VARIABILITY IN INTERVARIETAL F_1 HYBRIDS AND OPEN POLLINATED SEED PROGENIES OF BLACK PEPPER *(Piper nigrum L.)*

By

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Thesis

submitted in partial fulfilment of the requirement for the degree

MASTER OF SCIENCE IN AGRICULTURE

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DECLARATION

I hereby declare that this thesis entitled "Variability in intervarietal F_1 hybrids and open pollinated seed progenies of black pepper (*Piper nigrum* L.)" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or any other similar title of any other University or Society.

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Certified that this thesis entitled **"Variability in intervarietal F_1 hybrids and open pollinated seed progenies of black pepper (*Piper nigrum* L.)"** is a record of research work done independently by **Smt.R. SUJATHA** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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R. SUJATHA

Dedicated to

V. Sukumara Pillai

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INTRODUCTION

INTRODUCTION

Among the perennial Spice crops of India, Black pepper (*Piper nigrum* Lin.) enjoys a unique and foremost position in several aspects. The plant, a weak stemmed climbing vine is a native of the evergreen forests of the Western Ghats of Kerala and is said to have been domesticated several thousand years ago. This innocuous vine with its most unassuming crinkly black berries is known to have played a vital role in the history of the world itself. Europeans, enticed by the rich aroma of black pepper, undertook dangerous and costly expeditions to India in search of this valuable spice which had far-reaching and overwhelming historical consequences. Establishment of a sea route from Europe to India and the discovery of the American continent are the most striking examples. Also, it is a part of history that the Europeans who came to India as traders later became rulers of this country and several others in Asia and Africa.

Besides its historical importance, pepper is the biggest foreign exchange earning spice crop of India. During 1989-90 alone, the country exported 36,601 tonnes of black pepper worth Rs.159.88 crores. If the value of pepper products exported too is considered, the total figures will be around Rs.200 crores.

Kerala accounts for 95 per cent of area and production of pepper in the country and its share in the world market is estimated to be 38 per cent. According to FAO reports, the annual world demand for pepper may escalate from the present 1,30,000 tonnes to 1,85,000 tonnes by 2000 A.D. To meet this ever increasing demand and also for the betterment of our economy, the present low productivity of pepper in this country has to be urgently stepped up.

The key to higher productivity is improved varieties. Though more than a hundred cultivars with highly variable characters are known to exist in this country, only a few of them have been identified as productive types. So, efforts for crop improvement in pepper were started at Pepper Research Station, Panniyur as early as in 1953. The natural heterozygosity of this plant and the resultant variability has been identified as an exclusive and efficient tool in the hands of plant breeders. But systematic efforts to assess the extent and quantum of such variability in the plant have not been taken up so far. The study reported in this thesis is an humble beginning on this line.

Variability studies in a perennial crop pose several problems usually not encountered in the case of annuals. The unavoidable time lag required to study several generations of this plant is the foremost among them. To tide over this hurdle at least partly, one has to make use of available existing plant materials. It was in this context, that this study was taken up at Pepper Research Station, Panniyur utilising the plant population of intervarietal F_1 hybrids and open pollinated seed progenies maintained at the station under the crop improvement programme. Though more than 2000 such plants of different age are available at the station, only 537 plants of uniform age which are in the bearing stage along with their parents have been utilised in this work.

The extent of variability among these progenies and their parents in respect of two qualitative and twenty quantitative characters is estimated as coefficient of variation. A path coefficient analysis is also attempted to partition the cause and effect relationship among the characters. The magnitude of heritability of various characters and the quantum of heterosis in the F_1 hybrids too are estimated.

It is the hope that the findings from the studies will be instrumental towards the formulation of meaningful breeding strategies in the crop.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

A review of the available literature on the various aspects of the problem is attempted here. *Piper nigrum* is a unique crop and attempts to compare its genetic behaviour with that of any other crop may not be quite proper. As reported by De Waard and Zeven (1969), eventhough it belongs to the class dicotyledons, the stem characters are intermediate between those of dicotyledons and monocotyledons. This was further supported by the anatomical study conducted at the Pepper Research Station, Panniyur (unpublished work) which showed that the secondary xylem was arranged as radial groups, and not as a continuous single ring found in dicotyledons. Similarly, the quantity of secondary phloem was also more in the plant when compared to many other dicotyledons.

The family Piperaceae in which *P. nigrum* is a member belongs to Piperales which is one of the most primitive branches originated from the Ranales. Out of the nine species of *Piper* which were reported to have economic importance (Koorders, 1908; Rutgers, 1949; Martin and Gregory, 1962 and Melchior, 1964), significant research works have been carried out only in the case of *P. nigrum*. So, the review of literature attempted here is limited mainly to the work on this plant. However, to establish certain common genetic principles, works on some other crops too have been quoted.

Potentiality of a crop to respond favourably to improvement programmes depends upon the nature and magnitude of variability and other genetic parameters of important quantitative characters. The importance of genetic diversity in the improvement of a crop has been stressed in both cross and self pollinated crops as early as 1954 by Griffing and Lindstorm.

The array of cultivars available in pepper, which display wide spectrum of variation with respect to important economic characters and quality attributes provides considerable scope for effecting genetic improvement. According to Mathai et al. (1981), more than 70 biotypes of pepper are under cultivation. Krishnamurthy (1969) has reported that, pepper vine in its wild state is mostly dioecious, but most of the cultivated types are monoecious, a condition which probably originated from the wild ones as a result of continuous selection and vegetative propagation by man through ages.

Reports of De Waard (1969) and Ibrahim et al. (1986a) show that mode of pollination in pepper is geitonogamous. But predominantly unisexual types such as the cultivars Uthirenkotta and Irumaniyan are exceptions to this and the limited number of seeds produced in them may be due to allogamy effected by wind. But pepper is not suited for wind pollination as the pollengrains are existing in a glutinous mass. Gentry (1955) reported a possible case of apomixis. He found fruits on the cultivar Uthirenkotta without the presence of pollen sources in the neighbourhood. But this finding is not supported by other evidences.

The somatic chromosome number of black pepper was reported to show variation. Sharma and Bhattacharyya (1959) reported 2n = 48. Martin and Gregory (1962), Purseglove (1969) and Mathew (1972) reported that 2n = 52. Darlington and Wylie (1955) reported 2n = 128. Mathew (1972) reported that in cultivated varieties of pepper, the basic chromosome number was 13. But, in two wild varieties of P. nigrum he found that chromosome number was 2n = 104. De Waard and Zeven (1969) reported that this variation might be caused by polyploidization. Martin and Gregory (1962) found mainly bivalents and a few quadrivalents. This might point to an almost complete diploidization of an autopolyploid or to allopolyploidization of the cultivars studied.

Eventhough geitonogamy is the rule in pepper, the original variability present in the wild types has been conserved as such in the present day cultivars due to vegetative propagation practiced in the crop. Another reason for the wide variability observed is the suspected polyploid nature of the crop (De Waard and Zeven, 1969).

1 Variability in the existing cultivars

Ibrahim et al. (1986b) reported that eventhough allogamy was almost absent in pepper under open - pollination, the heterozygosity of the plant yielded considerable variation in the progenies which could be exploited for the improvement of the crop.

According to Nambiar et al. (1978), the germplasm collection at the Pepper Research Station, Panniyur has shown wide variation in berry size, spike length, percentage of dry to green pepper and volatile oil content. The wide variation found in the appearance, growth habit, vigour, yield and other morphological and productive characters of progenies raised from individual cultivars or from a particular cross indicated heterozygosity. A similar situation was reported by Antony (1982) in sugarcane.

A study was conducted by Ibrahim et al. (1984a) to differentiate the Travancore and Malabar cultivars of black pepper with respect to four vegetative and five productive characters. The mean values of different traits revealed that, in general, Malabar cultivars showed greater expression than Travancore cultivars for all the characters studied except number of developed berries per spike. Comparison of individual characters showed considerable variability between the populations with respect to the length of petiole and 1000 berry volume. The characters, length of orthotrope internode, length of plagiotrope internode and length of spike showed only moderate variation. The populations were shown to possess no difference with respect to the area of leaf lamina, number of flowers per spike and number of developed berries per spike.

The intra-group variability was found to be more among the cultivars of Malabar group for characters, length of orthotrope internode, length of spike, number of flowers per spike, number of developed berries per spike, 1000 berry weight and 1000 berry volume. The Travancore cultivars showed more intra-group variability with respect to characters length of plagiotrope internode and area of leaf lamina. Length of petiole showed more or less equal variability in both groups.

When various combinations of characters were considered viz., vegetative characters, reproductive characters and vegetative and reproductive characters together, based on the discriminant functions, then also the two groups showed significant difference.

Studies of Ponnuswami et al. (1983) revealed that there was significant variation in quantitative characters exhibited by the progenies. They showed a wide range and coefficient of variation for the traits like number of nodes and vine length. This suggested ample scope for bringing out improvement of this population.

A stability analysis was conducted by Ibrahim et al. (1985a) using the hybrid variety Panniyur-1 and four other local cultivars viz., Arakkulam Munda, Kalluvally, Balankotta and Kuthiravaly. The results showed that Kuthiravaly was the most stable variety followed by Panniyur-1.

Potty et al. (1979) reported that adaptability to shade was a varietal character in pepper. Results of their study revealed that under shaded conditions, Panniyur-1 and Karimunda recorded the highest percentage of survival in that order and in height and number of leaves, in the reverse order. Kalluvally was found to be poorest with respect to survival (16.6%) whereas in respect of growth and number of functional leaves, Kottanadan was the poorest. There was not much difference between the different varieties in respect of internodal length. On the whole, Karimunda and Panniyur-1 were found to be better than Kalluvally, Balankotta, Kottanadan and Narayakodi for multistoried cropping system.

The studies of Mathai and Chandy (1988) supported the above study. They found that among Panniyur-1, Kalluvally, Karimunda, TMB-3 and Doddiga, number of berries produced per unit surface area of vine under varying growth light regimes was maximum for Panniyur-1 followed by Karimunda.

1.1 Important diagnostic characters to assess the extent of variability

To assess the extent of variability in the germplasm of black pepper, emphasis was laid on several vegetative and productive characters by many authors.

1.1(a) Vegetative characters

Ibrahim et al. (1986a) pointed out that the genotypes differed with respect to the colour of leafsheath. Most of the varieties were found to have anthocyanin pigmentation while a few are non-pigmented (i.e., leaf sheath green in colour). Their study on the inheritance of anthocyanin pigmentation revealed that it involved a dominant-recessive intra-allelic interaction wherein the allels governing pigmentation was observed to be dominant. A model of two pairs of genes acting in a complementary fashion was proposed by them. Kanakamany (1982) also reported that colour of the leaf sheath was a variable character and classified the 45 genotypes studied, into Russet group, Oasis, Sallow, Silver fern, Mastic, Olive sheen and Sudan.

Upshall (1924), Alderman and Shoemaker (1925), Winter (1925) and Roberts and Colby (1943) have stressed the importance of shape of the leaf and/or the size of the leaf in the rapid identification of varieties; these characters according to them were constant.

Purseglove (1969) and George and Mercy (1978) have described the leaves of pepper plant as coriaceous evergreen stipulate with ovate, cordate or elliptical in shape ranging in length from 12.5 cm – 17.5 cm and 5 cm - 12.5 cm in width, entire, sometimes glaucus beneath with two halves of the blade equal or unequal.

Nambiar et al. (1978) reported the results of observations on three morphological attributes viz., length of petiole, length of lamina and width of lamina in 24 cultivars and found that they exhibited wide variability ranging from 1.8 cm to 2.7 cm in petiole length, 11.7 cm to 19.8 cm in length of lamina and 5 cm to 13.5 cm in width of lamina. Their observations also showed that all the three characters were independent and were not necessarily related to any other.

Kanakamany (1982) reported that petiole length ranged from 0.82 cm to 2.31 cm. With respect to leaf shape, the cultivars were grouped into three classes viz., elliptic, ovate and cordate and with respect to leaf base, into cordate, round and cuneate. Leaf tip did not show any varietal difference, with all the varieties having accuminate tips. The leaf area ranged from 39.05 cm^2 - 101.48 cm^2.

Ibrahim et al. (1985b) based on a study on 40 varieties of black pepper have reported that leaf area varied from 34.611 sq cm to 118.408 sq cm and it was a function of length and length :

breadth ratio of the leaf, rather than its breadth. They also worked out a constant which when multiplied with the dimensions of the leaf would yield an estimate of its area with reasonable degree of accuracy. This technique has been used by Spencer (1962) in cassava, Yadav and Kumar (1974) in arecanut, Arora and Chanana (1975) in grapes and Rao (1975) in bajra.

Internodal length is an important economic character which exhibits wide variation with respect to different genotypes. As there is one leaf in every node, length of internode will decide the leaf area index. Further, orthotropes produce adventitious roots from every node and plageotropes produce at least one spike in every leaf axil. So the internodal length of the former will determine the holding ability of the plant while that of the later will decide the total spike yield of the vine (Chandy et al., 1984).

In a comparative study conducted by Ibrahim et al. (1986c) with the open pollinated seedlings of six cultivars of pepper viz., Uthirenkotta, Arakkulam Munda, Munda, Karimundi, Kalluvally (Ptb) and Panniyur-1, it was found that, in general, the internodal length varied between the varieties more than other characters like number of leaves and plant height. Seedlings of Panniyur-1 showed very short internode coupled with a high coefficient of variation whereas that of cultivar Munda was found to possess the least variability for internodal length. The considerable reduction in the size of internode was possibly due to the predominant expression of the internode character of the male parent of Panniyur-1 viz., Cheriyakaniakkadan, in the segregating generations of Panniyur-1.

Varietal difference for internodal length was reported by Kanakamany (1982) with a range of 2.7 cm to 12.58 cm in the case of orthotropes and 3.15 cm to 10.73 cm in the case of plageotropes. Also, the genotypes exhibited differences in the character thickness at node and internode. Thickness at nodal region ranged from 3.16 cm to 7.7 cm for orthotropes and 2 cm to 2.77 cm for plageotropes, whereas thickness at the internodal region varied from 2.08 cm to 6.8 cm for orthotropes and 1 cm to 1.52 cm for plageotropes.

The fruiting branches grow more or less at right angles to the main stem. However, Chandy and Pillai (1979) reported that the actual angle of insertion of the plageotropes on the orthotrope varied from variety to variety and was identified as a varietal character. They found that the angle of insertion varied from 45° to 130°. As a result, some of the varieties possessed drooping branches while others, semi erect branches.

Kanakamany (1982) designated the plageotrope as drooping when it subtended an angle more than 80° while a semierect plageotrope subtended an angle less than 80°.

As the intensity of sunlight falling on the leaves varies according to their degree of horizontality, the angle of insertion of the plageotropes has a direct bearing on the photosynthetic efficiency and yield of the plant (Candy and Pillai, 1979).

1.1(b) Productive characters

Hedrick (1925) and Pearl (1932) pointed out that the inflorescence characters were the least variable and more constant than any other characters even under varying conditions. Popenoe (1941) indicated the proportion of perfect and staminate flowers to be varying with the different varieties and races and was constant in each.

Kanakamany (1982) reported that the coefficient of variation varied considerably with reference to mean number of flowers per spike (34.2 - 126.7) and also with respect to the mean number of different types of flowers in a spike (hermaphrodite flowers - 0.00 to 125.8, staminate 0.00 to 4.2 and pistillate flowers - 0.00 to 68.7). The sexual composition as well as the percentage of fruitset calculated on the basis of total number of flowers showed wide variation.

Krishnamurthy (1969) reported that most of the popular and high yielding varieties were having 70 to 98 per cent of hermaphrodite flowers.

Most of the cultivated types of pepper were monoecious as reported by Hasan Iljas (1960), Nambiar and Sayed (1962) and Martin and Gregery (1962). According to them, the cultivar Kuthiravaly produced hermaphrodite, pistillate and staminate flowers, whereas Uthirenkotta appeared to possess pistillate flowers only.

Hasan Iljas (1960) reported that stamens present in a rudimentary form embedded in the tissue below the surface would provide an explanation for the restricted hermaphroditism in some of the cultivars. Male plants were rare and could be easily recognised by their vigorous vegetative appearance (Koorders, 1908; Marinet, 1953 and Hasan Iljas, 1960).

Nambiar et al. (1978) reported that the staminate flowers on a spike varied from 0 to 19 per cent while hermaphrodite flowers showed a wide variation of 2 to 93 per cent.

The proportion of pistillate flowers increased with an increase in the intensity of shade and the spikes produced during the off season were also characterised by more number of pistillate flowers than in those produced during the normal flowering season (Nambiar et al., 1978). The effect of season on sex of the pepper vines was reported by Shanmugavelu and Rao (1977) also. Cramer (1907) and Blacklock (1954) observed that a very high ratio of hermaphrodite to total number of flowers was essential for high potential production.

Kanakamany (1982) reported that cultivars showed variation with respect to pollen fertility (84.04% to 99.04%) and pollen production per flower (5004 to 10140).

Studying the spike development, Chandy et al. (1979) reported that, though the general expected rule is one spike for every leaf axil, it might not hold good uniformly. Some of the cultivars were superior in this aspect, which was recognised as a varietal character. But many spikes got aborted and the percentage of normal spikes would be less. In the 39 cultivars observed by them, the percentage of abortive flowers was least in Arakkulam Munda (17.4%) and maximum in Arissinimorata (86.2%). Kuriakose and Chandy (1978) reported the presence of branched spikes (cv. Aimpiriyan) and more than one spike in every leaf axil. Chandy et al. (1979) reported the development of more than one spike in a leaf axil in cultivar Arakkulam Munda and Karimunda.

Kanakamany (1982) reported that cultivars showed wide variation with respect to spike length which ranged from 4.22 cm to 15.52 cm.

Spike shedding affects the yield of the crop to a considerable extent. Pillai et al. (1977) reported that loss of crop due to spike shedding might be as high as 40% and the intensity of spike shedding varied with the variety. The cultivar Kalluvally and Cheriyakaniakkadan exhibited the least percentage of spike shedding whereas Kuthiravaly and Mundi shed a greater percentage of spikes formed. Menon (1981) observed 23.82% spike shedding in Panniyur-1. Geetha (1981) reported that the shedding of spike in Panniyur-1, Kottanadan and Karimunda was found to be significantly different with maximum shedding observed in Panniyur-1 (18.04%) followed by Kottanadan (5.38%) and minimum in Karimunda (2.8%).

Detailed studies on fruitset and ripening were done in pepper by Martin and Gregory (1962). Ovaries developed into three types viz., the completely developed fruit, underdeveloped fruit and undeveloped ovaries. The ovaries of the underdeveloped fruits started growing and stopped at a certain stage and they opined that insect damage might be the cause. The presence of undeveloped ovaries was due to lack of fertilization, insufficient pollination, poor quality pollen and loss of receptivity of the stigma when pollengrains were available.

Nambiar et al. (1978) have compared weight, volume, diameter and drying percentage of berries of 18 cultivars and found that they manifested pronounced variation. De Waard and Zeven (1969) reported that the berry weight, size and rate of fruit development were superior for the cultivars Balankotta and Uthirenkotta.

Kanakamany (1982) reported that varieties showed wide variation for number of well developed berries (10.12 to 106.85), number of underdeveloped berries (5.38 to 52.92), 1000 berry weight in the fresh condition (50.1 g to 162.8 g) and in dry condition (30.7 g to 65.78 g) and 1000 berry volume in fresh condition (80.05 cc to 180.98 cc) and in dry condition (37.2 cc to 65.2 cc).

2 Component characters of yield and their correlations

Yield is a complex character which is influenced by a number of other variables. Each variable is found to influence the character in a different fashion and in differing magnitude. It is necessary to have a knowledge about the relationship existing between yield and its components and their magnitude, before initiating a crop improvement programme. Galton (1889) conceived the correlation of variables for the first instance. Fisher (1954) developed the method of applying the theory of correlation of variables in the understanding of their influence in biological systems.

