh *et al.* (1974) studied the inheritance of seven important economic quantitative characters in an intervarietal cross of muskmelon between Hara Madhu and Earligold. The additive component of variance was high for days to opening of the first female flower, maturity, number of fruits per vine and TSS. In general, additive x additive were more effective than additive x dominance and dominance x dominance.

Chadha and Nandpuri (1980) reported that the additive genetic variance had a predominant role in expression of all the characters in muskmelon.

Om *et al.* (1987) reported that non-allelic interaction was evident in the control of TSS.

Epinat and Pitrat (1994) studied the genetics of resistance to *P. cubensis* by a half diallel analysis of 8 inbred lines. Tests of the hypotheses underlying Hayman's diallel analysis were performed and are discussed. Significance of dominance components indicated that dominance effect was not unidirectional and that dominant genes were not distributed uniformly among the parents.

2.4 Variety identification through sodium dodecyl sulphate poly acrylamide gel electrophoresis (SDS-PAGE)

Variety identification is an important component of crop improvement, variety release and seed production systems. The methods used to identify different germplasm and to evaluate their genetic relationships are principally based on morphological, ecological or biochemical data (Peters and Matinelli, 1989). However, rapid advancement in crop improvement programmes have resulted in a large number of new varieties which may not be distinguishable on the basis of morphological features alone. Hence analysis of seed proteins/isozymes through electrophoresis has become one of the most commonly used techniques to verify or establish the identity of a variety (Dadlani, 1998).

Pierce and Brewbaker (1973) defined electrophoresis as a process of forced diffusion within an electric field. Protein molecules of the sample are moved through a medium that is gel, paper or cellulose by applying an electrical gradient.

Seed proteins have the advantage of being scorable from inviable organs or tissues, and electrophoretic protocol for bulk protein assays is generally simpler than that for isozymes (Cooks, 1984 and Gepts, 1990). The proteins can represent primary gene products and seeds are considered physiologically stable and easy to handle (Ladizinsky and Hymowitz, 1979; Sarkar and Bose, 1984). The main features of the seed protein profile are stability, uniformity and additive nature (Ladizensky and Hymowitz, 1979).

To date, isozymes have been the genetic markers most frequently applied to plant germplasm management (Simpson and Wethers, 1986). They are generally (not always) governed by single Mendelian genes with codominant alleles and, after the appropriate genetic analyses, are interpretable by locus/allele models (Weeden and Wendel, 1989). They can be assayed from a wide variety of organs and analytical procedures are not exceptionally complicated (Murphy *et al.*, 1990). Varieties/cultivars and accessions have been examined for variability in different crops including, sorghum (Shechter and Dewet, 1975), muskmelon (Sujatha, 1991), cucumber (Isshiki , 1992 and Labeda and Dalezal, 1995).

Variation in protein profiles of different varieties/cultivars and germplasm have been observed in many cucurbits including bottlegourd (Upadhyay, 1995 and Singh, 1996), bittergourd (Tewari, 1997), Muskmelon (Yadav *et al.*, 1998; Shukla, 1998 and Choudhary, 1999). The relevant literature with reference to cucurbits has been reviewed as follows :

Staub *et al.* (1983) studied 47 enzymes and general protein in the fruit, seed and cotyledons of *Cucumis sativus* with respect to resolution for possible genetic analysis. In subsequent studies 19 enzymes in green cotyledons of 69 plants belonging to *Cucumis sativus* and 8 other were found to be polymorphic.

Digtyarenko *et al.* (1986) reported protein heterogeneity in cucumber seeds of 20 varieties and lines differing in [illegible], yield, fruit size and other morphological characteristics using electrophoresis. They separated albumin and globulin fractions of seed protein electrophoretically. The best varietal specificity was obtained with albumins using acid alcohol pactate system of electrophoresis.

Engalychev and Zhemchuzhnikova (1988) found marked heterogeneity protein fractions between varieties of different ecological groups in cultivated, semicultivated and wild forms of melon.

Kononkov *et al.* (1989) subjected seed proteins of *Cucumis sativus, Cucurbita pepo, Cucurbita maxima* and *Cucurbita moschata* varieties to separate cucurbitin subunits. They observed polymorphism for cucurbitin composition among and within species and within varieties. Among *Cucurbita pepo* varieties, 2-9 cucurbitin biotypes were identified while among *Cucumis sativus* varieties only 2 biotypes could be detected.

Pasha and Sen (1992) screened salt soluble proteins of seed of several texa of cucurbitaceae by sodium dodecyl sulphate polyacrylamide gel electrophoresis (SDS-PAGE). They detected 3-5 major protein bands in most of the 22 species studied with some variations. Most genera had distinctly different protein banding pattern.

Berg and Gabillard (1994) evaluated the genetic variability of melon seed protein. Electrophoretic analysis of 74 geographically diverse accessions, consisting of 19 morphological groups, revealed 270 reproducible seed protein bands of which 70 were variable. Genetic evaluation led to the conclusion that at least 20 loci govern the variation observed.

Shukla (1998) analysed seed protein profile of 32 germplasm lines of muskmelon. Seed protein could be resolved into a total of 18 bands distributed in 3 zones viz., A, B and C. There were not very significant and prominent differences in protein bands among genotypes however there were differences in the banding proteins in zone A and zone B.

Yadav *et al.* (1998) evaluated seed protein profile of 53 muskmelon genotypes and found that seed protein could be resolved into a total of 13 bands distributed in 4 zones viz., A, B, C and D. However, there were differences in the banding pattern in zone A and based on this difference, 53 germplasm lines could be grouped into 5 dissimilar protein profile groups.

Choudhary (1999) observed protein profile variation in 65 germplasm lines of muskmelon through SDS-PAGE. The seed proteins of 65 germplasm lines could be resolved into a total of 15 protein bands distributed into 4 distinct zone designated as A, B, C and D. The banding patterns were almost similar in C and D zones. Differential bands were located mainly in A zone. A single specific genotype MM-96-72 possessed 2 additional bands B_3 and B_4 in B region. The 65 genotypes were classified into 7 different groups based on their protein profiles.

MATERIALS AND METHODS

Chapter 3

MATERIALS AND METHODS

The present experiment was conducted during the summer season 1999 and rainy season 1999 at the Vegetable Research Centre, Patharchatta of the G.B. Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar (U.P.). It is situated at 29°N latitude, 79.3°E longitude and at an altitude of 243.83 m above the mean sea level.

During winter season of 1998, the six parental lines were grown under polyhouse conditions and all possible crosses, excluding reciprocals were made. Besides crossing, selfing of parents was also performed to get parental seeds. The chief features of the six parental lines of bittergourd used in this investigation are as follows :

S. No.	Line	Source	Fruit characteristics
1.	PBIG-1	Pantnagar	Extra long, glossy green moderately ridged fruits, fruit surface covered with medium sized prominent warts.
2.	PBIG-2	Pantnagar	Extremely short, whitish green, oblong fruits, ridged.
3.	PBIG-4	Pantnagar	Extra long, dark green, without ridges.
4.	Kalyanpur Sona	Kalyanpur	Fruit extremely short, pale green, fruit surface relatively non-ridged.
5.	Kalyanpur Baramasi	Kalyanpur	Extra long, dark green, ridged fruit surface.
6.	Priya White	Vellanikkara kerala	Long fruits white coloured and ridged.

Summer Season 1999 Experiment

This experiment consisted of evaluation of 6 parental cultivars (PBIG-1, PBIG-2, PBIG-4, Kalyanpur Sona, Kalyanpur Baramasi, and Priya White) and their 15 F_1's. All the 21 genotypes were planted in a randomized block design with 3 replications. Each entry was represented by 2.5 m long single row. Row to row distance was 2.0 m and plant to plant distance in single row was kept 50 cm. Seeds were sown in polythene bags under polyhouse for better germination during February, 1999. After 5 weeks, plants were transplanted in well prepared field. The plots were manured with well decomposed FYM @ 10 kg FYM/pit about 25 days ahead of sowing. Sixty g urea along with sixty g of DAP and 0.5 g thimet were applied per pit. After sowing again urea was top dressed in 2 splits @ 30 g/hill. Besides evaluation, fresh 15 F_1's were obtained and 6 parents were also maintained by selfing.

Rainy Season 1999 Experiment

This experiment included evaluation of 15 F_1's along with 6 parental lines. Twenty one genotypes were planted in randomized block design with 3 replications. Five plants were maintained in each entry. Each entry was represented by 3.5 m long single row. Plant to plant distance was 70cm and row to row distance was 2.5 m. Again seeds were planted in plastic bags under polyhouse condition for better germination. However, rainy season crop was not very good due to heavy and untimely rains.

3.1 Observations recorded

The data were recorded for various characters as given below :

3.1.1 Days to male flower

The number of days taken from sowing to opening of the first male flower on row basis was recorded.

3.1.2 Days to female flower

The number of days taken from sowing to opening of the first female flower on row basis was recorded.

3.1.3 Node number to first male flower

Node number from the base of the plant to which the first male flower appeared was counted in five plants and averaged.

3.1.4 Node number to first female flower

Node number from the base of plant to which the first female flower appeared was counted in five plants and averaged.

3.1.5 Number of primary branches per vine

The number of primary branches were counted on five plants at the time of last harvesting and average was calculated.

3.1.6 Vine length (cm)

The main creeper length was recorded in meter from the base of the plant to the tip with the measuring tape at the time of the last harvesting. The average values were used.

3.1.7 Number of fruits per vine

The total number of fruits per five vines over all the harvests was recorded and divided by 5 to get average number of fruits per vine.

3.1.8 Fruit length (cm)

Length of the five randomly selected fruits from a composite harvest was measured and averaged fruit length in centimeter was calculated.

3.1.9 Fruit diameter (cm)

Fruit diameter of the five randomly selected fruits from a composite harvest was measured and average fruit diameter in centimeter was determined.

3.1.10 Fruit density (g / cm^3)

The density of five representative fruits from a composite harvest was taken and the average fruit density was determined. Weight of representative fruits was taken in g. Volume was measured by measuring the volume of water (ml) replaced on dipping the fruit in jar, totally filled with water. Now weight of fruit is divided by volume to get density of fruit.

3.1.11 Fruit yield per vine (kg)

The total yield per five vines over all the harvests was divided by 5 to get average fruit yield per plant.

3.2 Statistical Analysis

3.2.1 Analysis of variance

Analysis of variance table for testing the significance of genotypic differences was as follows :

Sources of variation	Degrees of freedom	Mean square	F value
Replication	(r-1)	M_r	M_r/M_e
Genotype	(t-1)	M_t	M_t/M_e
Error	(r-1)(t-1)	M_e	

Where,

r = Number of replications

M_r = Mean square due to replication

M_t = Mean square due to genotype

M_e = Mean square due to error.

3.2.2 Test of significance

The value of critical differences (CD) was used for testing the significance of means and heterosis.

$$C.D. = \sqrt{\frac{2\,M_e}{r}} \times \text{t value at error degrees of freedom}$$

Where,

M_e = Error mean square

r = Number of replications

3.2.3 Coefficient of variation (CV)

Standard deviation (SD) expressed as percentage of mean is known as coefficient of variation. It was calculated using the following formula :

$$C.V.(\%) = \frac{SD}{\bar{X}} \times 100$$

Where,

SD	=	Standard deviation
	=	√Error mean square
$\bar{X}$	=	Mean of the character

This statistic is generally used to judge the precision of the experiment. The value less than 25% are usually accepted as normal.

3.2.4 Estimation of heterosis

The magnitude of heterosis over better parent (heterobeltiosis) and over local check (standard heterosis) was estimated with the help of following formula :

$$\text{Heterobeltiosis} = \frac{\bar{F}_1 - \overline{BP}}{\overline{BP}} \times 100$$

$$\text{Standard heterosis} = \frac{\bar{F}_1 - \overline{LC}}{\overline{LC}} \times 100$$

Where,

$\bar{F}_1$	=	Mean of F_1
$\overline{BP}$	=	Mean of better parent
$\overline{LC}$	=	Mean of local check

3.2.5 Test of significance

The value of critical differences (CD) was used for testing the significance of heterosis.

$$C.D. = \sqrt{\frac{2M_e}{r}} \text{ x t value at error degrees of freedom}$$

Where,

M_e = Error mean square

r = Number of replications

3.2.6 Combining ability analysis

It was in accordance with method 2 and model I of Griffing (1956b). General and specific combining ability sum of squares were calculated as follows :

$$S_g = \frac{1}{p+2}[S(X_i + X_{ii})^2 - \frac{4}{p}X^2..]$$

$$S_s = S X_{ij}^2 - \frac{1}{p+2} S(X_{i.} + X_{ii})^2 + \frac{2}{(p+1)(p+2)} X^2_{..}$$

Where,

$$\hat{S}_{ij} = X_{ij} - \frac{1}{P+2}(X_{i.} + X_{ii} + X_j + X_{jj}) + \frac{2}{(P+1)(P+2)} X..$$

S_g = Sum of squares due to general combining ability (GCA)

S_s = Sum of squares due to specific combining ability (SCA)

P = Number of parents

S = Summation

$X_{i.}$ = Total of i^{th} array

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

X.. = Grand total of $\frac{P \times (p-1)}{2}$ progenies and p parental values in diallel table.

For combining ability analysis, variance table was as follows :

Sources of variation	Degrees of freedom	M.S.
GCA	n-1= 5	Mgca
SCA	n(n-1)/2 = 15	Msca
Error	(r-1)(t-1) = 40	M'e

$$M'e = \frac{\text{Error variance}}{\text{Number of replications}}$$

3.2.7 Estimates of GCA and SCA effects

GCA and SCA effects were estimated using following formula :

$$\hat{g}_i = \frac{1}{P+2}(X_{i.} + X_{ii} - \frac{2}{P} X..)$$

Where,

g_i = GCA effect of i^{th} parent

S_{ij} = SCA effect of ij^{th} cross

The rest of notations are as explained earlier.

3.2.8 Standard error and critical differences of estimates

Following variances were used in calculation of appropriate S.E. and C.D. values.

$$\text{Var}(\hat{g}_i) = \frac{P-1}{P(P+2)} S^2$$

$$\text{Var}(\hat{S}_{ij}) = \frac{P^2+P+2}{(P+1)(P+2)} S^2$$

$$\text{Var}(\hat{g}_i - \hat{g}_j) = \frac{2}{P+2} S^2$$

$$\text{Var}(\hat{S}_{ij} - \hat{S}_{ik}) = \frac{2(P+1)}{P+2} S^2$$

$$\text{Var}(\hat{S}_{ij} - \hat{S}_{kl}) = \frac{2P}{P+2} S^2$$

Where,

$S^2 = M'e$

3.2.9 Estimation of genetic parameters

The genetic parameters were estimated following the procedure given by Hayman (1954b). The genetic parameters were estimated as follows :

$$\hat{D} = V_0L_0 - \hat{E}$$

$$\hat{F} = 2V_0L_0 - 4W_0L_{01} - 2(n-2)\frac{\hat{E}}{N}$$

$$\hat{H}_1 = V_0L_0 - 4W_0L_{01} + 4V_1L_1 - (3n-2)\frac{\hat{E}}{n}$$

$$\hat{H}_2 = 4V_1L_1 - 4V_0L_1 - 2\hat{E}$$

$$\hat{h}^2 = 4(ML_1 - ML_0)^2 - 4(n-1)\frac{\hat{E}}{n^2}$$

Where,

V_0L_0 = Variance of parents

V_1L_1 = Mean variance of arrays

W_0L_{01} = Mean covariance between parents and arrays

V_0L_1 = Variance of means of array

$(ML_1 - ML_0)^2$ = Square of difference between mean of parents and mean of their n^2 progenies

E = Error variance observed in analysis of variance (grouped randomization), and

$$= \frac{1}{r}\left[\frac{\text{S.S. due to rep.} + \text{SS due to Rep. x treatment}}{\text{Rep. df} + \text{rep. x treat. df}}\right]$$

(ungrouped randomization)

n = number of parents

D = Components of variation due to additive effects of genes

F = Covariance of additive and dominance effects

H_1 = Component of variation due to dominance effects of genes

H_2 = Dominance indicating asymmetry of positive and negative effects of genes.

= $H_1 [1 - (u - v)^2]$

Where,

u = Proportion of positive genes in the parents

v = Proportion of negative genes in the parents

H = Dominance effect (as algebric sum over all loci in heterozygous phase in all crosses)

3.2.10 Standard errors of the components of variation

Standard errors were calculated as follows :

S.E. = (S^2 x corresponding multipliers $)^{1/2}$

The multipliers were obtained from main diagonal of covariance matrix (Hayman, 1954).

S^2 = sum of squares of deviation of observed values from expected values of V_0L_0, V_0L_1, Vr, Wr and

$$\frac{1}{r}[\frac{(ML_1 - ML_0)^2}{34*})$$ in grouped randomization

Three diallel table supplied 45 statistics (6 V, 6W and one each for V_0L_0, V_0L_1 and $(ML_1 - ML_0)^2$
(6 F_r, 1D, 1H_1, 1H_2, 1h^2 and
45-11=34.

Expected values were calculated as follows :

$$Wr = \frac{1}{2}[W_0L_0 + W_r + V_r]$$

$$Vr = \frac{1}{2}(-W_0L_{01} + V_1L_1 + W_r + V_r)$$

$$V_0L_0 = \hat{D} + \hat{E}$$

$$V_0L_1 = \frac{1}{4}\hat{D} - \frac{1}{4}\hat{F} + \frac{1}{4}\hat{H}_1 - \frac{1}{4}\hat{H}_2 + \frac{\hat{E}}{2n}$$

$$(ML_1 - ML_0)^2 = \frac{1}{4}\hat{h}^2 + (n-1)\{(n-1)\hat{E} + \hat{E}\}/n^3$$

3.2.11 Determination of estimators

Following estimators were worked out :

1. $(H_1/D)^{1/2}$ = Mean degree of dominance.

2. $H_2/4H_1$ = Proportion of genes with positive and negative effects

3. $\frac{(4DH_1)^{1/2} + F}{(4DH_1)^{1/2} - F}$ = Proportion of dominant and recessive genes

4. $\frac{h^2}{H_2}$ = Number of groups of genes which control the character and exhibit dominance .

These were interpreted when relevant statistics were significant.

3.2.12 Test of uniformity of Wr - Vr

With ungrouped randomization, it was tested by using following formula (Askel and Johnson, 1963)

$$t^2 = \frac{n-2}{4} x \frac{(\text{Var. Vr - Var. Wr})^2}{(\text{Var. Vr x Var Wr - Cov}^2(\text{Vr, Wr})}$$

With n-2 degree of freedom.

With grouped randomization, it was tested by carrying out analysis of variance of Wr - Vr.

3.2.13 Graphical analysis

The analysis was based on Vr and Wr statistics derived from diallel tables (Jinks and Hayman, 1953). Regression coefficient of Wr on Vr was calculated as :

$$b = \frac{S_{xy}}{S_{xx}} \qquad X = X - \overline{X}, X = Vr$$

$$Y = Y - \overline{Y},\ Y = Wr$$

The standard error of the regression coefficient was calculated as :

$$S_b = [\frac{S(Y - \overline{Y})^2 - bS(X - \overline{X})(Y - \overline{Y})}{(n-2)S(X - \overline{X})^2}]^{1/2}$$

With n-2 degrees of freedom.

$1\text{-}b/S_b$ gave 't' value for testing significance of b from unity. The expected regression line was drawn by plotting Y against X, where Y = Y + b (X - X). Limiting parabola was constructed on the basis of $Wr^2 = Vr \times V_0L_0$ i.e. by plotting Vr and $(Vr \times V_0L_0)^{1/2}$ points.

3.3 Sodium dodecyl sulphate poly acrylamide gel electrophoresis (SDS- PAGE)

Composite seeds collected from 6 germplasm lines of bittergourd grown during summer 1999 were utilized for seed protein electrophoresis. The details were broadly as described by Laemmli (1970).

3.3.1 Equipments and accesseries

A vertical slab gel electrophoresis apparatus (Commercial or home made version) with all the accessories including glass plates, platinum electrode, well forming comb, spacers and buffer tank, for gels of approximately 150x150x1.5 mm dimensions were used. Other equipments and accessories used were :

- Power supply with adjustable constant current/voltage (200 m A, 500 V) output capacity.
- Balance for weighing in a 1 mg to 250 g range.
- A bench top microcentrifuge.
- A platform rocker for staining and destaining.
- White light box for gel viewing.

- A scalpel for cutting the seeds, and a hammer with smooth flat head and a smooth metal.
- Glasswares for making stock and working solution and eppendorf tubes for sample.
- Transparent plastic or glass trays preferably with lids for gel staining and destaining.
- Butter paper cut to ~ 3" x 3" square pieces.
- Latex gloves for handling toxic chemicals (acrylamide and trichloroacetic acid etc.)
- Glass syringe for pouring the gel.
- Gilson pipettes (P - 1000 and P- 200) with tips
- Hamelton glass micro-syringe (100 ml) for loading the sample.

3.3.2 Stock solutions and buffer

2 x Sample buffer (pH 6.8)

1.51 g	Tris Base
8 g	SDS
30 ml	Glycerol
2 mg	Bromophenol blue
64 ml	H_2O (Warm solution to dissolve)

Allow to cool to room temperature. Add concentrated HCl until pH falls to 7.4. Then 1 M HCl until pH falls to 7.1. It was left for a few minutes until pH fall 6.8. Volume was made upto 100 ml. Stored at 37°C in oven.

Ammonium persulphate (10%)

0.1 g Ammonium persulphate was dissolved in 1ml H_2O Ideally made fresh daily, but keeps for 5 days in fridge.

2X Separating gel buffer (pH 8.9)

45.4	g	Tris Base
1	g	SDS
460	ml	H_2O

Add conc. HCL drop wise until pH falls to 8.88. Make total 500 ml. Store in fridge.

Stock acrylamide for separating gels (0.8% C)

75	g	Acrylamide
0.6	g	Bisacrylamide
181	ml	H_2O

Make 250 ml (30% acrylamide 0.24% biscrylamide, 0.8% C). Store in dark bottle at 4°C.

Stock acrylamide for stacking gels (1.5% C)

75	g	Acrylamide
1.15	g	Bisacrylamide
181	ml	H_2O

Make 250 ml (30% acryfamide, 0.24% bisacrylamide, 0.8% C). Store in dark bottle at 4°C.

2 X Stacking gel buffer (pH 6.8)

6.06	g	Tris Base
0.4	g	SDS
190	ml	H_2O

Add HCl till pH falls to 6.8. Makes a total of 200 ml. Store in refrigerator.

Stock acrylamide for stacking gel

15	g	Acrylamide
0.4	g	Bisacrylamide
36	ml	H_2O

Make 50 ml (30% acrylamide, 0.8% bisacrylamide, 2.7% C). Store in dark bottle at 4°C.

10X Electrode buffer (pH 8.3)

30.3	g	Tris base
144.2	g	Glycine
10	g	SDS
885	ml	H_2O

pH is approximately 8.6. Make 1 litre. Store at room temperature. For use, 1 part of this solution is mixed with 9 parts of H_2O. The pH falls to approximately 8.4. A little more glycine is added to bring the pH to 8.3.

Staining solution

Step1

0.25	g	Coomassie Brilliant Blue R
25	ml	H_2O

Step 2

60	g	Trichloroacetic acid
720	ml	H_2O
180	ml	Methanol
60	ml	Glacial acetic acid

Step 3

Tip step 1 solution is added into step 2 solution and mix by stirring. Make 1 litre. Store in dark bottle at room temperature.

Destaining solution (3% NaCl)

150 g NaCl in 5 litre H_2O

Store at room temperature.

Additional chemicals required

TEMED
2-mercaptoethanol

3.3.3 Total protein extraction

Cut the seed into two halves and save the embryo half in small paper packet. Crush the brush end of the seed between a folded butter paper with a hammer on a metal plate. Alternatively, 20 mg of crushed sample was used. Transfer the crushed seed into an eppendorf tube and add 200 µl of sample buffer (pH 6.8) containing 2% mercaptoethanol. Extract for atleast 1 h in a 37°C incubator. Extraction was done overnight for convenience. Centrifuge for 10 min at 10,000 rpm (about 12,000 g) just before loading the supernatant in the gel slots (20 µl/well with a 20 well comb and 1.5 mm thick gel).

3.3.4 Gel preparation

Two gels, namely separating gel and stacking gel were prepared. The details are as follows :

Separating gel (60 ml for 2 gels)

2x Separating gel buffer pH 8.9	30 ml
Stock acrylamide for separating gel	20 ml
Distilled water	10 ml
TEMED	100 µl
10% Ammonium persulphate*	100 µl

Stacking gel (9 ml for 2 gels)

2X Stacking gel buffer pH 6.8	4.5 ml
Distilled water	3.5 ml
Stock acrylamide for stacking gel	1.0 ml
TEMED	20 µl
10% Ammonium persulphate*	

*Add just before pouring the gels.

3.3.5 Procedure

The glass plates were cleaned spotlessly using detergent, water and then wiped with ethanol. Silicon grease was applied at the bottom margin of the lower plate of the gel mold. The spacers were positioned and the upper plate was fixed with clamps. The leak was checked by pouring water between the glass plates. Prepared separating gel was poured in space between the plates leaving about 2.5 cm space from the top. 1 ml of water was carefully layered over the separating gel to seal off the gel from air which inhibits gel polymerization. The gel could set in about 30 minutes. It could be easily known by checking the gel solution left in the beaker. During this gel setting period, electrode buffer (1X) was prepared. Once the gel is fully set, a clear interface will be visible between the top of the gel and the water layered earlier on the gel. The excess water was removed from the top of the gel using a 1 ml syringe. The comb was inserted in place leaving a 10 mm gap between the comb and the separating gel. Then, the stacking gel solution was poured between the glass plates using a 5 ml syringe followed by immediate rinsing of the syringe. The stacking gel could set in about 15 minutes. The gel was left for one hour for complete polymerization.

Now sample was ready for loading. The comb was removed once the gel has set. The wells were cleaned with a syringe. The lower spacer was removed and the gel was placed in the lower buffer tank of assembly already filled with electrode buffer. Air bubbles if any were removed carefully by agitating the buffer with glass rod. Electrode buffer was filled to the upper tank and the samples were loaded with a micro syringe. 12 µl of prepared samples were loaded in individual wells. The run was performed at a constant current of 45 mA/gel throughout. The run was performed until the bromophenol blue dye migrated to about 0.5 cm from the bottom of the separating gel.

After completion of the run the power supply was switched off. The gel apparatus was dismantled. The upper tank buffer was discarded. The lower tank buffer may be used for several runs. The gel was removed after separating the two glass plates with the help of spatula. The position of first sample of the gel marked by cutting the corner of the bottom side of the last sample.

The gel was transferred to the staining tray with 200 ml of staining solution/gel/tray. Staining continued overnight. Next morning, the staining solution was drained off in a separate container to use it once more. About 500 ml of 3% NaCl was added for de-staining of the gel. It may take two hours to get a clear back ground. The electrophoregrams of the seed protein profiles were prepared and the gels were photographed and stored in sealed plastic bags after a brief rinse in distilled water to remove excess salt solution.