Ibrahim et al. (1985c) have conducted a study on 28 genotypes to understand the association between various pairs of component characters as well as component characters and yield. General feature of their investigation was that genotypic correlation coefficients possessed higher values for most pair in comparison to their phenotypic correlation. This indicates that the strong inherent relationship between such characters is impeded by the influence of environmental factors. Similar results were obtained in soybean

(Johnson et al., 1955a), Pearl millet (Pokhriyal et al., 1967) and mung bean (Singh et al., 1968).

Their studies further revealed that the highest positive and significant genotypic correlation was between spike number and spike yield followed by spike length and spike yield, number of berries per spike and spike yield and lastly, spike length and number of berries per spike. Spike number acted independently of spike length and number of berries per spike to contribute to the yield. But its real contribution on the yield was seen enhanced to certain extent by the berry weight. Similarly, the contribution of spike length to the yield was independent of other components except the number of berries per spike.

Highest negative and significant correlation was observed between berry weight and number of berries per spike. Berry weight was also negatively correlated with spike number and hence exerted a negative and significant influence on spike yield. In pepper, berry weight, by virtue of its high degree of association with the boldness of berry is a character of economic important since bigger berries fetch a higher price for the produce. So due weightage should be placed on this component while selecting high yielding genotypes (Ibrahim et al., 1985c).

Similar results were obtained in green gram by Saraswathy et al. (1979) where the yield was positively and significantly correlated with length of pod and number of pods whereas 100 seed weight was found to have nonsignificant association.

A background information on the relative contribution of eacn of the component characters towards the ultimate realization in terms of yield, will be instrumental towards the formulation of meaningful breeding strategies in the crop (Ibrahim et al., 1985d). The results of a path coefficient analysis carried out by these authors in pepper are as follows.

The direct effect of spike number on yield was found to be the highest (0.8742). Its indirect effect was small and positive via number of developed berries per spike where as it was small and negative via. spike length and 100 berry weight. Also it was found that spike number tended to enhance the effect of spike length and number of developed berries per spike on yield indirectly. So the character spike number was considered as the most important component contributing to yield and it should be given preferential consideration over others as an index in selection for high yielding types.

The direct effect of number of developed berries per spike on yield (+0.4172) was found next to that of spike number. When the indirect effect of it through spike number was positive, those through the other components were negative. They also found that the character number of berries per spike was likely to show lesser intra-varietal variability than spike number and should be given due importance during selection.

The direct effect of 100 berry weight on yield was only +0.1202 and its indirect effects on yield via. all the components were negative and values small. Though this character was found to be negatively correlated with yield, the path analysis revealed that this negative correlation was only due to the counteraction of other components and that actually it contributed positively towards yield.

The direct effect of spike length on yield was negative (-0.0887) while its indirect effect via. all other components was positive, a large proportion of which was through the number of developed berries per spike. Though spike length was reported to show a positive and significant correlation on yield, its path coefficient is small and negative. This is due to the fact that it is the number of hermaphrodite flowers per spike and not the length of the spike itself that determines the production of berries.

In pepper, the berry yield was assumed to be directly a function of the total number of berries. This assumption was further stressed by the findings that the spike number and number of developed berries per spike had high path coefficients. These two components had direct bearing on determining the total number of berries.

3 Genetic parameters

Yield is a highly complex character where inheritance is dependent upon the functioning of an intricately organized polygenic system. Further, the character is influenced by other variables as well. So genetic parameters like heritability, genetic advance and genetic gain under different probability levels of selections, have been often found to be of great use for assessing the relative importance of these inherited and correlated variables.

Ibrahim et al. (1985e) reported that the characters spike yield, closely followed by spike number showed the maximum phenotypic and genotypic coefficient of variations whereas these values were lowest in the case of berry weight. So spike yield and spike number were more amenable for improvement than other characters during selection as indicated by the high p.c.v. and due to their high g.c.v., genetic gain will be more in them than others. A high g.c.v. indicated that the major part of total variation in them was due to genetic causes. Similar results were obtained in cowpea (Ramachandran et al., 1980).

Ibrahim et al. (1985e) also reported a high heritability for berry weight followed by spike length. Spike yield showed very low value and was a shade better only to spike number. It suggested that these characters were considerably prone to the environmental fluctuations. A low estimate of heritability for yield was reported also in crops like pearl millet (Burton, 1951), soybean (Johnson et al., 1955b), wheat (Sikka and Jain, 1958) and cluster bean (Sanghi et al., 1965).

From the point of view of breeders, the characters which are markedly influenced by environmental factors will not serve very useful as indices of selection. But Johnson et al. (1955b) in their studies with soybeans pointed out that heritabiiity estimates along with genetic gain were more useful than heritability alone, in predicting the resultant effect of selection of superior genotypes. Studies of Ibrahim et al. (1985e) showed that spike yield had higher genetic advance. Hence there would be good scope for selection in this character in general, eventhough the predicted result might vary in tune with the environmental effects. Berry weight showed the lowest value for genetic advance inspite of its high heritability, which suggested only marginal improvement on selection. But the range of variation of the predicted gain due to the interference of environment would be small in berry weight compared to that in other characters. The character number of berries per spike combined medium heritability value and high genetic advance.

This was a desirable point and satisfied the concept of Johnson *et al*. (1955b) in predicting the resultant effect of selection of superior genotypes.

4 **Heterosis**

Heterosis breeding is extensively explored and utilized for boosting up yield in a number of economically important crops. The term heterosis refers to the phenomenon in which the F_1 population obtained by the crossing of the genetically dissimilar gametes or individuals show increased or decreased vigour over the better parent or over the mid parental value (Rai, 1979). This phenomenon is the result of the action and interaction of the unlike gametes in the heterozygote.

While studying the principles of breeding vegetatively propagated crop, Herbert and Henderson (1959) reported that the general performance of the progeny derived from a cross could be predicted to a reasonably relative degree from the performance of the parents.

The expression of heterosis varies with different parental combinations due to the different degree of genetic diversity between the parents. It is generally agreed that the genetically diverse parents often produce maximum heterosis. The importance of genetic diversity of parents for hybridization has been stressed by many workers. Singh and Gupta (1968) working on upland cotton stated that the progenies derived from a set of diverse crosses exhibited a broad spectrum of variability. They emphasised the importance of genetic diversity of parents in hybrid breeding programme.

Pillai et al. (1987) had reported that there was good scope for exploiting heterosis in black pepper. They assessed the heterobeltiosis as well as relative heterosis of Panniyur-1 for most of the vegetative and productive characters. They found that there was positive and significant heterosis over better parent for most of the characters. In the case of internodal length such superiority could be seen only in comparison to mid-parental value (35.76%). A negative and significant heterosis over mid-parental value was seen only for underdeveloped berries per spike (-34.11%). Similarly a negative and significant heterosis over better parent was seen for number of pistillate flowers per spike (-98.73%). Berry characters such as 1000 green berry weight, 1000 dry berry weight and 1000 berry volume did not show any significant difference from mid-parental value. Positive and significant heterosis was exhibited for spike length (39.28%), developed berries per spike (758.21%), bisexual flowers per spike (250.75%) as well as for yield (176.9%). Among the productive characters, only berry characters were found to be intermediate. Positive and significant heterosis was seen for all the foliar characters such as length of leaf (21.41%), breadth of leaf (75.08%), area of leaf (33.65%) and length of petiole (45.45%).

The heterosis for yield reported was found to be very high in comparison to that in other crops as seen compiled by Rai (1979). This high heterosis in Panniyur-1 was chiefly attributable to the overall combination of the favourable cumulative effects of a number of component characters.

Panniyur-1 is reported to be capable of giving a very high yield under favourable agro climatic and soil conditions. Nambiar (1978) reported that at Pepper Research Station, Panniyur the average yield obtained for the hybrid was 6.26 kg green pepper as compared to 3.22 kg and 0.82 kg obtained for Karimunda and Kalluvally. At the CPCRI Regional Station, Vittal, a single vine of Panniyur-1 trained on a mango tree gave 37 kg of green pepper. When it was grown as intercrop in coconut garden, Panniyur-1 out-yielded other cultivars like Balankotta and Kalluvally.

Studies conducted by Kannan (1985) at RARS, Ambalavayal revealed that Panniyur-1 gave high yield under the agro climatic conditions of the hill district. The maximum yield recorded from a single vine was 10.7 kg dry pepper. Out of the 270 vines studied, about 90% yielded more than 2 kg dry berries per vine and 65% recorded an yield of 4 kg dry berries per vine during 1982.

A comparative study was conducted by Ramankutty (1977) using Panniyur-1 and Kalluvally, Balankotta, Uthirenkotta, Karimunda, Kuthiravaly and Arakkulam Munda. He found that Panniyur-1 excelled others in all the spike characters. But in percentage recovery of dry pepper, it was next only to Karimunda and Kuthiravaly.

Sikka et al. (1984) reported that Panniyur-1 was superior to other cv. viz., Karimunda, Kalluvally and Kottanadan with regard to the proportion of bold pepper. In Panniyur-1 40% berries belonged to the grade TGSEB (Tellicherry Garbled Special Extra Bold) and when the percentage of the two grades TGSEB and TG (Tellicherry Garbled) were taken together, then also Panniyur-1 had the highest value of 75.3%.

Ibrahim et al. (1986b) conducted a comparative study of Panniyur-1 and four other cv., viz., Kuthiravaly, Balankotta, Arakkulam Munda and Kalluvally. They found that Panniyur-1 was the most precocious of all, with 75% of the vines flowering in the second year itself.

Panniyur-1 was studied by Ibrahim et al. (1984b) for its morphological resemblance to Malabar and Travancore groups of pepper cv., employing discriminant functions. The hybrid was observed to share more in common with Malabar group than Travancore group for combinations of characters viz., vegetative characters alone and vegetative and reproductive characters together. The hybrid had shown no tilt in either direction when reproductive characters alone were considered.

Open pollinated seedling progenies of Panniyur-1 produced internodes considerably shorter than the seedlings of Uthirenkotta, Arakkulam Munda, Munda, Karimundi and Kalluvally (Ptb) (Ibrahim et al., 1986c). The considerable reduction observed in the size of internode was possibly due to the predominant expression of the internode character of Cheriyakaniakkadan, the pollen parent of Panniyur-1, in the segregating generation of Panniyur-1. Cheriyakaniakkadan was endowed with remarkably short internodes.

The stability analysis conducted by Ibrahim et al. (1985a) showed that, though Panniyur-1 was a good performer, its performance during all seasons could not be relied upon as suggested by its unpredictable nature. The same authors (1986b) in another study also reported that the effect of seasons on the yield was maximum in the case of Panniyur-1. Generally, high yielding varieties were observed to be increasingly susceptible to the environmental variation in various crops (Perkins and Jinks, 1968; Hanson, 1970; Verma et al., 1972; Brennan and Byth, 1979; Mehra and Ramanujam, 1979 and Ibrahim, 1980).

MATERIALS AND METHODS

MATERIALS AND METHODS

The investigations reported herein were undertaken partly in the Pepper Research Station, Panniyur and partly in the College of Horticulture, Vellanikkara, during the year 1989-1990 with the objective of throwing light on the extent of genetic divergence exhibited by the existing germplasm as well as open pollinated seedling progenies and hybrids of black pepper which would make the crop improvement programmes of this crop more effective and efficient.

MATERIALS

Forty five F_1 hybrids belonging to eight different inter-varietal combinations of crosses along with their parents and 492 open pollinated seedling progenies from 35 cultivars/cultures planted during 1982-83 in the Pepper Research Station, Panniyur were made use of in the study. They have all been receiving uniform management practices as suggested in the Package of Practices Recommendations for Pepper published by Kerala Agricultural University.

Details of the F_1s and the open pollinated seedlings included in the study are given in Table 1.

Table 1. Details of F_1s and open pollinated seed progenies

Sl. No.	Particulars	Number included in the study
F_1 hybrids and parents		
1	Uthirenkotta x Karimunda	21
2	Uthirenkotta x Balankotta	3
3	Uthirenkotta x Kottanadan	4
4	Uthirenkotta x Kuthiravaly	2
5	Uthirenkotta x Cheriyakaniakkadan	1
6	Karivilanchy x Cheriyakaniakkadan	1
7	Panniyur-1 x Kuthiravaly	1
8	Panniyur-1 x Karimunda	12
Open pollinated seedlings		
9	Arakkulam Munda	8
10	Arikkottanadan	2
11	Balankotta I	7
12	Balankotta II	1
13	Cheriyakaniakkadan	47
14	Irumaniyan	74
15	Kalluvally	28
16	Kaniakkadan	1
17	Karimunda	25
18	Karimundi	16
19	Karivilanchy	39
20	Kottanadan	7
21	Kuthiravaly	22
22	Kumbhakodi	1
23	Sullia	2

Contd.

Sl. No.	Particulars	Number included in the study
24	Mundi	3
25	Panniyur-1	9
26	Perumkodi	6
27	Poonjarmunda	10
28	TMB II	1
29	TMB IV	1
30	TMB V	2
31	Uthirenkotta	105
32	Vally	1
33	Culture 94	5
34	Culture 120	1
35	Culture 141	1
36	Culture 239	32
37	Culture 292	2
38	Culture 331	6
39	Culture 341	11
40	Culture 498	2
41	Culture 527	10
42	Culture 774	2
43	Culture 1297	2

METHODS

Observations on the following characters were recorded from all the F_1 hybrids, their parents and open pollinated seedling progenies. Estimations on oleoresin, pepper oil and piperin contents were made in the College of Horticulture, Vellanikkara.

Vegetative characters

A. Qualitative characters

1. Shape of lamina, leaf tip and leaf base

The above attributes of all the genotypes were described as per Lawrence (1973).

2. Colour of leaf sheath

The colour of leaf sheath of different genotypes was recorded. They were classified based on the presence or absence of anthocyanin pigmentation into coloured and green in that order.

B. Quantitative characters

(a) Vegetative characters

3. Length of petiole

This was measured in cm from 25 petioles of leaves produced on plageotropes selected at random and the mean worked out.

4. Length and breadth of leaf

Mature, undamaged leaves produced on plageotropes were selected. The maximum length and breadth were recorded in cm from 25 such randomly selected leaves and mean worked out.

From the length and breadth, leaf area was computed as per Ibrahim et al. (1985b) for each of the 25 pairs and mean arrived at.

5. Length of internode (orthotrope)

This was measured in cm for 25 internodes selected at random for each genotype and the mean worked out.

6. Thickness at node and internode (orthotrope)

The circumference at the nodal as well as internodal regions was separately measured in cm with the help of a twine and meter scale at the rate of 25 observations per vine and mean arrived at.

7. Length of internode (plageotrope)

This was measured in cm with the help of a meter scale for 25 internode per type selected at random and the mean arrived at.

8. Thickness at node and internode (plageotrope)

This was separately measured in cm with the help of a twine and meter scale. Twenty five observations were recorded per vine and the mean arrived at.

9. Angle of laterals with the stem

The angle subtended by the lateral with the main stem was measured in degrees and if it was more than 80°, the lateral was designated as drooping and if less than 80°, it was designated as semierect. A protractor was used for the measurement.

(b) Productive characters

10. Length of spike

After harvest, 25 spikes were randomly selected from each vine and the length was measured in cm.

11. Number of spikes per vine

The total number of spikes produced by each vine was counted at the time of harvest and their mean value calculated.

12. Number of developed berries per spike

Number of well developed berries was counted from 25 randomly selected spikes from each vine and the mean arrived at.

13. Number of underdeveloped berries per spike

Number of underdeveloped berries was counted from 25 randomly selected spikes from each vine and the mean arrived at.

14. Weight of 100 green berries

Weight in g of 100 well developed berries was determined soon after harvest for each vine.

15. Volume of 100 green berries

The volume in cc of 100 well developed berries was measured soon after harvest for each vine by water displacement method.

16. Weight of 100 dried berries

After proper drying, weight in g of 100 berries was determined for each vine.

17. Green spike yield per vine

The weight in g of the total spikes produced by each vine was determined soon after harvest.

18. Green berry yield per vine

After determining the spike yield, the berries were separated from spike and the total weight of green berries in g was determined for each vine.

19. Dried berry yield per vine

After proper drying of the total berries produced by each vine, weight was measured in g.

(c) Quality attributes

20. Oleoresin content of dried berries

The oleoresin content of the berries was estimated using the Soxhlet method of extraction as per Horwitz (1980). After coarsely grinding the dried pepper berries, 25 g of the powder was transferred into the extraction thimble of the apparatus. Solvent used was 100% acetone. The acetone extract was transfered into a previously weighed kjeldahl digestion flask and was kept in a waterbath at 60-65°C to evaporate the solvent. The weight was again determined to obtain the weight of oleoresin. From this the percentage of oleoresin was calculated.

This was determined only for selected 13 genotypes.

21. Pepper oil of dried berries

After determining the oleoresin content, the acetone extract was kept in a waterbath at 100°C to evaporate the volatile oil till constant weight is obtained. From the difference in weights, the percentage of volatile oil in the dried berries was determined. This observation was also confined to the selected 13 genotypes.

22. Piperin content of dried berries

The crude piperin content was determined using the macro-kjeldahl method of estimation of nitrogen. After the estimation of volatile oil, 10 g of catalyst mixture (10 g K_2SO_4 + 10 g $CuSO_4.5H_2O$ + 1 g Selenium powder) and 100 ml of concentrated H_2SO_4 were added to the non-volatile acetone extract and digested in direct flame till the digest is cleared to a bluish green colour. It was transfered to a 250 ml volumetric flask and made up with distilled water. 150 ml of the made up solution was transfered into the distillation flask of macrokjeldahl apparatus. To this, 40% NaOH was added till the solution became strongly alkaline. Added enough distilled water to bring the content of the flask up to the middle and the distillation was carried out. The distillate was collected in standard H_2SO_4 (2-3 drops of methyl orange as indicator) taken in the receiver. From this the percentage of nitrogen was estimated by neutralising the excess acid with standard NaOH. Then, crude piperin was estimated as

$$\text{crude piperin} = \% \text{ of N} \times 20.36$$

This observation was also confined to the selected 13 genotypes.

23. Statistical analysis

The details of the statistical analysis followed are given below.

Estimation of variability

Variability existing in the various characters under observation were estimated as coefficient of variation using the formula

$$\text{Coefficient of variation} = \frac{\text{Standard deviation}}{\text{Mean of the character}} \times 100$$

Estimation of correlation

Simple correlation between yield and the various vegetative and productive characters were calculated as per Falconer (1981). The formula used was

$$r = \frac{\text{Cov}}{\sigma_x \, \sigma_y}$$

where r = Correlation coefficient

Cov = Covariance for the two characters x and y

σ_x = Standard deviation of the character x

σ_y = Standard deviation of the character y

Path coefficient analysis

Path coefficient analysis as suggested by Wright (1921) and elaborated by Dewey and Lu (1959) was utilised to partition the cause and effect relationship among the characters. 14 characters showing maximum correlation with dry berry yield per vine were subjected to path coefficient analysis in order to separate the cause and effect relationship among the characters into measures of direct and indirect effects on yield, by assuming a linear model

$$y = a_1 x_1 + a_2 x_2 \ldots\ldots\ldots\ldots + a_{14} x_{14}$$

where, y and x's are standardised variates corresponding to yield and the 14 attributes, respectively. The following set of simultaneous equations were formed and solved for estimating the various direct and indirect effects.

$$r_{iy} = \sum_{j=i}^{14} P_{iy} \cdot r_{ij} \qquad i = 1, \ldots\ldots\ldots\ldots, 14$$

where, r_{iy} denotes coefficient of correlation between independent characters x_i and dependent character y, r_{ij} denotes the coefficient of correlation between i^{th} and j^{th} character and P_{iy} is the direct effect of the i^{th} character on y.

The above equation can be written in a matrix form as:

$$\begin{matrix} A & & B & & C \\ \begin{bmatrix} r_{1y} \\ r_{2y} \\ \vdots \\ r_{14y} \end{bmatrix} & = & \begin{bmatrix} r_{1\,1} & r_{1\,2} & \cdots & r_{1\,14} \\ r_{2\,1} & r_{2\,2} & \cdots & r_{2\,14} \\ \vdots & & & \\ r_{14\,1} & r_{14\,2} & \cdots & r_{14\,14} \end{bmatrix} & & \begin{bmatrix} P_{1y} \\ P_{2y} \\ \vdots \\ P_{14y} \end{bmatrix} \end{matrix}$$

where $r_{ij} = r_{ji}$; $r_{ii} = 1$

$A = BC$ hence $C = B^{-1}A$ where B^{-1} is the inverse of B.

The residual effect which measures the contribution of rest of the characters not included in the casual scheme was obtained by the formula $\sqrt{1-R^2}$ where

$$R^2 = \sum_{i=1}^{14} P^2_{iy} + 2 \sum_{i} \sum_{j} P_{iy} P_{jy} r_{ij} , \quad i < j$$

Estimation of heritability

Heritability is the potentiality of an individual to inherit a particular character to its offspring. The heritability in narrow sense was estimated as the regression of offspring on mid parent in the case of F_1 hybrids. In the case of open pollinated seed progenies, the regression coefficient of offspring on the female parent was multiplied by two to get the narrow sense heritability (Falconer, 1981).

Estimation of heterosis

For the 45 F_1 hybrids belonging to 8 different inter varietal crosses, heterosis was assessed over the better parent (heterobeltiosis) (Fonseca and Patterson, 1968), mid-parental value (relative heterosis) and standard variety (standard heterosis). Karimunda was considered as the standard variety.

These three types of heterosis were estimated using the relation,

$$H = \frac{(\bar{X}\ F_1 - \bar{X}\ P)}{\bar{X}\ P} \times 100$$

where $\bar{X}\ F_1$ = mean value of F_1

$\bar{X}\ P$ = mean value of better parent, mid parent or standard variety as the case may be

RESULTS

RESULTS

The data were collected on four qualitative and 21 quantitative characters from 45 F_1 hybrids belonging to eight different intervarietal crosses and 492 open pollinated seed progenies of 35 cultivars/cultures and those on quantitative characters were analysed and used to study genetic variability, correlation, path analysis, heritability and heterosis. From the F_1 hybrids and open pollinated seed progenies, which have not yet started yielding, observations were taken only on vegetative characters.

The results obtained in the present investigations are presented under the following titles.

I Expression of individual traits

II Variability analysis

III Correlation studies

IV Path coefficient analysis

V Heritability

VI Heterosis

I Expression of individual traits

(i) Qualitative characters

1. Leaf shape

Shape of leaf appeared to be a distinct varietal character in pepper. All the parents, progenies and hybrids fell under three major categories (Plate I). When the leaves were narrow and broadest at the middle with tapering ends in the form of an ellipse, they were elliptic. When the elliptic leaves had their maximum breadth nearest to the leaf base, they were classified as ovate. When the leaves were heart shaped, they were designated as cordate.

The data on percentage of individuals in parents, F_1 hybrids and open pollinated seed progenies belonging to the above three groups of leaf shape are given in Table 2.

In general, most of the vines had ovate leaves whereas cordate leaf shape was found to be the least common. F_1 hybrids showed the maximum percentage of vines with ovate leaves (64.44%) followed by the open pollinated seed progenies (56.71%). Parents had the minimum value (54.29%). Elliptic leaves were maximum in parents (31.43%) and minimum in F_1 hybrids (17.78%). Open pollinated seed progenies had 29.27 per cent vines with elliptic leaves. Cordate leaves were maximum in F_1 hybrids (17.78%). Parents (14.29%) and open pollinated seed progenies (14.02%) had almost same percentage of vines with cordate leaves.

Table 2 Variability in qualitative characters in parents, F_1 hybrids and open pollinated seed progenies (% of individuals under each group)

Particulars	Leaf shape			Leaf base			Colour of leafsheath	
	Ovate	Cordate	Elliptic	Round	Cordate	Cuneate	Purple	Green
1. Parents	54.29	14.29	31.42	42.86	14.28	42.86	91.43	8.57
2. F_1 hybrids	64.44	17.78	17.78	42.22	20.00	37.78	82.22	17.78
3. Open pollinated seed progenies	56.71	14.02	29.27	59.35	14.84	25.81	89.23	10.77

2. Leaf base

With respect to leaf base also there were three categories (Plate 1). When the leaf base was wedge shaped, it was classified as cuneate and when it was heart shaped, it was designated as cordate.

The data on percentage of individuals belonging to the above three categories are given in Table 2.

Round leaf base was found to be most common followed by cuneate type and lastly, by cordate type. Open pollinated seed progenies showed maximum percentage of vines with round leaf base (59.35%). Parents (42.86%) and F_1 hybrids (42.22%) had almost same percentage of vines with round leaf base. Cuneate leaf base was maximum in parents (42.86%) followed by F_1 hybrids (37.78%) and open pollinated seed progenies (25.81%). With respect to cordate leaf base, F_1 hybrids had the maximum (20.00%) whereas open pollinated seed progenies (14.84%) and parents (14.28%) had almost same percentage of vines.

3. Leaf tip

All the parents, F_1 hybrids and open pollinated seed progenies had accuminate leaf tip. So no data were given eventhough observations were taken for the same.

Plate 1. Variability in leaf shape and leaf base

Plate 1

4. Colour of leaf sheath

With respect to colour of leaf sheath, all the vines fell under two groups, purple and green. Purple colour was found to be predominant. Parents had the maximum percentage of vines (91.43%) with purple leaf sheath followed by open pollinated seed progenies (89.23%) and F_1 hybrids (82.22%). Vines with green leaf sheath were maximum in F_1 hybrids (17.78%) followed by open pollinated seed progenies (10.77%) and parents (8.57%).

(ii) Quantitative characters

The range in values and the mean value for the various vegetative and productive characters for the parents, F_1 hybrids and open pollinated seed progenies are given in Tables 3 and 4 respectively.

(A) Vegetative characters

(a) Leaf characters

The range in values is given in Table 3 and the details of parents, F_1 hybrids and open pollinated seed progenies are given in Appendix 1, 2 and 3 respectively. The mean values for parents, F_1 hybrids and open pollinated seed progenies are given Table 4.

Table 3 Range in different characters

Sl. No.	Characters	Parents	F_1 hybrids	Open pollinated seed progenies
	<u>Vegetative</u>			
1	Length of petiole (cm)	0.91 - 2.08	1.25 - 3.25	1.01 - 3.60
2	Length of leaf (cm)	10.61 - 17.28	10.86 - 17.21	9.13 - 21.57
3	Breadth of leaf (cm)	4.58 - 10.09	4.66 - 11.85	4.03 - 12.35
4	Area of leaf (sq. cm)	33.10 - 108.20	34.20 - 140.3	29.00 - 139.9
5	Length of internode - Orthotrope (cm)	5.82 - 12.93	5.16 - 8.00	2.15 - 17.42
6	Thickness of internode - Orthotrope (cm)	1.88 - 5.25	1.37 - 3.24	0.94 - 8.91
7	Thickness of node - Orthotrope (cm)	2.26 - 6.22	2.40 - 6.02	1.57 - 7.01
8	Length of internode - Plageotrope (cm)	2.76 - 6.95	3.19 - 9.54	2.26 - 9.99
9	Thickness of internode - Plageotrope (cm)	0.80 - 1.19	0.86 - 1.58	0.17 - 2.55
10	Thickness of node - Plageotrope (cm)	1.22 - 2.99	1.30 - 2.99	0.61 - 3.32
11	Angle of plageotrope with the Orthotrope	53.00 - 104.0	31.50 - 89.00	37.00 - 107.0
	<u>Productive</u>			
12	Volume of 100 green berries (cc)	10 - 20	8 - 19	6 - 25
13	Weight of 100 green berries (g)	11 - 21	9 - 21	6 - 25
14	Weight of 100 dry berries (g)	3 - 7	4 - 8	2 - 9.9
15	No. of spikes/vine	44 - 3165	16.00 - 2222	11 - 3165
16	Length of spike (cm)	6.65 - 17.07	7.10 - 16.37	3.04 - 20.14
17	No. of developed berries per spike	15.47 - 79.90	2.54 - 60.70	0.70 - 73.30
18	No. of underdeveloped berries per spike	0.60 - 10.51	0.00 - 14.90	0.00 - 10.80
19	Green spike yield/vine	195 - 12200	50 - 6860	17 - 13300
20	Green berry yield/vine	180 - 10820	42 - 5580	13 - 12950
21	Dry berry yield/vine	54 - 3600	16 - 1950	5 - 4172

Table 4 Mean of different characters

Sl. No.	Characters	Parents	F_1 hybrids	Open pollinated seed progenies
	Vegetative			
1	Length of petiole (cm)	1.51	1.77	1.70
2	Length of leaf (cm)	13.52	14.18	13.62
3	Breadth of leaf (cm)	7.17	8.47	7.51
4	Area of leaf (sq. cm)	66.86	82.76	75.11
5	Length of internode - Orthotrope (cm)	7.87	7.90	7.44
6	Thickness of internode - Orthotrope (cm)	3.28	2.61	2.53
7	Thickness of node - Orthotrope (cm)	4.00	3.51	3.24
8	Length of internode - Plageotrope (cm)	4.69	5.11	3.60
9	Thickness of internode - Plageotrope (cm)	1.02	1.18	1.14
10	Thickness of node - Plageotrope (cm)	1.60	1.69	1.73
11	Angle of Plageotrope with the Orthotrope (°)	73.21	64.07	63.39
	Productive			
12	Volume of 100 green berries (cc)	13.46	14.00	12.24
13	Weight of 100 green berries (g)	14.43	14.95	13.30
14	Weight of 100 dry berries (g)	5.10	5.84	5.04
15	Number of spikes per vine	866.77	340.88	330.50
16	Length of spike (cm)	10.25	10.55	9.17
17	No. of developed berries per spike	38.63	30.24	30.04
18	No. of underdeveloped berries per spike	3.83	2.28	1.95
19	Green spike yield per vine (g)	3512.86	1379.05	1217.92
20	Green berry yield per vine (g)	2911.20	1184.03	1065.18
21	Dry berry yield per vine (g)	1057.20	437.45	404.08

1. Length of petiole

In parents, the minimum length was for cv. Cheriyakaniakkadan (0.91 cm) and maximum for vally (2.08 cm). In F_1 hybrids, the length varied from 1.25 cm in cross Uthirenkotta x Balankotta to 3.25 cm in cross Uthirenkotta x Karimunda. The open pollinated seed progeny of Irumaniyan showed the minimum length (1.01 cm) and that of Kalluvally showed the maximum length (3.60 cm).

The mean length was found to be maximum in F_1 hybrids (1.77 cm) followed by open pollinated seed progenies (1.70 cm) and minimum in parents (1.51 cm).

2. Length of leaf

In parents, the length varied from 10.61 cm in Cheriyakaniakkadan to 17.28 cm in vally. In F_1 hybrids, the range was 10.86 cm to 17.21 cm, both the minimum and maximum values belonging to the cross Uthirenkotta x Karimunda. The open pollinated seed progeny of Poonjarmunda showed the minimum length (9.13 cm) and that of Kalluvally showed the maximum length (21.57 cm).

The mean length was found to be maximum in F_1 hybrids (14.18 cm). The mean length was almost same in open pollinated seed progenies (13.62 cm) and parents (13.52 cm).

3. Breadth of leaf

In parents, the breadth of leaf varied from 4.58 cm in cv. Cheriyakaniakkadan to 10.09 cm in cv. Panniyur-1. In F_1 hybrids, the breadth of leaf was minimum (4.66 cm) in the cross Uthirenkotta x Karimunda and maximum (11.85 cm) in the cross Panniyur-1 x Karimunda. The open pollinated seed progeny of cv. Karimunda showed the minimum breadth (4.03 cm) and that of cv. Irumanivan showed the maximum (12.35 cm).

The mean breadth was maximum in F_1 hybrids (8.47 cm) followed by open pollinated seed progenies (7.51 cm) and parents (7.17 cm).

4. Area of leaf

In parents, the leaf area was minimum in Cheriyakaniakkadan (33.10 cm^2) and maximum in Culture-292 (108.20 cm^2). In F_1 hybrids, the minimum leaf area was in the cross Uthirenkotta x Karimunda (34.20 cm^2) whereas it was maximum in the cross Panniyur-1 x Karimunda (140.30 cm^2). The open pollinated seed progeny of Cheriyakaniakkadan showed the minimum leaf area (29.00 cm^2) and that of Culture-341 showed the maximum (139.90 cm^2).

The mean leaf area was maximum in F_1 hybrids (82.76 cm^2) followed by open pollinated seed progenies (75.11 cm^2) and parents (66.86 cm^2).

(b) Stem characters - Orthotrope

The range in values is given in Table 3 and the details of parents, F_1 hybrids and open pollinated seed progenies are given in Appendix 4, 5 and 6 respectively. The mean values for parents, F_1 hybrids and open pollinated seed progenies are furnished in Table 4.

5. Length of internode - Orthotrope

In parents, the length was minimum in Karimundi (5.82 cm) and maximum, in Culture-341 (12.93 cm). In F_1 hybrids, it was minimum in the cross Panniyur-1 x Karimunda (5.16 cm) and maximum in the cross Uthirenkotta x Kathiravaly (16.22 cm). The open pollinated seed progeny of cv. Kalluvally showed the minimum length (2.15 cm) and that of Irumaniyan showed the maximum length (17.42 cm).

The mean value was maximum for F_1 hybrids (7.90 cm) closely followed by parents (7.87 cm) and open pollinated seed progenies (7.44 cm).

6. Thickness of internode - Orthotrope

In parents, the minimum thickness was exhibited by Culture 527 (1.88 cm) and the maximum, by Sullia (5.25 cm). In F_1 hybrids, the thickness was minimum in the cross Uthirenkotta x Balankotta (1.37 cm) and maximum in Panniyur-1 x Karimunda (3.24 cm).

The open pollinated seed progeny of Culture 341 showed the minimum thickness (0.94 cm) and that of Karimunda showed the maximum (8.91 cm).

The mean value was maximum in parents (3.28 cm) followed by F_1 hybrids (2.61 cm) and open pollinated seed progenies (2.53 cm).

7. Thickness of node - Orthotrope

In parents, the minimum thickness was exhibited by Culture 527 (2.26 cm) and the maximum, by Sullia (6.22 cm). In hybrids, the minimum thickness was found in the cross Uthirenkotta x Balankotta (2.40 cm) and the maximum in Uthirenkotta x Kottanadan (6.02 cm). The open pollinated seed progeny of Kalluvally, showed the minimum thickness (1.38 cm) and that of Cheriyakaniakkadan showed the maximum (7.01 cm).

The mean value was maximum in parents (4.00 cm) followed by F_1 hybrids (3.51 cm) and open pollinated seed progenies (3.24 cm).

(c) Stem characters - Plageotrope

The range of values is given in Table 3 and the details of parents, F_1 hybrids and open pollinated seed progenies are given in Appendix 7, 8 and 9 respectively. The mean values for parents, F_1 hybrids and open pollinated seed progenies are furnished in Table 4.

8. Length of internode - Plageotrope

In parents, the minimum length was shown by Mundi (2.76 cm) and the maximum by TMB. V (6.96 cm). In F_1 hybrids, the minimum length was found in the cross Uthirenkotta x Karimunda (3.19 cm) and the maximum in Karivilanchy x Cheriyakaniakkadan (9.54 cm). The open pollinated seed progeny of Karimunda showed the minimum length (2.26 cm) and that of Kuthiravaly showed the maximum (9.99 cm).

The mean value was maximum for F_1 hybrids (5.11 cm) followed by parents (4.69 cm) and open pollinated seed progenies (3.60 cm).

9. Thickness of internode - Plageotrope

In parents, the minimum thickness was found in Cheriyakaniakkadan (0.80 cm) and maximum in Culture 120 (1.21 cm). In F_1 hybrids, the minimum (0.86 cm) and maximum (1.58 cm) thickness were exhibited by the cross Uthirenkotta x Karimunda. The open pollinated seed progeny of Irumaniyan showed the minimum thickness (0.17 cm), and that of Culture 341 showed the maximum (2.73 cm).

The mean was maximum in F_1 hybrids (1.18 cm) closely followed by open pollinated seed progenies (1.14 cm) and parents (1.02 cm).

10. Thickness of node - Plageotrope

In parents, minimum thickness was found in Arikkottanadan (1.22 cm) and maximum in Culture-1297 (2.99 cm). In F_1 hybrids, minimum thickness was found in the cross Panniyur-1 x Karimunda (1.30 cm) and maximum in the cross Panniyur-1 x Kuthiravaly (2.99 cm). The open pollinated seed progeny of Cheriyakaniakkadan showed the minimum thickness (0.61 cm) and that of Uthirenkotta showed the maximum thickness (3.43 cm).

The mean value was maximum in open pollinated seed progenies (1.73 cm) followed by F_1 hybrids (1.69 cm) and parents (1.60 cm).

11. Angle of plageotrope with orthotrope

In parents, minimum angle was found in Arikkottanadan (53.00^o) and maximum in Culture-239 (104.00^o). In F_1 hybrids minimum angle was found in the cross Uthirenkotta x Karimunda (31.50^o) and maximum in the cross Panniyur-1 x Karimunda (89.00^o). The open pollinated seed progeny of Uthirenkotta showed the minimum angle (27.00^o) as well as showed the maximum angle (107.00^o).

The mean value was found maximum in parents (73.21^o) followed by F_1 hybrids (64.07^o) and open pollinated seed progenies (63.39^o).

(B) Productive characters

(a) Berry characters

The range in values is given in Table 3 and the details of parents, F_1 hybrids and open pollinated seed progenies are given in Appendix 10, 11 and 12 respectively. The mean values are furnished in Table 4.

12. Volume of 100 green berries

In parents the minimum value was found in TMB II and Culture-239 (10cc) and the maximum value was found in Culture-120 (20cc) In F_1 hybrids the minimum value was found in the cross, Panniyur-1 x Karimunda (8cc) and the maximum value was found in the cross Uthirenkotta x Karimunda (19cc). The open pollinated seed progeny of Cheriyakaniakkadan showed the minimum value (6cc) and that of Karimundi showed the maximum value (25cc).

The mean value was maximum in F_1 hybrids (14.00cc) followed by parents (13.46cc) and open pollinated seed progenies (12.24cc).

13. Weight of 100 green berries

In parents the minimum value was found in Arakkulam Munda and Culture-239 (11.00g) and the maximum value, was found in Culture-120 (21.00 g) In F_1 hybrids the minimum value was found in the cross Panniyur-1 x Karimunda (9.00g) and the maximum value was found in the cross Uthirenkotta x Karimunda (21.00g). The open pollinated seed progenies of Culture-239 showed the minimum value (6.00g) and that of Karimundi showed the maximum value (25.00 g).

The mean value was maximum in F_1 hybrids (14.95g) closely followed by parents (14.43g). The open pollinated seed progenies had the lowest mean value (13.30 g).

14. Weight of 100 dry berries

In parents the minimum value was found in Sullia (3.00 g) and the maximum value was found in Culture-120 and Culture-341 (7.00 g). In F_1 hybrids the minimum value was found in the crosses Uthirenkotta x Karimunda, Uthirenkotta x Kottanadan and Panniyur-1 x Karimunda (4.00 g) and the maximum value was found in the crosses Uthirenkotta x Karimunda and Uthirenkotta x Kuthiravaly (8.00 g). The open pollinated seed progeny of Culture-239 showed the minimum value (2.00 g) and that of Karimundi showed the maximum value (9.90 g).

The mean value was maximum in F_1 hybrids (5.84g) closely followed by parents (5.10 g) and open pollinated seed progenies (5.04 g).

(b) Spike characters

The range in values is given in Table 3 and the details of parents, F_1 hybrids and open pollinated seed progenies are given in Appendix 13, 14 and 15 respectively. The mean values are furnished in Table 4.

15. Number of spikes/vine

In parents the minimum value was found in Irumaniyan (44.00) and the maximum value was found in Culture 498 (3165.00). In F_1 hybrids the minimum value was found in the cross Uthirenkotta x Kuthiravaly (16.00) and the maximum value in the cross Uthirenkotta x Balankotta (2222.00). The open pollinated seed progeny of Culture 341 showed the minimum value (11.00) and that of Uthirenkotta showed the maximum (3165.00).

The mean value was maximum in parents (866.77) followed by F_1 hybrids (340.88) and open pollinated seed progenies (330.50).