EXPERIMENTAL RESULTS

Chapter 4

EXPERIMENTAL RESULTS

The present experiment dealing with determination of heterosis, combining ability, component of genetic variation and gene action was undertaken involving 15 F_1's and 6 parental lines of indigenous strains of bittergourd on the basis of evaluation in a randomized block design for two seasons, namely, summer season, 1999 and rainy season, 1999. The 21 genotypes were evaluated for 11 Horticultural traits, namely days to male flower, days to female flower, node number to male flower, node number to female flower, number of primary branches per vine, vine length (m), number of fruits per vine, fruit length (cm), fruit diameter (cm), fruit density (g/cm^3) and fruit yield per vine (kg).

Besides this field experiment, seeds of 6 parents were subjected to sodium dodecyl sulphate poly acrylamide gel electrophoresis (SDS-PAGE) for detecting variation in protein banding pattern. The results are presented as follows :

4.1 Analysis of variance

Analysis of variance for various agronomic traits for both the seasons is given in Table 4.1. The genotypic differences were highly significant, in both the seasons for all the characters namely days to male flower, days to female flower, node number to male flower, node number to female flower, number of

Table 4.1 : Analysis of variance for various horticultural traits (summer season, 1999 and rainy season, 1999)

Sources of variation	Degrees of freedom	Mean square									
		Days to male flower		Days to female flower		Node number to first male flower		Node number to first female flower		Number of primary branches per vine	
		Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
Replication	2	3.11	0.11	2.68	11.63	3.44	1.06	0.83	0.19	2.02	10.11
Genotype	20	55.90**	60.09**	51.96**	71.36**	8.11**	11.11**	10.15**	11.18**	61.58**	63.73**
Error	40	3.74	3.98	6.07	5.40	0.71	1.49	0.58	1.62	2.17	2.01

Mean square											
Vine length (m)		Number of fruits per vine		Fruit length (cm)		Fruit diameter (cm)		Fruit density (g/cm^3)		Fruit yield per vine (kg)	
Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
0.04	0.16	6.05	150.91	0.91	1.69	0.08	0.04	0.06	0.02	0.06	0.01
0.47**	0.36**	51.77**	193.25	52.83**	52.29**	1.21**	0.96**	0.41**	0.43	0.43**	0.27**
0.03	0.09	17.56	160.02	0.99	0.44	0.04	0.14	0.01	0.02	0.04	0.04

*, ** Significant at 0.05 and 0.01 levels of probability, respectively.

primary branches per vine, vine length (m), fruit length (cm), fruit diameter (cm), fruit density (g/cm^3) and fruit yield per vine (kg). The genotypic differences for number of fruits per vine was highly significant in summer season experiment only.

4.2 Mean performance of the parental genoytpes

Mean values for various horticultural traits measured on parental cultivars and the F_1 generation are summarized in Table 4.2. In cases where F-test was found to be non-significant in analysis of variance (Table 4.1), critical difference was not calculated and differences between varietal means were treated to be non-significant. The CV values were below 25 per cent for all the characteristics except number of fruits per vine (73.59%) during rainy season. This indicated that except for number of fruits per plant (rainy season), the precision of the experiment was within the accepted normal limit of coefficient of variation.

Among the parental cultivars PBIG-2 (Plate 3) was the earliest for days to male flowers in both the seasons. PBIG-2 took 37.00 and 32.00 days in summer season and rainy season, respectively. The genotype which took maximum days to male flower was Priya White (Plate 2) taking on an average, 46.67 days in both the seasons. For days to female flowers, Kalyanpur Sona (44.00) (Plate 3) proved to be the earliest in summer season experiment, whereas PBIG-2 (36.00) was the earliest in rainy season experiment. Kalyanpur Baramasi (55.00) (Plate 2) took maximum days to female flower in summer whereas in rainy season experiment, Priya White was the latest variety (Table 4.2).

For number of primary branches per plant, Kalyanpur Sona proved to be the best with 20.33 and 21.00 branches per vine in summer and rainy season experiment, respectively. The lowest values were shown by PBIG-1 (Plate 1) in both the seasons (Table 4.2). The length of vine was observed to be the highest in PBIG-4 (3.16 and 2.84 m) (Plate 1) in both summer and rainy season experiment, respectively. In case of Priya White length of vine was found to be minimum (1.81 and 1.82 m) in summer and rainy season, respectively.

Maximum number of fruits per vine (22.00) were harvested from Priya White in summer season. In rainy season, maximum number of fruits per vine were produced by Kalyanpur Sona. PBIG-4 produced minimum number of fruits (12.66) in summer season and PBIG-4 and Kalyanpur Baramasi, produced minimum number of fruits (11.00) in rainy season Kalyanpur Baramasi had the longest fruits in both rainy and summer season experiments having 21.58 cm and 21.17 cm fruit length, respectively. Kalyanpur Sona, with fruit length of 8.68 cm and 7.75 cm in summer and rain season respectively however represented the lowest values.

Substantial variability was observed for fruit diameter as lowest value was 2.50 cm and 2.58 cm in summer and rainy season experiments, respectively in Kalyanpur Baramasi. The maximum value of fruit diameter

Plate 1 : Long fruited parental lines of bittergourd PBIG-1 and PBIG-4


PBIG-1


PBIG-4

Plate 2 : Long fruited parental lines of bittergourd
Kalyanpur Baramasi and Priya White


KB


PW

Plate 3 : Small fruited parental lines of bittergourd
Kalyanpur Sona and PBIG-2


KS


PBIG-2

was detected in Kalyanpur Sona which was 4.15 cm and 3.92 cm in summer and rainy season experiments respectively.

Kalyanpur Sona was detected the genotype with lowest fruit density in both the seasons. The values were 0.75 g/cm^3 and 0.79 g/cm^3 in summer and rainy season experiments, respectively. Highest fruit density was detected in Priya White with value 1.88 g/cm^3 in both the seasons.

Kalyanpur Sona proved to be the highest yielder per vine (1.45 kg) in summer season whereas PBIG-2 produced the highest (1.29 kg) in rainy season.

4.3 Mean performance of hybrid cultivars and estimation of heterosis

The estimates of heterobeltiosis and standard heterosis for various horticultural traits for the experiment conducted during summer season, 1999 and rainy season, 1999 are given in Table 4.3 and 4.4 respectively.

4.3.1 Days to male flower

F_1 hybrid exhibited a wide range of variation in summer season for days to male flower. PBIG-2 x Kalyanpur Sona (Plate 4) was the earliest (32.33) followed by Kalyanpur Sona x Priya White (36.33) and PBIG-4 x Kalyanpur Sona (36.33) (Table 4.2 and Plate 5). During rainy season PBIG-2 x Kalyanpur Sona (30.67) was found earliest followed by PBIG-1 x Kalyanpur Sona (31.00) (Plate 5). The latest F_1 was PBIG-4 x Kalyanpur Baramasi (42.33). PBIG-2 x Kalyanpur Sona showed highly significant negative heterobeltiosis (-12.62%)

Table 4.2 : Mean values of parents and crosses for various horticultural traits (summer season,1999 and rainy season,1999)

Parents and crosses	Days to male flower			Days to female flower			Node number to first male flower			Node number to first female flower			Number of primary branches per vine		
	Summer	Rainy	Average	Summer	Rainy	Average	Summer	Rainy	Average	Summer	Rainy	Average	Summer	Rainy	Average
PBIG-1	40.00	36.00	38.00	46.00	42.67	44.34	7.67	8.33	8.00	8.00	9.67	8.84	11.00	9.33	10.17
PBIG-2	37.00	32.00	34.50	44.67	36.00	40.34	4.00	5.00	4.50	4.33	5.67	5.00	18.66	18.00	18.33
PBIG-4	44.67	42.00	43.34	49.67	46.33	48.00	9.00	8.67	8.84	10.33	9.67	9.50	13.33	10.66	12.00
K.S.	37.33	32.33	34.83	44.00	36.67	40.34	4.67	4.33	4.50	8.67	5.00	6.84	20.33	21.00	20.67
K.B.	47.33	43.33	45.33	55.00	51.00	53.00	10.67	12.67	11.67	13.00	13.67	13.34	14.67	15.33	15.00
P.W.	47.67	44.67	46.17	51.67	53.00	52.34	7.00	9.33	8.17	7.33	11.00	9.17	12.33	10.33	11.33
PBIG-1 x PBIG-2	36.67	32.00	34.34	43.00	37.33	40.17	6.33	6.67	6.50	7.33	7.33	7.33	12.67	16.00	14.34
PBIG-1 x PBIG-4	37.00	33.33	35.17	49.67	43.67	46.67	6.33	8.00	7.17	8.33	8.67	8.50	10.00	11.00	10.50
PBIG-1 x K.S.	36.33	31.00	33.67	42.00	38.67	40.34	5.00	4.67	4.84	7.33	6.33	6.83	22.33	20.33	21.33
PBIG-1 x K.B.	41.33	36.00	38.67	44.33	44.67	44.50	7.33	6.67	7.00	9.33	8.00	8.67	9.00	22.33	10.65
PBIG-1 x P.W.	44.67	35.00	39.84	50.00	43.00	46.50	5.33	5.67	5.50	7.67	6.67	7.17	12.00	11.00	11.50
PBIG-2 x PBIG-4	43.67	37.33	40.50	47.33	44.33	45.83	5.00	5.33	5.17	6.67	6.67	6.67	12.33	21.67	17.00
PBIG-2 x K.S.	32.33	30.67	31.50	36.33	36.00	36.17	4.33	4.67	4.50	6.33	6.67	6.50	21.00	21.00	21.00
PBIG-2 x K.B.	47.00	42.00	44.50	50.67	48.33	49.50	8.00	8.00	8.00	11.00	9.00	10.00	12.67	13.33	12.50
PBIG-2 x P.W.	39.67	37.33	38.50	45.00	44.33	44.67	5.66	5.33	5.50	7.33	6.33	6.83	22.00	19.00	20.50
PBIG-4 x K.S.	42.33	39.33	40.83	47.00	46.33	46.67	7.00	6.67	6.84	9.33	8.00	8.67	17.00	16.33	16.67
PBIG-4x K.B.	43.00	42.33	42.67	47.33	48.67	48.00	4.67	7.00	5.84	7.67	8.00	7.84	14.67	15.67	15.17
PBIG-4 x P.W.	38.00	37.33	37.67	44.67	44.00	44.34	6.33	7.00	6.67	8.67	8.33	8.50	9.00	9.33	9.17
K.S. x K.B.	44.67	42.00	43.34	49.00	47.00	48.00	6.67	6.33	6.50	9.00	7.66	8.33	14.67	14.33	14.50
K.S. x P.W.	36.33	37.00	36.67	41.33	41.67	41.50	6.67	7.00	6.84	9.67	8.00	8.84	21.67	21.33	21.50
K.B. x P.W.	38.66	42.33	40.50	43.67	48.67	46.17	7.67	7.33	7.50	10.00	8.66	9.33	9.33	10.00	9.67
C.D. 5%	3.19	3.29		4.05	3.86		1.39	2.02		1.25	2.10		2.42	2.34	
CV (%)	4.75	5.33		5.31	5.29		13.09	17.76		8.98	15.83		9.95	9.09	

Table 4.2 Contd...

Parents and crosses	Vine length (m)			Number of fruits per vine			Fruit length (cm)		
	Summer	Rainy	Average	Summer	Rainy	Average	Summer	Rainy	Average
PBIG-1	2.70	2.63	2.67	18.00	15.67	16.84	20.17	19.08	19.63
PBIG-2	2.69	2.58	2.64	17.33	14.33	15.83	9.10	7.92	8.51
PBIG-4	3.16	2.84	3.00	12.66	11.00	11.83	19.67	19.17	19.42
K.S.	2.29	2.32	2.31	18.33	14.33	16.33	8.68	7.75	8.22
K.B.	2.10	2.39	2.25	14.00	11.00	12.50	21.17	21.58	21.38
P.W.	1.81	1.82	1.82	22.00	11.33	18.67	16.50	18.38	17.44
PBIG-1 x PBIG-2	2.71	1.67	2.19	21.67	14.33	18.00	18.92	19.00	18.96
PBIG-1 x PBIG-4	2.56	2.16	2.36	22.67	11.67	17.17	23.88	22.08	22.98
PBIG-1 x K.S.	2.58	2.22	2.40	16.33	13.33	14.83	14.32	15.33	14.83
PBIG-1 x K.B.	2.86	2.38	2.62	24.67	15.33	20.00	19.78	20.83	20.31
PBIG-1 x P.W.	3.35	2.74	3.05	26.67	16.67	21.67	17.76	18.17	17.97
PBIG-2 x PBIG-4	2.41	2.21	2.31	25.33	17.33	21.33	12.80	12.83	12.82
PBIG-2 x K.S.	2.36	2.18	2.27	23.67	17.67	20.67	11.72	11.42	11.51
PBIG-2 x K.B.	2.53	1.90	2.22	20.00	16.00	18.00	17.33	16.92	17.13
PBIG-2 x P.W.	3.13	2.33	2.73	24.33	18.00	21.17	14.80	15.00	14.90
PBIG-4 x K.S.	2.61	2.50	2.56	22.67	22.00	22.34	15.67	15.83	15.75
PBIG-4x K.B.	3.15	2.63	2.89	24.00	16.67	20.34	24.18	23.25	23.72
PBIG-4 x P.W.	2.63	2.20	2.42	21.33	19.67	20.50	16.80	15.80	16.30
K.S. x K.B.	2.46	2.23	2.35	28.33	21.67	25.00	14.57	14.67	14.62
K.S. x P.W.	3.37	3.17	3.27	25.33	16.67	21.00	13.72	15.85	14.79
K.B. x P.W.	2.53	2.43	2.48	18.67	16.67	17.67	15.17	14.80	14.99
C.D. 5%	0.27	0.50	-	0.91	NS	-	1.63	1.09	-
CV (%)	6.06	12.92	-	19.65	73.59	-	6.02	4.01	-

Table 4.2 Contd…

Parents and crosses	Fruit diameter (cm)			Fruit density (g/cm^3)			Fruit yield per vine (kg)		
	Summer	Rainy	Average	Summer	Rainy	Average	Summer	Rainy	Average
PBIG-1	2.75	2.90	2.83	1.16	1.13	1.15	1.10	0.75	0.93
PBIG-2	3.90	3.50	3.70	0.90	0.94	0.92	1.27	1.29	1.28
PBIG-4	2.88	2.72	2.80	1.81	1.80	1.81	0.86	0.73	0.80
K.S.	4.15	3.92	4.04	0.75	0.79	0.77	1.45	0.91	1.18
K.B.	2.50	2.58	2.54	1.82	1.79	1.87	0.83	0.70	0.77
P.W.	3.33	3.42	3.38	1.87	1.88	1.88	1.02	0.86	0.94
PBIG-1 x PBIG-2	3.63	3.40	3.52	1.59	1.59	1.59	1.62	1.30	1.46
PBIG-1 x PBIG-4	3.53	3.75	3.64	1.33	1.39	1.38	1.57	1.30	1.44
PBIG-1 x K.S.	4.15	4.10	4.13	0.76	0.80	0.78	1.27	0.94	1.11
PBIG-1 x K.B.	4.23	4.23	4.23	0.98	0.99	0.99	1.61	1.37	1.49
PBIG-1 x P.W.	3.58	3.45	3.52	1.79	1.91	1.85	1.72	1.41	1.57
PBIG-2 x PBIG-4	3.49	3.73	3.61	1.57	1.59	1.58	1.66	0.98	1.32
PBIG-2 x K.S.	4.23	4.83	4.53	1.56	1.46	1.51	1.80	1.54	1.67
PBIG-2 x K.B.	3.56	3.80	3.68	1.11	1.02	1.07	1.11	1.04	1.08
PBIG-2 x P.W.	4.23	4.20	4.22	1.019	0.954	0.987	2.29	1.40	1.85
PBIG-4 x K.S.	3.18	3.28	3.23	1.016	0.988	1.002	1.72	1.54	1.63
PBIG-4x K.B.	2.58	2.75	2.67	0.987	1.000	0.994	1.43	0.95	1.19
PBIG-4 x P.W.	3.43	3.60	3.52	1.095	1.095	1.095	1.23	1.09	1.16
K.S. x K.B.	4.65	4.62	4.64	1.023	0.991	1.007	2.07	1.80	1.94
K.S. x P.W.	4.73	4.17	4.45	1.312	1.280	1.296	1.81	1.33	1.57
K.B. x P.W.	3.50	3.57	3.54	0.855	0.859	0.859	1.41	1.83	1.62
C.D. 5%	0.34	0.61	-	0.19	0.28	-	0.33	0.32	-
CV (%)	5.69	10.13	-	9.32	10.27	-	13.42	16.57	-

*, ** Significant at 0.05 and 0.01 levels of probability, respectively.

K.S. = Kalyanpur Sona

K.B. = Kalyanpur Baramasi

P.W. = Priya White

and standard heterosis (-19.89%) in summer season. Estimates of standard heterosis (-19.18%) showed consistency in rainy season also (Table 4.3) but heterobeltiosis for this cross was found to be non-significant in rainy season.

Kalyanpur Baramasi x Priya White exhibited highly significant heterobeltiosis in summer season experiment (-18.32%). Highly significant heterobeltiosis was observed in PBIG-4 x Priya White (-14.91%) for summer season and for rainy season experiment (-11.12%) also.

PBIG-1 x PBIG-2 (-8.33% and -11.11%) and PBIG-1 x Kalyanpur Sona (-9.18% and -13.89) exhibited highly significant standard heterosis in both seasons, respectively. Whereas, Kalyanpur Sona x Priya White (-3.35%) gave significant standard heterosis in summer season.

4.3.2 Days to female flower

For both the seasons PBIG-2 x Kalyanpur Sona was detected as earliest F_1 hybrid. Days taken by this F_1 were 36.33 and 30.00 in summer and rainy season respectively. Maximum days were taken by PBIG-4 x Priya White (44.67) in summer season and by Kalyanpur Bramasi x Priya White (48.67) in rainy season. During rainy season, 2 crosses PBIG-1 x PBIG-2 (37.33 and PBIG-1 x Kalyanpur Sona (38.67) were also earlier than other crosses.

Cross, Kalyanpur Baramasi x Priya White showed highly significant heterobeltiosis in summer season experiment. Estimates of heterobeltiosis was -20.60%. Crosses PBIG-2 x Kalyanpur Sona (-18.67%) and PBIG-4 x Priya White (-10.07%) showed highly significant heterobeltiosis whereas, Kalyanpur

Plate 4 : Promising F_1 hybrids for earliness and high yield
PBIG-2 x Kalyanpur Sona
Kalyanpur Sona x Kalyanpur Baramasi


PBIG-2 x KS


KS x KB

Sona x Priya White (-3.07%) were found to express significant heterobeltiosis in summer season.

Three Crosses, PBGI-2 x Kalyanpur Sona, PBIG-1 x Kalyanpur Sona and PBIG-1 x PBIG-2 showed highly significant standard heterosis in both the seasons. Estimates in summer season and rainy seasons are given in Table 4.4.

During rainy season, earlier crosses were, PBIG-2 x Kalyanpur Sona (36.00), PBIG-1 x PBIG-2 (37.33)and PBIG-1 x Kalyanpur Sona (38.67).

4.3.3 Node number to first male flower

Cross, PBIG-2 x Kalyanpur Sona showed lowest value for number to first male flower in summer as well as rainy season. Values are 4.33 and 4.67 respectively. The highest value was exhibited by PBIG-2 x Kalyanpur Baramasi (8.00) in both the season. Besides PBIG-2 x Kalyanpur Baramasi, another cross PBIG-1 x PBIG-4 expressed the same value in rainy season. Some crosses showed earlier emergence of male flower those were PBIG-1 x Kalyanpur Sona (5.00), PBIG-2 x PBIG -4 (5.00), PBIG- 4 x Kalyanpur Baramasi (4.67) in summer season and PBIG-2 x Priya White (5.33), PBIG-2 x PBIG-4 (5.33) and PBIG-1 x Priya White (5.67) in rainy season.

Two crosses, PBIG-4 x Kalyanpur Baramasi (-43.11%) and PBIG-1 x Priya White (-23.86%) showed highly significant heterobeltiosis in summer season, whereas in rainy season, PBIG-1 x Priya White (-31.93%), PBIG-1 x Kalyanpur Baramasi (-19.93%), PBIG-4 x Kalyanpur Baramasi (-19.26%), PBIG-4 x Priya White (-19.26%) and Kalyanpur Baramasi x Priya White (-21.44%) exhibited highly significant heterobeltiosis.

PBIG-2 x Priya White and PBIG-4 x Priya White exhibited highly significant standard heterosis in both the seasons. It's value for summer and rainy seasons is -26.21% and -36.02% respectively for PBIG-2 x Priya white and (-17.47%) and -15.97% for PBIG-4 x Priya White. PBIG-1 x PBIG-2 (-39.98%), PBIG-1 x Kalyanpur Sona (-43.93%), PBIG-4 x Kalyanpur Sona (-19.93%), and Kalyanpur Sona x Kalyanpur Baramasi (-24.02%) gave highly significant estimate for rainy season experiment. Three F_1 cross namely, Kalyanpur Sona x Kalyanpur Baramasi (-13.04%) showed significant standard heterosis in summer season experiment and PBIG-4 x Priya White (-15.97%), PBIG-4 x Kalyanpur Baramasi (-15.97%) and Kalyanpur Sona x Priya White (-15.97%) showed significant standard heterosis in rainy season experiment.

4.3.4 Node number to first female flower

PBIG-4 x Kalyanpur Sona (6.33) was detected as earliest during summer season experiment followed by PBIG-2 x PBIG-4 (6.67), whereas PBIG-1 x Kalyanpur Sona (6.33) and PBIG-2 x Priya White (6.33) was the earliest in rainy season followed by PBIG-1 x Priya White (6.67), PBIG-2 x PBIG-4 (6.67) and PBIG-2 x Kalyanpur Baramasi (6.67).

During summer season experiment, only one cross, PBIG-4 x Kalyanpur Baramasi (-25.7%) could show highly significant heterobeltiosis. Whereas in rainy season experiment, PBIG-1 x Kalyanpur Baramasi (-17.27%) and PBIG-1 x Priya White (-31.02%) showed highly significant heterobeltiosis.

Crosses PBIG-1 x PBIG-2 (-24.20%), PBIG-1 x Kalyanpur Sona (-34.54%), PBIG-2 x Kalyanpur Sona (-31.02%), PBIG - 2 x Priya White (-34.54%), PBIG-4 x Kalyanpur Sona (-17.27%), PBIG - 4 x Priya White (-13.81%), Kalyanpur Sona x Kalyanpur Baramasi (-20.79%) and Kalyanpur Sona x Priya White (-17.27%) showed highly significant standard heterosis during rainy season experiment.

In summer season experiment, only two crosses, PBIG-2 x PBIG - 4 (-16.75%) and PBGI-2 x Kalyanpur Sona (-20.88%) showed significant standard heterosis.

4.3.5 Number of primary branches per vine

The range of number of primary branches per vine among F_1 hybrids was 9.00 (PBIG-4 x Priya White) to 22.33 (PBIG-1 x Kalyanpur Sona) during summer season experiment. During rainy season experiment, it was 9.33 (PBIG-4 x Priya White) to PBIG-1 x Kalyanpur Baramasi (22.33).

PBIG-2 x Priya White (22.00), PBIG-2 x Kalyanpur Sona (21.00) and PBIG-1 x Kalyanpur Sona (22.33) produced more number of primary branches per vine during summer season experiment. PBIG-1 x Kalyanpur Sona (20.33) and PBIG-2 x Kalyanpur Sona (21.00) showed consistency in rainy season experiment also for the same character. No cross could show consistent heterobeltiosis in both the seasons. However, PBIG-1 x Kalyanpur Sona

(9.84%) and PBIG-2 x Priya White (17.89%) showed highly significant heterosis during summer season experiment, whereas PBIG-2 x PBIG-4 (20.39%) and PBIG-2 x Kalyanpur Sona (16.67%) showed highly significant heterosis for rainy season experiment.

Highly significant standard heterosis for both summer and rainy season experiment respectively, was detected in PBIG-2 x Kalyanpur Baramasi (15.18% and 21.18%), PBIG- 2 x Kalyanpur Sona (90.91% and 90.09%), PBIG-2 x Priya White (10.00% and 72.73%), PBIG-4 x Kalyanpur Sona (54.56% and 48.46%), PBIG-4 x Kalyanpur Baramasi (33.36%) and 42.91%) and Kalyanpur Sona x Kalyanpur Baramasi (33.36% and 30.27%).

4.3.6 Vine length (m)

For vine length (m), F_1 varied from 2.41 (PBIG-2 x PBIG-4) to 3.31 (Kalyanpur Sona x Priya White) during summer season experiment. Other food performers were PBIG-2 x Priya White (3.13), PBIG-4 x Kalyanpur Baramasi (3.15) and PBIG-1 x Priya White (3.35) during summer season experiment. During rainy season experiment, best performing F_1 was Kalyanpur Sona x Priya White (13.17) followed by PBIG-1 x Priya White (2.79).

The cross namely Kalyanpur Sona x Priya White exhibited highly significant heterobeltiosis during both summer and rainy seasons. The estimates were 47.16% and 36.64% in respective seasons. PBIG-2 x Priya White (16.38%), PBIG-1 x Priya White (24.04%) and Kalyanpur Baramasi x

Priya White (24.48%) showed highly significant heterobeltiosis during summer season experiment.

4.3.7 Number of fruits per vine

Kalyanpur Sona x Kalyanpur Baramasi (28.33) was detected as a genotype producing maximum number of fruits followed by PBIG-1 x Priya White (26.67) during summer season experimen. Other proved good F_1's were PBIG-2 x PBIG-4 (25.33), Kalyanpur Sona x Priya White (25.33) and PBIG-1 x Kalyanpur Baramasi (24.67). During rainy season outstanding performers were PBIG-4 x Priya White (49.67) and PBIG-4 x Kalyanpur Sona (22.00)

Three crosses, PBIG-4 x Kalyanpur Baramasi (71.43%), Kalyanpur Sona x Kalyanpur Baramasi (54.56%) and Kalyanpur Sona x Priya White (15.19%) showed highly significant heterobeltiosis in summer season experiment. Not a single cross could show heterobeltiosis during rainy season experiment.

Six crosses, PBIG-1 x PBIG-4 (25.94%), PBIG-1 x Kalyanpur Baramasi (37.06%) and PBIG-1 x Priya White (48.17%), PBIG-2 x PBIG-4 (40.72%), Kalyanpur sona x Kalyanpur Baramasi (57.39%) and Kalyanpur Sona x Priya White (40.72%) showed significant standard heterosis, whereas, one cross PBIG-4 x Kalyanpur Sona (25.94%) showed highly significant standard heterosis in summer season experiment.

4.3.8 Fruit length (cm)

Out of all 15 F_1's longest fruits (cm) were produced by PBIG-4 x Kalyanpur Baramasi (24.18 cm and 23.25 cm) followed by PBIG-1 x PBIG-4 (23.88 cm and 22.08 cm) in both summer and rainy season respectively. PBIG-1 x Kalyanpur Baramasi was also proved high performer by producing 19.78 cm and 20.83 cm long fruits in summer and rainy season respectively.

PBIG-1 x PBIG-4 and PBIG-4 x Kalyanpur Baramasi were 2 F_1's which proved highly heterotic in both the seasons experiments (Table 4.3). Highly significant heterobeltiosis was expressed by PBIG-2 x Kalyanpur Sona in summer as well as rainy season experiments and their estimates were 28.79% and 44.19% in summer and rainy seasons experiments, respectively.

4.3.9 Fruit diameter (cm)

Value of fruit diameter (cm) in F_1's varied from 2.58 cm (PBIG-4 x Kalyanpur Baramasi) to4.73 cm (Kalyanpur Sona x Priya White) during rainy season. Some outstanding performers were PBIG-1 x Kalyanpur Sona (4.15 cm), PBIG-1 x Kalyanpur Baramasi (4.23 cm), PBIG-2 x Kalyanpur Sona (4.23 cm), PBIG-2 x Priya White (4.23 cm) and Kalyanpur Sona x Kalyanpur Baramasi (4.65 cm). PBIG-2 x Kalyanpur Sona (4.83 cm) proved to be the best performer followed by Kalyanpur Sona x Kalyanpur Baramasi (4.62 cm) during rainy season. Other genotypes with good performance were PBIG-1 x Kalyanpur Sona (4.10 cm), PBIG-1 x Kalyanpur Baramasi (4.23 cm), PBIG-2 x Priya White (4.20 cm) and Kalyanpur Sona x Kalyanpur Baramasi (4.02 cm).

Plate 5 : Promising F_1 hybrids for high yield
PBIG-1 x Kalyanpur Baramasi,
PBIG-1 x PBIG-2
PBIG-1 x Kalyanpur Sona,
PBIG-4 x Kalyanpur Sona


PBIG-1 x PBIG-4


PBIG-4 x KB

PBIG-1 x Kalyanpur Baramasi and PBIG-1 x PBIG-4 were the crosses which showed consistent highly significant heterobeltiosis in both the seasons. Estimates of heterobeltiosis for PBIG-1 x Kalyanpur Baramasi were 53.82% and 45.86% and for PBIG-1 x PBIG-4 were 22.57% and 29.31% for summer and rainy season respectively. Kalyanpur Sona x KalyanpurBaramasi (12.05%) and Kalyanpur Sona x Priya White (13.98%) also exhibited highly significant heterobeltiosis but during summer only. PBIG-2 x Kalyanpur Sona (23.21%) showed highly significant heterobeltiosis during rainy season experiment. Crosses PBIG-1 x PBIG-2, PBIG-1 x PBIG-4, PBIG-1 x Kalyanpur Sona, PBIG-2 x Kalyanpur Baramasi and Kalyanpur Sona x Kalyanpur Baramasi showed highly significant standard heterosis for both the seasons (Table 4.4).

4.3.10 Fruit density (g / cm^3)

During both the seasons (summer and rainy seasons) best and worst performing F_1's were the same. PBIG-1 x Kalyanpur Sona represented the lowest limits with values 0.76 g/cm^3, and 0.80 g/cm^3 in respective seasons. PBIG-1 x Priya White was detected as best performer with values, 1.79 g/ cm^3 and 1.91 g/cm^3 in respective seasons. Other better performing F_1's were PBIG-2 x PBIG-4 (1.57 g /cm^3 in summer and 1.59 g/cm^3 in rainy season), and PBIG-2 x Kalyanpur Sona (1.46 g/cm^3 in both seasons experiments).

Two crosses, PBIG-1 x PBIG-2 and PBIG-2 x Kalyanpur Sona showed highly significant heterobeltiosis during both the seasons (Table 4.3). Most of the crosses exhibited highly significant standard heterosis for fruit diameter (Table 4.4).

PBIG-1 x PBIG-4 (29.31%) showed highly significant standard heterosis in rainy season. PBIG-2 x PBIG-4and Kalyanpur Baramasi x Priya White showed highly significant standard heterosis in both the seasons. Values for PIBG-2 x PBIG-4 were 26.91% and 28.62% during respective seasons and for Kalyanpur Baramasi x Priya White were 27.27% and 23.10% in respective seasons experiments.

4.3.11 Fruit yield per vine (kg)

Some promising F_1's according to their yielding performance were PBIG-2 x Priya White (2.29 kg per vine), Kalyanpur Sona x Kalyanpur Baramasi (2.07 kg per vine) (Plate 4), PBIG-2 x Kalyanpur Sona (1.80 kg per vine), Kalyanpur Sona x Priya White (1.81 kg per vine), PBIG-4 x Kalyanpur Sona (1.72 kg per vine) and PBIG-1 x PBIG-2 (1.62 kg per vine) (Plate 5) during summer season. In general all the F_1's performed better than parents during summer season. However, yields during rainy season were not as high as in summer due to unfavourable weather conditions.

During rainy season Kalyanpur Baramasi x Priya White (1.83 kg per vine), Kalyanpur Sona x Kalyanpur Baramasi (1.80 kg per vine) and PBIG-4 x Kalyanpur Sona (1.54 kg per vine) proved to be high yielder F_1's.

In general, most of the crosses showed good amount of heterosis for fruit yield. Six crosses namely PBIG-1 x PBIG-4 , PBIG-1 x Kalyanpur

Plate 6 : F_1 hybrids showing heterosis for fruit length
PBIG-1 x PBIG-4
PBIG-4 x Kalyanpur Baramasi


PBIG-1 x KB


PBIG-1 x PBIG-2


PBIG-1 x KS


PBIG-4 x KS

Baramasi (Plate 5), PBIG-1 x Priya White, PBIG-2 x Kalyanpur Sona, PBIG-4 x Kalyanpur Sona, and Kalyanpur Sona x Kalyanpur Baramasi exhibited highly significant heterobeltiosis during both the seasons experiments. Estimates of heterobeltiosis for respective seasons in PBIG-1 x PBIG-4 were 42.73% and 73.73%. The value of heterobeltiosis in the other crosses were 46.36% and 91.71%, 56.36% and 63.95%, 24.14% and 19.38%, 18.62% and 69.23%, 42.76% and 97.80% for respective seasons.

Two crosses, PBIG-1 x PBIG-2 and PBIG-4 x Priya White showed significant heterobeltiosis in both the seasons (Table 4.3).

Cross that showed highly significant heterobeltiosis during summer season only was PBIG-2 x Priya White (80.32%). It showed significant heterobeltiosis during same season.

Highly significant standard heterosis was expressed in both the seasons by PBIG-1 x PBIG-2 (47.27% and 73.33%), PBIG-2 x PBIG-4 (50.91% and 30.67%), PBIG-2 x Priya White (63.64% and 105.33%), PBIG-4 x Kalyanpur Sona (56.36% and 105.33%) and Kalyanpur Baramasi x Priya White (64.09% and 46.27%). PBIG-2 x Kalyanpur Sona, showed highly significant (63.64% and 105.33%) standard heterosis during summer and rainy season experiments, respectively. PBIG-4 x Kalyanpur Baramasi exhibited highly significant (30.00% and 26.67%) standard heterosis during summer and rainy season experiment, respectively.

Table 4.3 : Estimates of heterbeltiosis for various horticultural traits (summer season, 1999 and rainy season, 1999)

Crosses	Days to male flower			Days to female flower			Node number to first male flower			Node number to first female flower			Number of primary branches per vine		
	Summer	Rainy	Average	Summer	Rainy	Average	Summer	Rainy	Average	Summer	Rainy	Average	Summer	Rainy	Average
PBIG-1 x PBIG-2	-0.89	0.00	0.45	-3.74	3.42	-0.16	58.25**	33.40**	45.83	69.28**	29.28**	49.28	-32.10**	-11.11**	-21.61
PBIG-1 x PBIG-4	-17.17**	-7.40**	-12.29	7.98**	2.34	5.16	-17.47**	-3.96	-10.72	4.13	-10.34	-3.11	-24.98**	3.19	-10.89
PBIG-1 x K.S.	-2.68	-4.11	-3.40	-4.55	5.45*	0.45	7.07	7.85*	7.46	-8.38	26.60*	9.11	9.84**	-3.19	3.33
PBIG-1 x K.B.	-3.23	0.00	-1.62	-3.63	4.69	0.53	-4.43	-19.93**	-12.18	16.63**	-17.27**	-0.32	-38.65**	-19.57**	-29.11
PBIG-1 x P.W.	11.68**	-13.80**	-1.06	8.69**	0.77	4.73	-23.86**	-31.93**	-27.89	4.64	-31.02**	-13.19	9.09	6.49	7.79
PBIG-2 x PBIG-4	18.03**	16.66**	17.35	5.96*	23.14	14.55	25.00**	6.60	15.80	54.02**	17.64*	35.83	-33.93**	20.39**	-6.77
PBIG-2 x K.S.	-12.62**	-4.16	-8.39	-18.67**	0.00	-9.34	8.25	7.85	8.05	46.19**	33.4**	41.29	3.29	16.67**	9.98
PBIG-2 x K.B.	27.03**	31.25**	29.14	13.43**	34.25**	23.84	100.00**	60.00**	80.00	154.04**	58.73**	106.39	-32.10**	-13.05**	-22.58
PBIG-2 x P.W.	7.22**	16.66**	11.94	0.74	23.14**	11.94	41.50**	6.60	24.05	69.28**	11.64	40.46	17.89**	5.55	11.72
PBIG-4 x K.S.	13.39**	21.63**	17.52	6.82*	26.34**	16.58	49.89**	54.04**	51.97	7.61	60.00**	33.81	-16.38**	-22.24**	-19.31
PBIG-4x K.B.	-3.74	0.79	-1.48	5.16*	5.05	5.11	-48.11**	-19.26**	-31.19	-25.70**	-17.27**	-21.49	0.00	2.22	1.11
PBIG-4 x P.W.	-14.93**	-11.12**	-13.03	-10.07**	-5.03	-7.55	-9.57	-19.26**	-14.42	18.28**	-13.86	2.21	-32.48**	-12.48	-22.48
K.S. x K.B.	19.66**	29.91**	24.79	11.36**	28.17**	19.77	42.83**	46.19**	44.51	3.81	53.20**	28.51	-27.84**	-31.76**	-29.8
K.S. x P.W.	-2.67	14.44**	5.89	-3.07*	13.63*	5.28	-4.71	61.66**	28.48	31.92**	60.00**	45.96	6.59	1.57	4.08
K.B. x P.W.	-18.32**	-2.31	-10.32	-20.60**	-26.1	22.85	9.57	-21.44**	-5.94	36.43**	-21.27**	7.58	-36.40**	-22.06**	-29.23

Table 4.3 Contd...

Crosses	Vine length (m)			Number of fruits per vine			Fruit length (cm)		
	Summer	Rainy	Average	Summer	Rainy	Average	Summer	Rainy	Average
PBIG-1 x PBIG-2	0.37	-35.50**	-17.47	20.39	-8.55	5.92	-6.19*	-0.42	-.331
PBIG-1 x PBIG-4	-5.19	-23.94**	-14.57	25.94*	-25.53	0.21	18.39**	15.18**	16.99
PBIG-1 x K.S.	-4.44	-15.59**	-10.02	-10.91	-14.93	-12.92	-29.00**	-19.65**	-24.32
PBIG-1 x K.B.	5.93*	-9.51	-1.79	37.06**	-2.17	17.45	-1.93	-3.47*	-2.70
PBIG-1 x P.W.	24.07**	4.18	14.13	21.23*	6.38	13.81	-11.94**	-6.24**	-9.09
PBIG-2 x PBIG-4	-10.41**	-22.18**	-16.30	46.16**	20.94	33.55	-34.93**	-33.07**	-34.00
PBIG-2 x K.S.	-12.27**	-15.50**	-13.89	29.13*	23.31	26.12	28.79**	44.19**	36.49
PBIG-2 x K.B.	-5.94*	-26.36**	-16.15	15.41	11.65	13.53	-18.14**	-21.59**	-19.87
PBIG-2 x P.W.	16.36**	-9.69*	3.34	10.59	25.61	18.09	-10.30**	-18.39**	-14.35
PBIG-4 x K.S.	-17.41*	-11.97*	-14.69	23.68*	53.52	38.6	-20.34**	-17.42**	-18.88
PBIG-4x K.B.	-0.32	-7.39	-3.86	71.43**	51.55	61.49	14.22**	7.74	10.98
PBIG-4 x P.W.	-16.77**	-22.54	-19.66	-3.05	73.61	35.28	-14.59**	-17.58**	-16.09
K.S. x K.B.	7.42*	-3.87	1.78	54.56**	51.22	52.89	-31.18**	-32.02**	-31.60
K.S. x P.W.	47.16**	36.64**	41.90	38.18**	16.33	27.26	-16.85**	-13.77**	-15.31
K.B. x P.W.	20.48**	29.32**	24.84	-15.14	47.13	15.99	-28.34**	-31.42**	-29.88

Table 4.3 Contd...

Crosses	Fruit diameter (cm)			Fruit density (g/cm^3)			Fruit yield per vine (kg)		
	Summer	Rainy	Average	Summer	Rainy	Average	Summer	Rainy	Average
PBIG-1 x PBIG-2	-6.92**	-2.86	-4.89	37.07**	40.71**	38.89	27.56**	0.78	14.17
PBIG-1 x PBIG-4	22.57**	29.31**	25.94	-26.52**	-22.78**	-24.65	42.73**	73.33**	58.03
PBIG-1 x K.S.	0.00	4.59	2.30	-34.48**	-29.20**	-31.84	-12.41	25.33**	6.46
PBIG-1 x K.B.	53.82**	45.86**	49.84	-46.15**	-44.69**	-45.42	46.36**	91.71**	69.04
PBIG-1 x P.W.	7.51*	0.88	4.20	-4.28	1.59	-1.35	56.36**	63.95**	60.16
PBIG-2 x PBIG-4	-10.51**	6.57	-1.97	-13.26**	-11.67**	-12.47	30.71**	-24.03**	3.34
PBIG-2 x K.S.	-1.93	23.21**	10.64	73.33**	55.32**	64.33	24.14**	19.38**	21.76
PBIG-2 x K.B.	-8.72**	8.57	-0.08	-39.01**	-43.02**	-41.02	-12.59	-19.38	-15.99
PBIG-2 x P.W.	8.46**	20.00**	14.23	-45.46**	-49.47**	-47.47	80.32**	8.53	44.43
PBIG-4 x K.S.	-23.37**	-16.33	-19.85	-43.65**	-45.00**	-44.33	18.62**	69.23**	43.93
PBIG-4x K.B.	-10.42**	1.10	-4.66	-45.60**	-44.44**	-45.02	66.28**	30.14*	48.21
PBIG-4 x P.W.	3.00	5.26	4.13	41.18**	-41.81**	-41.50	20.59*	26.74*	23.67
K.S. x K.B.	12.05**	17.86**	14.96	-43.96**	-44.69**	-44.33	42.76**	97.80**	70.28
K.S. x P.W.	13.98**	6.37	10.18	-29.95**	-31.92**	-30.94	24.83**	46.15**	35.49
K.B. x P.W.	5.11	4.38	4.75	-54.01**	-54.26**	-54.14	38.24**	112.79**	75.52

*, ** Significant at 0.05 and 0.01 levels of probability, respectively.
K.S. = Kalyanpur Sona
K.B. = Kalyanpur Baramasi
P.W. = Priya White

Table 4.4 : Estimates of standard heterosis for various horticultural traits (summer season,1999 and rainy season, 1999)

Crosses	Days to male flower			Days to female flower			Node number to first male flower			Node number to first female flower			Number of primary branches per vine		
	Summer	Rainy	Average	Summer	Rainy	Average	Summer	Rainy	Average	Summer	Rainy	Average	Summer	Rainy	Average
PBIG-1 x PBIG-2	-8.33**	-11.11**	-9.72	-6.52*	-12.75**	-9.64	-17.47**	-19.93**	-18.70	-8.37	-24.20**	-16.29	15.18*	45.46**	30.32
PBIG-1 x PBIG-4	-7.50**	-742**	-7.46	7.98**	2.34	5.16	-17.47**	-3.96	-10.72	4.12	-10.34	-3.11	-9.09	0.00	4.55
PBIG-1 x K.S.	-9.18**	-13.89**	-11.54	-8.69**	-9.37**	-9.03	-34.81**	-43.93**	-39.37	-8.38	-34.54**	-21.46	103.00**	84.82**	93.91
PBIG-1 x K.B.	3.33	0.00	1.67	-3.63	4.69	0.53	-4.43	-19.93**	-12.18	16.63**	-17.27**	-0.32	-18.18**	12.09	-3.05
PBIG-1 x P.W.	11.68**	-13.89**	-1.11	8.69**	0.77	4.73	-30.51**	-31.94**	-31.23	-4.13	-31.02**	-17.58	9.09	0.00	4.55
PBIG-2 x PBIG-4	9.18**	3.70	6.44	2.89	3.89	3.39	-34.81**	-36.01**	-35.41	-16.63**	-31.02**	-23.83	12.09	97.00**	54.55
PBIG-2 x K.S.	-19.18**	14.81**	-2.19	-21.02**	-15.63**	-18.33	-43.55**	-43.94**	43.75	-20.88**	-31.02**	-25.95	90.91**	90.91**	90.91
PBIG-2 x K.B.	17.50**	16.67**	17.09	10.15**	13.27**	11.71	4.30	-3.96	0.17	30.50**	-6.93	11.79	15.18*	21.18**	18.18
PBIG-2 x P.W.	-8..30	3.69	-2.31	-2.17	1.55	-0.31	-26.21**	-36.02**	-31.12	-8.37	-34.54**	-21.46	100.00**	72.73**	86.37
PBIG-4 x K.S.	5.83*	9.25**	7.54	2.17	8.58**	5.38	-8.74	-19.93	-14.34	16.63**	-17.27**	-0.32	54.56**	48.46**	51.51
PBIG-4x K.B.	7.50**	17.58**	12.54	2.87	14.06**	8.47	-39.11**	-15.97*	-27.54	-4.13	-17.27**	-10.92	33.36**	42.46**	37.91
PBIG-4 x P.W.	-5.00*	3.69	-0.66	-2.89	3.12	-0.12	-17.47**	-15.97*	-16.72	8.37	-13.81*	-2.75	-18.18**	-15.18*	-16.68
K.S. x K.B.	11.68**	16.67**	14.18	6.52*	10.15**	8.34	-13.04*	-24.01**	-18.53	12.50**	-20.79**	-4.15	33.36**	30.27**	31.82
K.S. x P.W.	-9.18**	2.78	-3.20	-10.15**	-2.34	-6.25	-13.04	-15.97*	-14.51	20.88**	-17.28**	1.59	97.00**	93.91**	95.46
K.B. x P.W.	-3.35	17.50**	7.12	-5.07	14.06**	14.50	0.00	-12.01	6.01	25.00**	-10.45	7.28	-15.18	-9.09	12.14

Table 4.4 Contd…

Crosses	Vine length (m)			Number of fruits per vine			Fruit length (cm)		
	Summer	Rainy	Average	Summer	Rainy	Average	Summer	Rainy	Average
PBIG-1 x PBIG-2	0.37	-36.50**	-18.06	20.39	-8.55	5.92	-6.19*	-0.42	-3.30
PBIG-1 x PBIG-4	-5.19	-17.87**	-11.53	25.94*	-25.53	0.20	18.39**	15.73**	17.06
PBIG-1 x K.S.	-4.44	-15.59**	-10.01	-9.27	-14.93	-12.1	-29.00**	-19.65**	-24.32
PBIG-1 x K.B.	5.93*	-9.51	-3.38	37.06**	-2.17	17.44	-1.93	9.17**	3.62
PBIG-1 x P.W.	24.07**	4.18	14.12	48.17**	6.38	27.27	-11.95**	-4.77**	-8.36
PBIG-2 x PBIG-4	-10.74**	-15.97**	-13.35	40.72**	10.59	25.65	-36.54**	-32.76**	-34.65
PBIG-2 x K.S.	-12.59**	-17.11**	-14.85	31.50**	12.76	22.13	-41.89**	-40.15**	-41.02
PBIG-2 x K.B.	-6.29*	-27.76**	-17.02	11.11	2.11	6.61	-14.08**	-11.32**	-12.70
PBIG-2 x P.W.	15.93**	-11.41*	2.26	35.17**	14.87	25.02	-26.62**	-21.38**	-24.00
PBIG-4 x K.S.	-3.33	-4.94	-4.13	25.94*	40.39	33.06	-22.31**	-17.03**	-19.67
PBIG-4x K.B.	16.67**	0.00	8.33	33.33**	6.38	19.85	19.88**	21.86**	20.87
PBIG-4 x P.W.	-2.59	-16.35**	-9.47	18.50	25.53	22.01	-16.71**	-17.19**	-16.95
K.S. x K.B.	-8.89**	-15.21**	-12.05	57.39**	38.29	47.84	-27.76**	-23.11**	-22.47
K.S. x P.W.	24.82**	20.53**	22.67	40.72**	6.82	23.77	-31.98**	-16.93**	-24.45
K.B. x P.W.	-6.29*	-7.61	-4.45	3.72	6.38	5.05	-24.79**	-22.43**	-23.61

Table 4.4 Contd...

Crosses	Fruit diameter (cm)			Fruit density (g/cm^3)			Fruit yield per vine (kg)		
	Summer	Rainy	Average	Summer	Rainy	Average	Summer	Rainy	Average
PBIG-1 x PBIG-2	32.00**	17.24**	24.62	37.07**	40.71**	38.89	47.27**	73.33**	60.30
PBIG-1 x PBIG-4	28.36**	29.31**	28.84	14.66**	23.01**	18.84	42.73**	73.33**	58.03
PBIG-1 x K.S.	50.91**	41.38**	46.15	-34.48**	-29.20**	-31.84	15.46	25.33*	20.40
PBIG-1 x K.B.	53.82**	45.80**	49.84	-15.52**	-12.39*	-13.95	46.36**	82.67**	64.52
PBIG-1 x P.W.	30.18**	18.97**	24.58	54.31**	69.03**	61.67	56.36**	88.00**	72.18
PBIG-2 x PBIG-4	26.91**	28.62**	27.77	35.35**	40.71**	38.03	50.91**	30.67*	40.79
PBIG-2 x K.S.	53.82**	66.55**	60.19	34.48**	29.20**	31.84	63.64**	105.33**	84.49
PBIG-2 x K.B.	29.46**	31.03**	30.25	-4.31	-9.74	-10.03	0.91	38.67**	19.79
PBIG-2 x P.W.	53.82**	44.83**	49.08	-12.07*	-15.93**	-14.00	108.18**	86.67**	97.43
PBIG-4 x K.S.	-15.63	13.10*	-1.27	-12.07*	-12.39*	-12.23	56.36**	105.33**	80.85
PBIG-4x K.B.	-6.18	-5.17	-5.68	-14.66**	-11.50*	-13.08	30.00**	26.67*	28.34
PBIG-4 x P.W.	24.73**	24.14**	24.44	-5.17	-2.66	-3.91	11.81	45.33**	28.57
K.S. x K.B.	69.09**	59.31**	64.20	-12.07*	-12.39*	-12.23	88.18**	140.00**	114.09
K.S. x P.W.	72.00**	43.79**	57.90	12.93**	13.27*	13.10	64.55**	77.33**	70.94
K.B. x P.W.	27.27**	23.10**	25.19	-25.86**	-23.89**	-24.87	28.18**	144.00**	86.09

*, ** Significant at 0.05 and 0.01 levels of probability, respectively.

K.S. = Kalyanpur Sona

K.B. = Kalyanpur Baramasi

P.W. = Priya White

4.4 Combining ability analysis

The gca and sca mean squares calculated from the 6 parental cultivars and the 15 F_1 hybrids during Griffings's method 2 and model 2 are presented in Table 4.5. Estimates for general and specific combining ability are given in Tables 4.6 and 4.7 respectively. Characterwise presentation of the results is as follows :

4.4.1 Days to male flower

Both gca and sca mean squares for both the seasons were highly significant. gca variance was approximately two times larger than sca variance in summer season experiment and several times larger in rainy season experiment (Table 4.5).

Estimates of gca effects for individual parents are given in Table 4.6. Table indicated that 3 parents had positive and 3 had negative effects during summer season experiment. Parents with negative gca effects were PBIG-1 (-1.36), PBIG-2 (-1.69) and Kalyanpur Sona (-1.90). On the basis of gca effects, the parents were ranked in the following order : Kalyanpur Sona (-1.90), PBIG-2 (-1.69), PBIG-1 (-1.36), Priya White (0.72), PBIG-4 (0.81 and Kalyanpur Baramasi (3.43). The gca effects of Priya White were not significant.

Out of 15 sca effects, 8 sca effects were found highly significant and 3 were found significant during summer season experiment. Crosses associated with positive sca effects were PBIG-1 x Priya White (4.32), PBIG-2 x

Table 4.5 : Analysis of variance for combining ability for various horticultural traits (summer season, 1999 and rainy season, 1999)

Sources of variation	Degrees of freedom	Mean square									
		Days to male flower		Days to female flower		Node number to first male flower		Node number to first female flower		Number of primary branches per vine	
		Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
GCA	5	34.05**	44.15**	28.98**	38.07**	5.61**	4.74**	8.69**	4.53**	50.03**	21.19**
SCA	15	17.68**	9.05**	13.42**	19.03**	1.69*	3.36**	1.62**	3.46**	10.69**	21.26**
Error	40	1.25	1.33	2.02	1.80	0.29	0.49	0.19	0.54	0.72	0.67

Mean square											
Vine length (m)		Number of fruits per vine		Fruit length (cm)		Fruit diameter (cm)		Fruit density (g/cm^3)		Fruit yield per vine (kg)	
Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
0.08**	0.07	5.79	78.24	56.99**	8.59**	0.84**	0.38	0.12**	0.12**	0.11**	0.16**
0.02	0.14**	21.07**	59.81	4.47**	20.37**	0.26**	0.30**	0.14**	0.15**	0.16	0.67**
0.01	0.03	5.89	53.34	0.33	0.45	0.01	0.05	0.01	0.01	0.01	0.01

*, ** Significant at 0.05 and 0.01 levels of probability, respectively.

Kalyanpur Baramasi (4.28) and Kalyanpur Sona x Kalyanpur Baramasi (7.15). Those having negative sca effects were PBIG-1 x PBIG-4 (-3.47), PBIG-2 x Kalyanpur Sona (-5.05), PBIG-4 x Priya White and Kalyanpur Sona x Priya White (-3.47).

In rainy season experiment, 3 parents had positive gca effects and 3 had negative, gca effects (Table 4.6). The gca effects of PBIG-1 and PBIG-4 were not significant. As per gca effects parents could be ranked as, PBIG-2 (-3.81), Kalyanpur Sona (-1.13), PBIG-4 (-0.22), PBIG-1 (0.57), Priya White (1.78) and Kalyanpur Baramasi (2.36).

During rainy season experiment, 6 highly significant and 2 significant sca effects were observed. Crosses with positive effect were PBIG-1 x PBIG-4 (4.26), PBIG-1 x Priya White (4.92) and Kalyanpur Sona x Kalyanpur Baramasi. Crosses associated with negative effects were PBIG-1 x Kalyanpur Sona (-4.45). Crosses associated with negative effects were PBIG-1 x Kalyanpur Sona (-4.45), PBIG-4 x Kalyanpur Sona (-5.33) and Kalyanpur Baramasi x Priya White (-5.04).

4.4.2 Days to female flower

Highly significant gca and sca mean square were observed in both the seasons. Value of gca mean square is very high as compare to sca mean square.