16. Length of spike

In parents the minimum length was exhibited by Sullia (6.65 cm) and the maximum by Culture 1297 (16.67 cm). In F_1 hybrids the minimum value was found in the cross Panniyur-1 x Karimunda (7.10 cm) and the maximum in the cross Panniyur-1 x Kuthiravaly

(16.67 cm).The open pollinated seed progeny of Karimunda showed the minimum value (3.04) and that of Kalluvally showed the maximum (20.14 cm).

The mean value was maximum in F_1 hybrids (10.55cm) followed by parents (10.25cm) and open pollinated seed progenies (9.17 cm).

17. Number of developed berries per spike

In parents the minimum value was found in TMB V (15.47) and the maximum in Panniyur-1 (79.90). In F_1 hybrids the minimum value was found in the cross Uthirenkotta x Karimunda (2.54) and the maximum in the cross Uthirenkotta x Balankotta (60.70). The open pollinated seed progeny of Arakkulam Munda showed the minimum value (0.70) and that of Kalluvally showed the maximum value (76.90).

The mean value was maximum in parents (38.63) followed by F_1 hybrids (30.24) and open pollinated seed progenies (30.04).

18. Number of underdeveloped berries per spike

In parents the minimum value was found in TMB V (0.60) and the maximum in Poonjarmunda (10.51). In F_1 hybrids the minimum value was found in the cross Uthirenkotta x Kuthiravaly (0.00) and maximum in Panniyur-1 x Karimunda (14.90). The open

Plate 2a. Variability in spike length and setting percentage

Plate 2b. Variability in spikes of different genotypes

Plate 2a

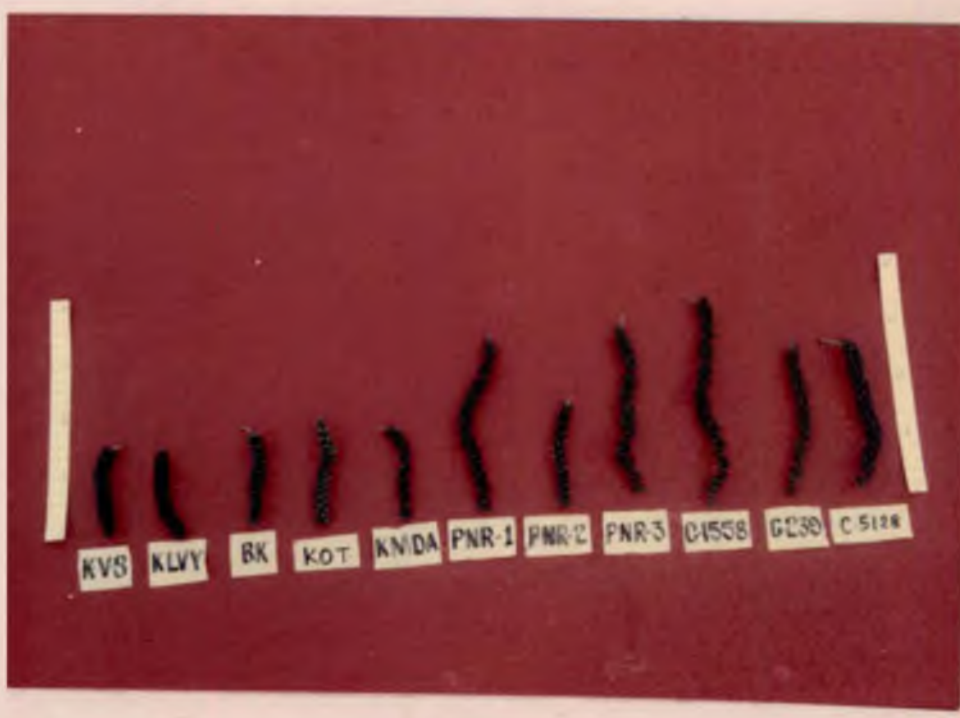

Plate 2b

Plate 3. Variability in leaf and spike characters of parents and F_1 hybrids

Plate 3a. Uthirenkotta x Cheriyakaniakkadan

Plate 3b. Uthirenkotta x Karimunda

Plate 3a

Plate 3b

Plate 3c. Panniyur-1 x Karimunda

Plate 3c

Plate 4. Variability in leaf and spike characters of parent and its open pollinated seed progenies

Plate 4a. Balankotta and its open pollinated seed progeny

Plate 4b. Perumkodi and its open pollinated seed progeny

Plate 4a

Plate 4b

Plate 4c. Kalluvally and its open pollinated seed progenies

Plate 4d. Uthirenkotta and its open pollinated seed progenies

Plate 4c

Plate 4d

Plate 4e. Karimunda and its open pollinated seed progenies

Plate 4f. Kuthiravaly and its open pollinated seed progenies

Plate 4e

Plate 4f

Plate 4g. Karivilanchy and its open pollinated seed progenies

Plate 4h. Cheriyakaniakkadan and its open pollinated seed progenies

Plate 4g

Plate 4h

Plate 4i. Irumaniyan and its open pollinated seed progenies

Plate 4j. Culture-239 and its open pollinated seed progenies

Plate 4i

Plate 4j

pollinated seed progeny of Kottanadan showed the minimum value (0.00) and that of Kalluvally showed the maximum (10.80).

The mean value was maximum in parents (3.83) followed by F_1 hybrids (2.28) and open pollinated seed progenies (1.95).

(c) Yield

The range in values is given in Table 3 and the details of parents, F_1 hybrids and open pollinated seed progenies are given in Appendices 16, 17 and 18. The mean values are furnished in Table 4.

19. Green spike yield per vine

In parents, the minimum yield was found in Irumaniyan (195.00 g) and the maximum yield was obtained for Culture-498 (12200.00 g). In F_1 hybrids, the minimum yield was found in the cross Uthirenkotta x Karimunda (50.00 g) and the maximum in the cross Uthirenkotta x Balankotta (6860.00 g). The open pollinated seed progeny of Culture-341 showed the minimum yield (17.00 g) and that of Karimunda showed the maximum (13300.00 g).

The mean value was found maximum for parents (3512.86 g) followed by F_1 hybrids (1379.05 g) and open pollinated seed progenies (1217.92 g).

20. Green berry yield per vine

In parents, the minimum yield was obtained for Irumaniyan (180.00 g) and the maximum for Culture-498 (10,820.00 g). In F_1 hybrids, the minimum yield was found in the cross Uthirenkotta x Karimunda (42.00 g) and the maximum, in Uthirenkotta x Balankotta (5580.00 g). The open pollinated seed progeny of Culture-341 showed the minimum yield (13.00 g) and that of Karimunda showed the maximum (12,950.00 g).

The mean value was found maximum for parents (2911.20 g) followed by F_1 hybrids (1184.03 g) and open pollinated seed progenies (1065.18 g).

21. Dry berry yield per vine

In parents, the minimum yield was found in Irumaniyan (54.00 g) and the maximum, in Culture-498 (3600.00 g). In F_1 hybrids, the minimum yield was found in the cross Uthirenkotta x Karimunda (16.00 g) and the maximum in Uthirenkotta x Balankotta (1950.00 g). The open pollinated seed progeny of Culture-341 showed the minimum yield (5.00 g) and that of Karimunda showed the maximum (4172.00 g).

The mean value was found maximum for parents (1057.20 g) followed by F_1 hybrids (437.45 g) and open pollinated seed progenies (404.08 g).

II Variability analysis

Coefficient of variation for the different characters of parents, F_1 hybrids and open pollinated seed progenies were estimated and the values are furnished in Table 5.

(A) Vegetative characters

(a) Leaf characters

Coefficient of variation for length of petiole was maximum in open pollinated seed progenies (21.30%) followed by parents (19.10%) and F_1 hybrids (17.44%). For length of leaf also, coefficient of variation was maximum in open pollinated seed progenies (13.55%) followed by parents (12.97%) and F_1 hybrids (10.68%). Breadth of leaf showed a high coefficient of variation in open pollinated seed progenies (43.68%) followed by parents (17.72%) and F_1 hybrids (15.47%). Area of leaf showed a maximum coefficient of variation in open pollinated seed progenies (27.09%) closely folllowed by parents (26.42%) and F_1 hybrids (23.78%).

(b) Stem characters - Orthotrope

Length of internode showed a very high coefficient of variation in open pollinated seed progenies (70.69%) followed by F_1 hybrids (24.39%) and parents (18.70%). For thickness of internode maximum coefficient of variation was found in parents (35.69%)

Table 5 Coefficient of variation for different characters (%)

Sl. No.	Characters	Parents	F_1 hybrids	Open pollinated seed progenies
	Vegetative			
1	Length of petiole	19.10	17.44	21.30
2	Length of leaf	12.97	10.68	13.55
3	Breadth of leaf	17.72	15.47	43.68
4	Area of leaf	26.42	23.78	27.09
5	Length of internode - Orthotrope	18.70	24.39	70.69
6	Thickness of internode - Orthotrope	35.69	33.87	29.17
7	Thickness of node - Orthotrope	25.49	25.79	22.08
8	Length of internode - Plageotrope	22.80	23.33	23.66
9	Thickness of internode - Plageotrope	11.96	12.80	36.63
10	Thickness of node - Plageotrope	19.50	16.17	19.44
11	Angle of plageotrope with the orthotrope	17.13	19.72	19.28
	Productive			
12	Volume of 100 green berries	18.50	20.01	24.65
13	Weight of 100 green berries	17.41	19.22	23.62
14	Weight of 100 dry berries	20.09	20.56	23.68
15	Number of spike per vine	79.61	126.84	114.93
16	Length of spike	25.52	24.80	29.73
17	No. of developed berries per spike	37.63	48.98	42.45
18	No. of underdeveloped berries per spike	70.26	115.12	91.12
19	Green spike yield per vine	82.56	115.81	130.81
20	Green berry yield per vine	83.47	116.17	134.16
21	Dry berry yield per vine	82.08	113.45	126.69

followed by F_1 hybrids (33.87%) and open pollinated seed progenies (29.17%). Thickness of node showed same coefficient of variation in parents (25.49%) and F_1 hybrids (25.79%). For open pollinated seed progenies it was 22.08%.

(c) Stem character - Plageotrope

Coefficient of variation for length of internode was almost same in open pollinated seed progenies (23.66%), F_1 hybrids (23.33%) and parents (22.80%). For thickness of internode, coefficient of variation was high in open pollinated seed progenies (36.63%) followed by F_1 hybrids (12.80%) and parents (11.96%). For thickness of node, coefficient of variation was maximum in parents (19.50%) followed by open pollinated seed progenies (19.44%) and F_1 hybrids (16.17%). Coefficient of variation for angle of plageotrope with the orthotrope was maximum for F_1 hybrids (19.72%) followed by open pollinated seed progenies (19.28%) and parents (17.13%).

(B) Productive characters

(a) Berry characters

For volume of 100 green berries, coefficient of variation was maximum in open pollinated seed progenies (24.65%) followed by F_1 hybrids (20.01%) and parents (18.50%). Coefficient of variation for weight of 100 green berries was maximum in open pollinated seed progenies (23.62%) followed by F_1 hybrids (19.22%) and parents (17.41%). For weight of 100 dry berries, open pollinated seed progenies showed the maximum coefficient of variation (23.68%) followed by F_1 hybrids (20.56%) and parents (20.09%).

(b) Spike characters

For number of spikes per vine, F_1 hybrids showed the maximum coefficient of variation (126.84%) followed by open pollinated seed progenies (114.93%) and parents (79.61%). Coefficient of variation for length of spike was maximum in open pollinated seed progenies (29.73%) followed by parents (25.52%) and F_1 hybrids (24.80%). For number of developed berries per spike, coefficient of variation was maximum in F_1 hybrids (48.98%) followed by open pollinated seed progenies (42.45%) and parents (37.63%). Number of underdeveloped berries per spike showed maximum coefficient of variation in F_1 hybrids (115.12%) followed by open pollinated seed progenies (91.12%) and parents (70.26%).

(c) Yield

Green spike yield per vine showed maximum coefficient of variation in open pollinated seed progenies (130.81%) followed by F_1 hybrids (115.81%) and parents (82.56%). For green berry yield per vine coefficient of variation was maximum in open pollinated seed progenies (134.16%) followed by F_1 hybrids (116.17%) and parents (83.47%). For dry berry yield per vine, coefficient of variation was maximum in open pollinated seed progenies (126.69%) followed by F_1 hybrids (113.45%) and parents (82.08%).

III Correlation studies

Correlation coefficients between dry berry yield and the various vegetative and productive characters as well as the inter-correlation among the characters were worked out and the results are presented in Tables 6 and 7.

(A) Correlation among yield and its components

Green berry yield per vine showed the highest positive and significant correlation with dry berry yield (0.991) closely followed by green spike yield per vine (0.990) and number of spikes per vine (0.937). The characters such as length of spike (0.305), number of developed berries per spike (0.335), number of underdeveloped berries per spike (0.218), thickness of internode in orthotrope (0.366), thickness of node in orthotrope (0.310) and angle of plageotrope with orthotrope (0.226) showed significant positive correlations with dry berry yield. Weight of 100 green berries (0.051), volume of 100 green berries (0.048), length of internode in orthotrope (0.050), length of leaf (0.033), length of internode in plageotrope (0.165), thickness of node in plageotrope (0.017), length of petiole (-0.012), breadth of leaf (-0.054), area

Table 6 Correlation between dry berry yield per vine and the various vegetative and productive characters

Sl. No.	Character	Correlation coefficient with yield
	<u>Vegetative</u>	
1	Length of petiole	-0.012
2	Length of leaf	0.033
3	Breadth of leaf	-0.054
4	Area of leaf	-0.029
5	Length of internode - Orthotrope	0.050
6	Thickness of internode - Orthotrope	0.366**
7	Thickness of node - Orthotrope	0.310**
8	Length of internode - Plageotrope	0.165
9	Thickness of internode - Plageotrope	-0.045
10	Thickness of node - Plageotrope	0.017
11	Angle of plageotrope with orthotrope	0.226*
	<u>Productive</u>	
12	Volume of 100 green berries	0.048
13	Weight of 100 green berries	0.051
14	Weight of 100 dry berries	-0.023
15	Number of spikes per vine	0.937**
16	Length of spike	0.305**
17	Number of developed berries per spike	0.335**
18	No. of underdeveloped berries per spike	0.218*
19	Green spike yield per vine	0.990**
20	Green berry yield per vine	0.991**

** Significant at $P < 0.01$
* Significant at $P < 0.05$

of leaf (-0.029), thickness of internode in plageotrope (-0.045) and weight of 100 dry berries (-0.023) did not have significant correlation with dry berry yield.

(B) Intercorrelation among yield components

1. Volume of 100 green berries

Highest positive and significant correlation was found between volume of 100 green berries and weight of 100 green berries (0.982). It also showed a significant positive correlation with length of leaf (0.242) and length of internode of plageotrope (0.219). With number of underdeveloped berries per spike, it showed a significant but negative correlation (-0.215). The correlation of this character with green spike yield per vine (0.046), green berry yield per vine (0.052), length of spike (0.075), length of internode (0.098), thickness of internode (0.069) and thickness of node (0.023) in orthotrope, number of spikes per vine (-0.015), number of developed berries per spike and angle of plageotrope with orthotrope (-0.063), were not significant.

2. Weight of 100 green berries

It showed a positive significant correlation with length of leaf (0.229) and length of internode in plageotrope (0.212) and a negative significant correlation with number of underdeveloped

Table 7 Inter correlation matrix of dry berry yield per vine and plant characters

Characters	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}
Y	X	0.048	0.051	0.990**	0.991**	0.937**	0.305**	0.335**	0.218*	0.033	0.050	0.366**	0.310**	0.165	0.226*
X_1			0.982**	0.046	0.052	-0.015	0.075	-0.052	-0.215*	0.242*	0.098	0.069	0.023	0.219*	-0.063
X_2			X	0.046	0.051	-0.010	0.076	-0.057	-0.209*	0.229*	0.121	0.064	0.033	0.212*	-0.066
X_3				X	0.998**	0.938**	0.317**	0.330**	0.234*	0.046	0.049	0.377**	0.332**	0.166	0.220*
X_4					X	0.931**	0.309**	0.331**	0.239*	0.045	0.050	0.386**	0.331**	0.165	0.228*
X_5						X	0.227*	0.213*	0.183	-0.019	0.041	0.326**	0.290**	0.127	0.192
X_6							X	0.493**	0.278**	0.370**	0.068	0.301**	0.273**	0.269**	0.030
X_7								X	0.254*	0.141	0.006	0.137	0.152	0.092	0.101
X_8									X	0.053	-0.016	0.115	0.107	0.046	0.084
X_9										X	0.125	0.203*	0.178	0.350**	-0.042
X_{10}											X	0.038	0.036	0.036	-0.023
X_{11}												X	0.749**	0.073	0.205*
X_{12}													X	0.055	0.146
X_{13}														X	0.029
X_{14}															X

*Significant at $P < 0.05$ **Significant at $P < 0.01$

Y - Dry berry yield per vine

X_1 - Volume of 100 green berries

X_2 - Weight of 100 green berries

X_3 - Green spike yield per vine

X_4 - Green berry yield per vine

X_5 - Number of spikes per vine

X_6 - Length of spike

X_7 - Number of developed berries per spike

X_8 - Number of underdeveloped berries per spike

X_9 - Length of leaf

X_{10} - Length of internode - Orthotrope

X_{11} - Thickness of internode - Orthotrope

X_{12} - Thickness of node - Orthotrope

X_{13} - Length of internode - Plageotrope

X_{14} - Angle of Plageotrope with the Orthotrope berries per spike (-0.209). The correlation with green spike yield per vine (0.046), green berry yield (0.051), length of spike (0.076), length of internode (0.121), thickness of internode (0.064) and thickness of node (0.033) of orthotrope, number of spikes per vine (-0.010), number of developed berries per spike (-0.057) and angle of plageotrope with orthotrope (-0.066) were not significant.

3. Green spike yield per vine

It showed a highly significant positive correlation with green berry yield per vine (0.998), number of spikes per vine (0.938), length of spike (0.317), number of developed berries per spike (0.330), thickness of internode (0.377) and node (0.332) of orthotrope, number of underdeveloped berries per spike (0.234) and angle of plageotrope with orthotrope (0.220). It did not have significant correlation with volume and weight of 100 green berries, length of leaf, length of internode of orthotrope and length of internode of plageotrope.

4. Green berry yield per vine

As green spike yield per vine, green berry yield per vine also showed a highly significant positive correlation with number of spikes per vine (0.931), length of spike (0.309), number of developed berries per spike (0.331), thickness of internode (0.386) and node (0.331) of orthotrope, number of underdeveloped berries per spike (0.239) and angle of plageotrope with orthotrope (0.226). However, positive correlation with volume (0.052) and weight (0.051) of 100 green berries, length of leaf (0.045), length of internode of orthotrope (0.050) and length of internode of plageotrope (0.165) were not significant.

5. Number of spikes per vine

Highly significant and positive correlation was observed with green spike yield per vine (0.938), green berry yield per vine (0.931), length of spike (0.227), thickness of internode (0.326) and node (0.290) of orthotrope and number of developed berries per spike (0.213). With number of underdeveloped berries per spike (0.183), length of internode of orthotrope (0.041), length of internode of plageotrope (0.127), angle of plageotrope with orthotrope (0.192) and length of leaf (-0.019), its correlations were not significant.

6. Length of spike

The correlation between length of spike and characters such as green spike yield per vine (0.317), green berry yield per vine (0.309), number of spikes per vine (0.227), number of developed berries per spike (0.493), number of underdeveloped berries per spike (0.278), length of leaf (0.370), thickness of internode (0.301) and node (0.273) of orthotrope and length of internode in plageotrope (0.269) were found positive and highly significant. With length of internode of orthotrope (0.068) and angle of plageotrope with orthotrope (0.030) it showed a positive but non-significant correlation.