During summer season experiment, 3 parents had positive and 3 had negative gca effects. Parents with positive gca were PBIG-4 (1.40), Kalyanpur

Baramasi (2.61) and Priya White (0.49). Priya White was again non-significant. Parents can be ranked as follows: Kalyanpur Sona (-2.55), PBIG-2 (-1.56), PBIG-4 (1.40) and Kalyanpur Baramasi (2.61)

In rainy season experiment, direction of effect was same except PBIG-4 (-0.01) which was negative. Direction of PBIG-1 was positive in rainy season experiment. On the basis of gca effects ranking could be as follows : PBIG-2 (-3.35), Kalyanpur Sona (-1.34), Priya White (1.99) and Kalyanpur Baramasi (2.31). Kalyanpur Sona was consistently good general combiner in both the season.

Five sca effects were found highly significant and 8 sca effects were found significant. Out of 15 effects during summer season experiment. Significant crosses with positive effects were PBIG-1 x PBIG-4 (2.35), PBIG-2 x Kalyanpur Baramasi (3.31), PBIG-4 x Kalyanpur Sona (1.85) and Kalyanpur Sona x Kalyanpur Baramasi (2.64). Crosses associated with negative effect were PBIG-1 x Kalyanpur Baramasi (-4.19), PBIG-1 x Priya White (3.60), PBIG-2 x Kalyanpur Sona (-5.86), PBIG-4 x Priya White (-3.53) and Kalyanpur Baramasi x Priya White (-5.73).

4.4.3 Node number to first male flower

Mean square for gca and sca were highly significant for rainy season experiment. In summer season experiment, mean square due to gca was highly significant whereas mean square due to sca was significant. Four parents showed positive gca effects and two showed negative gca effect during summer season.

Parents with positive gca effects were PBIG-1 (0.24), PBIG-4 (0.19), Kalyanpur Baramasi (1.23) and Priya White (0.24). Parents with negative gca were PBIG-2 (-1.04) and Kalyanpur Sona (-0.85). Parrents could be ranked according to gca effects and ranking would be as follows : PBIG-2 (-1.04), Kalyanpur Sona (-0.85), PBIG-4 (0.19), PBIG-1 (0.65), Priya White (0.24) and Kalyanpur Baramasi (1.23).

Out of 15 sca effects one sca effect was highly significant and 2 sca effects were significant. Only one highly significant cross was negative and it was PBIG-4 x Kalyanpur Baramasi (-3.31).

During rainy season experiment, 3 parents exhibited positive gca effects and 3 parents exhibited negative gca effects (Table 6). According to gca effects parents could be ranked as follows, Kalyanpur Sona (-0.90), PBIG-2 (-0.61), PBIG-4 (-0.36), Priya White (0.09), Kalyanpur Baramasi (-.72) and PBIG-1 (1.06).

Out of 15 sca effects, 4 sca effects were found to be highly significant and 2 were observed as significant. Crosses, associated with positive sca effects were PBIG-1 x Kalyanpur Baramasi (4.00) and PBIG-2 x PBIG-4 (2.08). Crosses associated with negative sca effects were PBIG-1 x PBIG-2 (-2.33) and PBIG-1 x Kalyanpur Sona (-2.71).

4.4.4 Node number to first female flower

Mean square of gca was highly significant during summer experiment, whereas mean square of sca was non-significant. During rainy season experiment mean square of both gca and sca were found highly significant.

Three parents showed positive and three showed negative gca effects during summer season experiment (Table 4.6). Ranking of parents could be done as follows : PBIG-2 (-1.47), PBIG-1 (-0.39). Priya White (-0.14), Kalyanpur Sona (0.01), PBIG-4 (0.28) and Kayanpur Baramasi (1.74).

Out of 15 sca effects, 4 sca effects were found highly significant and 2 sca effects were found significant. Crosses associated with positive sca effects were PBIG-1 x Kalyanpur Baramasi (3.91) and PBIG-1 x Priya White (1.79). Crosses associated with negative sca effects were PBIG-1 x PBIG-2 (-2.59) and PBIG-1 x Kalyanpur Sona (-3.29).

4.4.5 Number of primary branches per vine

Both gca and sca mean squares were found to be highly significant during summer as well as rainy season experiment. During summer season, 2 parents had positive gca effects and 4 parents negative gca effects. Parents with positive gca effects were PBIG-2 (1.81) and Kalyanpur Sona (4.22). On the basis of gca effects parents could ranked as follows : Kalyanpur Sona (-4.22), PBIG-2 (-1.81), Priya White (-0.61), PBIG-4 and Kalyanpur Baramasi (-1.74) and PBIG-1 (-1.95).

Out of 15 sca effects were highly significant and 1 sca effect was significant during summer season. Crosses associated with positive sca effects were PBIG-1x Kalyanpur Sona (5.94), PBIG-2 x Priya White (6.01), PBIG-4 x Kalyanpur Baramasi (3.35) and Kalyanpur Sona x Priya White (3.27). Crosses associated with negative effects were PBIG-1 x Kalyanpur Baramasi (-2.11), PBIG-2 x PBIG-4 (-2.53), PBIG-2 x Kalyanpur Baramasi (-2.19), PBIG-4 x Priya White (-3.45), Kalyanpur Sona x Kalyanpur Baramasi (-2.61) and Kalyanpur Baramasi x Priya White (-3.12).

4.4.6 Vine length (m)

Variance for gca was highly significant in summer season experiment and in rainy season experiment only variance for sca was observed to be highly significant. During summer season experiment, 2 parents had positive gca effects and 4 parents had negative gca effects. Parents with positive effects were PBIG-1 (0.10) and PBIG-4 (0.13). On the basis of gca effects, parents could be ranked as follows : PBIG - 4 (0.13), PBIG-1 (0.10), Priya White (-0.004), PBIG-2 (-0.02), Kalyanpur Sona (-0.09) and Kalyanpur Baramasi (0.12). Effects of PBIG-2 and Priya White were non-significant.

Out of 15 effects, 6 sca effects were highly significant and 2 sca effects were significant. Crosses associated with positive effects were PBIG-1 x Priya White (0.59), PBIG-2 x Priya White (0.43), PBIG-4 x Kalyanpur Baramasi (0.48) and Kalyanpur Sona x Priya White (0.79). Crosses with negative effects were, PBIG-1 x PBIG-4 (-0.33), PBIG-2 x PBIG-4 (-0.37) and PBIG-2 x Kalyanpur Sona (-0.20).

During rainy season experiment, 4 parents showed positive effects and two parents showed negative effects. Parents with positive effects were PBIG-1 (0.09), Kalyanpur Baramasi (0.05), Kalyanpur Sona (0.01) and Priya White (0.08) and all were non-significant. Only one parent, PBIG-2 (0.14) had negative significant gca effect. Out of 15 effects, 3 effects were highly significant and 2 were significant. Crosses associated with positive effects were PBIG-1 x PBIG-4 (0.48) and Kalyanpur Baramasi x Priya White (0.68) and cross associated with negative effects was PBIG-1 x Priya White (-0.70).

4.4.7 Number of fruits per vine

Only sca variance during summer season experiment was found highly significant. No parent could have significant gca effects in both seasons. During summer season experiment. Out of 15 crosses, only one cross had highly significant sca effects and 3 crosses showed significant sca effects. Cross associated with positive effect was Kalyanpur Sona x Kalyanpur Baramasi (7.25).

In rainy season only one cross was found to be highly significant with positive sca effect and it was Kalyanpur Sona x Priya White (24.98).

4.4.8 Fruit length (cm)

Both gca and sca variances were highly significant for both the seasons (Table 4.5). During summer season experiment, 3 parents showed positive gca effects and 3 parents showed negative gca effects. PBIG-1 (2.43), PBIG-4 (2.12) and Kalyanpur Baramasi (2.24) were the parents with positive effects and all were highly significant. On the basis of gca effects ranking of parents was as follows :PBIG-1 (2.43), Kalyanpur Baramasi (2.24), PBIG-4 (2.12), Priya White (-0.53), PBIG-2 (-2.71) and Kalyanpur Sona (-3.55).

Out of 15 sca effects 6 sca effects were highly significant whereas 4 sca effects were significant. Crosses with positive sca effects were PBIG-1 x PBIG-2 (2.70), PBIG-1 x PBIG-4 (2.85), PBIG-2 x Kalyanpur Sona (1.49), PBIG-2 x Priya White (1.55), PBIG-4 x Kalyanpur Baramasi (3.33), Kalyanpur Sona x Priya White (1.31). During rainy season experiment, 3 parents showed positive gca effects and 3 parents showed negative gca effects. Parents with positive effects were PBIG-1 (0.28), PBIG-2 (0.88), Kalyanpur Baramasi (1.57). According to gca effects parents could be ranked as Kalyanpur Baramasi (1.57), PBIG-2 (0.88), PBIG-1 (0.28), Priya White (-0.30), PBIG-4 (-0.62) and Kalyanpur Sona (-1.25).

Out of 15 sca effects, 11 sca effects were highly significant whereas 2 sca effects were significant. Crosses associated with positive sca effects were PBIG-1 x PBIG-4 (3.61), PBIG-1 x Kalyanpur Baramasi (3.84), PBIG-1 x Priya White (2.50), PBIG-2 x PBIG-4 (5.36), PBIG-2 x Kalyanpur Baramasi (1.92), PBIG-2 x Priya White (1.12) and Kalyanpur Sona x Kalyanpur Baramasi (6.47). Crosses with negative sca effects were PBIG -1 x PBIG-2

(-9.51), PBIG-1 x Kalyanpur Sona (-7.18), PBIG-4 x Kalyanpur Sona (-3.17) and Kalyanpur Baramasi x Priya White (-1.88).

4.4.9 Fruit diameter (cm)

During summer season experiment both gca and sca mean squares were highly significant whereas in rainy season experiment only sca mean square was highly significant. Three parents showed positive gca effects and 3 parents showed negative gca effects during summer season. Parents with sca effects were PBIG-2 (0.19), Kalyanpur Sona (0.48) and Priya White (0.09). According to gca effects, different parents could be ranked as Kalyanpur Sona (0.48), PBIG-2 (0.19), Priya White (0.09), PBIG-1 (-0.10), Kalyanpur Baramasi (-0.24) and PBIG-4 (-0.43).

Out of 15 sca effects, 6 sca effects were found to be highly significant. Crosses with positive sca effects were PBIG-1 x PBIG-4 (0.43), PBIG-1 x Kalyanpur Baramasi (0.93), PBIG-2 x Priya White (0.32), Kalyanpur Sona x Kalyanpur Baramasi (0.78) and Kalyanpur Sona x Priya White (0.58), PBIG-4 x Kalyanpur Baramasi (-0.39) had negative sca effects.

During rainy season experiment, only one parent, namely Kalyanpur Baramasi (0.18) had significant positive gca effect. Four sca effects were highly significant and one gca effect was significant out of 15 crosses. Crosses with positive gca effect were PBIG-1 x Kalyanpur Sona (0.53) and PBIG-4 x Kalyanpur Sona (0.65). Crosses with negative effect were PBIG-1 x PBIG-4 (-0.59) and PBIG-1 x Kalyanpur Baramasi (-0.74).

4.4.10 Fruit density (g/cm^3)

Both gca variance as well as sca variances were highly significant during summer season experiment and rainy season experiment. During summer season experiment, 3 parents have positive gca effects and 3 parents had negative gca effects. Parents with positive values were PBIG-1 (0.004), PBIG-4 (0.11) and Priya White (0.19). Ranking of parents according to gca effects could be done as follows : Priya White (0.19), PBIG-4 (0.11) and PBIG-1 (0.004). Effect of PBIG-1 was non-significant.

Out of 15 sca effects, 10 effects were highly significant whereas 2 effects were significant. Crosses with positive effects were PBIG-1 x PBIG-2 (0.36), PBIG-1 x Priya White (0.40), PBIG-2 x PBIG-4 (0.23),PBIG-2 x Kalyanpur Sona (0.44). Crosses with negative effects were PBIG-1 x Kalyanpur Sona (-0.29), PBIG-1 x Kalyanpur Baramasi (-0.26), PBIG-2 x Priya White (-0.32), PBIG-4 x Kalyanpur Baramasi (-0.35), PBIG-4 x Priya White (-0.70) and Kalyanpur Baramasi x Priya White (-0.57).

During rainy season experiment, 4 parents exhibited positive gca effects and 2 parents expressed negative gca effects. Parents with positive gca were PBIG-1 (0.09), PBIG-2 (0.05), PBIG-4 (0.13) and Priya White (0.01). Ranking of parents, according to gca effects could be as follows : PBIG-4 (0.13), PBIG-1 (0.09), PBIG-2 (0.05), Priya White (0.01), Kalyanpur Sona (-0.20) and

Kalyanpur Baramasi (-0.09). Eleven effects were found to be highly significant. During rainy season experiment, crosses with positive effects were PBIG-1 x PBIG-4 (0.33), PBIG-1 x Kalyanpur Baramasi (0.56), PBIG-1 x Priya White (0.53), PBIG-2 x Priya White (0.59) and PBIG-4 x Kalyanpur Sona (0.29). Crosses with negative effects were PBIG-1 x PBIG-2 (-0.45), PBIG-1 x Kalyanpur Sona (-0.35), PBIG-2 x Kalyanpur Sona (-0.31), PBIG-2 x Kalyanpur Baramasi (-0.23), PBIG-4 x Kalyanpur Baramasi (-0.27) and PBIG-4 x Priya White (-0.44).

4.4.11 Fruit yield per vine (kg)

During summer season experiment, only gca variance was highly significant whereas in rainy season experiment, both gca and sca variances were found highly significant. In summer season 3 parents gave positive gca effects and 3 parents gave negative gca effects. Parents with positive gca values were PBIG-2 (0.09), Kalyanpur Sona (0.16) and Priya White (0.03). Effects for Priya White was non-significant. According to gca, ranking of parents would be as follows : Kalyanpur Sona (0.16), PBIG-2 (0.09), Priya White (0.03), PBIG-1 (-0.04), PBIG-4 (-0.12) and Kalyanpur Baramasi (-0.12).

Out of 15 sca effects, 5 effects were highly significant and 2 effects were significant. Crosses with positive sca effects were PBIG-1 x Kalyanpur Baramasi (0.30), PBIG-2 x Priya White (0.70) and PBIG-4 x Priya White

Table 4.6 : Estimates of general combining ability effects for various horticultural traits (summer season, 1999 and rainy season,1999)

Parents	Days to male flower			Days to female flower			Node number to first male flower			Node number to first female flower			Number of primary branches per vine		
	Summer	Rainy	Average	Summer	Rainy	Average	Summer	Rainy	Average	Summer	Rainy	Average	Summer	Rainy	Average
PBIG-1	-1.36**	0.57	-0.40	-0.38	0.11	-0.13	0.24	1.06**	0.65	-0.39**	1.00**	0.31	-1.95**	-1.89**	-1.92
PBIG-2	-1.69**	-3.81**	-2.75	-1.56**	-3.35**	-2.45	-1.04**	-0.61*	-0.82	-1.47**	-0.79**	-1.13	1.81**	0.69*	1.25
PBIG-4	0.81*	-0.22	0.30	1.40**	-0.01	0.70	0.19	-0.36	-0.08	0.28	-0.33	-0.03	-1.74**	1.15**	-0.30
K.S.	-1.90**	-1.13**	-1.52	-2.55**	-1.34**	-1.94	-0.85**	- 0.90**	-0.87	0.01	-0.75**	-0.37	4.22**	1.35**	2.79
K.B.	3.43**	2.36**	2.89	2.61**	2.31**	2.46	1.23**	0.72**	0.97	1.74*	0.77**	1.23	-1.74**	0.94**	-0.40
P.W.	0.72	1.78**	1.25	0.49	1.99**	1.24	0.24	0.09	0.16	-0.14	0.17	0.12	-0.61*	-2.26**	-1.44
SE (gi)	0.36	0.37		0.46	0.43		0.18	0.23		0.14	0.24		0.27	0.26	
SE (gi-gj)	0.56	0.58		0.71	0.67		0.27	0.35		0.22	0.37		0.43	0.41	

Table 4.6 Contd...

Parents	Vine length (m)			Number of fruits per vine			Fruit length (cm)		
	Summer	Rainy	Average	Summer	Rainy	Average	Summer	Rainy	Average
PBIG-1	0.10**	0.09	0.10	-0.16	-3.38	-1.77	2.43**	0.28*	1.08
PBIG-2	-0.02	-0.14*	-0.08	0.04	-2.54	-1.25	-2.71**	0.88**	-0.92
PBIG-4	0.13**	-0.09	0.02	-1.00	-1.42	-1.21	2.12**	-0.62**	0.75
K.S.	-0.09**	0.01	-0.04	0.46	4.42	2.44	-3.55**	-1.25**	-2.40
K.B.	-0.12**	0.05	-0.04	-0.71	-0.17	-0.44	2.24**	1.57**	1.21
P.W.	-0.004	0.08	0.04	1.37	3.08	2.23	-0.53**	-0.30*	-0.42
SE (gi)	0.03	0.06		0.78	2.63		0.19	0.12	
SE (gi-gj)	0.05	0.09		1.21	3.65		0.29	0.19	

Parents	Fruit diameter (cm)			Fruit density (g/cm^3)			Fruit yield per vine (kg)		
	Summer	Rainy	Average	Summer	Rainy	Average	Summer	Rainy	Average
PBIG-1	-0.10*	-0.43**	-0.27	0.004	0.09**	0.05	-0.04	-0.27**	-0.16
PBIG-2	0.19**	0.06	0.13	-0.24**	0.05**	-0.18	0.09*	0.09*	0.09
PBIG-4	-0.43**	0.12	-0.16	0.11**	0.13**	0.12	-0.12**	-0.02	-0.07
K.S.	0.48**	-0.002	0.24	-0.20**	-0.20	-0.20	0.16**	0.15**	0.16
K.B.	-0.24**	0.18*	-0.03	-0.02	-0.09**	-0.06	-0.12**	0.11**	0.01
P.W.	0.09*	0.08	0.09	0.19**	0.01	0.08	0.03	0.04	0.04
SE (gi)	0.04	0.07		0.02	0.02		0.04	0.04	
SE (gi-gj)	0.06	0.11		0.03	0.04		0.06	0.06	

*, ** Significant at 0.05 and 0.01 levels of probability, respectively.
K.S. = Kalyanpur Sona
K.B. = Kalyanpur Baramasi
P.W. = Priya White

Table 4.7 : Estimates of specific combining ability of crosses for various horticultural traits (summer season, 1999 and rainy season, 1999)

Crosses	Days to male flower			Days to female flower			Node number to first male flower			Node number to first female flower			Number of primary branches per vine		
	Summer	Rainy	Average	Summer	Rainy	Average	Summer	Rainy	Average	Summer	Rainy	Average	Summer	Rainy	Average
PBIG-1 x PBIG-2	-1.27	-2.16*	-1.72	-1.36*	-4.68**	-.3.02	0.61	-2.33**	-0.86	0.75	-2.59**	-0.91	-1.99*	3.61*	0.81
PBIG-1 x PBIG-4	-.3.47**	4.26**	0.39	2.35*	2.32	2.34	-0.64	1.08	0.22	0.001	0.95	0.48	-1.11	-4.18**	-2.65
PBIG-1 x K.S.	-1.39	-4.45**	-2.92	-1.36*	-6.02**	-3.69	-0.92	-2.71**	-1.82	-0.71	-3.29**	-2.00	5.26**	5.94**	5.60
PBIG-1 x K.B.	-1.72	2.50*	0.39	-4.19**	4.63**	0.22	-0.67	4.00**	1.67	-0.45	3.91**	1.73	-2.11**	0.69	-0.71
PBIG-1 x P.W.	4.32**	4.92**	4.62	-3.60**	6.98**	1.69	0.32	1.29*	0.81	-0.25	1.79**	0.77	-0.24	-1.10	-0.67
PBIG-2 x PBIG-4	3.57*	-0.04	1.77	1.19	3.11*	2.15	-0.68	2.08**	0.70	-0.59	1.74*	0.58	-2.53**	-6.44**	-4.49
PBIG-2 x K.S.	-5.05**	-1.41	-3.23	-5.86**	-0.56	-3.21	-0.30	-0.71	0.51	-0.62	-0.17	-0.39	0.18	2.69**	1.44
PBIG-2 x K.B.	4.28**	-0.45	1.92	3.31*	1.48	2.39	1.28*	-0.33	0.48	2.29**	0.04	1.17	-2.19**	5.11**	1.46
PBIG-2 x P.W.	-0.34	-0.37	-0.36	-0.23	0.44	0.11	-0.68	-0.71	-0.70	0.50	-0.76	-0.13	6.01**	3.02**	4.52
PBIG-4 x K.S.	2.45*	-5.33**	-1.44	1.85*	-6.56**	-2.36	1.12*	-0.96	0.08	0.63	-0.29	0.17	-0.28	2.89**	1.31
PBIG-4x K.B.	-2.22*	1.96	-0.13	-2.98*	1.82	-0.58	-3.31**	0.75	-1.28	-2.79**	0.58	-1.11	3.35**	-.435**	-0.50
PBIG-4 x P.W.	-4.51**	-1.62	-3.07	-3.53**	-1.56	-2.55	-0.64	-1.29*	0.97	0.08	-1.55*	-0.74	-3.45**	2.52**	-0.47
K.S. x K.B.	7.15**	3.26**	5.21	2.64*	3.48**	3.06	-0.26	0.29	0.02	-1.16**	-0.01	-0.59	-2.61**	-2.23**	-2.42
K.S. x P.W.	-.347**	-0.66	-2.07	-2.89*	-0.56	-1.73	0.74	0.92	0.83	1.37**	0.87	1.12	3.27**	-5.35**	-1.04
K.B. x P.W.	-6.47**	-5.04**	-5.76	-5.73**	-6.85**	-6.29	0.35	-0.71	-0.18	-0.04	-0.92	0.48	-3.12**	7.07**	1.98
SE (S_{ij})	0.99	1.02		1.26	1.19		0.48	0.63		0.39	0.65		0.75	0.73	
SE (S_{ij}-S_{ik})	1.48	1.52		1.88	1.77		0.72	0.93		0.58	0.97		1.12	1.08	
SE (S_{ij}-S_{kl})	1.37	1.41		1.74	1.64		0.67	0.87		0.54	0.90		1.04	1.00	

Table 4.7 Contd...

Crosses	Vine length (m)			Number of fruits per vine			Fruit length (cm)		
	Summer	Rainy	Average	Summer	Rainy	Average	Summer	Rainy	Average
PBIG-1 x PBIG-2	0.04	0.27	0.12	0.46	3.06	1.76	2.70**	-9.51**	-3.41
PBIG-1 x PBIG-4	-0.33**	0.48**	0.08	2.50	-1.39	0.55	2.85**	3.61**	3.23
PBIG-1 x K.S.	0.10	-0.13	-0.02	-5.29*	-3.89	-4.59	-1.06*	-7.18**	4.12
PBIG-1 x K.B.	0.21*	-0.11	0.05	4.20	-2.65	0.78	-1.33	3.84**	1.26
PBIG-1 x P.W.	0.59**	-0.70**	-0.06	4.13	-5.57	-0.72	-0.72	2.50**	0.89
PBIG-2 x PBIG-4	-0.37**	0.03	-0.17	4.96*	-1.57	1.70	-0.09	5.36**	2.64
PBIG-2 x K.S.	-0.20*	-0.01	-0.11	1.84	-5.73	-1.95	1.49**	-0.77*	0.36
PBIG-2 x K.B.	0.001	0.10	0.05	-0.66	0.85	0.10	1.31*	1.92**	1.62
PBIG-2 x P.W.	0.43**	0.46*	0.45	1.56	-1.06	0.25	1.55**	1.12**	1.34
PBIG-4 x K.S.	-0.09	-0.10	0.09	1.88	-2.52	-0.32	0.31	-3.17**	-1.43
PBIG-4x K.B.	0.48**	-0.43*	0.03	4.37*	0.39	2.38	3.33**	-0.49	1.42
PBIG-4 x P.W.	-0.16	-0.02	0.09	-0.37	-0.86	-0.62	-1.27*	-0.54	-0.91
K.S. x K.B.	0.001	0.22	0.11	7.25**	-4.77	1.24	-0.61	6.47**	2.93
K.S. x P.W.	0.79**	-0.24	0.28	2.17	24.98**	13.58	1.31*	0.89*	1.10
K.B. x P.W.	-0.01	0.68**	0.34	-3.33	-3.44	-3.39	-3.03**	-1.88**	-2.46
SE (S_{ij})	0.08	0.16	-	2.15	6.47	-	0.51	0.34	-
SE (S_{ij}-S_{ik})	0.12	0.23	-	3.20	9.66	-	0.76	0.53	-
SE (S_{ij}-S_{kl})	0.11	0.21	-	2.97	8.95	-	0.70	0.47	-

Table 4.7 Contd…

Crosses	Fruit diameter (cm)			Fruit density (g/cm^3)			Fruit yield per vine (kg)		
	Summer	Rainy	Average	Summer	Rainy	Average	Summer	Rainy	Average
PBIG-1 x PBIG-2	-0.09	0.25	0.08	0.36**	-0.45**	-0.05	0.10	0.30	0.20
PBIG-1 x PBIG-4	0.43**	-0.59**	-0.08	-0.03	0.33**	0.15	0.25*	-0.14	0.06
PBIG-1 x K.S.	0.14	0.53**	0.34	-0.29**	-0.35**	-0.32	-0.33**	-0.04	-0.19
PBIG-1 x K.B.	0.93**	-0.74**	0.09	-0.26**	0.56**	0.15	0.30**	-0.29**	0.01
PBIG-1 x P.W.	-0.04	0.15	0.06	0.40**	0.53**	0.47	0.26*	-0.07	0.10
PBIG-2 x PBIG-4	0.09	-0.05	0.02	0.23**	-0.05	0.09	0.21	0.06	0.14
PBIG-2 x K.S.	-0.07	0.42*	0.18	0.44**	-0.31**	0.07	0.08	-0.37**	-0.15
PBIG-2 x K.B.	-0.03	0.38	0.18	-0.09	-0.23**	-0.16	-0.33**	0.002	-0.16
PBIG-2 x P.W.	0.32**	-0.31	0.01	-0.34**	0.59**	0.13	0.70**	0.11	0.41
PBIG-4 x K.S.	-0.49	0.65**	0.08	-0.14*	0.29**	0.08	0.21	0.36**	0.29
PBIG-4x K.B.	-0.39**	-0.12	0.26	-0.35**	-0.27**	-0.31	0.21	-0.21	0.00
PBIG-4 x P.W.	0.14	0.38	0.26	-0.70**	-0.44**	-0.57	-0.15	0.22*	0.04
K.S. x K.B.	0.78**	-1.04	-0.13	0.001	0.04	0.02	0.56**	0.36**	0.46
K.S. x P.W.	0.58**	-0.09	0.25	0.14*	0.04	0.09	0.16	-0.15	0.01
K.B. x P.W.	0.02	0.29	0.16	-0.57**	0.10	-0.24	0.04	0.02	0.03
SE (S_{ij})	0.11	0.19	-	0.06	0.07	-	0.11	0.09	-
SE (S_{ij}-S_{ik})	0.16	0.28	-	0.08	0.09	-	0.15	0.15	-
SE (S_{ij}-S_{kl})	0.14	0.26	-	0.07	0.09	-	0.14	0.14	-

*, ** Significant at 0.05 and 0.01 levels of probability, respectively.

K.S. = Kalyanpur Sona

K.B. = Kalyanpur Baramasi

P.W. = Priya White

(0.56). Crosses with negative sca effects were PBIG-1 x Kalyanpur Sona (-0.33) and PBIG-2 x Kalyanpur Baramasi (-0.33).