7. Number of developed berries per spike

Green spike yield per vine (0.330), green berry yield per vine (0.331), number of spikes per vine (0.213), length of spike (0.493) and number of underdeveloped berries per spike (0.254) showed significant positive correlation with number of developed berries per spike. All other characters such as length of leaf (0.141), length of internode (0.006), thickness of internode (0.137) and node (0.152) of orthotrope, length of internode of plageotrope (0.092), angle of plageotrope with orthotrope (0.101), volume and weight of 100 green berries (-0.052 and -0.057) showed a non-significant correlation with this character.

8. Number of underdeveloped berries per spike

This character did not have significant correlation with any of the other characters considered except those mentioned earlier.

9. Length of leaf

Significant and positive correlation was found with thickness of internode of orthotrope (0.203) and length of internode of plageotrope (0.350). With length of internode (0.125) and thickness of node (0.178) of orthotrope also a positive correlation was found but not significant. Angle of plageotrope with orthotrope showed a non-significant and negative correlation (-0.042).

10. Length of internode of orthotrope

This character showed a non-significant positive correlation with thickness of internode (0.038) and node (0.036) of orthotrope and length of internode of plageotrope (0.036). Angle of plageotrope with orthotrope showed a negative but non-significant correlation with the character (-0.023).

11. Thickness of internode of orthotrope

Highly significant and positive correlation was observed with thickness of node of orthotrope (0.749) and angle of plageotrope with orthotrope (0.205). With length of internode of plageotrope, the correlation was not significant (0.073).

12. Thickness of node of orthotrope

This character also did not have any significant correlation with any of the characters considered except those mentioned earlier.

13. Length of internode of plageotrope

Significant positive correlation was observed with characters such as volume (0.219) and weight (0.212) of 100 green berries, length of spike (0.269) and length of leaf (0.350). With angle of plageotrope with orthotrope the correlation (0.029) was not significant.

14. Angle of plageotrope with orthotrope

It showed significant positive correlation with green spike yield per vine (0.220), green berry yield per vine (0.226) and thickness of internode of orthotrope (0.205).

IV Path coefficient analysis

Path coefficient analysis was done with 14 characters inorder to partition the total association of these characters with yield into direct and indirect effects (Table 8).

The path analysis revealed that green berry yield per vine exerted the maximum positive direct effect (1.029) followed by number of spikes per vine (0.128). The indirect effect of green berry yield per vine through number of spikes per vine was also positive and significant (0.119) but the total effect was reduced to 0.991 as it has a negative indirect effect through green spike yield per vine (-0.157). The indirect effects through the rest of the characters were negligibly low. The total effect of number of spikes per vine was very high (0.937) due to its high positive indirect effect through green berry yield per vine (0.958). This

Table 8 Direct and indirect effects of component characters on yield

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	Correlation with yield
X_1	-0.078	0.079	-0.007	0.054	-0.002	0.001	-0.001	0.005	-0.002	-0.000	-0.000	-0.000	0.001	-0.000	0.048
X_2	-0.076	0.081	-0.007	0.053	-0.001	0.001	-0.001	0.004	-0.001	-0.000	-0.000	-0.001	0.001	-0.000	0.051
X_3	-0.004	0.004	-0.158	1.028	0.120	0.002	0.008	-0.005	-0.000	-0.000	-0.002	-0.005	0.001	0.001	0.990
X_4	-0.004	0.004	-0.157	1.029	0.119	0.002	0.008	-0.005	-0.000	-0.000	-0.002	-0.005	0.001	0.001	0.991
X_5	0.001	-0.001	-0.148	0.958	0.128	0.002	0.005	-0.004	0.000	-0.000	-0.002	-0.004	0.001	0.001	0.937
X_6	-0.006	0.006	-0.050	0.318	0.029	0.008	0.012	-0.006	-0.002	-0.000	-0.002	-0.004	0.001	0.000	0.305
X_7	0.004	-0.005	-0.052	0.341	0.027	0.004	0.025	-0.005	-0.001	-0.000	-0.001	-0.002	0.000	0.001	0.335
X_8	0.017	-0.017	-0.037	0.246	0.023	0.002	0.006	-0.021	-0.000	0.000	-0.001	-0.002	0.000	0.001	0.218
X_9	-0.019	0.018	-0.007	0.047	-0.002	0.003	0.003	-0.001	-0.007	-0.000	-0.001	-0.003	0.002	-0.000	0.033
X_{10}	-0.008	0.010	-0.008	0.051	0.005	0.001	0.000	0.000	-0.001	-0.001	-0.000	-0.001	0.000	-0.000	0.050
X_{11}	-0.005	0.005	-0.059	0.397	0.042	0.002	0.003	-0.002	-0.001	-0.000	-0.006	-0.011	0.000	0.001	0.366
X_{12}	-0.002	0.003	-0.052	0.341	0.037	0.002	0.004	-0.002	-0.001	-0.000	-0.004	-0.015	0.000	0.001	0.310
X_{13}	-0.017	0.017	-0.026	0.170	0.016	0.002	0.002	-0.001	-0.002	-0.000	-0.000	-0.001	0.005	0.000	0.165
X_{14}	0.005	-0.005	-0.035	0.233	0.025	0.000	0.002	-0.002	0.000	-0.000	-0.001	-0.002	0.000	0.007	0.226

Residual effect = 0.119

X_1 - Volume of 100 green berries
X_2 - Weight of 100 green berries
X_3 - Green spike yield per vine
X_4 - Green berry yield per vine
X_5 - Number of spikes per vine
X_6 - Length of spike
X_7 - Number of developed berries per spike
X_8 - Number of underdeveloped berries per spike
X_9 - Length of leaf
X_{10} - Length of internode - Orthotrope
X_{11} - Thickness of internode - Orthotrope
X_{12} - Thickness of node - Orthotrope
X_{13} - Length of internode - Plageotrope
X_{14} - Angle of Plageotrope with the Orthotrope

character also had a negative indirect effect through green spike yield per vine (-0.148). The direct effects through all other characters were negligibly low.

Volume of 100 green berries had a negative direct effect (-0.078) but the indirect effects through weight of 100 green berries (0.079) and through green berry yield (0.054) were positive making the total effect, positive.

Direct effect of weight of 100 green berries (0.081) and its indirect effect through green berry yield (0.053) were positive but its negative indirect effect through volume of 100 green berries (-0.076) reduced the total effect. The indirect effects through all other characters were negligibly low.

The high correlation of green spike yield per vine on yield was due to its high positive indirect effect through green berry yield per vine (1.028) and through number of spikes per vine (0.120) as its direct effect was negative (-0.158). Indirect effects through all other characters were negligibly low.

Length of spike had a low direct effect though positive (0.008). Its significant correlation with yield was mainly due to the high indirect effects through green berry yield per vine (0.318), number of spikes per vine (0.029) and number of developed berries per vine (0.012). It had a negative indirect effect through green spike yield per vine (-0.050).

Number of developed berries per spike had a positive direct effect (0.025). Its indirect effects through green berry yield per vine (0.341) and number of spikes per vine (0.027) were also high. The indirect effect through green spike yield per vine was negative (-0.052). The indirect effects through the rest of the characters were negligibly low.

Number of under developed berries per spike had a low negative direct effect (-0.021). It had positive indirect effects through green berry yield per vine (0.246) and number of spikes per vine (0.023) and negative indirect effects through green spike yield per vine (-0.037). Indirect effects through the rest of the characters were low.

Length of leaf had a negative direct effect (-0.007) which was very low. The indirect effects through all the characters except green berry yield per vine (0.047) were also very low.

Direct effect of length of internode of orthotrope was negative and very low (-0.001). The indirect effects were also very low except that through green berry yield per vine (0.051).

Thickness of internode of orthotrope had a low negative direct effect (-0.006). But its indirect effect through green berry yield per vine was high and positive (0.397). The indirect effect through number of spikes per vine was positive (0.042) and that through green spike yield per vine was negative (-0.059).

Thickness of node of orthotrope had a negative direct effect (-0.015). The indirect effects through green berry yield per vine (0.341) and number of spikes per vine (0.037) were positive and that through green spike yield per vine was negative (-0.052).

Length of plageotrope internode had a positive but low direct effect (0.005). It had positive indirect effects through green berry yield per vine (0.170) and number of spikes per vine (0.016) and a negative indirect effect through green spike yield per vine (-0.026).

Angle of plageotrope with orthotrope had a positive but low direct effect (0.007). Indirect effects through green berry yield per vine (0.233) and number of spike per vine (0.025) were positive and that through green spike yield per vine was negative (-0.035). All other indirect effects were negligible.

The 14 component characters alone and in combination contributed 98 per cent of the variability in dry berry yield per vine (R^2 = 0.986). The residual effect (0.119) obtained was low.

V Heritability

Heritability in the narrow sense was estimated for the 21 quantitative characters for F_1 hybrids and open pollinated seed progenies (Table 9).

(A) Vegetative character

(a) Leaf characters

Length of petiole showed higher heritability in open pollinated seed progenies (34.09%) than in F_1 hybrids (22.11%). Length of leaf showed a very high heritability in F_1 hybrids (70.41%) and very low heritability in open pollinated seed progenies (4.60%). Heritability of breadth of leaf was found low both in F_1 hybrids (3.10%) and in open pollinated seed progenies (8.99%). Area of leaf showed a slightly higher heritability in F_1 hybrids (24.65%) than in open pollinated seed progenies (17.04%).

(b) Stem characters - Orthotrope

High heritability estimates were obtained for length of internode (76.03%) and thickness of internode (92.41%) in F_1 hybrids whereas in open pollinated seed progenies, both these characters were found having negative values of heritability (-15.32% and -4.95% respectively). Thickness of node had a low heritability both in F_1 hybrids (9.14%) and open pollinated seed progenies (10.34%).

(c) Stem characters - Plageotrope

Length of internode (15.42%) and thickness of internode (40.25%) showed moderate heritability in open pollinated seed progenies but they were having negative values of heritability in F_1 hybrids (-24.69% and -77.67% respectively). Thickness of node

Table 9 Heritability of different characters in F_1 hybrids and open pollinated seed progenies

Sl. No.	Character	F_1 hybrids (%)	Open pollinated seed progenies (%)
	Vegetative		
1	Length of petiole	22.11	34.09
2	Length of leaf	70.41	4.60
3	Breadth of leaf	3.10	8.99
4	Area of leaf	24.65	17.04
5	Length of internode - Orthotrope	76.03	-15.32
6	Thickness of internode - Orthotrope	92.41	-4.95
7	Thickness of node - Orthotrope	9.14	10.34
8	Length of internode - Plageotrope	-24.69	15.42
9	Thickness of internode - Plageotrope	-77.67	40.25
10	Thickness of node - Plageotrope	33.82	15.09
11	Angle of plageotrope with orthotrope	-22.62	25.45
	Productive		
12	Volume of 100 green berries	85.72	35.82
13	Weight of 100 green berries	62.09	30.51
14	Weight of 100 dry berries	-5.15	34.76
15	Number of spikes per vine	-13.52	20.65
16	Length of spike	-17.96	5.27
17	Number of developed berries per spike	-6.97	-15.62
18	Number of underdeveloped berries per spike	77.37	61.78
19	Green spike yield per vine	-35.08	31.83
20	Green berry yield per vine	-25.54	33.34
21	Dry berry yield per vine	-17.87	27.06

showed higher heritability estimate (33.82%) than that of open pollinated seed progenies (15.09%). Angle of plageotrope with orthotrope showed a negative value for heritability (-22.62%) in F_1 hybrids whereas it had moderate heritability in open pollinated seed progenies (25.45%).

(B) Productive characters

(a) Berry characters

High heritability estimates were obtained for volume of 100 green berries (85.72%) and weight of 100 green berries (62.09%) in F_1 hybrids but they were found moderate (35.82% and 30.51% respectively) in open pollinated seed progenies. Weight of 100 dry berries showed a negative value for heritability (-5.15%) in F_1 hybrids whereas it showed a moderate heritability estimate (34.76%) in open pollinated seed progenies.

(b) Spike characters

Number of spikes per vine showed a moderate heritability estimate in open pollinated seed progenies (20.65%) whereas it showed a negative value for heritability (-13.52%) in F_1 hybrids. Length of spike had a low heritability in open pollinated seed progenies (5.27%) and in F_1 hybrids, it was negative (-17.96%). Number of developed berries per spike showed negative values in both F_1 hybrids and open pollinated seed progenies (-6.97% and -15.62%

respectively) whereas number of underdeveloped berries per spike showed high heritability estimates in both F_1 hybrids (77.37%) and open pollinated seed progenies (61.78%).

(c) Yield

Moderate heritability estimates were obtained for green spike yield per vine (31.83%), green berry yield per vine (33.34%) and dry berry yield per vine (27.06%) in open pollinated seed progenies whereas in F_1 hybrids all these three characters showed negative values for heritability (-35.08%, -25.54% and -17.87% respectively).

VI Heterosis

Heterosis was worked out over the better parent (heterobeltiosis), mid parental value and standard variety for the characters dry berry yield per vine, number of spikes per vine, length of spike and number of developed berries per spike for the 45 F_1 hybrids belonging to 8 different parental combinations.

1 Dry berry yield per vine

The results are given in Table 10. The minimum heterobeltiosis was exhibited by one of the 21 hybrids of the cross Uthirenkotta x Karimunda (-98.68%) and it was maximum in the cross Uthirenkotta x Balankotta (94.03%). The hybrid of the cross Karivilanchy x Cheriyakaniakkadan (79.17%) and that of Uthirenkotta x Cheriyakaniakkadan (61.62%) also showed high heterobeltiosis.

Table 10 Heterosis for dry berry yield per vine

Sl. No.	Parental combinations	No. of hybrids	Per cent heterosis over					
			Better parent		Mid parent		Standard variety	
			Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
1	Uthirenkotta x Karimunda	21	-98.68	-25.00	-96.99	50.38	-98.68	-25.00
2	Uthirenkotta x Balankotta	3	-67.16	94.03	-40.81	249.78	-72.95	59.85
3	Uthirenkotta x Cheriyakaniakkadan	1	61.52		167.09		-30.49	
4	Uthirenkotta x Kottanadan	4	-96.26	-93.80	-93.80	-88.90	-97.13	-95.25
5	Uthirenkotta x Kuthiravaly	2	-97.55	-92.34	-95.47	-92.33	-97.38	-91.80
6	Karivilanchy x Cheriyakaniakkadan	1	79.17		131.65		40.98	
7	Panniyur-1 x Kuthirvaly	1	-20.79		-9.34		13.36	
8	Panniyur-1 x Karimunda	12	-97.42	-31.84	-96.97	-19.76	-96.31	-2.46

Heterosis over mid parental value was minimum in the cross Uthirenkotta x Karimunda (-96.99%) and maximum in Uthirenkotta x Balankotta (249.78%). The hybrid of Uthirenkotta x Cheriyakaniakkadan (167.09%) and that of Karivilanchy x Cheriyakaniakkadan (131.65%) also showed high heterosis over the mid parental value. Heterosis over standard variety ranged from -98.68% in the cross Uthirenkotta x Karimunda to 59.85% in Uthirenkotta x Balankotta. The hybrid of the cross Karivilanchy x Cheriyakaniakkadan had high heterosis over standard variety also (40.98%).

2 Number of spike per vine

The results are given in Table 11. The hybrid belonging to the cross Uthirenkotta x Karimunda showed the minimum heterobeltiosis (-99.81%), heterosis over mid parental value (-96.97%) and heterosis over standard variety (-99.81%) and that of Uthirenkotta x Balankotta showed the maximum heterobeltiosis (206.06%), heterosis over mid parental value (474.16%) and over standard variety (106.70%).

3 Length of spike

The results are given in Table 12. The hybrids belonging to the cross Panniyur-1 x Karimunda showed the minimum heterobeltiosis (-58.49%), heterosis over mid parental value (-45.68%) and over standard variety (-21.34%). Hybrid belonging to the cross

Table 11 Heterosis for number of spikes per vine

Sl. No.	Parental combinations	No. of hybrids	Per cent heterosis over					
			Better parent		Mid parent		Standard variety	
			Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
1	Uthirenkotta x Karimunda	21	-99.81	14.33	-96.97	118.88	-99.81	14.33
2	Uthirenkotta x Balankotta	3	-66.80	206.06	-37.73	474.16	-77.58	106.70
3	Uthirenkotta x Cheriyakaniakkadan	1	-78.50		-58.32		-69.95	
4	Uthirenkotta x Kottanadan	4	-97.08	-96.41	-94.33	-93.05	-95.91	-94.98
5	Uthirenkotta x Kuthiravaly	2	-97.97	-84.41	-96.18	-70.61	-95.81	-88.56
6	Karivilanchy x Cheriyakaniakkadan	1	-24.10		-11.35		6.05	
7	Panniyur-1 x Kuthiravaly	1	13.56		18.75		-16.65	
8	Panniyur-1 x Karimunda	12	-97.58	-22.79	-97.10	-7.52	-97.10	-7.52

Table 12 Heterosis for length of spike

Sl. No.	Parental combinations	No. of hybrids	Per cent heterosis over					
			Better parent		Mid parent		Standard variety	
			Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
1	Uthirenkotta x Karimunda	21	-44.29	11.01	-33.75	41.79	-18.28	74.88
2	Uthirenkotta x Balankotta	3	-8.44	31.59	0.80	44.87	34.32	93.04
3	Uthirenkotta x Cheriyakaniakkadan	1	-3.86		13.26		41.94	
4	Uthirenkotta x Kottanadan	4	-26.37	-24.92	-17.99	-16.38	8.02	10.14
5	Uthirenkotta x Kuthiravaly	2	-32.64	-9.81	-19.35	7.99	-1.18	32.31
6	Karivilanchy x Cheriyakaniakkadan	1	66.59		82.35		70.52	
7	Panniyur-1 x Kuthiravaly	1	3.73		36.52		96.58	
8	Panniyur-1 x Karimunda	12	-58.49	-3.24	-45.68	26.63	-21.34	83.37

Karivilanchy x Cheriyakaniakkadan showed the maximum hetero-beltiosis (66.59%) as well as heterosis over mid parental value (82.35%) whereas heterosis over standard variety was maximum in the cross Panniyur-1 x Kuthiravaly (96.58%). Hybrids of Uthirenkotta x Balankotta and Uthirenkotta x Karimunda also showed good heterosis over mid parental value (44.87%, 41.79% respectively) and over standard variety (93.04%, 74.88% respectively).

4 Number of developed berries per spike

The results are given in Table 13. Hybrid belonging to the cross Panniyur-1 x Karimunda showed minimum heterobeltiosis (-90.80%) and heterosis over standard variety (-72.37%). Heterosis over mid parental value was minimum for the hybrid belonging to the cross Uthirenkotta x Karimunda (-88.29%). Maximum hetero-beltiosis was exhibited by the hybrid belonging to the cross Uthirenkotta x Karimunda (75.94%) where as heterosis over mid parent (133.91%) and over standard variety (128.20%) were maximum in the cross Uthirenkotta x Balankotta. Hybrid belonging to the cross Uthirenkotta x Karimunda showed good heterosis over mid parental value (115.67%) and that belonging to the cross Panniyur-1 x Karimunda showed good heterosis over standard variety (112.41%).

Table 13 Heterosis for number of developed berries per spike

Sl. No.	Parental combination	No. of hybrids	Per cent heterosis over					
			Better parent		Mid parent		Standard variety	
			Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
1	Uthirenkotta x Karimunda	21	-56.77	75.94	-88.29	115.67	-56.77	75.94
2	Uthirenkotta x Balankotta	3	-47.01	72.93	-28.32	133.91	-30.08	128.20
3	Uthirenkotta x Cheriyakaniakkadan	1	33.57		90.82		110.90	
4	Uthirenkotta x Kottanadan	4	-41.05	13.00	-21.69	50.22	-26.32	41.35
5	Uthirenkotta x Kuthiravaly	2	-54.29	-23.10	-35.01	9.35	-28.95	19.55
6	Karivilanchy x Cheriyakaniakkadan	1	-25.24		-9.51		18.05	
7	Panniyur-1 x Kuthiravaly	1	-59.47		-46.07		22.93	
8	Panniyur-1 x Karimunda	12	-90.80	-29.29	-86.20	-1.60	-72.37	112.41

Quality attributes

Oleoresin crude piperin and volatile oil contents of selected 13 genotypes i.e. two F_1 hybrids and eleven open pollinated seed progenies, were estimated and the coefficient of variation was worked out for each of the characters. The results are given in Table 14.