During rainy season experiment, 4 parents showed positive gca effects and 2 showed negative gca effects. Parents showing positive gca effects were, PBIG-2 (0.09), Kalyanpur Sona (0.15), Kalyanpur Baramasi (0.11) and Priya White (0.04). Out of these 4 parents, Priya White was showing non-significant gca effects. Kalyanpur Sona (0.15) proved best combiner folllowed by Kalyanpur Baramasi (0.11), PBIG-2 (0.09) and PBIG-1 (-0.27).

Out of 15 effects, 4 effects were highly significant and one effect was significant. PBIG-4 x Kalyanpur Sona (0.36) was the only cross with positive sca effect and crosses with negative sca effects were PBIG-1 x Kalyanpur Sona (-0.29), PBIG-2 x Kalyanpur Sona (-0.37) and Kalyanpur Sona x Kalyanpur Baramasi (-0.36).

4.5 Genetic components of variation and Vr/Wr graph

4.5.1 Days to male flower

Non-significance of '1-b' (Table 4.8) indicated the validity of the basic assumptions of diallel analysis for summer season experiment. Components of variation analysis (Table 4.9) indicated highly significant additive genetic component (D). Various forms of dominance (H_1, H_2) were also highly significant. F was positive indicating excess of dominant genes in the parents.

Mean degree of dominance over all loci $(H_1/D)^{1/2}$ was 1.75 which was greater than unity and suggested presence of overdominance. The mean value

Table 4.8 : Values of $b_{Wr/Vr}$ and test of significance of 1-b for various horticultural traits (summer season, 1999 and rainy season, 1999)

	Mean square									
	Days to male flower		Days to female flower		Node number to first male flower		Node number to first female flower		Number of primary branches per vine	
	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
$b_{Wr/Vr}$	0.74 ±0.45	0.47 ±0.18	0.83 ±0.25	0.51 ±0.16	-0.11 ±0.42	0.02 ±0.16	0.83 ±0.42	0.09 ±0.14	0.51 ±0.14	1.36 ±0.55
$1\text{-}b_{Wr/Vr}$	NS	*	NS	*	-	*	NS	*	*	NS

Mean square											
Vine length (m)		Number of fruits per vine		Fruit length (cm)		Fruit diameter (cm)		Fruit density (g/cm^3)		Fruit yield per vine (kg)	
Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
0.69 ±0.41	-0.39 ±0.53	-0.03 ±0.25	0.06 ±0.05	0.83 ±0.11	-0.44 ±0.48	0.36 ±0.23	0.41 ±0.47	0.18 ±0.43	-0.27 ±0.24	0.61 ±0.24	0.88 ±0.28
NS	-	-	*	NS	-	*	-	-	-	NS	NS

*, ** Significant at 0.05 and 0.01 level of probability, respectively.
NS = Non significant
- = SE larger than regression coefficient.

of uv over all the loci estimated from $H_2/4H_1$ was 0.22. It was close to its maximum value 0.25 which arises when u=v=0.50 at all loci. The value of effective factor (k) was found very low (0.16) which suggested maximum one block of dominance genes. Proportion of dominant and recessive alleles pooled over all parents was detected 1.42 which explained asymmetry of distribution of dominant and recessive alleles. As it was found more than unity it referred to excess of dominant alleles.

The Vr/Wr graph for days to female flower for summer season experiment is presented in Fig. 4.1. Regression coefficient was near to unity indicated fulfilment of assumptions. The regression line passed below the origin, suggesting presence of overdominance. Position of array points along the line of regression decides relative proportion of dominant and recessive alleles present in parent. PBIG-4 had preponderance of dominant alleles and is located near the origin. Kalyanpur Sona and PBIG-2 were located at the opposite end of the regression line and indicated higher proportion of recessive alleles. PBIG-1, and Kalyanpur Baramasi occupied intermediate positions.

During rainy season experiment, '1-b' was found to be significant and thus the validity of the assumptions could not be met and accordingly Vr/Wr graph was not drawn. Additive genetic component variance, (D) was detected to be significant whereas dominant components (H_1 and H_2) were highly significant (Table 4.9). The value of degree of dominance $(H_1/D)^{1/2}$ was 1.83 and 1.75 for rainy season and summer season experiment respectively. Thus it was

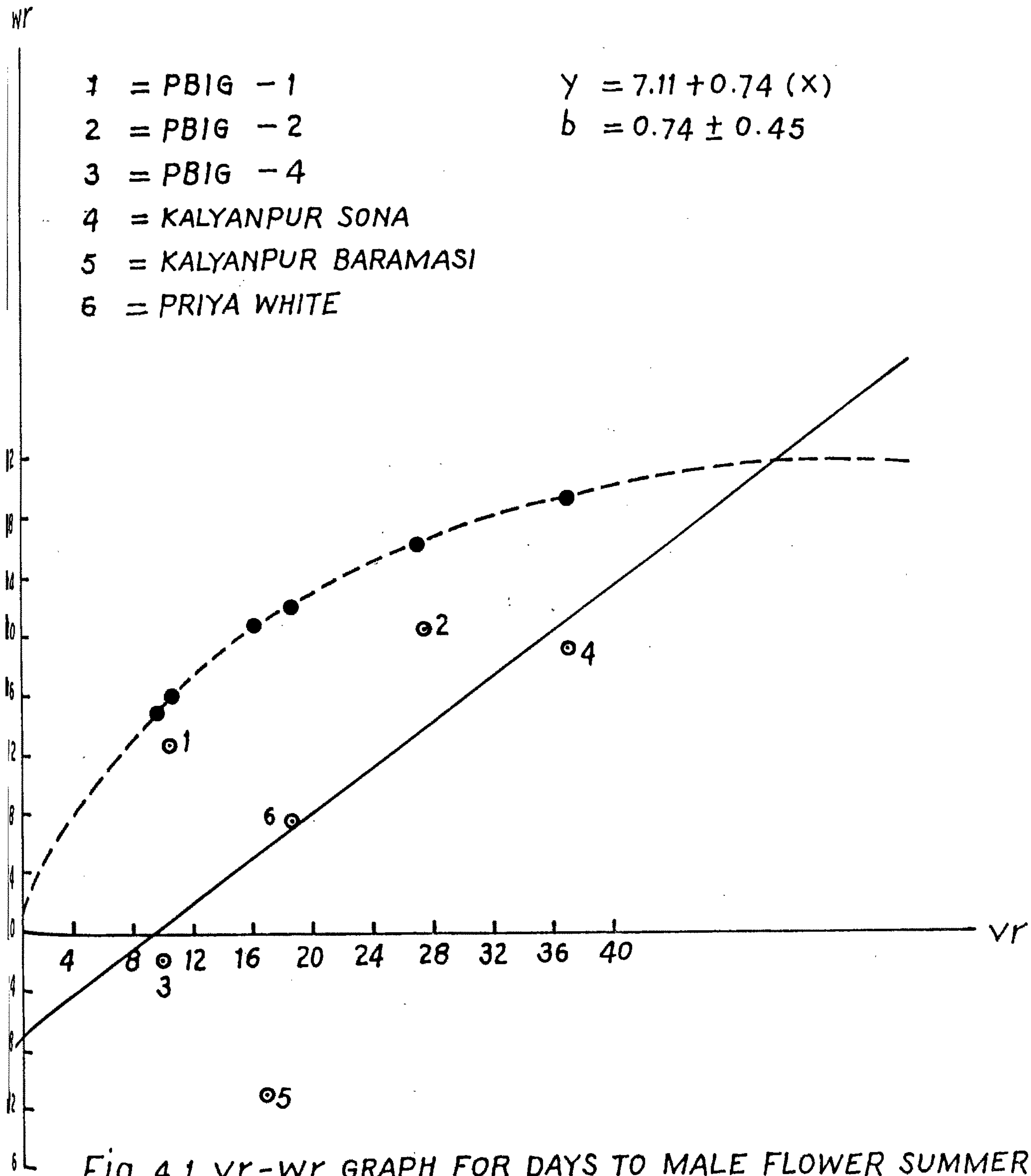


Fig. 4.1 vr-wr GRAPH FOR DAYS TO MALE FLOWER SUMMER-99

consistent over seasons. Since these estimates were more than one, the degree of dominance was overdominance. The value of F was negative which showed that an excess of recessive genes controlled the expression of days to male flower. The results pertaining to F over seasons were inconsistent. The value of effective factor was detected 4. It means 4 blocks of dominant genes were present. The ratio of dominant and recessive in parents was found less than unity (0.89) indicating more ratio of recessive alleles in parents.

4.5.2 Days to female flower

The assumptions of diallel analysis were proved to be valid for summer season experiment as '1-b' was non-significant. Components of variation analysis is presented in Table 4.9. Additive genetic component (D) was highly significant (16.94) and various forms of dominance (H_1, H_2 and h^2) were also highly significant. The positive value of F indicated an excess of dominant genes in the parents for days to female flower.

Mean degree of dominance over all loci estimated through $(H_1/D)^{1/2}$, was found to be grater than one (1.59) which suggested presence of over dominance. The value of $H_2/4H_1$ was found 0.23 which is close to its maximum theoretical value 0.25 which arises when u=v=0.5 at all loci. Thus an equal number of negative and positive alleles for this character were present in the parents. The ratio of dominant and recessive alleles in parents for days to female flower was found to be more than unity (1.28) which indicated presence of more dominant alleles in parents. Very low value of h^2/H_2 (0.02) indicated presence of maximum one block of dominant genes in parents.

Vr/Wr graph for summer season experiment is presented in Fig.4.2. Recession coefficient (0.83) was near unity. Line of regression intersected the X axis below the origin. This indicated presence of over dominance. This result confirmed the estimated value of $(H_1/D)^{1/2}$ where it was more than unity indicating overdominance. Distribution of parents was also observed. PBIG-2 and PBIG-4 were located at the opposite side of origin are believed to have recessive alleles for days to female flower. PBIG-1was located near origin, so had dominant alleles.

In rainy season experiment, additive genetic variance (D) was significant whereas both H_1 and H_2 were found to be highly significant. The degree of dominance, $(H_1/D)^{1/2}$ was found greater than one (2.25) so indicated overdominance. Proportion of dominant genes with positive and negative effects, determined by $H_2/4H_1$ is 0.22, very near to its maximum theoretical value, 0.25 which indicated $\mu = v = 0.5$ at all loci. Number of dominant gene blocks were found to be 2.

4.5.3 Node number to first male flower

In summer season experiment, value of regression coefficient b was less than standard error. All the genetic parameters were non-significant except additive component of variance (D) which was found to be highly significant (6.13). $(H_1/D)^{1/2}$ was 0.99, very near to unity exhibiting complete dominance.

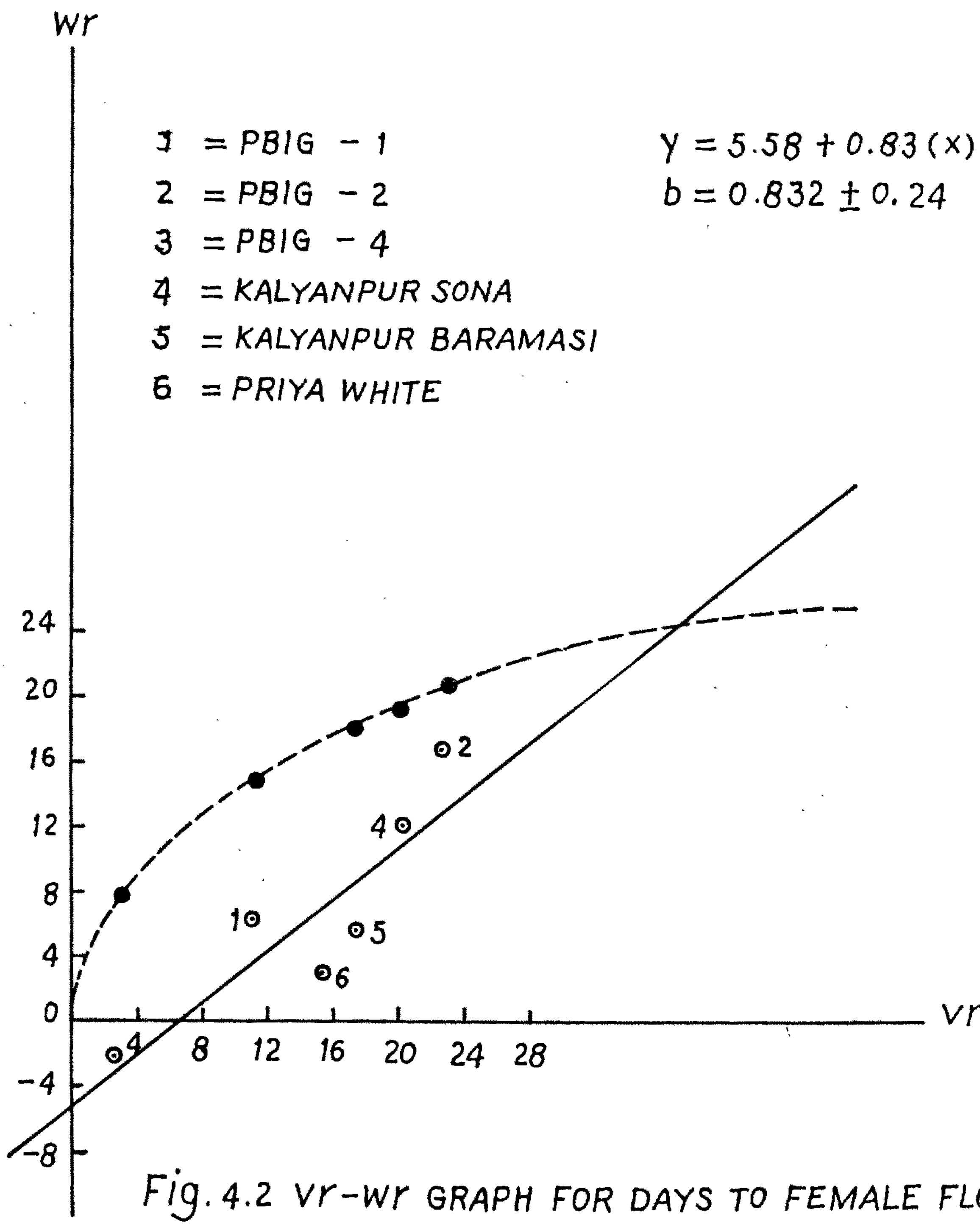


Fig. 4.2 Vr-Wr GRAPH FOR DAYS TO FEMALE FLOWER
SUMMER-99

($H_2/4H_1$) was detected to be 0.18 which indicated asymmetrical distribution of positive and negative dominant genes in the parents. Positive value of F (5.86) indicated excess of dominant genes in the parents for node number to first male flower. The ratio, $(4DH_1)^{1/2} + F /(4DH_1)^{1/2} - F$ was detected more than unity (2.84) suggesting excess of dominant genes in the parents. Estimate of h^2/H_2 was very low (0.11) indicating presence at the most one block of dominant genes for node number to first male flower. Vr/Wr graph was not drawn, as '1-b' was significant (0.89) indicating failure of fulfilment of assumptions of diallel analysis.

In the rainy season experiment, 1-b was again significant which indicated presence of non-allelic interaction and non-validity of basic assumptions of diallel analysis. Dominance components, (H_1 and h^2) were found to be significant. $(H_1/D)^{1/2}$ was higher than unity (5.02) indicating overdominance. This result showed inconsistency as this estimate was less than unity in the summer season experiment, indicating partial dominance. Proportion of dominant genes with positive and negative effect ($H_2/4H_1$) was 0.19, which was less than theoretical maximum value of 0.25. This result showed asymmetrical distribution of positive and negative dominant genes in the parents. Proportion of dominant and recessive alleles pooled over parents $(4DH_1)^{1/2} + F/(4DH_1)^{1/2} - F$ was 0.93, suggesting excess of recessive alleles and minority of dominant alleles. A high value of h^2/H_2 (8.23) demonstrated involvement of about 8 blocks of dominant genes/effective factors in expression of node number to first male flower.

4.5.4 Node number to first female flower

Assumptions for diallel analysis were proved to be valid, in summer season experiment as b was close to unity. Genetic components of variation are presented in Table 4.9. Additive genetic component (D) was highly significant (8.32). Dominance component of variance (H_1) was also significant (6.49), value of F was positive which suggested excess of dominant genes in the parents for node number of first female flower. Degree of dominance $(H_1/D)^{1/2}$ was 0.88 which was less than unity indicating partial dominance. Value of ($H_2/4H$) was 0.19 suggesting, asymmetrical distribution of positive and negative effects of dominant genes in the parents. The ratio of dominant and recessive alleles in the parents was 2.65 indicating presence of more dominant alleles in the parent for node number to first female flower. The values of h^2/H_2 was 0.01, which was very low.

Vr/Wr graph for summer season experiment is illustrated in Fig.4.3. Regression coefficient b was near unity (0.83). Value of Wr intercept, a, was greater than zero (0.69). Thus the Vr/Wr graph which passed above origin also indicated that there was average partial dominance in the experimental material. The position of the array points along the line of regression of Wr on Vr exhibits the relative proportion of dominant and recessive alleles present in the common parent of each array. Five parents (PBIG-1, PBIG-4, Kalyanpur

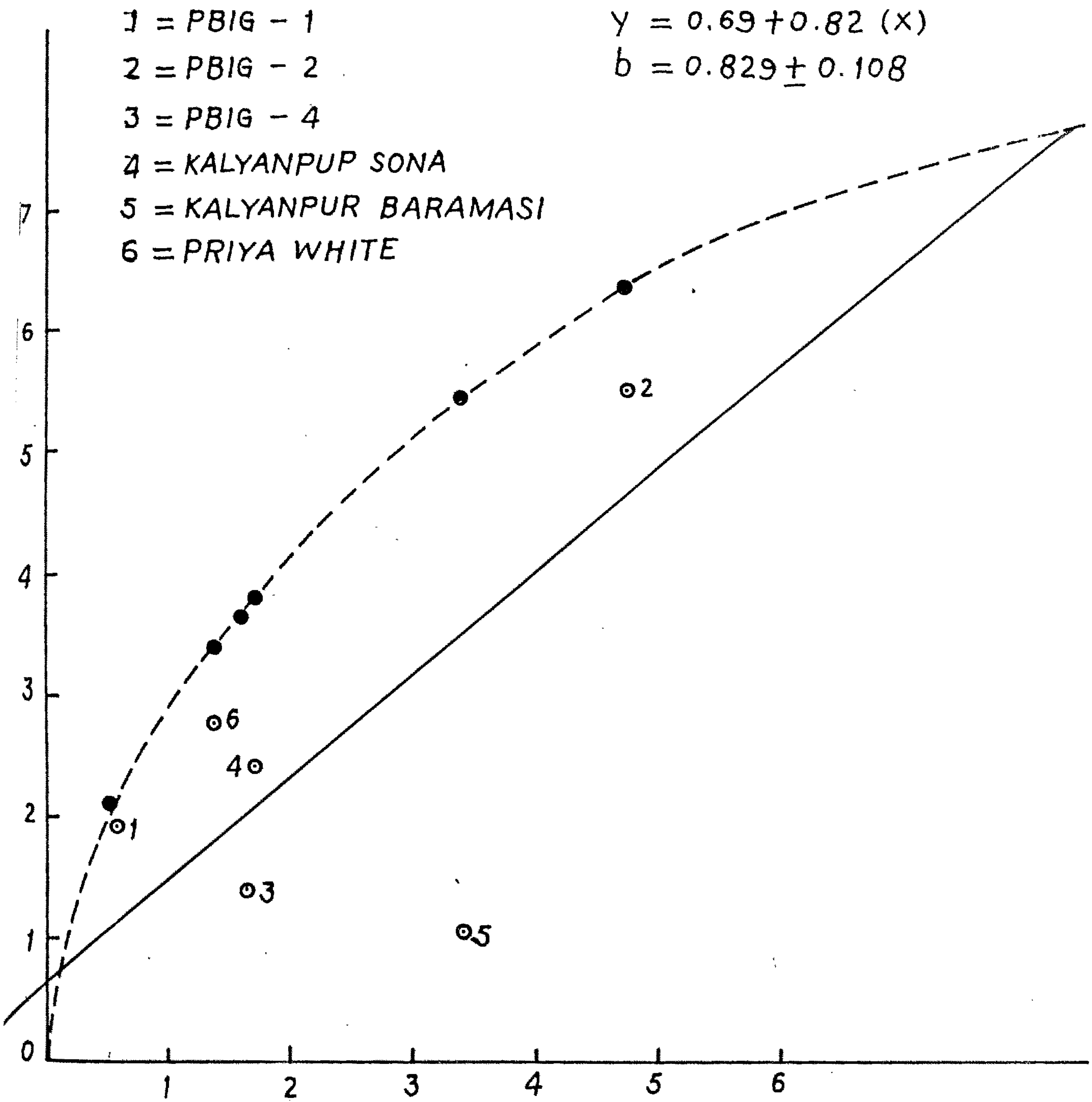


Fig. 4.3 Vr-Wr GRAPH FOR NUMBER OF NODES TO FIRST FEMALE FLOWER - SUMME -99

Sona, Kalyanpur Baramasi and Priya White) exhibited preponderance of dominant alleles as they were located near the origin in the Vr, Wr graph. Only one parent (PBIG-2), located at the opposite end of the regression line, had mostly the recessive alleles..

In the rainy season experiment, dominance components of variance (H_1 and h^2) were found to be significant. The negative value of F (-0.44) indicated excessive presence of recessive alleles. Degree of dominance $(H_1/D)^{1/2}$ was 4.71 suggesting presence of overdominance. ($H_2/4H_1$) was 0.21 which was less than its theoretical maximum value (0.25). This arises when there is asymmetrical distribution of positive and negative alleles. Proportion of dominant and recessive alleles, $(4DH_1)^{1/2} + F/ (4DH_1)^{1/2} - F$ was less than unity (0.85). It indicated excess of recessive alleles and minority of dominant alleles. Number of blocks of dominant genes (h^2/H_2) was found to be 5.02 indicating that atleast 5 genes showing dominance influenced the expression of node number to female flower.

Due to non-validity of assumptions of diallel analysis, during rainy season experiment, Vr/ Wr graph was not drawn.

4.5.5 Number of primary branches per vine

'1-b' was proved to be significant in summer season experiment, indicating failure of basic assumptions of diallel analysis. Additive genetic component (D) of variance was significant (12.86) and different dominance components of variance ($H_1$and H_2) were highly significant (Table 4.9) for number of primary branches per vine in summer season experiment. Negative F value (-9.58) suggested prevalence of recessive alleles in parents.

Mean value of degree of dominance $(H_1/D)^{1/2}$ was more than unity (1.85) suggesting overdominance. $(H_2/4H_1)$ was 0.24 which is different from its theoretical value (0.25) indicated asymmetric distribution of positive and negative effect of dominant alleles in parents. The ratio, $(4DH_1)^{1/2} + F/ (4DH_1)^{1/2} - F$ was less than unity indicated that parents carried rather more recessive than dominant alleles. Gene blocks for dominance effect (h^2/H_2) was 5.05, indicated 5 genes showing dominance influenced the expression of number of primary branches per vine. '1-b' was non-significant during rainy season experiment, indicating validity of assumptions for diallel analysis. Only dominance components of variance (H_1 and H_2) were found to be significant other component of dominance (h^2) was found to be highly significant. Positive F (0.13) indicated excess of dominant alleles. $(H_1/D)^{1/2}$ was detected more than unity (2.29) indicating overdominance. This result was found consistent for both the seasons. Distribution of u and v was found to be asymmetrical as value of $(H_2/4H_1)$ was very less than its maximum theoretical value (Table 4.9). Proportion of recessive and dominant alleles expressed as $(4DH_1)^{1/2} + F/(4DH_1)^{1/2}$-F was more than one so indicated more prevalence of dominant alleles in parents, h^2/H_2 was found very less (0.08).

Vr/Wr graph for number of primary branches is presented in Fig.4.4. Regression coefficient was 1.36. Value of Wr intercept, a was -25.15 (Fig.

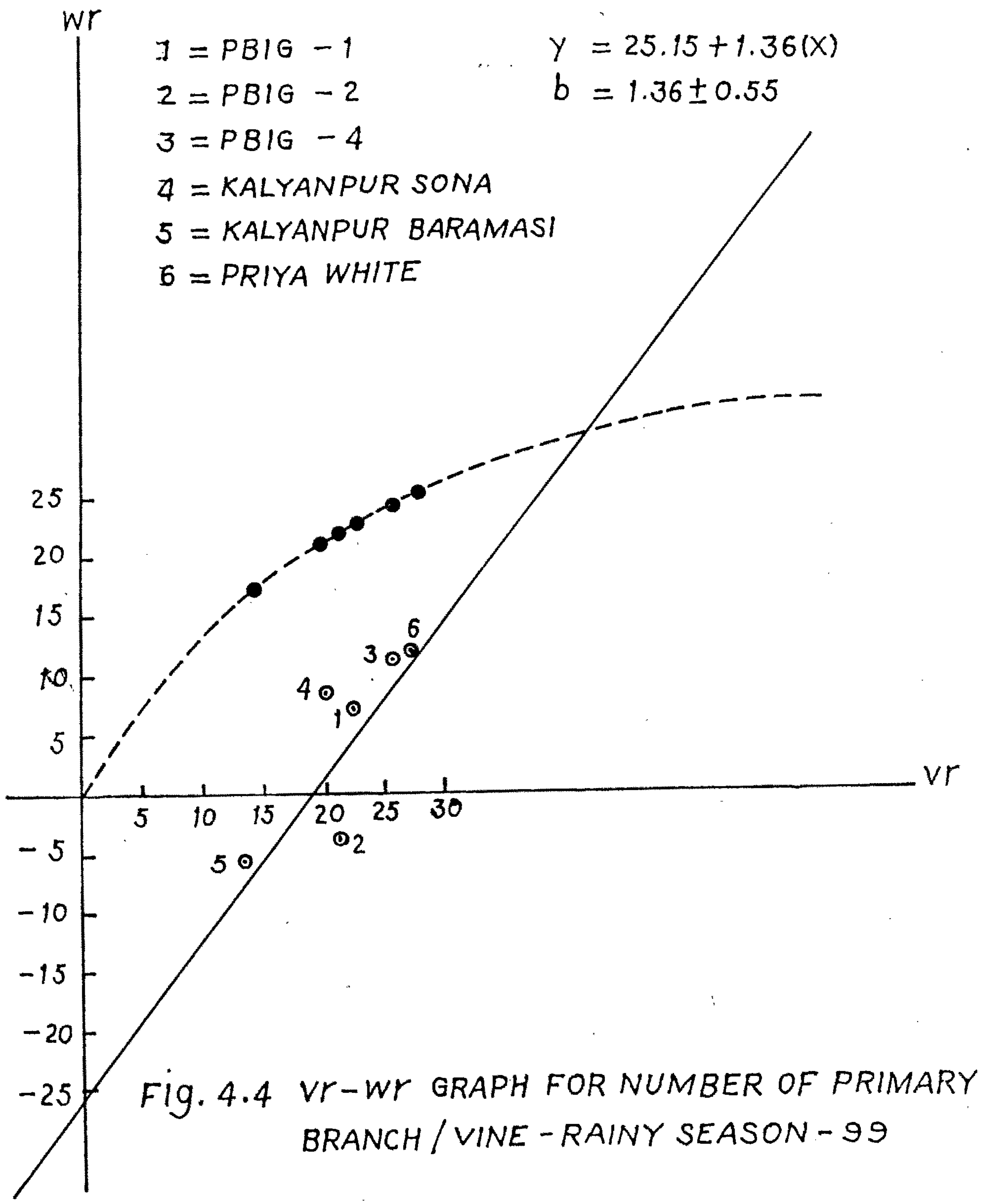


Fig. 4.4 vr-wr GRAPH FOR NUMBER OF PRIMARY BRANCH / VINE - RAINY SEASON - 99

4.4), which was less than zero. Thus, the (Vr, Wr) graph also indicated that average overdominance is present. Most of the parents (PBIG-2, Kalyanpur Baramasi, PBIG-1 and PBIG-4) were located near the origin suggesting excess of dominant alleles. Only two parents occupied intermediate place on regression line (PBIG-4 and Priya White).

4.5.6 Vine length (m)

During summer season experiment, 1-b was non-significant indicating fulfilment of assumption for diallel analysis. Additive genetic component of variance (D) was highly significant (0.23) and various components of dominance variance (H_1, H_2 and h^2) were also detected highly significant for vine length. Positive value of 'F' (0.44) indicated that parents carried more dominant alleles. Mean degree of dominance $(H_1/D)^{1/2}$ was greater than one (1.85) thus suggested presence of overdominance. $H_2/4H_1$ was very less than its maximum theoretical value (0.25) indicating asymmetrical distribution of u and v. Proportion of dominant and recessive alleles was 3.16 which was higher than unity suggesting more occurrence/preponderance of dominance alleles in parents. h^2/H_2, giving the information about gene block for dominance was found very low (0.04).

Vr/Wr graph for vine length during summer season experiment is depicted in Fig.4.´ . Regression coefficient is 0.69. The value of Wr intercept, a was -0.099 which is less than zero, so graph indicated that there was average

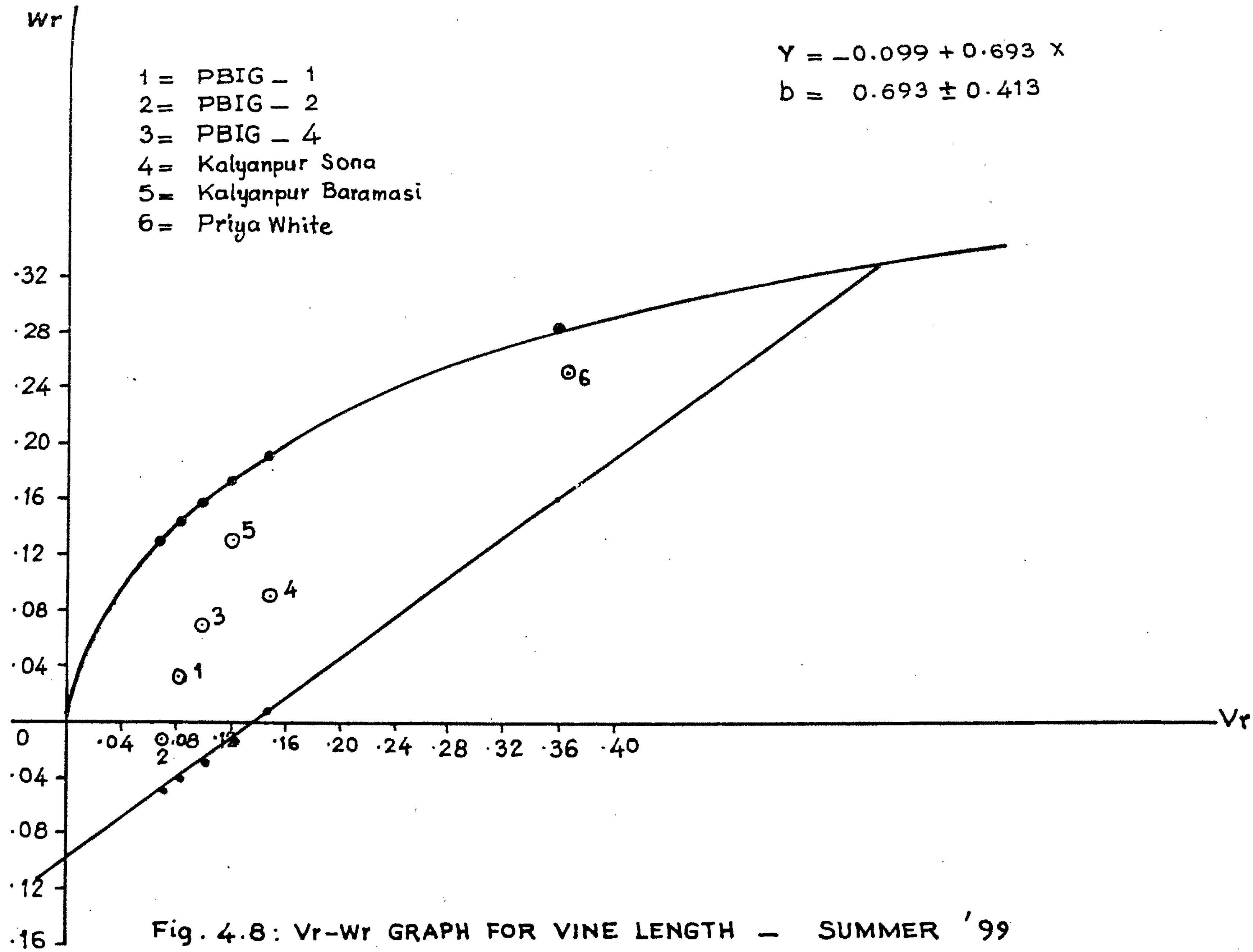


Fig. 4.8: Vr-Wr GRAPH FOR VINE LENGTH — SUMMER '99

overdominance. In general, most of the parents were located near origin indicating preponderance of dominant alleles in parents.

In rainy season degree of dominance, only dominance component of variance (H_2, h^2) were found significant. Ratio $(H_1/D)^{1/2}$ was more than unity suggesting overdominance. This result is in agreement with summer season experiment result. $H_2/4H_1$ was very near to maximum theoretical value thus indicated asymmetric distribution of positive and negative alleles. Proportion of dominant and recessive alleles $(4DH_1)^{1/2} + F/ (4DH_1)^{1/2}$-F was 1.98, greater than unity indicating excess of dominant alleles. h^2/H_2 was very low (0.08) indicating maximum one block of dominance gene block for expression of vine length.

4.5.7 Number of fruits per vine

Dominance components, H_1, H_2 and h^2 were highly significant (Table 4.9). Positive value of F (7.15) indicated excess of dominant alleles in the parents for this trait. Mean value of degree of dominance $(H_1/D)^{1/2}$ was more than unity (2.91) suggesting overdominance. $(H_1/4H_1)$ was equal to its maximum theoretical value, 0.25 and indicated symmetrical distribution of positive and negative alleles over all loci i.e. u=v=0.5. $(4DH_1)^{1/2}+F/(4DH_1)^{1/2}$-F had a value of 1.61 indicating excess of dominant alleles. Number of blocks of dominant genes were estimated by h^2/H_2 and the value was 2 suggesting involvement of 2 effecting factors for the number of fruits per vine.

In the rainy season experiment, basic assumptions of diallel analysis could not be satisfied as '1-b' was significant. No genetic component of variation was significant in the rainy season experiment. The genetic component F was had a negative value (-75.72) suggesting presence of recessive values. Mean degree of dominance $(H_1/D)^{1/2}$ was less than unity (0.84) and indicated the presence of partial dominance, however, approaching to complete dominance. $H_2/4H_1$ was unequal to its maximum theoretical value of 0.25 (Table 4.9) and thus, there was asymmetrical distribution of positive and negative alleles. Proportion of dominance and recessive alleles was less than unity indicating preponderance of recessive alleles in the parents.

4.5.8 Fruit length (cm)

For summer season experiment, basic assumptions for diallel analysis was fulfilled as '1-b' was non-significant (Table 4.8). Genetic components of variation (Table 4.9) indicated highly significant additive genetic component (D). Various forms of dominance (H_1, H_2 and h^2) were also highly significant. Positive value of F (5.49) indicated excess of dominant genes in the parents.

Mean degree of dominance over all the loci $(H_1/D)^{1/2}$ was 0.74 which was less than unity and suggested presence of partial dominance. The mean of uv, over all the loci, estimated from $H_2/4H_1$ was 0.22, close to its maximum theoretical value 0.25, which arises when u=v=0.50 at all loci. Proportion of dominant and recessive alleles $(4DH_1)^{1/2}+F/(4DH_1)^{1/2}-F)$ was more than unity (1.27) indicating more dominant alleles in the parents. Number of blocks of dominant genes estimated by h^2/H_2 was 2.15. Thus at least 2 effective factors were involved to control the fruit length.

Vr/Wr graph for fruit length (summer season) represented in Fig.4.5. Regression coefficient was very near to unity (0.83). Intercept on Wr was 5.18 which was much greater than zero. Thus, the graph (Vr/Wr) also indicated that there was average partial dominance for fruit length. The parent number 3 (PBIG-4) having a high array variance and covariance was away from origin and was most recessive parent for fruit length. Contrary to this, parent number 6 (Priya White) had a low array variance and covariance and was near origin with preponderance of dominant alleles. The remaining four parents had the intermediate levels of dominance.

In the rainy season experiment, the standard error of the regression coefficient of Wr on Vr was larger than the regression coefficient, and therefore this regression coefficient was ignored. The dominance components of variation viz., H_1, H_2 and h^2 were significant. Average degree of dominance $(H_1/D)^{1/2}$ was greater than unity (3.78) indicating overdominance. These results were inconsistent as in summer season experiment, partial dominance was observed. Ratio of dominant and recessive alleles $(4DH_1)^{1/2} + F/ (4DH_1)^{1/2}-F$ was greater than unity (1.88) and this suggested excess of dominant alleles in the parents. The estimated value of h^2/H_2 was 3.79.

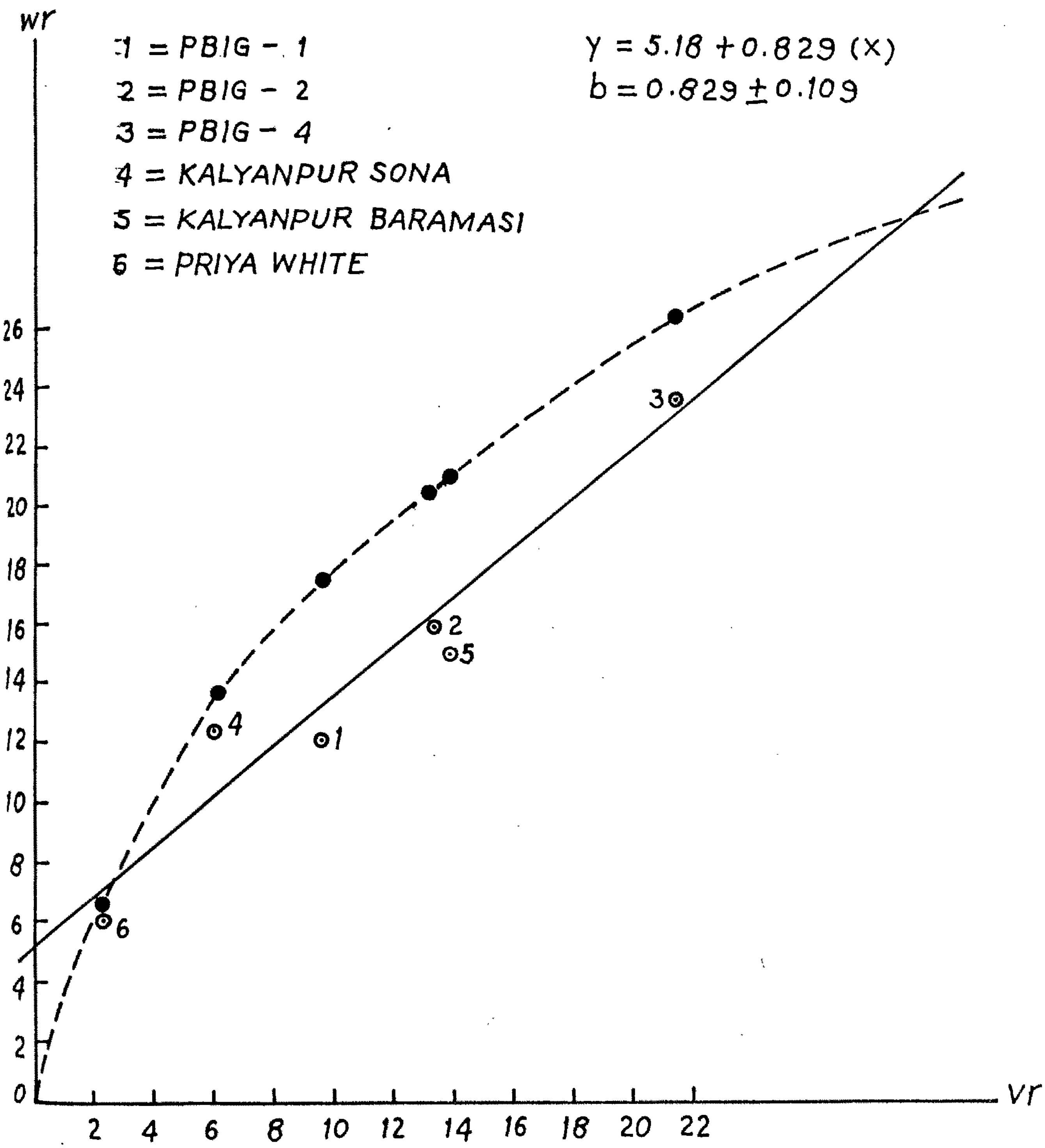


Fig. 4.5 vr-wr GRAPH FOR FRUIT LENGTH-SUMMER-99

4.5.9 Fruit diameter (cm)

Basic assumptions of diallel analysis were not fulfilled because of significance of 1-b. So graphs for both the rainy and summer season experiments were not drawn (Table 4.8). The genetic components of variation are presented in Table 4.9. In the rainy season experiment additive genetic component (D) was highly significant (0.42). Various forms of dominance (H_1,H_2 and h^2) were also highly significant. Positive value of F (0.14) suggested excess of dominant alleles in the parents.

The value of $(H_1/D)^{1/2}$ was more than unity (1.47) indicating the involvement of overdominance. $H_2/4H_1$ was 0.21 which was less than its maximum theoretical value 0.25 indicating asymmetrical distribution of positive and negative alleles. The ratio $(4DH_1)^{1/2}$ + F/ $(4DH_1)^{1/2}$ - F was 1.25, again suggesting excess of dominant alleles in the parents. Number of locks of dominant gene was 2.06 indicating involvement of 2 factors in expression of fruit diameter.

In the rainy season experiment only dominance component of variance (H_1,H_2 and h^2) were highly significant. The value of F was positive (0.32) which indicated presence of more dominant alleles than the recessive ones in the parents. Mean degree of dominance $(H_1/D)^{1/2}$ was 1.96 suggesting overdominance. Value of $(H_2/4H_1)$ was found to be 0.20 which was less than its maximum theoretical value of 0.25. This indicated asymmetrical distribution of positive and negative dominant. The ratio of dominant and recessive alleles $(4DH_1)^{1/2}+F/(4DH_1)^{1/2}-F$ was greater than unity (1.79) indicating excess of dominant alleles in the parents. The value of h^2/H_2 was very low (0.01).

4.5.10 Fruit density (g/cm^3)

During both the seasons, SE of b was larger than regression coefficient and therefore, the graphical analysis was not carried out.

During rainy season experiment, additive genetic component of variance (D) was highly significant (0.26). Various dominance components of variance (H_1, H_2 and h^2) were also found to be highly significant (Table 4.9). Positive value of F suggested excess of dominant alleles in the parents.

Mean degree of dominance $(H_1/D)^{1/2}$ was greater than one (1.58) suggesting presence of overdominance. $H_2/4H_1$ was 0.17 indicating asymmetrical distribution of positive and negative alleles. Proportion of dominant and recessive alleles $(4DH_1)^{1/2}+F/(4DH_1)-F$ was 3.20 indicating excess of dominant alleles in the parents. Blocks of dominant genes was 0.08, which was an under estimate of the potential number.

In rainy season experiment, dominance components of variance (H_2 and h^2) were highly significant. Positive value of F indicated excess of dominant alleles in the parents. Average degree of dominance, $(H_1/D)^{1/2}$ was greater than unity (2.59) suggesting overdominance. The mean value of uv over all the loci estimated from $H_2/4H_1$ was 0.21. This was less than its maximum theoretical value of 0.25 suggesting asymmetrical distribution of positive and negative effects of dominant alleles. Proportion of dominant and recessive alleles $(4DH_1)^{1/2}+F$ / $(4DH_1)^{1/2}-F$ was 1.73 indicating prevalence of dominant alleles in the parents. Number of block of dominant genes was 2.47.

4.5.11 Fruit yield per vine (kg)

It was the only character for which 1-b was non-significant and Vr/Wr graph could be plotted for both the seasons (Table 4.8). Additive component of variance was found to be non-significant in both the seasons (Table 4.9). H_1 and H_2 were highly significant in summer as well as rainy season experiments (Table 4.9). Value of $(H_1/D)^{1/2}$ was more than unity in summer (3.12) and rainy (1.40). Thus, there was considerable consistency in the results over seasons. Only $H_2/4H_1$ gave non-consistent results over seasons. During summer season it was equal to 0.25 showing symmetrical distribution of positive and negative effects of dominant genes (u=v=0.5) whereas in rainy season experiment it was 0.18 and this showed asymmetrical distribution of dominant genes with positive and negative effects. Vr/Wr graphs for fruit yield in summer and rainy seasons experiments are presented in Figs. 4. and 4. respectively. In both the cases the position of the regression line confirmed the results based on $(H_1/D)^{1/2}$ estimate. The regression line cut the X axis below the origin, suggesting the presence of overdominance, which was also inferred from the value of $(H_1/D)^{1/2}$ which was more than 1. Regression coefficient for summer season experiment was 0.61 and for rainy season experiment, it was 0.88. Position of parents along the regression line indicated that PBIG-1, PBIG-2,

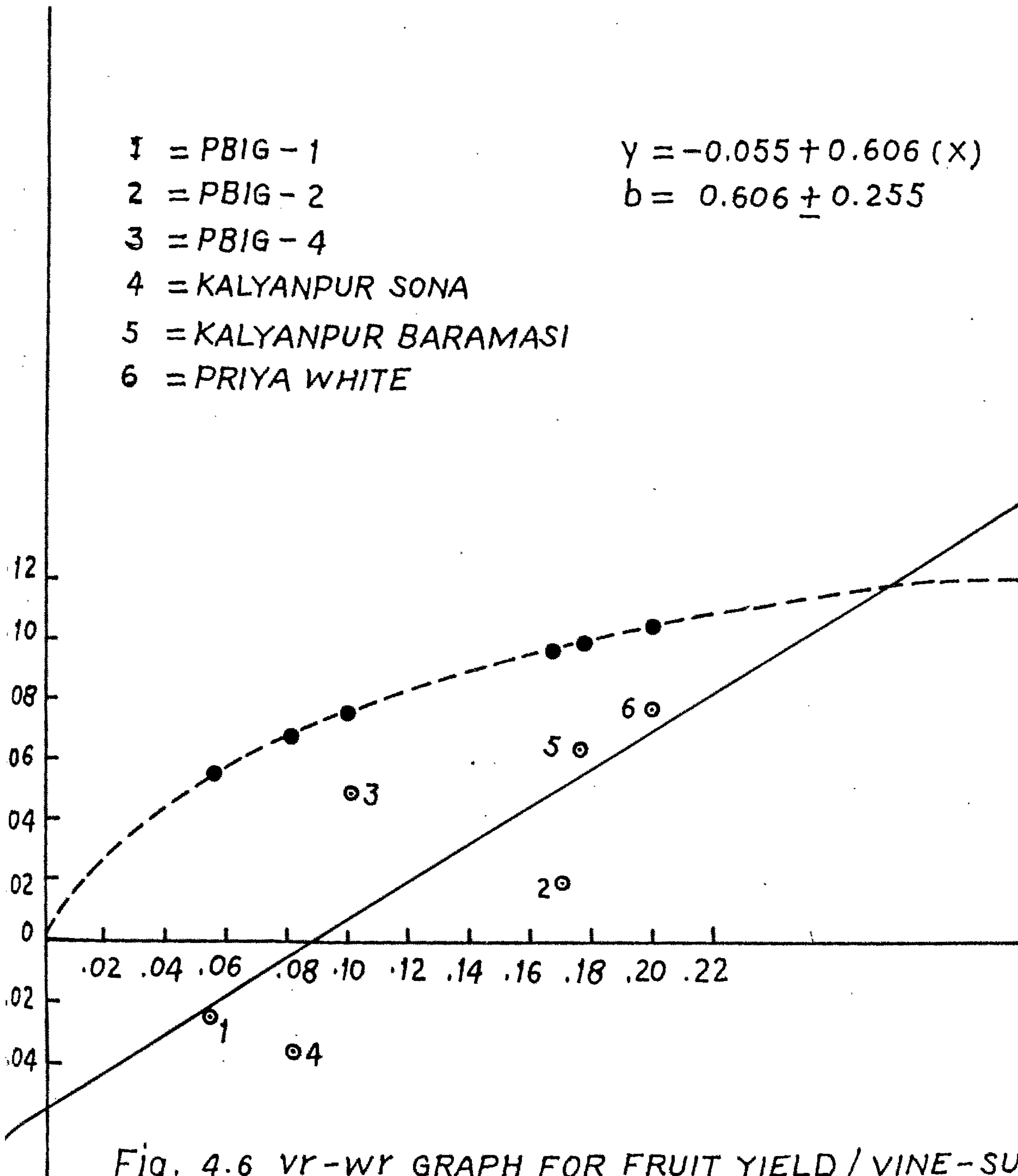


Fig. 4.6 Vr-Wr GRAPH FOR FRUIT YIELD / VINE-SUMMER-99

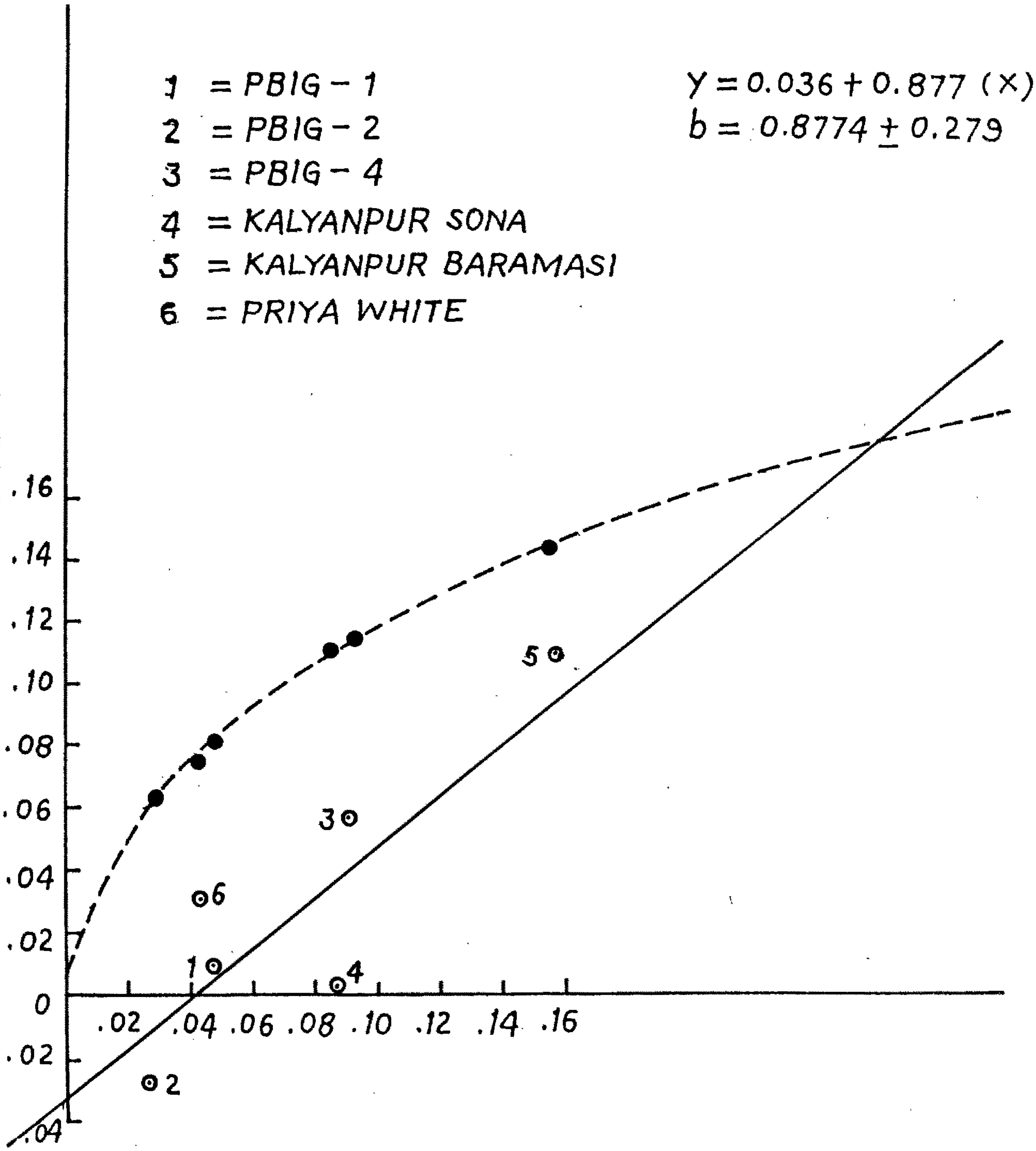


Fig. 4.7 Vr-Wr GRAPH FOR FRUIT YIELD / VINE
RAINY SEASON -99

Table 4.9 : Genetic components of variation for horticultural traits (summer season, 1999 and rainy season, 1999)

Components/ proportions	Days to male flower			Days to female flower			Node number to first male flower			Node number to first female flower		
	Summer	Rainy	Average	Summer	Rainy	Average	Summer	Rainy	Average	Summer	Rainy	Average
D	22.29** ±7.53	14.04* ±4.94	18.17	16.94** ±2.76	14.53* ±6.66	15.74	6.13** ±1.26	0.51 ±2.41	3.22	8.32** ±1.08	0.57 ±2.64	4.45
F	13.54 ±18.39	-2.83 ±12.07	5.36	6.74 ±6.74	2.62 ±16.27	4.68	5.86 ±3.08	-0.18 ±5.88	2.88	6.64* ±2.63	-0.44 ±6.44	3.10
H_1	67.98** ±19.12	46.91** ±12.07	57.19	42.78** ±7.06	73.85** ±16.91	58.32	6.06 ±3.19	12.79* ±6.11	9.43	6.49* ±2.74	12.69** ±1.69	9.59
H_2	60.39** ±17.08	37.58** ±11.20	48.99	39.95** ±6.27	63.95** ±15.11	51.95	4.44 ±2.86	10.17 ±5.46	7.31	4.88 ±2.44	10.75 ±5.98	7.82
h^2	-1274.12 ±11.49	-666.91 ±7.54	-970.52	-2330.63 ±4.22	-478.74 ±10.17	-1404.69	-92.14 ±1.92	17.72** ±3.68	54.93	-32.81 ±1.65	8.45* ±4.02	12.18
$(H_1/D)^{1/2}$	1.75	1.83	1.79	1.59	2.25	1.92	0.99	5.02	3.01	0.88	4.71	2.80
$(H_2/4H_1)$	0.22	0.20	0.21	0.23	0.22	0.22	0.18	0.19	0.19	0.19	0.21	0.20
$\frac{(4DH_1)^{1/2}+F}{(4DH_1)^{1/2}-F}$	1.42	0.89	1.16	1.28	1.08	1.18	2.84	0.93	1.89	2.65	0.85	1.75
H^2/H_2	0.16	3.45	1.81	0.02	3.79	1.91	0.11	8.23	4.17	0.01	10.02	5.02