Variability in respect of quality characters was highest for volatile oil content (54.6%), the contents ranging from 0.40 to 3.6%. The lowest variability was observed in case of crude piperin content (17.6%). Culture 4307 was characterized by the highest contents of oleoresin and volatile oil but its crude piperin content was the lowest. Open pollinated seed progenies exhibited greater variability than F_1 hybrids in respect of quality attributes.

Table 14 Variability in quality attributes of berries on dry weight basis (%)

Genotype No.	Pedigree	Oleoresin	Crude piperin	Volatile oil
141	Balankotta II	10.8	6.1	2.0
239	Perumkodi	9.2	4.2	1.2
331	Uthirenkotta x Cheriyakaniakkadan	7.6	4.6	0.4
341	Karimunda x Panniyur-1	8.0	4.2	1.6
1558	Kalluvally	8.4	5.0	0.8
4180	Arakkulam munda	13.2	5.6	1.2
4220	Panniyur-1	10.8	4.1	1.0
4307	Vally	16.0	3.3	3.6
4848	Uthirenkotta	10.4	4.0	1.0
4880	Uthirenkotta	10.8	3.9	2.4
5035	Irumaniyan	14.0	5.9	1.2
5128	Cheriyakaniakkadan	11.8	4.2	1.2
5293	Karivilanchy	13.2	4.4	1.2
Mean		11.1	4.6	1.4
CV(%)		21.7	17.6	54.6

DISCUSSION

DISCUSSION

Piper nigrum is one of the oldest and most important spice crops. Being a native of Kerala, the state is a rich gene pool of the plant. More than 40 different types are being cultivated in Kerala which display wide spectrum of variations with respect to important economic characters and quality attributes. But many fundamental informations about the genetic behaviour of the crop are still unavailable which retards the improvement works in this crop.

The choice of the most suitable breeding method for the rational improvement of yield and its components in any crop largely depends on the available genetic variability, association between characters, heritability etc. Plant breeding in its true sense relates to the efficient management and utilisation of variability. It is the pre-requisite, before embarking on any plant breeding programme, to survey and assess the genetic variability present in a population in respect of various yield attributes, genetic association between various characters, heritability of characters, the type of gene action operating in the expression of these characters etc. Knowledge of these parameters helps the breeder for direct selection and in choosing the appropriate parent material for the most suitable breeding methodology. The present investigation aims at obtaining some of these basic genetic information in black pepper. The results obtained from the present study are discussed below.

In pepper, ovate leaves with round base was found most common. Similarly purple leaf sheath was found predominant to green colour. Ibrahim et al. (1986a) also reported similar results. Wide variation was observed with respect to all the vegetative and productive characters in parents, F_1 hybrids as well as in open pollinated seed progenies (Plates 1, 2, 3 and 4). The investigations of Nambiar et al. (1978), Kanakamany (1982), Chandy et al. (1984), Ibrahim et al. (1986b), Chandy and Pillai (1979) and Pillai et al. (1977) in pepper have shown that a wide range of variations were present for most of the characters considered in this crop.

I Variability studies

Variability is the basis of any crop improvement programme. Wide genetic variability in the base population provide the ways for crop improvement through systematic breeding procedures. It is a pre-requisite in the improvement of any cultivable crop, to precisely assess the nature of variability occurring in a base population and the factors influensing it.

To make a more valid comparison, coefficient of variation was computed which is free from the unit of measurement.

For all the leaf characters viz., length of petiole, length of leaf, breadth of leaf and area of leaf, open pollinated seed progenies showed a higher coefficient of variation followed by parents and then F_1 hybrids which indicated that variability for these leaf characters was higher in open pollinated seed progenies than parents which in turn was higher than F_1 hybrids. Length of internode of orthotrope showed higher variability in open pollinated seed progenies than in F_1 hybrids which in turn was higher than parents whereas, thickness of internode and node showed highest variability in parents followed by F_1 hybrids and open pollinated seed progenies. In the case of plageotropes, variability for length of internode was same in parents, hybrids and progenies whereas thickness of internode showed highest variability in progenies and thickness of node showed highest variability in parents. Angle of plageotrope with orthotrope showed highest variability in hybrids. In the case of productive characters, open pollinated seed progenies showed highest variability for volume of 100 green berries, weight of 100 green berries, weight of 100 dry berries, length of spike, green spike yield per vine, green berry yield per vine and dry berry yield per vine. For the rest of the productive characters viz., number of spikes per vine, number of developed berries per spike and number of underdeveloped berries per spike, F_1 hybrids showed highest variability.

In general the characters number of spikes per vine, number of developed berries per spike, number of underdeveloped berries per spike, green spike yield per vine, green berry yield per vine and dry berry yield per vine showed very high coefficient of variations in F_1 hybrids and open pollinated seed progenies, which indicated the wide variations for these characters in pepper. From a breeder's point of view, there is great significance for this since variability is the most essential pre-requisite in any breeding programme.

II Correlation studies

Yield is a complex quantitative character and many other metric traits which are inter related influence it. A selection applied on one trait may show a correlated response on other characters also, since these component characters show intercorrelation. Therefore, estimation of correlation between yield and yield components and also among yield components themselves form a pre-requisite for making effective selection especially when two or more characters are simultaneously considered in the selection programme.

In the present study, green berry yield per vine showed the highest positive and significant correlation with dry berry yield closely followed by green spike yield per vine and number of spikes per vine. Ibrahim et al. (1985c) also reported high positive correlation of spike number with yield. The significant positive correlations of length of spike and number of developed berries per spike were also in confirmity with the findings of Ibrahim et al. (1985c).

Data on interrelationships among the yield components give a more reliable information rather than a knowledge of association between yield and its components. The significant positive correlation of number of underdeveloped berries per spike with yield was due to the significant inter correlation of number of underdeveloped berries with spike length and also with number of developed berries per spike. Similarly thickness of node and internode of orthotrope showed high correlation with yield as their inter correlation with green spike yield, green berry yield, number of spikes per vine and length of spike were significant. This high inter correlation may be due to the increased transportation of food materials, as the girth increases.

Angle of plageotrope with orthotrope showed a significant positive correlation with yield. This agrees with the reports of Chandy and Pillai (1979). Positive but nonsignificant correlation was found between dry berry yield and length of internode of orthotrope and plageotrope. But this is not in agreement with the findings of Chandy et al. (1984). The positive correlation observed in this study may be due to physiological reasons because as internodal length increases, the leaves will be well spread and light interception will be more.

Volume and weight of 100 green berries showed positive correlation with yield as bold and heavy berries increases the total berry weight. Length of leaf also showed positive correlation with yield.

In the present study, the inter-relations among green spike yield per vine, green berry yield per vine, number of spikes per vine, length of spike, number of developed berries per spike, thickness of node and internode of orthotrope were high and positive suggesting the possibility of simultaneous improvement of these characters in a selection programme involving any one of these traits.

Since the above characters showed high magnitude of correlation with yield and inter-relationships among themselves, selection can perhaps be based on these characters for improving yield in pepper.

III Path analysis

Path analysis suggested by Dewey and Lu (1959) provides a method for separating the correlation coefficient into direct and indirect effects and it measures the relative importance of the component characters in influencing yield. Many workers utilised this method to measure the degree of influence of the component characters on yield. These contributing characters exhibit different degree of association among themselves. A change in one character alters its relationship with other associated characters and finally will reflect on yield. To determine the relative contribution of different characters towards yield and to measure the co-ordinated relationship existing among these traits, 14 characters in black pepper were subjected to path analysis. Out of these 14 chacters, seven viz., weight of 100 green berries, green berry yield per vine, number of spikes per vine, length of spike, number of developed berries per spike, length of internode of plageotrope and angle of plageotrope with orthotrope exhibited positive direct effect and the rest viz., volume of 100 green berries, green spike yield per vine, number of underdeveloped berries per spike, length of leaf, length of internode of orthotrope, thickness of internode of orthotrope and thickness of node did not show positive direct effect.

The maximum contribution to yield is through green berry yield per vine. Green spike yield per vine had a negative direct effect but its high correlation with yield is due to the high indirect effect through green berry yield per vine. Number of spikes per vine had positive direct effect as well as high indirect effect through green berry yield per vine. Ibrahim et al. (1985d) reported a high direct effect of spike number on yield.

Length of spike had a small direct effect but its significant correlation with yield was due to its high indirect effect through green berry yield. The small direct effect of spike length is because of the particular floral morphology of pepper spike. The spike has a composition of male, female and bisexual flowers, which varies from variety to variety. And it would be the number of bisexual flowers per spike and not the length of spike itself that determines the production of berries.

Number of developed berries per spike had high correlation with yield due to its positive direct effect and high indirect effect through green berry yield per vine and through number of spikes per vine.

Number of underdeveloped berries per spike had a significant correlation with yield because of its indirect effect through green berry yield per vine. Actually, it had a negative and small direct effect on yield. Similarly, thickness of internode and node of orthotrope also showed significant correlation with yield due to their significant indirect effect through green berry yield. Both of these traits had negative and small direct efffects.

The direct effect of angle of plageotrope with orthotrope was positive though small and it had a positive significant indirect effect through green berry yield per vine. The increased angle will result in well spread laterals by which light interception and through it berry development increases.

From the above findings, it can be concluded that selection for the improvement of dry berry yield can be efficient if it is based on green berry yield, number of spikes per vine, length of spike and number of developed berries per spike, since these characters satisfy both the requirements of correlation and path analysis.

IV Heritability

Heritability values give an indication of the effectiveness of selection on the basis of phenotypic performance.

In general, most of the vegetative and productive characters showed moderate heritability values in open pollinated seed progenies whereas in F_1 hybrids many of the productive traits showed negative values for heritability. The heritability values for the vegetative characters in F_1 hybrids showed wide variation ranging from 3.10 per cent for breadth of leaf to 92.41 per cent for thickness of internode in orthotrope, whereas that of open pollinated seed progenies showed onlv moderate values.

In the case of productive characters, F_1 hybrids showed heritability only for three characters out of 10 viz., volume and weight of 100 green berries and number of underdeveloped berries per spike. But in open pollinated seed progenies all the productive characters except number of developed berries per spike showed moderate heritability values.

Heritability will always be positive. But in the present study, many of the traits showed negative values. This is because, the heritability in the narrow sense was estimated as the regression of offspring on mid parental value in the case of hybrids and as the regression of offspring on female parent in the case of open pollinated seed progenies. In all the eight crosses studied, it was found that, in general, the performance of the hybrids was poor even when the corresponding parents showed good performance with respect to these characters. Also the number of hybrids evaluated under each cross were meagre. These may be the reasons for obtaining negative heritability values for many of the traits in F_1 hybrids.

V Heterosis

The importance of heterosis in breeding had been stressed by many workers. The prevalence of heterosis has practical implications only if heterosis is explored on a rather extensive scale and highly heterotic crosses were easily and quickly separated out.

With respect to dry berry yield per vine and the three most important component characters of yield viz., number of spikes per vine, length of spike and number of developed berries per spike, high heterosis was exhibited by one of the hybrids, viz., Culture 4968, belonging to the cross Uthirenkotta x Balankotta. Other promising parental combinations found were, Uthirenkotta x Cheriyakaniakkadan which showed high heterosis for dry berry yield per vine and number of developed berries per spike and Karivilanchy x Cheriyakaniakkadan which showed high heterosis for dry berry yield per vine and length of spike (Plate 3). The crosses Uthirenkotta x Kuthiravaly and Uthirenkotta x Kottanadan were found least promising.

SUMMARY

SUMMARY

The investigations reported herein were undertaken partly in Pepper Research Station, Panniyur and partly in the College of Horticulture, Vellanikkara during 1989-90 with the objective of estimating the extent and magnitude of genetic divergence exhibited by the existing germplasm as well as open pollinated seedling progenies and F_1 hybrids of black pepper which would assist in the formulation of meaningful crop improvement strategies in pepper (Piper nigrum L.).

Forty five F_1 hybrids belonging to eight different inter-varietal combinations of crosses along with their parents and 492 open pollinated seedling progenies from 35 cultivars/cultures planted during 1982-83 in Pepper Research Station, Panniyur were made use of in the study. The extent and magnitude of variability among the plants in respect of four qualitative and 21 quantitative characters was estimated as coefficient of variation. A path coefficient analysis was also attempted to partition the cause and effect relationship among the characters. The magnitude of heritability of various characters and the quantum of heterosis in the F_1 hybrids too were estimated.

Wide variation was observed with respect to all the vegetative and productive characters in parents, F_1 hybrids as well as in

open pollinated seed progenies. However, the magnitude and extent of variability of the various characters did not follow a uniform pattern among the three groups of plants.

Several characters viz., green spike yield per vine, green berry yield per vine, number of spikes per vine, length of spike, number of developed berries per spike and thickness of node and internode of orthotrope registered a high and positive correlation with yield. Also, the inter-relationships among the characters too were high and positive. These findings point to the possible advantages of selection based on these characters for higher productivity of pepper plants.

The path analysis revealed that number of spikes per vine, length of spike and number of developed berries per spike were the most important characters influencing net yield.

However, in general, most of the vegetative and productive characters showed moderate heritability values in open pollinated seed progenies whereas in F_1 hybrids, many of the productive traits showed negative values for heritability. Relatively better performance of the parents than the small population of hybrids might be the reason for this phenomenon.

Some of the hybrids showed significant heterosis in respect of some important characters such as number of spikes per vine, length of spike and number of developed berries per spike. However, it is felt that the study of a larger population of hybrids is required to correctly spell out desirable parental cross combinations in the crop.

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APPENDICES

APPENDICES

APPENDIX 1

Variability in leaf characters in parents

Sl. No.	Name	Length of petiole (cm)	Length of leaf (cm)	Breadth of leaf (cm)	Area of leaf (sq.cm)
1	2	3	4	5	6
1	Arakkulam munda	1.28	13.34	6.66	61.50
2	Arikkottanadan	1.24	12.04	6.08	50.50
3	Balankotta I	1.68	16.39	7.13	81.50
4	Balankotta II	1.77	14.88	7.01	76.20
5	Cheriyakaniakkadan	0.91	10.61	4.58	33.10
6	Irumaniyan	1.16	14.16	6.62	64.30
7	Kalluvally	1.57	16.28	6.91	64.00
8	Kaniakkadan	1.30	11.09	6.40	48.50
9	Karimunda	1.30	10.98	5.32	40.10
10	Karimundi	1.26	12.65	6.50	58.00
11	Karivilanchy	1.13	12.39	7.02	59.50
12	Kottanadan	1.77	12.92	8.41	74.10
13	Kuthiravaly	1.50	12.10	7.94	65.20
14	Kumbhakodi	1.21	10.73	5.79	42.50
15	Sullia	1.13	15.69	5.95	63.30
16	Mundi	1.18	12.51	5.81	49.70
17	Panniyur-1	1.93	14.45	10.09	99.20
18	Perumkodi	1.36	12.57	6.22	53.80
19	Poonjarmunda	1.96	13.97	8.44	80.30

Contd.

Appendix 1. Continued

1	2	3	4	5	6
20	TMB II	1.70	12.74	8.47	74.50
21	TMB IV	1.51	13.91	5.96	56.10
22	TMB V	1.47	14.84	6.28	62.90
23	Uthirenkotta	1.80	13.73	6.57	61.10
24	Vally	2.08	17.28	8.30	97.50
25	Culture-94	1.79	13.73	9.20	88.30
26	Culture-120	1.66	15.19	8.80	90.70
27	Culture-141	1.13	13.37	7.40	67.20
28	Culture-239	1.31	15.36	8.44	88.10
29	Culture-292	1.85	16.90	9.34	108.20
30	Culture-331	1.64	13.36	8.49	79.10
31	Culture-341	1.58	12.17	7.10	58.70
32	Culture-498	1.66	12.15	5.59	46.50
33	Culture-527	1.64	12.69	6.63	57.80
34	Culture-774	1.53	11.76	7.49	60.20
35	Culture-1297	1.86	14.26	8.07	77.90

APPENDIX 2

Variability in leaf characters in F_1 hybrids

Sl. No.	Parents	No.of hybrids	Length of petiole (cm)		Length of leaf (cm)		Breadth of leaf (cm)		Area of leaf (sq. cm)	
			Range	Mean	Range	Mean	Range	Mean	Range	Mean
1	Uthirenkotta x Karimunda	21	1.39 - 3.25	1.88	10.86 - 17.21	13.87	4.66 - 9.36	8.00	34.20 - 111.10	76.07
2	Uthirenkotta x Balankotta	3	1.25 - 1.60	1.48	14.56 - 16.51	15.81	6.45 - 9.25	8.27	67.20 - 104.50	91.77
3	Uthirenkotta x Cheriyakaniakkadan	1	-	1.64	-	13.36	-	8.49	-	79.10
4	Uthirenkotta x Kottanadan	4	1.52 - 1.83	1.70	11.67 - 14.45	13.40	6.88 - 9.29	8.18	54.80 - 92.00	75.73
5	Uthirenkotta x Kuthiravaly	2	1.97 - 2.14	2.06	14.83 - 15.88	15.36	8.38 - 10.42	9.40	90.30 - 104.10	97.20
6	Karivilanchy x Cheriyakaniakkadan	1	-	1.56	-	13.06	-	8.56	-	75.30
7	Panniyur-1 x Kuthiravaly	1	-	1.86	-	14.26	-	8.07	-	77.90
8	Panniyur-1 x Karimunda	12	1.35 - 1.99	1.64	12.17 - 17.15	14.53	7.10 - 11.85	9.30	58.70 - 140.30	93.49