Table 4.9 Contd…

Components/ proportions	Number of primary branches/vine			Vine length(m)			Number of fruits per vine			Fruit length (cm)		
	Summer	Rainy	Average	Summer	Rainy	Average	Summer	Rainy	Average	Summer	Rainy	Average
D	12.86* ±4.80	0.08 ±0.08	6.47	0.23** ±0.07	0.08 ±0.09	0.16	5.25 ±5.98	-43.04 ±69.28	-18.89	31.43** ±1.42	6.21 ±14.22	18.82
F	-9.58 ±11.73	0.13 ±0.21	-4.73	0.44* ±0.17	0.13 ±0.21	0.29	7.15 ±14.62	-75.72 ±169.24	-34.29	5.49 ±3.46	14.34 ±34.23	9.92
H_1	44.02** ±12.19	0.44 ±0.22	22.23	0.79** ±0.18	0.44 ±0.22	0.62	44.38** ±15.19	30.21 ±175.36	37.45	17.17** ±3.60	88.57* ±36.09	52.84
H_2	35.81** ±10.89	0.39* ±0.19	18.10	0.55** ±0.16	0.39* ±0.19	0.47	44.26** ±3.57	32.51 ±157.10	38.39	15.36** ±3.22	72.96* ±32.24	44.16
h^2	-89.92 ±7.33	4.43** ±0.13	-42.75	13.41** ±0.11	4.43 ±0.13	8.92	22.96** ±9.14	-305.20 ±105.74	995.4	239.00** ±2.17	164.56** ±21.70	201.78
$(H_1/D)^{1/2}$	1.85	2.29	2.07	1.85	2.29	2.07	2.91	0.84	1.88	0.74	3.78	2.26
$(H_2/4H_1)$	0.20	0.22	0.21	0.17	0.22	0.20	0.25	0.27	0.26	0.22	0.21	0.22
$\frac{(4DH_1)^{1/2}+F}{(4DH_1)^{1/2}-F}$	0.67	1.98	1.33	3.16	1.98	2.57	1.61	-0.24	0.69	1.27	1.38	1.33
H^2/H_2	5.39	0.08	2.74	0.04	0.08	0.06	2.15	80.31	41.23	1.47	3.79	2.63

Table 4.9 Contd…

Components/ proportions	Fruit diameter (cm)			Fruit density (g/cm^3)			Fruit yield per vine (kg)		
	Summer	Rainy	Average	Summer	Rainy	Average	Summer	Rainy	Average
D	0.42** ±0.13	0.29 ±0.18	0.36	0.26** ±0.03	0.09 ±0.06	0.18	0.05 ±0.06	0.13 ±0.19	0.09
F	0.14 ±0.33	0.32 ±0.43	0.23	0.42** ±0.08	0.13 ±0.15	0.28	0.01 ±0.07	0.14* ±0.05	0.08
H_1	0.92** ±0.34	1.12* ±0.45	1.02	0.63** ±0.08	0.62** ±0.16	0.63	0.43** ±0.08	0.26** ±0.5	0.35
H_2	0.76* ±0.31	0.91* ±0.40	0.84	0.42** ±0.07	0.51** ±0.14	0.47	0.44** ±0.07	0.18** ±0.05	0.31
h^2	33.28** ±0.21	3.28** ±0.27	18.28	-3.81 ±0.05	1.75** ±0.09	-1.03	14.28** ±0.05	-2.51 ±0.03	5.89
$(H_1/D)^{1/2}$	1.47	1.96	1.72	1.58	2.54	2.06	3.12	1.40	2.26
$(H_2/4H_1)$	0.21	0.20	0.21	0.17	0.21	0.02	0.25	0.18	0.22
$\frac{(4DH_1)^{1/2}+F}{(4DH_1)^{1/2}-F}$	1.25	1.79	1.52	3.20	1.73	2.47	1.97	2.19	2.08
h^2/H_2	2.06	0.01	1.04	0.08	2.47	1.28	0.52	0.02	0.27

*, ** Significant at 0.05 and 0.01 level of probability, respectively.

Kalyanpur Sona and Priya White showed more dominant alleles as those were located near origin. PBIG-4 was intermediate in location. Kalyanpur Baramasi was far away from origin indicating excess of recessive genes. In the summer season experiment PBIG-1, Kalyanpur Sona occupied places near origin indicating prevalence of dominant genes, PBIG-2, PBIG-4 were intermediate in position and carried dominant and recessive genes. Kalyanpur Baramasi and Priya White were located away from the origin suggesting higher proportion of recessive alleles.

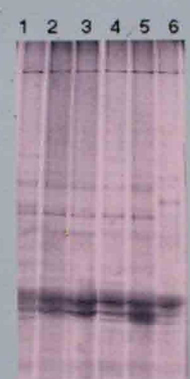
4.6 Electrophoretic characterization of parental cultivars based on SDS-PAGE of seed protein

Seed proteins extracted in extraction buffer (Tris-base, SDS, Glycerol, and Mercapto-ethenol) were subjected to Sodium dodecyl sulphate polyacrylamide gel electrophoresis (SDS-PAGE) in vertical slab gels. The representative gel photograph is shown in Plate 7 and diagrammatic illustration of the protein profiles is shown in Fig. 4.9.

The protein banding pattern was characterized by four distinct zones viz., A, B, C, and D in the increasing order of electrophoretic mobility i.e. zone A was nearest to the origin and the zone D farthest from the origin. The protein bands were stacked according to their molecular weight i.e. high molecular weight proteins were in the upper region and the lower molecular weight proteins were in the lower region of the gel. The first zone had 5 bands of which the uppermost light/faint band was present in PBIG-1 only. This was designated as A1. The other four bands designated as A_2, A_3, A_4 and A_5 were

Plate 7 : Photographic representation of seed protein profiles in parental lines.

1. PBIG-1, 2. PBIG-2, 3. Priya White, 4. PBIG-4
5. Kalyanpur Sona, 6. Kalyanpur Baramasi



SDS-PAGE of six bittergourd parents

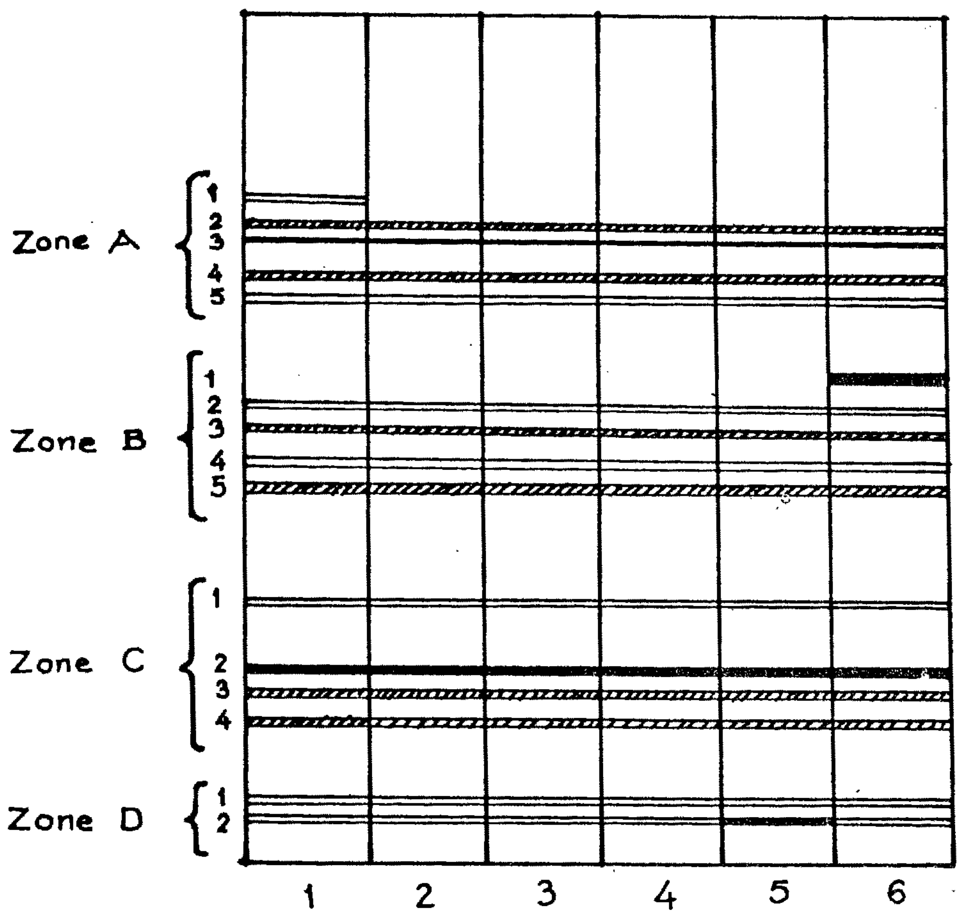
thin and sharp and were present in all the 6 parental cultivars. The next zone had two medium intensity bands, two very light bands and one thick dark band. The thick dark band, designated as B_1 was present only in one specific genotype i.e. Kalyanpur Baramasi. The other bands viz., B_2, B_3, B_4 and B_5 were present in all the 6 cultivars. Zone C comprised four bands of varying intensities. C_1 was very light whereas C_2 was thick and dark. The other two bands designated as C_3 and C_4 were of medium intensity but sharp. The fourth and the lowest region was characterized by two very light bands, viz., D_1 and D_2 which were common in all the 6 lines. Thus a total of 16 seed protein bands could be resolved across 6 genotypes of bittergourd.

The protein banding pattern of the 6 lines in terms of presence and absence of different bands in shown in Table 4.10. Based on similarity of banding pattern, these 6 genotypes were classified into 3 dissimilar groups as given in Table 4.11. In the C and D zones, there was not any difference where all the bands were present in all the 6 genotypes. The differential bands were seen in A and B zones. A very faint band A_1 was present only in PBIG-1, a long fruited variety. In zone B, a thick band B_1 was seen only in Kalyanpur Baramasi which is again a long fruited variety. To conclude the 6 parental lines could be kept into 3 groups. Group I had only one line PBIG-1, group II included PBIG-2, Kalyanpur Sona, PBIG-4 and Priya White and group III was consisted of Kalyanpur Baramasi.

Table 4.10 : Seed protein banding pattern in 6 parental lines of bittergourd

S. N.	Cultivars	Protein bands															
		A_1	A_2	A_3	A_4	A_5	B_1	B_2	B_3	B_4	B_5	C_1	C_2	C_3	C_4	D_1	D_2
1.	PBIG-1	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+
2.	PBIG-2	-	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+
3.	Priya White	-	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+
4.	PBIG-4	-	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+
5.	Kalyanpur Sona	-	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+
6.	Kalyanpur Baramasi	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

+ = Presence of band
- = Absence of band



1 = PBIG - 1
2 = PBIG - 2
3 = Priya White
4 = PBIG - 4
5 = Kalyanpur Sona and
6 = Kalyanpur Baramasi

Intensity scale : Dark, Medium, Light

Fig. 4.9: SCHEMATIC DIAGRAM OF THE SEED PROTEIN PROFILES OF 6 BITTERGOURD PARENTAL LINES.

Table 4.11 : Grouping of 6 bittergourd parental genotypes base on seed protein profile.

Groups	Genotypes	Protein bands															
		A_1	A_2	A_3	A_4	A_5	B_1	B_2	B_3	B_4	B_5	C_1	C_2	C_3	C_4	D_1	D_2
I.	PBIG-1	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+
II.	PBIG-2	-	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+
	Priya White	-	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+
	PBIG-4	-	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+
	Kalyanpur Sona	-	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+
III.	Kalyanpur Baramasi	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

DISCUSSION

Chapter 5

DISCUSSION

Bittergourd (*Momordica charantia* L., 2n =22), a native of world tropics, still remains an underutilized and unexploited crop from genetic and breeding point of views. Regions of eastern India and southern China, suggested as possible centres of domestication (Sands, 1928) are supposed to be reservoir of potential germplasm. As a matter of fact in bittergourd, Indian variability is quite distinct from that of African/S.E. Asian region (Seshadri and Chatterjee, 1996). Considering this fact, it is essential and desirable to carry out a successful bittergourd breeding programme utilizing the land races available in Indian subcontinent. Pantnagar, a subcentre under all India Coordinated Vegetable Improvement Programme, is one of the active centres working on the varietal improvement of bittergourd. More than 40 germplasm lines of bittergourd have been maintained here and recently one variety namely, Pant Karela-1 has been released by the U.P. State Variety Release Committee.

F_1 hybrid breeding is prominent among the methods used in the improvement of vegetable crops. The last fifty years, have seen the development of methods of breeding F_1 hybrids in vegetables, opening the new possibilities for improvements in earliness, uniformity, quality and increased shelf life. It further facilitates rapid deployment of dominant genes conferring resistance to diseases, insects and abiotic stresses (Riggs, 1988).

Being a cross pollinated and monoecious crop, the bittergourd offers opportunities for exploiting heterosis on a commercial scale by removal of male flowers and allowing insect pollination. Many workers (Celine and Sirohi, 1996; Ram *et al.*, 1999 and Tewari and Ram, 1999) have reported heterosis for various horticultural traits, in bittergourd. These further strengthen the scope of heterosis breeding in bittergourd. It is worth noting that bittergourd, like several other cucurbits does not respond to inbreeding and thus along with hybrid breeding, pureline breeding should also be given due consideration as here also the finish product is uniform and the seed cost is reasonably low as compared to that of hybrids.

The breeding methods for the improvement of crop depends on nature and magnitude of the components of genetic variances, combining ability of the parents and crosses and the extent of heterosis of quantitative traits. Choice of parents is considered an important aspect in any breeding programme aimed at improving yield and its components because superior parents may not necessarily transfer their superiority to the progenies in the crosses. The correlations between inbred traits and hybrid performance have generally been low and not predictive of hybrid performance (Hallauer *et al.*, 1988). The theory of diallel crosses and the usefulness of diallel cross technique in genetic analysis of population have received sufficient attention in the past. Several diallel cross techniques have been proposed and applied to diverse problems. For example, Sprague and Tatum (1942), Henderson (1948, 1952), Griffing

(1950, 1956a, 1956b), and Matzinger *et al.* (1959) have considered the utility of diallel crosses in investigation of the notions of general and specific combining ability in plant and animal materials. Another application to a practical problem the generation evaluation of parental materials in breeding programs - has been discussed by Jinks (1955), Allard (1956a, 1956b), and Whitehouse *et al.* (1958). The theory of diallel crosses, and procedures for estimating certain genetic parameters in terms of gene models in varying degrees of complexity, have been discussed by Hull (1952), Griffing (1950, 1956b), Hayman (1954a, 1954b, 1957, 1958, 1960), Jinks (1954, 1956), Dickinsow and Jinks (1956) and Kempthorne (1956). General and specific combining ability may also be estimated from a set of diallel crosses. Sprague and Tatum (1942) defined general combining ability as the average performance of a line in hybrid combination, and it was primarily a measure of additive gene action, specific combining ability described those instances in which certain hybrid combinations were relatively better or worse than would be expected on the basis of the average performance of the line involved, and it was regarded as an estimate of the effect of non-additive gene action. In addition to have an understanding of the combining ability and the genetic components of variation, one gets information on the average degree of dominance, proportion of positive and negative alleles, the relative frequency of dominant and recessive alleles in the parents and the number of effective factors controlling the characters studied. The graphic representation of the statistics Vr and Wr provides enough information on the degree of dominance, the dominance order of the parents. The distance between the parental points provides a measure of genetical diversity among parents. While deriving relevant genetic information from diallel crosses, one can make use of the data to determine heterosis and selection of parental combination worth exploitation as F_1 hybrids on a commercial scale. Therefore diallel cross analysis in totality is a useful biometrical technique in plant breeding.

Inspite of existence of wide range of genetic variability in bittergourd in India, for horticultural traits like fruit size, fruit number per vine, fruit weight and yield per vine, sufficient attention has not been given to the breeding and genetics of this important vegetable. So it was considered imperative to carry out a study to obtain information on heterosis, combining ability and gene action from a six parent diallel cross evaluated over two seasons that is summer season 1999 and rainy season, 1999 for various horticultural traits in order to devise a breeding strategy for improvement in bittergourd.

Out of 6 parental lines, 4 parents namely PBIG-1, PBIG-4, Kalyanpur Baramasi and Priya White were long fruited varieties whereas the other two PBIG-2 and Kalyanpur Sona were small fruited varieties. Long fruited varieties were generally associated with late maturing character whereas the small fruited varieties were found to be early maturing. The results obtained on heterosis, combining ability, gene action and the seed protein profiles are discussed below :

5.1 Heterosis

A brief tabular description of some promising F_1 hybrids has been given below:

Table 5.1 : Chief features of some promising F_1 hybrids of bittergourd

Sl. No.	Genotype		Character	Mean values		
				Summer season	Rainy season	Average
1.	PBIG-2 x Kalyanpur Sona	i)	Days to male flower	32.33	30.67	31.50
		ii)	Days to female flower	36.33	36.00	36.16
		iii)	Node number to first male flower	4.33	4.67	4.50
		iv)	Node number to first female flower	6.33	6.67	6.50
		v)	Fruit diameter (cm)	4.23	4.83	4.53
		vi)	Fruit length (cm)	11.72	11.42	11.51
		vii)	Fruit yield per vine (kg)	1.80	1.54	1.67
		viii)	Fruit density (g/cm^3)	1.56	1.46	1.52
2.	PBIG-1 x PBIG-4	i)	Fruit diameter (cm)	3.53	3.75	3.64
		ii)	Fruit yield per vine (kg)	1.57	1.30	1.44
		iii)	Fruit length (cm)	23.88	22.08	22.98
3.	PBIG-1 x Kalyanpur Baramasi	i)	Fruit diameter (cm)	4.23	4.23	4.23
		ii)	Fruit yield per vine (kg)	1.61	1.37	1.49
4.	PBIG-4 x Kalyanpur Baramasi	i)	Fruit yield per vine (kg)	1.43	0.95	1.19
		ii)	Fruit length (cm)	24.18	23.25	23.72
5.	PBIG-1 x PBIG-2	i)	Fruit yield per vine (kg)	1.62	1.30	1.46
		ii)	Fruit density (g/cm^3)	1.59	1.59	1.59
6.	PBIG-4 x Kalyanpur Sona	i)	Fruit yield per vine (kg)	1.72	1.54	1.63
7.	Kalyanpur Sona x Kalyanpur Baramasi	i)	Fruit yield per vine (kg)	2.07	1.08	1.94
		Ii)	Fruit diameter (cm)	4.65	4.62	4.64

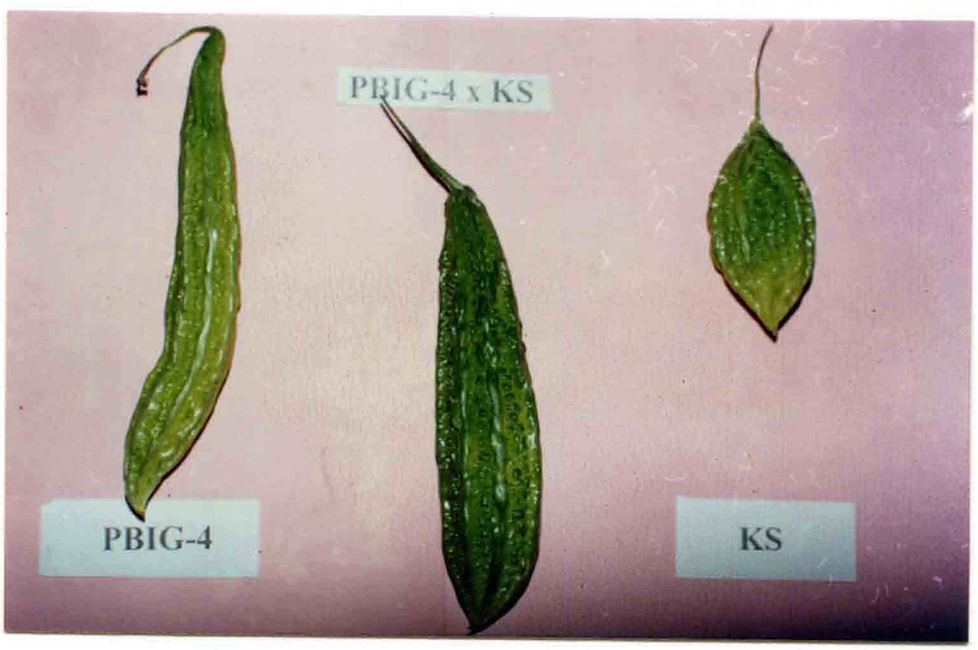
Certain crosses showed significant heterosis in both the seasons for earliness, high yield, fruit length (cm), fruit diameter, and fruit density, PBIG-2 x Kalyanpur Sona proved to be an outstanding cross as it exhibited highly significant heterobeltiosis for the above mentioned characters. PBIG-1 x Kalyanpur Sona was early maturing with increased fruit yield during rainy season experiment. PBIG-4 x Kalyanpur Baramasi proved to be highly heterotic for fruit length and fruit yield per vine and results were consistent over both the seasons. These results were in conformity with those of Celine and Sirohi (1996) who observed heterosis over top parent for fruit length in the range of 0.25% to 12.9%. Similar results for fruit length were reported by Tewari and Ram (1999) in bittergourd where standard heterosis for fruit length was detected as 37.08%. For fruit diameter, PBIG-1 x PBIG-4 showed highly significant heterobeltiosis of 22.57% and 22.67% in summer and rainy season experiments respectively. Those results were in agreement with findings of Tewari and Ram (1999) who observed standard heterosis (37.0%) for fruit diameter.

Most of the crosses were proved to be highly heterotic for yield. The yield ranged from 1.11 to 2.29 kg per vine in F_1 hybrids and from 0.83 to 1.45 kg per vine in the parents in the summer season. In the rainy season, the yield range in F_1 hybrid was 1.83 to 0.95 kg whereas parents yield ranged from 0.77 to 1.28 kg per vine. The highest yielding cross, PBIG-2 x Priya White (2.29 kg per vine) showed 80.32% superiority over the better parent and 57.79% above the best parent in the summer season. In the rainy season, the highest yielding F_1 was Kalyanpur Baramasi x Priya White (1.83 kg per vine) and it exceeded the better parent by 112.28% and the best performing genotype by 41.86%. The other crosses noted to be heterotic for yield per vine were PBIG-1 x PBIG-4, PBIG-4 x Kalyanpur Sona and Kalyanpur Sona x Kalyanpur Baramasi. These results are in agreement with the findings of Ram *et al.* (1997) where the results indicated that the yield per plant was a potential character for heterosis breeding in bittergourd. They observed 98% better parent heterosis for yield per plant. Cline and Sirohi also reported similar results for fruit yield per vine (54% standard heterosis). The results of Tewari and Ram (1999) also supported the results of present study where F_1 cross PBIG-1 x PBIG-2 showed the pronounced standard heterosis (37.08%) for fruit yield.

Total productivity in vegetables is often less important than marketable yield which is largely determined by uniformity and quality (Riggs, 1988). Keeping this fact in mind, one cross, PBIG-4 x Kalyanpur Sona deserves to be discussed from these view points. This F_1 appears to be of export quality (Plate 8) with attractive green colour, intermediate fruit length, very uniform, relatively non-ridged surface and high yielding capacity. It showed standard heterosis for node number to first female flower, indicating earliness and 55.94% and 105.73% standard heterosis for fruit yield per vine in both the seasons.

Plate 8 : A high yielding export quality F_1
PBIG-4 x Kalyanpur Sona


PBIG-4 x KS


PBIG-4 x KS
PBIG-4
KS

In certain crosses considerable heterosis was observed where both the parents were of low value as *per se* performance basis. For example PIBG-2 x Kalyanpur Sona, both the parents involved in cross were small fruited (8.51 and 8.22 cm fruit length respectively) however, the fruit length of the F_1 was 11.51 cm which was distinctly higher than what was observed on the parents. Likewise in PBIG-4 x Kalyanpur Baramasi, both the parents were of late maturity (44.67 and 47.67 days to male flower, respectively) and the corresponding value for the F_1 was 43.00 days. Thus the F_1 was earlier in maturity than both the late maturity parent. It is therefore obvious that while attempting potential crosses for exploiting heterosis in vegetables, *per se* performance of parental lines can not be sole criterion for selecting the parents.

It may be mentioned that heterosis for early maturity is common in hybrid varieties of vegetables as reviewed by Riggs (1988) and may greatly increase the economic yield when price differentials for early marketing are high.

5.2 Combining ability analysis

Combining ability analysis is one of the powerful tools available which gives the estimates of mean squares due to gca, sca and combining ability effects and aids in selecting desirable parents and crosses for further exploitation. The mean squares due to general and specific combining ability effects were highly significant for days to male flower, days to female flower, number of nodes to first male flower, number of nodes to first female flower, number of primary branches per vine, fruit length (cm), fruit diameter (cm), fruit density and fruit yield per vine (kg) in both the seasons, indicating that both additive and non-additive genetic variance were involved in determining these characters. Similar results have been reported by Mishra *et al.* (1994) and Khattra *et al.* (1994b) for bittergourd. In present study, gca mean squares were found to be predominant in the expression of days to male flower, days to female flower, node number to first male flower, node number to first female flower, number of primary branches, vine length. The specific combining ability mean squares were also found to be highly significant but lesser in magnitude than gca mean squares except for fruit density and fruit yield per vine. For these two characters, sca mean squares were found to be of more importance. This result is in conformity with the results of Munshi and Verma (1999) in muskmelon who detected higher sca mean squares than gca mean squares for yield per vine. However, these findings contradict the findings of Khattra *et al.* (1994b) in which they have reported that gca effects were prominent over the sca effect for total fruit yield per plant. General combining ability is a consequence of additive gene action and specific combining ability is that of non-additive gene action (dominance and epistasis). In case of non-additive gene action, heterosis breeding assumes significance and several crosses manifested considerable heterosis for fruit yield as discussed earlier. Thus there was agreement between the results based on combining ability analysis and estimation of heterosis particularly for fruit yield. The other characters viz., days to male flower, days to female flower, node number to first male flower, node number to first female flower, number of primary branches per vine, number of fruits per vine, fruit length, fruit diameter and vine length where additive gene action predominated could be improved through pureline breeding by selection in open pollinated populations or the segregating generations resulting from crosses between selected parents.

In terms of better general combiners (Table 4.6), PBIG-2 and Kalyanpur Sona were found to be as good general combiners for earliness, more number of primary branches and yield per vine. Both these cultivars were short fruited cultivars. Among the four long fruited cultivars, PBIG-1, PBIG-4 and Kalyanpur Baramasi were observed as good general combiners for increasing fruit length. Only PBIG-4 was detected as good general combiner for high fruit density. It is therefore, suggested that the crosses of PBIG-2 and Kalyanpur Sona with PBIG-1, PBIG-4 and Kalyanpur Baramasi shall be more productive in terms of throwing out desirable segregates.

In most of the cases it was observed that *per se* performance of the parents gave a direct reflection of their respective gca effects i.e. the parents showing highest gca effect for a particular character were also observed to be good performer with respect to that character. The results are in conformity with the findings of Sivakmi *et al.* (1987) in bottlegourd, Munshi and Sirohi (1994) in bittergourd, Moonsoo *et al.* (1996) and Munshi and Verma (1999) in muskmelon.

The crosses having high and desirable sca effects for the economically important characters was PBIG-1 x PBIG-4, PBIG-1 x Kalyanpur Sona, PBIG-2 x Kalyanpur Sona and Kalyanpur Baramasi x Priya White for earliness; PBIG-1 x Kalyanpur Sona, PBIG-2 x Kalyanpur Sona, and PBIG-2 x Priya White for number of primary branches; PBIG-1 x PBIG-4, PBIG-4, PBIG-2 x Kalyanpur Baramasi and PBIG-4 x Kalyanpur Baramasi for fruit length; PBIG-1 x Priya White for fruit density and PBIG-1 x PBIG-4, PBIG-1 x Kalyanpur Baramasi, PBIG-2 x Priya White, Kalyanpur Sona x Kalyanpur Baramasi and PBIG-4 x Kalyanpur Sona for fruit yield. All the crosses with desirable sca effects showed considerable amount of heterosis for the concerned characters except for PBIG-2 x Priya White for number of primary branches and PBIG-1x Priya White for fruit density. However, two crosses PBIG-1 x PBIG-2 and PBIG-2 x Kalyanpur Sona could not expressed high sca effect inspite of exhibiting considerable heterobeltiosis for fruit density. Crosses exhibiting high and desirable sca effects for yield are observed critically and it was observed that in PBIG-1 x PBIG-4 both the parents had poor gca effects. In case of PBIG-1 x Kalyanpur Baramasi again both the parents were poor combiners. In cross PBIG-2 x Priya White, PBIG-2 was a god combiner whereas gca estimates Priya White was non-significant. In PBIG-4 x Kalyanpur Sona and for Kalyanpur Sona x Kalyanpur Baramasi both the parents were poor combiner. So in majority most of the parents had poor gca effects, but good *per se* performance.

5.3 Genetic components of variation and Vr/Wr graphical analysis

Diallel analysis is based on certain assumptions. These include (i) diploid segregation, (ii) no difference between reciprocal crosses (iii) independent action of non-allelic genes (iv) non multiple allelism, (v) homozygous parents and (vi) genes independently distributed between the parents. For the material under reference, the assumptions regarding diploid segregation and homozygous parents are easily fulfilled as the parental lines used were inbreds. It is safe to assume no reciprocal cross difference based on review of literature. Likewise based on literature, the absence of multiple allelism can be assumed to be fulfilled. However, the assumptions regarding absence of epistasis and linkage were difficult to be fulfilled. However in case, regression of Wr and Vr is close to unity, it is presumed that largely all the assumptions are fulfilled and information derived from diallel table is reliable and valid. Accordingly Vr/Wr graphs were drawn only for the cases where 1-b was non-significant. The 8 situations falling under this category are depicted in Figs. 4.1 to 4.8.

Table 4.9 shows that additive genetic variance (D) was significant for all the characters except number of fruits per vine and fruit yield per vine in both the seasons. Dominance components (H_1 and H_2) were significant for all the characters viz., days to male flower, days to female flower, node number to first male flower, node number to first female flower, number of primary branches per vine, vine length, number of fruits per vine, fruit length, fruit diameter, fruit density and fruit yield per vine. Thus the additive and dominance variances were predominant components governing the expression of various horticultural traits in bittergourd. The mean squares due to gca and sca were also found to be significant/highly significant except number of fruits per vine; significant gca and sca mean squares indicating the presence of both additive and non-additive gene action. Therefore, there was close agreement between the results obtained from diallel and combining ability analysis. Mishra *et al.* (1998) also reported involvement of both additive and non-additive gene action through a diallel cross analysis having 9 parents of bittergourd for vine length, days to first female flower, days to harvest, fruits per plant, fruit length, fruit breadth and fruit weight. However, for yield per plant, they noted the role of only the dominance components. Degree of dominance $(H_1/D)^{1/2}$, was observed greater than unity for days to male flower, days to female flower, number of primary branches, vine length, fruit diameter, fruit density and yield per vine in both the seasons. This indicated presence of overdominance for the above mentioned characters. However, for fruit length, results showed non-consistency over the seasons. For summer season, $(H_1/D)^{1/2}$ was less than unity indicating partial dominance whereas for the rainy season, that was more than unity which indicated the presence of overdominance for fruit length. These findings were in agreement with the results of Mishra *et al.* (1998) who detected partial dominance for fruit length, fruit breadth and fruit weight. Ratio of dominant and recessive alleles $(4DH_1)^{1/2} + F_1/(4DH_1)^{1/2}-F_1$ was more than unity for days to male flower (summer season, days to female flower (both the seasons), node number to first male flower (summer season), vine length, fruit length, fruit diameter, fruit density and fruit yield per vine (both the seasons). Those values were confirmed by positive F values for each of the above mentioned characters and indicated higher proportion of dominant genes for expression of these character. This is in agreement with the finding of Srivastava and Nath (1976) in bittergourd. The proportion of genes with positive and negative effects ($H_2/4H_1$) in the parents was less than 0.25 for node number to first male flower, node number to first female flower, number of primary branches per vine, fruit yield (rainy season), fruit diameter, fruit density and fruit yield per vine (rainy season) which was also confirmed by H_1- H_2 being not equal to zero, denoting asymmetry at loci showing dominance. It is similar to the findings of Sidhu and Brar (1982) in watermelon, Sirohi and Choudhary (1983) in bittergourd, Sirohi *et al.* (1986) in bottlegourd and Mishra *et al.* (1998) in bittergourd. However, for fruit yield per vine, in summer season experiment this ratio was exactly 0.25 which results when u=v=0.5 i.e. both the positive and negative alleles were equal. This was confirmed by value of H_1-H_2 which was approximately zero. Same trend was observed for number of fruits per plant in summer season experiment.

For the characters, viz., days to male flower, days to female flower, node number to first male flower, node number to first female flower, vine length, fruit yield (summer season), number of primary branches, vine length and fruit diameter (rainy season) the ratio h^2/H_2 which is a measure of number of effective factor/ blocks of dominant gene was rather low (0.16, 0.020, 0.11, 0.010, 0.04, 0.52, 0.08, 0.08 and 0.01, respectively), but dominance being present it has to be accepted that atleast one group of genes is responsible for these characters. However, for number of primary branches, fruit diameter (summer season), fruit length (both the seasons) and days to male flower, days to female flower, node number to first male flower and node number to first female flower (rainy season). This value was in the range of 1.47 to 10.02 suggesting involvement of relatively large number of blocks of dominant genes.

Overdominance detected through Vr/Wr graphical analysis (line passing below the origin) for days to male flower (summer season), days to female flower (summer season), number of primary branches (rainy season), vine length (summer season), fruit yield per vine (both the seasons) was in agreement with the degree of dominance the detected through $(H_1/D)^{1/2}$. For the node to first female flower (summer season), line passed above the origin and showed partial dominance and the estimate of $(H_1/D)^{1/2}$ did not confirmed it as it gave a value of 0.99 which indicated partial dominance approaching complete dominance. For fruit length value of $(H_1/D)^{1/2}$ was less than unity suggesting partial dominance which was confirmed by the position of regression line in Vr/Wr graph which passed well above the origin.

The Vr/Wr graphical analysis demonstrated that PBIG-2 and Kalyanpur Sona which were located away from the origin had preponderance of recessive alleles for days to male flower and days to female flower. In contrast PBIG-1, PBIG-4, Kalyanpur Baramasi and Priya White lying near the origin had mostly the dominant alleles for these two characters. It is also to be noted that PBIG-2 and Kalyanpur Sona were early in flowering as compare to the remaining four parents which were late in flowering. Thus early flowering was conditioned primarily by the recessive genes and the late flowering by the dominant genes. A perusal of gca effects of the parents indicated that PBIG-2 and Kalyanpur Sona were good general combiners for early flowering.

It is therefore, expected that PBIG-2 and Kalyanpur Sona will be good parental lines as donors for early flowering. The crosses of PBIG-2 and Kalyanpur Sona with the remaining four parental lines are expected to throw still early flowering segregants due to accumulation of still larger number of recessive genes governing early flowering into PBIG-2 and Kalyanpur Sona. Incidently the F_1s involving PBIG-2 and Kalyanpur Sona on one hand and the remaining four on the other, were generally found to be earlier than better parents. Therefore, it is conclusively demonstrated that PBIG-2 and Kalyanpur Sona should be used as effective donors in bittergourd breeding programme to breed early flowering pure lines/ hybrids. Almost similar trend was noticed in the Vr/Wr graph for node number to first female flower where PBIG-2 was distinctly away from origin showing the presence of mostly the recessive alleles for node number to first female flower which is measure of early maturity.

For fruit length PBIG-4, a long fruited variety lying away from the origin carried mostly the recessive alleles and Priya White also a long fruited variety was close to origin and carried mostly the dominant alleles. The remaining four parents, occupied intermediate position and had almost equal proportion of dominant and recessive alleles. Since PBIG-4 and Priya White both were long fruited lines but occupied contrasting positions with respect to the relative distribution of dominant and recessive alleles, it was not posible to infer the association between dominant and recessive genes and the size of the fruit.

For fruit yield per vine there was no consistency with respect to the position of Priya White in Vr/Wr graph over the seasons. It was near the origin in the rainy season experiment and away from origin in the summer season experiment. This showed that the season affected drastically the results of Vr/Wr graphical analysis as far as the parental line Priya White was concerned. However, Kalyanpur Baramasi carried mostly the recessive gene and this was consistent over the seasons. Since the distribution of array points reflects the parental diversity, it is suggested that the crosses of Kalyanpur Baramasi with PBIG-1, PBIG-2, PBIG-4, Kalyanpur Sona and Priya White should be the potential ones to derive high yielding pure lines. It is further mentioned that Kalyanpur Sona was found to be a good general combiner for fruit yield in both the seasons and Kalyanpur Baramasi was the top general combiner in rainy season experiment. Thus, the cross Kalyanpur Sona x Kalyanpur Baramasi appear to be a potential cross for breeding high yielding bittergourd varieties specifically suited to rainy season on the basis of both gca effects of the parents and genetic diversity between these lines based on Vr/Wr graphical analysis.

A summary of selected parents based on mean performance, gca effects and genetic diversity in Vr/Wr graphical analysis for two important characters namely, early maturity and high fruit yield is given below :

Table 5.2 : Selection of parents for crosses based on different selection criteria

Selection criteria	Earliness	High yield
Mean	PIBG-2 x Kalyanpur Sona PBIG-1 x Kalyanpur Sona	PBIG-2 x Kalyanpur Sona PBIG-2 x Priya White PBIG-1 x Priya White PBIG-1 x Kalyanpur Sona Kalyanpur Sona x Priya White Kalyanpur Sona x Kalyanpur Baramasi
GCA effects	PBIG-2 x Kalyanpur Sona PBIG-1 x Kalyanpur Sona Kalyanpur Sona x Kalyanpur Baramasi	PBIG-2 x Kalyanpur Sona PBIG-2 x Kalyanpur Baramasi Kalyanpur Sona x Kalyanpur Baramasi
Genetic diversity (Based on Vr/Wr graph	PBIG-4 x Kalyanpur Sona PBIG-2 x PBIG-4 PBIG-1 x Kalyanpur Sona PBIG-2 x PBIG-4 PBIG-4 x Kalyanpur Sona PBIG-2 x Kalyanpur Sona	Kalyanpur Sona x Kalyanpur Baramasi PBIG-1 x Kalyanpur Baramasi PBIG-1 x Priya White PBIG-2 x Kalyanpur Baramasi Kalyanpur Sona x Kalyanpur Baramasi PBIG-1 x Kalyanpur Baramasi

While selecting the parents on the basis of mean values the desirable parents for the traits under reference were taken into consideration. Selection of parents for making crosses on the basis of gca effects took into account only the good general combiners. For selecting the parents on the basis of genetic diversity the basic assumption was that the crosses between the diverse parents shall be the potential ones for throwing out desirable segregants and therefore the crosses indicated in the table were between the parents located near the origin and those located away from the origin in the Vr/Wr graph. PBIG-2 x Kalyanpur Sona turned out to be a common cross across the three different selection criteria for breeding of early maturing variety. For high yield breeding, the common cross was Kalyanpur Sona x Kalyanpur Baramasi. As a matter of fact these two crosses were shown to be the promising ones with respect to exploitation of heterosis for earliness and high fruit yield. Therefore, it can be easily concluded that PBIG-2 x Kalyanpur Sona will be a potential cross for pureline as well as heterosis breeding towards early maturity and the counterpart cross for high fruit yield will be Kalyanpur Sona x Kalyanpur Baramasi. The other potential crosses as listed in the Table 5.2 should also be given due consideration in bittergourd breeding programmes.

5.4 Seed protein profiles for bittergourd parental lines

Seed protein and isozyme variants have been observed as the most widely used molecular genetic markers during the last quarter century. Protein electrophoretic migration rates are highly heritable and ample polymorphisms are available for characterizing germplasm lines accurately, if conducted according to proper laboratory procedures (Simpson and Withers, 1986). The proteins can represent primary gene products and seeds are considered physiologically stable and easy to handle (Ladizinsky and Hymowitz, 1979; Sarkar and Bose, 1984). Seeds proteins have advantage of being scorable from inviable organs and tissues and the electrophoretic protocol for bulk protein assay is generally simpler than that for isozymes (Cook, 1984; Gepts, 1990). Stability is one of the main features of the seed protein profiles. For this reason it has been suggested as an additional tool for species as well as cultivar identification beside other biosystematic approaches. Furthermore, the composition of seed protein is affected only slightly by environmental conditions or seasonal fluctuations. Seed proteins are mainly storage proteins and are not likely to be changed in dry mature seed. Thus, mature seeds of different age still possess the same protein profile (Robinson and Megarrity, 1975).

Sodium dodecyl sulphate poly acrylamide gel electrophoresis (SDS-PAGE) of seed protein extracted in buffer of specified concentration and volume could resolve seed proteins of the 6 bittergourd parental lines into 16 bands (A_1, A_2, A_3, A_4, A_5, B_1, B_2, B_3, B_4, B_5, C_1, C_2, C_3, C_4, D_1 and D_2) as summarized in Table 4.10. The 6 genotypes could be grouped into, 3 dis-similar groups based on presence or absence of certain protein bands. This indicated the effectiveness of protein profile in distinguishing several germplasm lines of bittergourd. No major difference could be detected in the banding patterns in C and D zones. Although differences in band intensity were found but were ignored because they could be due to minor differences in extraction procedure or extent of solubility of seed protein from different accessions. The differential bands were located mainly in A and B zones. In A region, only one differential extra faint/light band was present in PBIG-1, making it distinguishable from other genotypes. Presence of a thick B_1, band in Kalyanpur Baramasi, made it distinct from other parental lines.

Electrophoretic group I (presence of extra faint band, A_1) included only one parental line i.e. PBIG-1. Another electrophoretic group II devoid of two differential bands namely A_1 and B_1 included four parental lines i.e. PBIG-2, Priya White, Kalyanpur Sona and PBIG-4. The electrophoretic group III devoid of A_1 but with an extra band B_1 contained one genotype i.e. Kalyanpur Baramasi.

The most easily distinguishable phenotypic character of the 6 parental lines was fruit length where PBIG-2 and Kalyanpur Sona were small fruited and the remaining four parental lines i.e. PBIG-1, PBIG-4, Priya White and Kalyanpur Baramasi were long fruited types. Thus it was possible to distinguish Kalyanpur Baramasi, a green long fruited variety from other green and long fruited varieties like PBIG-1, and PBIG-4 on the basis of electrophoresis. However, the reverse was also true where morphologically distinguishable cultivars had similar profile patterns, for example, PBIG-2 and

Kalyanpur Sona which were small fruited had same protein profile pattern as the long fruited cultivar namely PBIG-4 and Priya White. Therefore, seed protein electrophoresis could be proved to be a successful technique to distinguish between otherwise, morphologically indistinguishable cultivars in certain cases. These results were in conformity with Upadhyay *et al.* (1998) and Singh (1996) in bottlegourd and Yadav (1998) and Choudhary (1999) in muskmelon.

SUMMARY

Chapter 6

SUMMARY

The present investigation entitled "Studies on heterosis, gene action and protein profile in bittergourd (*Momordica charantia* L.)" was undertaken in a diallel cross involving six parental cultivars and 15 F_1 hybrids. The parents were PBIG-1, PBIG-2, PBIG-4, Kalyanpur Sona, Kalyanpur Baramasi and Priya White. The 21 genotypes were evaluated in a randomized block design with 3 replications during the summer season, 1999 and the rainy season, 1999 at the Vegetable Research Centre of the G.B. Pant University of Agriculture and Technology, Pantnagar, Uttar Pradesh. Each entry was represented by a single row containing five plants. The observations were recorded on various horticultural traits, namely days to male flower, days to female flower, node number to first male flower, node number to first female flower, vine length (cm), number of fruits per vine, fruit length (cm), fruit diameter (cm), fruit density (g/cm^3) and yield per plant (kg). Observations were recorded on five plant basis and the values were averaged. The mean data obtained were statistically analysed for heterosis, combining ability, Vr/Wr graphical analysis and genetic components of variation. Seed proteins (without seed coat) of 6 parental lines were extracted in buffer (Tris base, Sodium dodecyl sulphate, glycerol, bromophenol blue) and subjected to sodium dodecyl sulphate poly

acrylamide gel electrophoresis (SDS-PAGE) to detect protein profile variation in the parents, if any. The result obtained are summarized as follows :

i) The genotypic differences were highly significant in both the seasons for days to male flower, days to female flower, node number to first male flower, node number to first female flower, vine length, fruit length, fruit diameter, number of primary branches per vine, fruit density and fruit yield per vine. The genotypic differences for number of fruits per vine was highly significant only in the summer season experiment.

ii) Out of 6 parents, 4 parents namely PBIG-1 (19.63 cm), PBIG-4 (19.42 cm), Kalyanpur Baramasi (21.38 cm) and Priya White (17.44 cm) were long fruited and the 2 parents viz., PBIG-2 (8.51 cm) and Kalyanpur Sona (8.22 cm) were small fruited. It was observed that the long fruited lines were late maturing whereas the small fruited ones were early maturing.

iii) Considerable amount of desirable heterobeltiosis was observed for earliness (-8.39% to -12.20%), fruit length (10.98 to 36.49%), fruit diameter (14.96 to 49.84%), fruit density (38.00 to 64.33%) and fruit yield per vine (21.76 to 69.04%) over both the seasons. PBIG-2 x Kalyanpur Sona proved to be an outstanding cross as exhibited by highly significant desirable negative heterobeltiosis (-12.62) in the summer season and the standard heterosis (-19.89% and -19.18%) in the summer and the rainy seasons respectively. The two crosses, PBIG-1 x PBIG-4 and PBIG-4 x Kalyanpur Baramasi proved to be highly heterotic for fruit length. Average heterobeltiosis over seasons for fruit length was 16.99% and 10.98% for PBIG-1 x PBIG-4 and PBIG-4 x Kalyanpur Baramasi respectively. For the fruit diameter, PBIG-1 x PBIG-4 (25.94%) and PBIG-1 x Kalyanpur Baramasi (49.84%) showed highly significant heterobeltiosis.

Most of the crosses were observed to be highly heterotic for fruit yield per vine which ranged from 1.11 to 2.29 kg per vine in F_1 hybrids and it was from 0.83 to 1.45 kg per vine in the parents in the summer season. In the rainy season, the yield range in the F_1 hybrids was 1.83 to 0.95 kg whereas the parents ranged from 0.77 to 1.28 kg per vine. The crosses which showed considerable heterobeltiosis for average fruit yield were PBIG-1 x PBIG-4 (58.03%), PBIG-1 x Kalyanpur Baramasi (69.04%), PBIG-1 x Priya White (60.16%), PBIG-2 x Kalyanpur Sona (21.76%), PBIG-4 x Kalyanpur Sona (69.23%) and Kalyanpur Sona x Kalyanpur Baramasi (70.28%).

iv) One F_1 hybrid PBIG-4 x Kalyanpur Sona deserved to be highlighted separately from the quality point of view. This F_1 appeared to be of export quality with attractive green colour, very uniform, intermediate fruit length, relatively non-ridged surface and high yielding capacity. It showed standard heterosis for node number to male flower to a level of -

14.34% indicating earliness. The fruit yield of standard heterosis (80.85%) as well as heterobeltiosis (48.93%) over the seasons were also substantial.

v) Analysis of variance for combining ability indicated highly significant gca mean squares for days to male flower, days to female flower, node number to first male flower, node number to first female flower, number of primary branches and vine length. Specific combining ability mean square was also highly significant for these characters but lesser in magnitude than gca mean square.

vi) For the two characters, namely fruit density and fruit yield sca mean squares were found to be greater than the gca mean squares.

vii) On the basis of average gca effects over seasons, PBIG-2 and Kalyanpur Sona were found to be good general combiners for earliness (-3.35 and -1.34 respectively) more number of primary branches (1.25 and 2.79, respectively) and fruit yield per vine (0.09 and 0.15 respectively). PBIG-1 and Kalyanpur Baramasi were observed to be good general combiners for increasing fruit length (1.08 and 1.21 respectively). PBIG-4 was detected as a good general combiners for high fruit density (0.12). Therefore, it is suggested that the crosses of PBIG-2 and Kalyanpur Sona with PBIG-1, PBIG-4 and Kalyanpur Baramasi will give rise to desirable segregants.

viii) The crosses having high and desirable sca effects (averaged over seasons) for the economically important characters were PBIG 1 x Kalyanpur Sona (-2.92), PBIG-2 x Kalyanpur Sona (-3.23), Kalyanpur Baramasi x Priya White (-5.76) for earliness; PBIG-1 x PBIG-4 (3.23), PBIG-2 x Kalyanpur Baramasi (1.62) and PBIG-4 x Kalyanpur Baramasi (1.42) for fruit length; PBIG-1 x Priya White (0.47) for fruit density and Kalyanpur Sona x Kalyanpur Baramasi (0.46) for fruit yield per vine.

ix) Additive genetic variance (D) was significant for all the characters except the number of fruits per vine and the fruit yield per vine in both the seasons. Dominance components (H_1 and H_2) were significant for all the characters viz., days to male flower, days to female flower, node number to first male flower, node number to first female flower, number of primary branches per vine, vine length, number of fruits per vine, fruit length, fruit diameter, fruit density and fruit yield per vine.

x) Degree of dominance averaged over the seasons $(H_1/D)^{1/2}$ was observed greater than unity for days to male flower (1.79), days to female flower (1.92), number of primary branches per vine (2.07), vine length (2.07), fruit diameter (1.72), fruit density (2.06) and fruit yield per vine (2.26) indicating overdominance. However, for fruit length this estimate was greater than unity in the summer season experiment and less than unity in the rainy season experiment.

xi) Ratio of dominant and recessive alleles $(4DH_1)^{1/2} + F/(4DH_1)^{1/2}-F$ was found to be greater than unity for days to male flower (summer season), days to female flower (both the seasons), node number to first male flower (summer season), vine length, fruit diameter, fruit density and fruit yield per vine (both the seasons). These values were well supported by positive F values for each of the above mentioned characters and indicated higher proportion of dominant genes for the expression of these characters.

xii) The proportion of positive and negative effects of genes $(H_2/4H_1)$ in the parents was less than 0.25 (the maximum theoretical value) for node number to first male flower, node number to first female flower, number of primary branches per vine, fruit yield (rainy season) indicating asymmetry at loci showing dominance. However, for fruit yield per vine (summer season) this ratio was exactly 0.25 denoting equal proportion of positive and negative alleles at loci showing dominance (u=v=0.5).

xiii) For days to male flower, days to female flower, node to first male flower, node to first female flower, vine length, fruit yield (summer season); number of primary branches, vine length and fruit diameter (rainy season) the ratio of h^2/H_2, a measure of blocks of dominant genes was found very low, but dominance being present it has to be accepted that at least one group of gene is responsible for these characters. For the number of primary branches per vine, fruit diameter (summer season), fruit length (both the seasons), days to male flower, days to female flower (rainy season) this ratio was ranged between 1.47 to 10.02 suggesting that relatively large number of blocks of dominant genes were involved for expression of these characters.

xiv) Vr/Wr graphical analysis indicated linearity of regression coefficient of Wr on Vr for days to male flower (summer season), days to female flower (summer season), node number to first female flower (summer season), number of primary branches per vine (rainy season), vine length (summer season), fruit length (summer season) and fruit yield (summer as well as rainy season) indicating that the assumptions of the diallel analysis were largely fulfilled for these characters.

xv) The position of regression line (below the origin) showed overdominance for days to male flowers, days to female flowers, number of primary branches per vine, vine length and fruit yield per vine. For nodes to first female flower, and fruit length the regression line passed above the origin indicating partial dominance. These results are in accordance with the results of degree of dominance, estimated by $(H_1/D)^{1/2}$

xvi) For days to male flower and days to female flower, the good performer parents with high gca effects were located for from the origin indicating the involvement of mostly the recessive alleles for expression of the earliness. In contrast late maturing parents based on higher number of days to male flower, days to female flower and node number to female flower lying near the origin in Vr/Wr graph carried mostly the dominant genes responsible for lateness. For fruit length, both the recessive as well as the dominant alleles were found to be important as the long fruited parents viz., Kalyanpur Baramasi and PBIG-1 were observed to be located at the middle of the regression line.

xvii) For two characters, namely earliness and fruit yield per vine, it was considered relevant to select parents on the basis of mean performance, higher general combining ability effects and genetic diversity through Vr/Wr graph. It is understood that the crosses between the diverse parents (those located near the origin and those located far away from the origin in Vr/Wr graph) will throw out desirable desirable segregants. For the earliness cross worth making on the basis of all the three selection criteria was PBIG-2 x Kalyanpur Sona whereas for the other character i.e. fruit yield per vine, Kalyanpur Sona x Kalyanpur Baramasi was found to be a potential cross. These two crosses can be exploited for high yield and earliness in bittergourd breeding programmes.

xviii) Seed protein of 6 bittergourd parental lines could be resolved into 16 bands (A_1, A_2, A_3, A_4, A_5, B_1, B_2, B_3, B_4, B_5, C_1, C_2, C_3, C_4, D_1 and D_2). The 6 genotypes could be grouped into three dissimilar groups. Group I included PBIG-1 which had one very faint/light extra band A_1. Group II included 4 genotypes namely PBIG-2, PBIG-4, Kalyanpur Sona and Priya White with 14 bands and these 4 genotypes were devoid of two bands namely A_1 and B_1. One genotype, namely Kalyanpur Baramasi was the only member of group III with one additional thick band B_1 alongwith 14 bands as in group II. Both PBIG-1 and Kalyanpur Baramasi which were green long fruited varieties could be distinguished on the basis of variation in protein banding pattern through SDS-PAGE. Therefore, seed protein electrophoresis could be a successful technique to distinguish between otherwise morphologically indistinguishable cultivars in certain cases.

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