APPENDIX 3

Variability in leaf characters in open pollinated seed progenies

Sl. No.	Parent	No. of progenies	Length of petiole (cm)		Length of leaf (cm)		Breadth of leaf (cm)		Area of leaf (sq.cm)	
			Range	Mean	Range	Mean	Range	Mean	Range	Mean
1	Arakkulam munda	8	1.28 - 1.76	1.56	11.92 - 14.65	13.30	6.05 - 8.35	7.46	53.50 - 85.30	68.39
2	Arikkottanadan	2	1.66 - 1.99	1.83	14.74 - 15.19	14.97	8.80 - 8.91	8.86	89.00 - 90.70	89.85
3	Balankotta I	6	1.17 - 2.16	1.71	11.36 - 15.26	13.20	5.46 - 9.74	8.00	42.40 - 100.10	72.92
4	Balankotta II	1	-	1.13	-	13.37	-	7.40	-	67.20
5	Cheriyakaniakkadan	47	1.15 - 3.00	1.64	9.47 - 17.19	13.51	4.51 - 10.38	7.62	29.00 - 119.30	71.45
6	Irumaniyan	74	1.01 - 2.88	1.77	10.85 - 16.63	13.79	4.77 - 12.35	8.40	48.60 - 129.00	79.12
7	Kalluvally	28	1.25 - 3.60	1.81	12.36 - 21.57	15.29	4.56 - 11.30	8.33	53.60 - 116.10	84.64
8	Kaniakkadan	1	-	2.77	-	18.27	-	10.53	-	135.30
9	Karimunda	25	1.03 - 2.04	1.34	9.31 - 16.19	11.27	4.03 - 9.34	6.11	29.60 - 108.20	48.70
10	Karimundi	16	1.12 - 1.82	1.44	10.93 - 15.59	13.15	6.20 - 10.20	7.76	46.30 - 98.50	70.87
11	Karivilanchy	39	1.10 - 2.40	1.61	11.52 - 18.00	13.53	6.11 - 11.17	8.21	50.70 - 129.10	77.30
12	Kottanadan	7	1.14 - 2.40	1.56	10.47 - 13.54	11.95	6.67 - 8.55	7.46	48.00 - 76.20	60.96
13	Kuthiravaly	22	1.24 - 2.25	1.74	10.53 - 15.27	12.99	6.17 - 10.78	8.13	43.90 - 99.00	72.96
14	Kumbhakodi	1	-	1.34	-	14.24	-	6.77	-	65.00
15	Şullia	2	1.21 - 1.32	1.27	12.15 - 15.88	13.87	5.98 - 10.27	8.13	52.70 - 108.50	80.60
16	Mundi	3	1.61 - 1.73	1.69	12.20 - 12.97	12.49	7.85 - 9.50	8.77	63.50 - 83.90	76.10
17	Panniyur - 1	9	1.30 - 2.20	1.77	11.16 - 16.44	13.89	7.88 - 11.40	10.04	59.70 - 113.40	95.61
18	Perumkodi	6	1.19 - 1.52	1.36	11.42 - 15.36	13.03	6.11 - 9.60	7.94	47.60 - 95.50	72.52
19	Poonjarmunda	10	1.50 - 2.24	1.67	9.13 - 15.62	11.93	6.61 - 9.53	7.54	41.00 - 86.90	61.77
20	TMB II	1	-	1.72	-	11.93	-	6.55	-	53.00
21	TMB IV	1	-	1.83	-	12.26	-	8.44	-	71.60
22	TMB V	2	1.38 - 1.95	1.67	12.95 - 15.00	13.98	6.81 - 9.93	8.37	60.30 -101.10	80.70
23	Uthireṅkotta	105	1.04 - 2.99	1.93	10.68 - 17.93	14.27	5.23 - 11.07	7.84	37.90 - 131.80	77.10
24	Vally	1	-	2.10	-	13.42	-	8.60	-	85.00
25	Culture-94	5	1.13 - 1.77	1.47	12.47 - 13.11	12.87	4.87 - 9.85	7.28	54.40 - 86.10	70.14
26	Culture-120	1	-	1.80	-	14.17	-	9.77	-	97.80
27	Culture-141	1	-	1.21	-	11.87	-	6.53	-	52.50
28	Culture-239	32	1.20 - 1.91	1.52	12.66 - 15.76	14.53	6.51 - 10.87	8.02	58.10 - 133.10	80.38
29	Culture-292	2	1.56 - 1.67	1.62	12.18 - 13.22	12.70	8.00 - 8.43	8.22	66.60 - 75.20	70.90
30	Culture-331	6	1.27 - 1.86	1.61	13.20 - 17.69	15.25	5.88 - 10.34	8.55	69.70 - 118.90	90.27
31	Culture-341	11	1.24 - 1.99	1.57	9.86 - 17.37	13.31	6.80 - 12.20	8.35	46.20 - 139.90	75.78
32	Culture-498	2	1.29 - 2.14	1.72	11.35 - 14.49	12.92	6.74 - 8.82	7.78	51.10 - 86.50	68.80
33	Culture-527	10	1.10 - 2.38	1.75	11.00 - 16.89	14.00	5.79 - 9.43	7.51	46.60 - 102.20	71.91
34	Culture-774	2	1.23 - 1.57	1.40	11.49 - 11.57	11.53	7.01 - 9.42	8.22	55.70 - 75.00	65.35
35	Culture-1297	2	1.30 - 1.68	1.49	10.73 - 14.25	12.49	5.50 - 8.30	6.90	40.10 - 81.70	60.90

APPENDIX 4

Variability in stem characters (Orthotropes) in parents

Sl. No.	Name	Length of internode (cm)	Thickness of internode (cm)	Thickness of node (cm)
1	Arakkulam munda	6.72	3.03	3.84
2	Arikkottanadan	6.28	2.74	3.39
3	Balankotta I	9.43	4.73	5.46
4	Balankotta II	7.39	3.94	5.11
5	Cheriyakaniakkadan	6.26	3.05	4.13
6	Irumaniyan	8.79	3.76	4.75
7	Kalluvally	9.73	3.64	4.39
8	Kaniakkadan	6.15	2.68	3.43
9	Karimunda	8.53	3.07	3.35
10	Karimundi	5.82	1.93	2.54
11	Karivilanchy	6.27	4.53	5.49
12	Kottanadan	6.46	2.27	2.85
13	Kuthiravaly	8.01	2.90	3.35
14	Kumbhakodi	7.77	2.67	3.41
15	Sullia	10.63	5.25	6.22
16	Mundi	7.42	3.58	4.33
17	Panniyur-1	8.30	5.14	5.71
18	Perumkodi	7.42	2.05	2.79
19	Poonjarmunda	6.05	2.41	2.88
20	TMB II	8.81	2.59	3.40

Contd.

Appendix 4. Continued

1	2	3	4	5
21	TMB IV	9.28	2.44	3.26
22	TMB V	6.65	2.91	3.81
23	Uthirenkotta	7.31	3.42	4.16
24	Vally	7.45	4.28	5.39
25	Culture-94	7.73	2.51	3.16
26	Culture-120	8.55	3.93	4.25
27	Culture-141	8.46	3.91	4.64
28	Culture-239	7.91	3.29	4.02
29	Culture-292	7.31	3.94	4.74
30	Culture-331	7.40	2.61	4.01
31	Culture-341	12.93	3.24	3.64
32	Culture-498	9.21	4.08	4.32
33	Culture-527	6.00	1.88	2.26
34	Culture-774	8.08	2.52	3.00
35	Culture-1297	9.01	3.81	4.60

APPENDIX 5

Variability in stem characters (Orthotropes) in F_1 hybrid

Sl. No.	Parents	No. of hybrids	Length of internode (cm)		Thickness of internode (cm)		Thickness of node (cm)	
			Range	Mean	Range	Mean	Range	Mean
1	Uthirenkotta x Karimunda	21	6.63 - 11.18	8.53	1.80 - 3.14	2.45	2.54 - 4.54	3.49
2	Uthirenkotta x Balankotta	3	6.73 - 11.12	8.54	1.37 - 2.47	2.08	2.40 - 5.80	3.92
3	Uthirenkotta x Cheriyakaniakkadan	1	-	7.40	-	2.61	-	4.01
4	Uthirenkotta x Kottanadan	4	5.62 - 8.00	6.61	2.61 - 2.98	2.78	3.57 - 6.02	4.32
5	Uthirenkotta x Kuthiravaly	2	6.10 - 16.22	11.16	2.32 - 2.69	2.51	2.74 - 3.25	3.00
6	Karivilanchy x Cheriyakaniakkadan	1	-	7.31	-	3.08	-	3.69
7	Panniyur-1 x Kuthiravaly	1	-	9.01	-	7.80	-	4.60
8	Panniyur-1 x Karimunda	12	5.16 - 12.93	6.53	1.66 - 3.24	2.50	2.46 - 4.02	3.11

APPENDIX 6

Variability in stem characters (Orthotropes) in open pollinated seed progenies

Sl. No.	Parent	No. of hybrids	Length of internode (cm)		Thickness of internode (cm)		Thickness of node (cm)	
			Range	Mean	Range	Mean	Range	Mean
1	Arakkulam munda	8	5.50 - 9.40	7.19	2.06 - 3.55	2.60	2.70 - 3.82	3.19
2	Arikkottanadan	2	7.74 - 8.55	8.15	2.52 - 3.93	3.23	2.70 - 4.25	3.48
3	Balankotta I	6	5.44 - 8.15	6.87	1.44 - 2.96	2.13	2.12 - 3.70	2.80
4	Balankotta II	1	-	8.46	-	3.91	-	4.64
5	Cheriyakaniakkadan	47	4.28 - 9.72	7.37	1.64 - 4.41	2.60	2.27 - 7.01	3.53
6	Irumaniyan	74	3.81 - 17.42	7.65	1.01 - 4.36	2.33	1.48 - 4.74	3.05
7	Kalluvally	28	2.15 - 16.24	8.06	1.19 - 5.61	2.81	1.32 - 5.98	3.36
8	Kaniakkadan	1	-	7.96	-	2.13	-	3.22
9	Karimunda	25	4.10 - 16.91	7.10	1.24 - 8.91	2.62	1.99 - 5.30	3.11
10	Karimundi	16	5.59 - 8.06	7.27	1.53 - 3.66	2.64	2.62 - 4.78	3.64
11	Karivilanchy	39	4.45 - 11.86	7.38	1.54 - 4.53	2.49	2.34 - 5.49	3.32
12	Kottanadan	7	3.97 - 6.23	5.23	1.41 - 3.65	2.54	1.98 - 4.35	3.36
13	Kuthiravaly	22	4.16 - 12.12	6.74	1.94 - 4.16	2.68	2.40 - 4.41	3.22
14	Kumbhakodi	1	-	6.18	-	3.66	-	4.33
15	Sullia	2	9.38 - 9.62	9.50	2.12 - 2.30	2.21	3.18 - 3.76	3.47
16	Mundi	3	6.00 - 6.75	6.26	2.09 - 3.20	2.75	3.15 - 3.72	3.41
17	Panniyur-1	9	4.20 - 8.88	6.66	2.10 - 2.86	2.44	2.40 - 4.17	3.19
18	Perumkodi	6	5.20 - 9.30	6.94	2.13 - 4.91	3.01	2.30 - 4.02	3.12
19	Poonjarmunda	10	4.25 - 9.47	5.90	1.83 - 3.19	2.47	2.15 - 3.87	3.16
20	TMB II	1	-	6.90	-	2.34	-	2.90
21	TMB IV	1	-	7.05	-	2.75	-	3.14
22	TMB V	2	9.31 - 9.45	9.38	3.01 - 3.09	3.05	3.34 - 4.03	3.69
23	Uthirenkotta	105	4.40 - 13.87	8.29	1.21 - 4.08	2.35	1.79 - 6.99	3.03
24	Vally	1	-	8.33	-	3.17	-	4.02
25	Culture-94	5	5.17 - 6.92	6.60	2.23 - 3.18	2.73	2.79 - 3.92	3.55
26	Culture-120	1	-	6.50	-	2.21	-	3.06
27	Culture-141	1	-	5.86	-	1.94	-	2.53
28	Culture-239	32	4.94 - 13.55	6.59	2.18 - 4.42	2.95	3.06 - 5.92	3.59
29	Culture-292	2	6.45 - 8.25	7.35	2.72 - 3.40	3.06	3.02 - 3.86	3.44
30	Culture-331	6	5.57 - 9.34	7.27	2.11 - 3.13	2.46	3.19 - 3.72	3.46
31	Culture-341	11	4.06 - 8.82	6.30	0.94 - 3.56	2.62	1.57 - 4.54	3.37
32	Culture-498	2	7.65 - 7.83	7.74	1.40 - 2.58	1.99	2.60 - 3.55	3.08
33	Culture-527	10	4.39 - 9.29	7.65	1.65 - 3.07	2.31	2.55 - 3.82	3.03
34	Culture-774	2	5.21 - 5.27	5.24	2.08 - 2.60	2.34	2.65 - 3.04	2.85
35	Culture-1297	2	7.00 - 9.46	8.23	1.75 - 3.90	2.83	2.29 - 4.45	3.37

APPENDIX 7

Variability in stem characters (Plageotropes) in parents

Sl, No.	Name	Length of internode (cm)	Thickness of internode (cm)	Thickness of node (cm)	Angle of plageotrope with orthotrope (°)
1	2	3	4	5	6
1	Arakkulam munda	2.79	0.92	1.39	63.50
2	Arikkottanadan	3.51	0.92	1.22	53.00
3	Baiankotta I	6.95	0.98	1.56	67.00
4	Baiankotta II	4.98	0.94	1.64	74.50
5	Cheriyakaniakkadan	3.00	0.80	1.28	62.50
6	Irumaniyan	3.90	0.84	1.37	70.70
7	Kalluvally	5.34	1.12	1.64	67.50
8	Kaniakkadan	4.38	1.17	1.61	65.50
9	Karimunda	5.26	0.94	1.38	85.50
10	Karimundi	5.57	0.98	1.74	56.00
11	Karivilanchy	5.40	1.12	1.62	63.00
12	Kottanadan	5.70	1.13	1.76	66.00
13	Kuthiravaly	3.51	1.00	1.38	87.50
14	Kumbhakodi	4.63	1.00	1.61	72.50
15	Sullia	4.58	0.98	1.72	93.50
16	Mundi	2.76	0.86	1.22	67.50
17	Panniyur-1	3.68	1.10	1.86	90.50
18	Perumkodi	5.20	1.17	1.51	68.00
19	Poonjarmunda	3.24	1.01	1.55	70.50
20	TMB II	4.40	0.94	1.45	73.50

Contd.

Appendix 7. Continued

1	2	3	4	5	6
21	TMB IV	3.84	1.06	1.54	63.50
22	TMB V	6.96	0.98	1.49	67.00
23	Uthirenkotta	4.36	0.99	1.53	78.50
24	Vally	6.44	0.94	1.69	80.50
25	Culture-94	6.42	1.09	1.79	56.50
26	Culture-120	4.83	1.21	1.63	69.00
27	Culture-141	4.77	1.19	1.76	80.50
28	Culture-239	5.44	1.14	1.66	104.00
29	Culture-292	4.43	1.13	1.69	71.00
30	Culture-331	4.94	1.18	1.78	88.50
31	Culture-341	4.81	1.20	1.87	81.00
32	Culture-498	4.87	1.00	1.41	70.00
33	Culture-527	4.05	0.88	1.32	51.50
34	Culture-774	3.81	0.80	1.33	99.00
35	Culture-1297	5.28	1.05	2.99	83.80

APPENDIX 8

Variability in stem characters (Plageotropes) in F_1 hybrids

Sl. No.	Parents	No. of hybrids	Length of internode (cm)		Thickness of internode (cm)		Thickness of node (cm)		Angle of Plageotrope with Orthotrope (°)	
			Range	Mean	Range	Mean	Range	Mean	Range	Mean
1	Uthirenkotta x Karimunda	21	3.19 - 6.86	4.86	0.86 - 1.58	1.19	1.33 - 2.04	1.63	31.50 - 78.50	58.71
2	Uthirenkotta x Balankotta	3	3.96 - 6.70	5.12	0.90 - 1.33	1.14	1.32 - 1.66	1.52	59.50 - 63.00	61.00
3	Uthirenkotta x Cheriyakaniakkadan	1	-	4.94	-	1.18	-	1.78	-	88.50
4	Uthirenkotta x Kottanadan	4	4.11 - 7.51	5.81	1.02 - 1.30	1.16	1.51 - 2.00	1.75	69.50 - 81.50	76.63
5	Uthirenkotta x Kuthiravaly	2	4.99 - 6.07	5.53	1.08 - 1.17	1.13	1.44 - 1.65	1.55	60.50 - 75.50	68.00
6	Karivilanchy x Cheriyakaniakkadan	1	-	9.54	-	1.35	-	1.73	-	74.00
7	Panniyur-1 x Kuthiravaly	1	-	5.28	-	1.05	-	2.99	-	83.80
8	Panniyur-1 x Karimunda	12	3.50 - 6.07	4.87	0.98 - 1.45	1.20	1.30 - 1.94	1.71	43.50 - 89.00	64.88

APPENDIX 9

Variability in stem characters (Plageotropes) in open pollinated seed progenies

Sl. No.	Parent	No. of progenies	Length of internode (cm)		Thickness of internode (cm)		Thickness of node (cm)		Angle of Plageotrope with Orthotrope (°)	
			Range	Mean	Range	Mean	Range	Mean	Range	Mean
1	Arakkulam munda	8	3.46 - 6.23	4.70	0.71 - 1.35	0.93	1.32 - 1.99	1.54	49.60 - 86.00	66.14
2	Arikkottanadan	2	4.47 - 4.83	4.65	1.03 - 1.21	1.12	1.63 - 1.87	1.75	37.00 - 69.00	53.00
3	Balankotta I	6	3.06 - 6.02	4.66	0.97 - 1.56	1.20	1.59 - 2.26	1.86	57.50 - 92.00	69.33
4	Balankotta II	1	-	4.77	-	1.19	-	1.76	-	80.50
5	Cheriyakaniakkadan	47	2.28 - 8.03	4.49	0.82 - 1.68	1.13	0.61 - 2.51	1.59	41.50 - 80.00	62.04
6	Irumaniyan	74	3.00 - 6.63	4.80	0.17 - 1.67	1.19	1.21 - 2.88	1.82	29.50 - 92.00	63.01
7	Kalluvally	28	2.88 - 6.80	5.13	0.80 - 1.37	1.07	1.27 - 2.89	1.87	34.50 - 95.00	64.73
8	Kaniakkadan	1	-	5.19	-	1.38	-	2.04	-	62.50
9	Karimunda	25	2.26 - 6.14	3.66	0.80 - 1.81	1.04	1.20 - 2.74	1.54	42.50 - 89.50	63.80
10	Karimundi	16	2.76 - 5.79	4.09	0.78 - 1.28	1.12	1.22 - 2.22	1.62	51.50 - 76.00	59.34
11	Karivilanchy	39	3.12 - 6.22	4.87	0.80 - 2.12	1.18	1.28 - 2.94	1.85	33.50 - 84.70	63.27
12	Kottanadan	7	2.95 - 6.38	4.47	0.88 - 1.50	1.21	1.43 - 2.07	1.68	50.00 - 82.00	65.14
13	Kuthiravaly	22	2.85 - 9.99	4.46	0.90 - 1.98	1.26	1.42 - 2.36	1.82	46.50 - 93.50	70.09
14	Kumbhakodi	1	-	4.02	-	1.12	-	1.78	-	78.50
15	Sullia	2	4.83 - 5.13	4.98	0.87 - 1.07	0.97	1.73 - 1.96	1.85	55.30 - 78.70	67.00
16	Mundi	3	3.15 - 3.63	3.45	1.05 - 1.38	1.17	1.47 - 1.90	1.65	56.50 - 64.50	59.50
17	Panniyur-1	9	3.27 - 8.32	5.09	0.89 - 1.53	1.21	1.27 - 2.04	1.67	43.00 - 66.00	58.17
18	Perumkodi	6	2.82 - 5.60	4.43	1.06 - 1.50	1.20	1.61 - 1.92	1.72	56.00 - 104.00	81.42
19	Poonjarmunda	10	2.47 - 6.99	3.55	0.97 - 1.19	1.10	1.37 - 1.79	1.54	42.00 - 83.50	64.73
20	TMB II	1	-	3.46	-	1.05	-	1.51	-	65.50
21	TMB IV	1	-	4.03	-	0.87	-	1.54	-	54.00
22	TMB V	2	3.97 - 5.41	4.69	1.00 - 1.29	1.15	1.49 - 1.90	1.70	63.70 - 64.50	64.10
23	Uthirenkotta	105	2.59 - 8.86	4.99	0.70 - 2.55	1.09	1.11 - 3.49	1.71	27.00 - 107.00	61.91
24	Vally	1	-	5.35	-	1.34	-	1.61	-	65.00
25	Culture-94	5	3.35 - 4.33	3.92	0.90 - 1.24	1.11	1.52 - 2.88	1.88	56.00 - 72.00	63.74
26	Culture-120	1	-	4.16	-	1.15	-	1.81	-	69.00
27	Culture-141	1	-	5.13	-	1.07	-	1.73	-	54.00
28	Culture-239	32	3.70 - 5.92	4.58	0.90 - 1.51	1.20	1.34 - 2.73	1.71	42.50 - 82.00	63.83
29	Culture-292	2	4.83 - 7.18	6.01	0.92 - 1.01	0.97	1.50 - 1.57	1.54	43.50 - 58.00	50.75
30	Culture-331	6	3.92 - 5.39	4.66	1.17 - 1.33	1.22	1.79 - 2.24	1.97	54.00 - 76.00	66.50
31	Culture-341	6	3.29 - 7.65	4.61	0.87 - 2.73	1.31	1.39 - 3.32	1.84	61.30 - 96.50	68.08
32	Culture-498	2	4.23 - 5.18	4.05	1.12 - 1.18	1.15	1.56 - 1.71	1.62	41.60 - 51.50	46.55
33	Culture-527	10	2.94 - 7.13	4.76	0.83 - 1.31	1.08	1.17 - 1.90	1.56	42.00 - 70.00	56.60
34	Culture-774	2	3.89 - 4.33	4.11	1.11 - 1.12	1.12	1.54 - 1.57	1.56	56.00 - 75.00	65.50
35	Culture-1297	2	3.07 - 4.77	3.92	1.19 - 1.32	1.26	1.62 - 1.63	1.63	65.50 - 75.50	70.50

APPENDIX 10

Variability in berry characters in parents

Sl. No.	Name	Volume of 100 green berries (cc)	Weight of 100 green berries (g)	Weight of 100 dry berries (g)
1	2	3	4	5
1	Arakkulam Munda	11.0	11.0	3.5
2	Arikkottanadan	13.0	14.0	5.5
3	Baiankotta I	14.0	14.5	4.0
4	Balankotta II	16.0	17.0	6.5
5	Cheriyakaniakkadan	11.0	12.0	5.5
6	Irumaniyan	17.0	17.0	5.0
7	Kalluvally	14.0	15.0	6.7
8	Kaniakkadan	11.0	13.0	4.0
9	Karimunda	12.0	13.0	5.0
10	Karimundi	12.0	13.0	4.0
11	Karivilanchy	14.0	15.0	5.0
12	Kottanadan	11.0	12.0	4.4
13	Kuthiravaly	12.0	13.0	5.0
14	Kumbhakodi	13.0	15.0	5.5
15	Sullia	12.0	13.0	3.0
16	Mundi	12.0	12.0	4.5
17	Panniyur-1	16.0	16.0	6.0
18	Perumkodi	16.0	17.5	6.0
19	Poonjarmunda	12.0	13.0	4.6
20	TMB II	10.0	11.5	5.0

Contd.

Appendix 10. Continued

1	2	3	4	5
21	TMB IV	11.0	11.5	4.0
22	TMB V	14.0	15.0	4.6
23	Uthirenkotta	18.0	20.0	6.0
24	Vally	16.0	17.0	5.5
25	Culture-94	11.0	12.0	4.6
26	Culture-120	20.0	21.0	7.0
27	Culture-141	11.0	12.0	4.0
28	Culture-239	10.0	11.0	4.0
29	Culture-292	14.0	16.0	5.0
30	Culture-331	12.0	13.0	4.5
31	Culture-341	17.0	18.0	7.0
32	Culture-498	14.0	15.5	5.0
33	Culture-527	17.0	17.0	7.0
34	Culture-774	13.0	14.0	5.5
35	Culture-1297	14.0	15.0	6.0

APPENDIX 11

Variability in berry characters in F_1 hybrids

Sl. No.	Parents	No. of hybrids	Volume of 100 green berries (cc)		Weight of 100 green berries (g)		Weight of 100 dry berries (g)	
			Range	Mean	Range	Mean	Range	Mean
1	Uthirenkotta x Karimunda	21	9 - 19	15.33	11 - 21	16.38	4 - 8	6.19
2	Uthirenkotta x Balankotta	3	12 - 14	13.00	13 - 15	14.00	5 - 6	5.33
3	Uthirenkotta x Cheriyakaniakkadan	1	-	12.00	-	13.00	-	4.50
4	Uthirenkotta x Kottanadan	2	11 - 13	12.00	12 - 14	13.00	4 - 7	5.50
5	Uthirenkotta x Kuthiravaly	2	12 - 18	15.00	12 - 19	15.50	6 - 8	7.00
6	Karivilanchy x Cheriyakaniakkadan	1	-	11.00	-	12.00	-	5.00
7	Panniyur-1 x Kuthiravaly	1	-	14.00	-	15.00	-	6.00
8	Panniyur-1 x Karimunda	9	8 - 17	12.00	9 - 18	12.78	4 - 7	5.22

APPENDIX 12

Variability in berry characters in open pollinated seed progenies

Sl. No.	Parent	No. of progenies	Volume of 100 green berries (cc)		Weight of 100 green berries (g)		Weight of 100 dry berries (g)	
			Range	Mean	Range	Mean	Range	Mean
1	Arakkulam munda	£	8 - 14	11.13	9 - 15	12.00	4 - 6	4.88
2	Arikkottanadan	1	-	20.00	-	21.00	-	7.00
3	Balankotta I	5	11 - 15	13.80	11 - 16	14.00	3 - 6	4.80
4	Balankotta II	1	-	11.00	-	12.00	-	4.00
5	Cheriyakaniakkadan	43	6 - 16	10.33	7 - 17	11.30	3 - 6	4.51
6	Irumaniyan	64	9 - 19	13.59	10 - 20	14.59	3 - 8	5.58
7	Kalluvally	24	8 - 15	12.08	9 - 16	12.92	4 - 7	5.04
8	Kaniakkadan	1	-	10.00	-	11.00	-	5.00
9	Karimunda	23	6 - 18	10.61	7 - 18	11.52	3 - 6	4.09
10	Karimundi	12	9 - 25	11.67	11 - 25	14.75	4 - 9.9	5.49
11	Karivilanchy	35	7 - 14	11.57	8 - 18	12.66	3 - 7	4.86
12	Kottanadan	6	8 - 15	11.00	8 - 18	12.17	3 - 6	4.83
13	Kuthiravaly	16	6 - 21	13.00	7 - 23	13.94	3 - 7	5.03
14	Kumbhakodi	1	-	11.00	-	12.00	-	4.00
15	Sullia	2	7 - 12	9.50	8 - 12	10.00	3 - 4	3.50
16	Mundi	3	12 - 4	13.00	12 - 15	13.67	5	5.00
17	Pannlyur-1	6	9 - 20	13.00	9 - 22	13.83	3 - 7	5.50
18	Perumkodi-	6	9 - 14	11.33	10 - 15	12.50	4 - 5	4.33
19	Poonjarmunda	10	8 - 16	12.43	9 - 18	13.43	4 - 7	5.29
20	TMB II	1	-	12.00	-	13.00	-	5.00
21	TMB IV	1	-	13.00	-	15.00	-	6.00
22	TMB V	2	9 - 22	15.50	10 - 23	16.50	3 - 8	5.50
23	Uthirenkotta	92	9 - 19	14.25	9 - 20	15.30	3 - 8	5.68
24	Vally	1	-	10.00	-	12.00	-	3.00
25	Culture-94	4	8 - 12	9.25	9 - 13	10.25	3 - 5	3.75
26	Culture-120	1	-	12.00	-	13.00	-	5.00
27	Culture-141	1	-	11.00	-	12.00	-	4.00
28	Culture-239	26	6 - 12	8.50	6 - 13	9.35	2 - 5	3.54
29	Culture-292	2	9 - 10	9.50	10 - 11	10.50	4	4.00
30	Culture-331	6	9 - 15	12.67	10 - 16	13.67	4 - 6	5.17
31	Culture-341	9	8 - 13	10.67	9 - 14	11.67	3 - 6	4.89
32	Culture-498	2	2 - 14	13.00	13 - 15	14.00	4 - 6	5.00
33	Culture-527	9	8 - 19	12.44	9 - 21	13.67	4 - 8	5.56
34	Culture-774	2	11 - 14	12.50	12 - 15	13.50	5	5.00
35	Culture-1297	2	14 - 18	16:00	15 - 20	17.50	6 - 8	7.00

APPENDIX 13

Variability in spike characters in parents

Sl. No.	Name	No. of spikes/ vine	Length of spike (cm)	No. of developed berries/ spike	No. of under-developed berries/ spike
1		3	4	5	6
1	Arakkulam munda	1712	9.60	31.50	5.2
2	Arikkottandan	645	7.50	28.95	2.0
3	Balankotta I	726	10.15	35.10	7.3
4	Balankotta II	710	12.44	52.00	7.0
5	Cheriyakaniakkadan	1502	8.68	42.00	5.5
6	Irumaniyan	44	8.70	19.00	1.2
7	Kalluvally	2030	7.44	51.40	1.9
8	Kaniakkadan	825	8.20	24.00	5.7
9	Karimunda	1075	8.48	26.60	2.1
10	Karimundi	355	8.96	33.81	3.0
11	Karivilanchy	1070	7.18	27.40	1.6
12	Kottanadan	1505	9.90	33.25	1.7
13	Kuthiravaly	781	8.34	41.35	3.3
14	Kumbhakodi	1235	8.89	64.95	2.3
15	Sullia	1005	6.65	44.00	6.0
16	Mundi	1355	9.10	28.20	2.0
17	Panniyur-1	720	16.07	79.90	2.6
18	Perumkodi	890	10.74	26.40	3.8
19	Poonjarmunda	568	9.12	38.05	10.51
20	TMB II	941	6.92	36.40	2.80

Contd.

Appendix 13. Continued

1	2	3	4	5	6
21	TMB IV	410	8.08	29.20	1.56
22	TMB V	715	8.60	15.47	0.60
23	Uthirenkotta	48	12.44	16.80	1.80
24	Vally	1012	9.97	41.00	4.20
25	Culture-94	191	11.32	49.80	10.20
26	Culture-120	180	15.51	60.50	1.90
27	Culture-141	1110	11.37	34.70	9.20
28	Culture-239	299	14.03	41.90	2.80
29	Culture-292	958	13.42	60.30	6.90
30	Culture-331	323	11.96	56.10	1.00
31	Culture-341	482	11.99	56.50	1.90
32	Culture-498	3165	11.53	28.70	4.40
33	Culture-527	128	10.99	34.10	2.90
34	Culture-774	726	7.76	30.00	6.20
35	Culture-1297	896	16.67	32.70	0.90

APPENDIX 14

Variability in spike characters in F_1 hybrids

Sl. No.	Parents	No. of hybrids	Total No. of spike/vine		Length of spike (cm)		Number of developed berries/spike		No. of under-developed berries/spike	
			Range	Mean	Range	Mean	Range	Mean	Range	Mean
1	Uthirenkotta x Karimunda	21	17 - 1229	322.95	7.55 - 14.83	10.07	2.54 - 46.80	27.80	0.20 - 7.00	1.92
2	Uthirenkotta x Balankotta	3	241 - 2222	956.00	11.39 - 16.37	13.81	18.60 - 60.70	41.17	1.5 - 5.20	2.80
3	Uthirenkotta x Cheriyakaniakkadan	1	-	323.00	-	11.96	-	56.10	-	1.00
4	Uthirenkotta x Kottanadan	2	44 - 54	49.00	9.16 - 9.34	9.25	19.60 - 37.60	28.60	0.20 - 1.50	0.85
5	Uthirenkotta x Kuthiravaly	2	16 - 123	69.50	8.38 - 11.22	9.80	18.90 - 31.80	25.35	0 - 0.70	0.35
6	Karivilanchy x Cheriyakaniakkadan	1	-	1140.00	-	14.46	-	31.40	-	7.20
7	Panniyur-1 x Kuthiravaly	1	-	896.00	-	16.67	-	32.70	-	0.90
8	Panniyur-1 x Karimunda	9	26 - 830	154.33	7.10 - 11.99	9.74	9.30 - 56.50	30.49	0.40 - 14.90	3.44

APPENDIX 15

Variability in spike characters in open pollinated seed progenies

Sl. No.	Parent	No. of progenies	Total number of spikes/vine		Length of spike (cm)		No. of developed berries per spike		No.of underdeveloped berries per spike	
			Range	Mean	Range	Mean	Range	Mean	Range	Mean
1	Arakkulam munda	8	68 - 1190	579.75	5.28 - 14.83	9.98	0.70 - 6.40	2.81	1.28 - 1.76	1.52
2	Arikkottanadan	1	-	180.00	-	15.51	-	60.50	-	1.90
3	Balankotta I	5	42 - 207	111.80	9.57 - 11.48	10.02	21.20 - 49.30	36.08	0.20 - 4.60	2.54
4	Balankotta II	1	-	1110.00	-	11.37	-	34.70	-	9.20
5	Cheriyakaniakkadan	43	38 - 1480	380.81	4.54 - 13.39	9.16	8.20 - 55.40	27.66	0.10 - 7.10	1.93
6	Irumaniyan	64	21 - 1750	301.52	4.80 - 10.96	7.06	2.64 - 73.30	28.48	0.20 - 6.00	1.20
7	Kalluvally	24	22 - 991	354.96	5.34 - 20.14	10.16	3.71 - 76.90	35.99	0.30 - 10.80	2.98
8	Kaniakkadan	1	-	574.00	-	13.76	-	40.40	-	2.30
9	Karimunda	23	24 - 3042	350.78	3.04 - 14.22	6.73	6.20 - 60.30	18.89	0.20 - 6.90	1.94
10	Karimundi	12	87 - 1310	367.08	6.70 - 16.88	10.32	2.75 - 65.40	30.90	0.10 - 1.80	0.96
11	Karivilanchy	35	32 - 2100	366.31	4.65 - 15.37	8.90	16.60 - 62.50	31.51	0.20 - 4.10	1.65
12	Kottanadan	6	27 - 945	233:17	5.07 - 10.08	7.89	18.00 - 48.70	33.23	0.00 - 7.00	3.12
13	Kuthiravaly	16	15 - 693	159.31	5.86 - 13.37	8.81	12.30 - 53.80	27.90	0.20 - 4.60	1.13
14	Kumbhakodi	1	-	956.00	-	13.16	-	35.00	-	3.30
15	Sullia	2	595 - 725	660.00	9.68 - 12.00	10.84	38.33 - 45.30	41.82	3.80 - 4.40	4.10
16	Mundi	3	120 - 872	529.00	11.33 - 12.81	12.10	34.30 - 36.60	35.53	1.00 - 2.40	1.67
17	Panniyur-1	6	20 - 750	264.33	4.92 - 12.92	10.11	17.50 - 41.30	30.77	0.05 - 2.80	1.60
18	Perumkodi	6	28 - 879	287.67	8.21 - 15.90	11.54	32.00 - 56.30	41.83	1.80 - 7.60	3.79
19	Poonjarmunda	10	23 - 1336	295.28	5.54 - 10.25	7.51	9.50 - 35.70	22.33	0.30 - 1.40	1.03
20	TMB II	1	-	1360.00	-	5.35	-	20.40	-	1.40
21	TMB IV	1	-	517.00	-	10.50	-	28.00	-	0.10
22	TMB V	2	160 - 450	305.00	9.54 - 10.36	9.95	35.20 - 45.30	40.25	0.10 - 0.90	0.50
23	Uthirenkotta	92	17 - 3165	353.70	4.55 - 15.91	10.11	10.10 - 70.50	29.26	0.10 - 10.60	2.11
24	Vally	1	-	805.00	-	13.86	-	3.83	-	8.20
25	Culture-94	4	51 - 399	187.00	8.48 - 9.99	9.46	27.70 - 59.60	41.68	2.00 - 6.90	3.80
26	Culture-120	1	-	128.00	-	9.71	-	19.70	-	1.30
27	Culture-141	1	-	253.00	-	11.40	-	33.60	-	6.80
28	Culture-239	26	21 - 570	248.88	6.81 - 16.82	11.06	20.00 - 50.70	35.70	0.40 - 6.50	3.05
29	Culture-292	2	34 - 255	144.50	7.94 - 8.30	8.12	17.30 - 39.60	28.45	2.20 - 4.70	3.45
30	Culture-331	6	283 - 840	588.17	7.21 - 12.80	9.38	15.10 - 46.50	32.68	0.80 - 4.10	2.02
31	Culture-341	9	11 - 700	188.22	6.98 - 14.98	11.37	9.70 - 56.80	29.82	0.20 - 4.90	1.59
32	Culture-498	2	146 - 300	223. 00	9.75 - 11.77	10.76	33.50 - 52.20	42.85	0.30 - 1.30	0.80
33	Culture-527	9	17 - 980	200.67	6.09 - 16.65	10.03	21.60 - 58.30	28.56	0.90 - 5.90	2.18
34	Culture-774	2	25 - 34	29.50	5.88 - 6.83	6.36	22.80 - 27.90	25.35	0.30 - 0.80	0.55
35	Culture-1297	2	47 - 140	93.50	8.31 - 9.14	8.73	16.70 - 20.60	18.65	0.10 - 0.80	0.45

APPENDIX 16

Variability in yield in parents

Sl. No.	Name	Green spike yield per vine (g)	Green berry yield per vine (g)	Dry berry yield per vine (g)
1	2	3	4	5
1	Arakkulam munda	5850	5030	1610
2	Arikkottanadan	1480	1180	470
3	Balankotta I	3765	3470	1005
4	Balankotta II	4080	3730	1212
5	Cheriyakaniakkadan	2320	1700	525
6	Irumaniyan	195	180	54
7	Kalluvally	4065	3170	1078
8	Kaniakkadan	2780	2400	804
9	Karimunda	3800	3380	1220
10	Karimundi	1145	1030	320
11	Karivilanchy	3300	2820	960
12	Kottanadan	4110	3430	935
13	Kuthiravaly	3805	3435	1305
14	Kumbhakodi	6150	5530	1880
15	Sullia	5540	5020	1245
16	Mundi	5660	5070	1927
17	Panniyur-1	4905	4540	1746
18	Perumkodi	4075	3660	1300
19	Poonjarmunda	2600	2350	825
20.	TMB II	3100	2700	1020

Contd.

Appendix 16. Continued

1	2	3	4	5
21	TMB IV	1200	1020	355
22	TMB V	2020	1800	710
23	Uthirenkotta	405	380	110
24	Vally	5925	5480	1590
25	Culture-94	770	700	270
26	Culture-120	1370	1300	533
27	Culture-141	5470	4950	1510
28	Culture-239	1905	1705	572
29	Culture-292	5580	5160	1740
30	Culture-331	2635	2337	848
31	Culture-341	3130	2900	1190
32	Culture-498	12200	10820	3600
33	Culture-527	580	530	230
34	Culture-774	2675	2300	910
35	Culture-1297	4260	3785	1383

APPENDIX 17

Variability in yield in F_1 hybrids

Sl. No.	Parents	No. of hybrids	Green spike yield/vine (g)		Green berry yield/vine (g)		Dry berry yield/vine (g)	
			Range	Mean	Range	Mean	Range	Mean
1	Uthirenkotta x Karimunda	21	50 - 3300	1213.90	42 - 2770	1034.05	16 - 1000	380.52
2	Uthirenkotta x Balankotta	3	1000 - 6860	3086.67	805 - 5580	2530.00	330 - 1950	901.67
3	Uthirenkotta x Cheriyakaniakkadan	1	-	2635.00	-	2337.00	-	848.00
4	Uthirenkotta x Kottanadan	2	105 - 195	150.00	94 - 157	125.50	35 - 58	46.50
5	Uthirenkotta x Kuthiravaly	2	90 - 275	182.50	80 - 237	158.50	32 - 100	66.00
6	Karivilanchy x Cheriyakaniakkadan	1	-	5180.00	-	4650.00	-	1720.00
7	Panniyur-1 x Kuthiravaly	1	-	4260.00	-	3785.00	-	1383.00
8	Panniyur-1 x Karimunda	9	100 - 3130	852.22	75 - 2900	742.33	45 - 1190	291.78

APPENDIX 18

Variability in yield in open pollinated seed progenies

Sl. No.	Parent	No. of progeny	Green spike yield/vine (g)		Green berry yield/vine (g)		Dry berry yield/vine (g)	
			Range	Mean	Range	Mean	Range	Mean
1	Arakkulam munda	8	212 - 3190	2004.00	183 - 2705	1734.38	57 - 1125	682.50
2	Arikkottanadan	1	-	1370.00	-	1300.00	-	533.00
3	Balankotta I	5	173 - 900	460.20	135 - 805	407.60	35 - 245	134.60
4	Balankotta II	1	-	5470.00	-	4950.00	-	1510.00
5	Cheriyakaniakkadan	43	38 - 11015	1343.53	30 - 9065	1205.58	12 - 2600	420.49
6	Irumaniyan	64	42 - 4090	1060.80	33 - 3660	938.25	7 - 1425	452.67
7	Kalluvally	24	102 - 8000	1508.54	88 - 7135	1318.04	30 - 2189	473.67
8	Kaniakkadan	1	-	1970.00	-	1631.00	-	628.00
9	Karimunda	23	25 - 13300	1231.96	18 - 12950	1144.17	9 - 4172	399.00
10	Karimundi	12	120 - 6050	1472.17	98 - 5300	1250.92	45 - 1890	443.92
11	Karivilanchy	35	80 - 5980	1229.00	65 - 5410	1086.26	26 - 1995	393.49
12	Kottanadan	6	76 - 2190	686.83	63 - 1990	621.50	38 - 890	254.83
13	Kuthiravaly	16	43 - 2525	568.13	35 - 2420	497.50	15 - 715	184.81
14	Kumbhakodi	1	-	3930.00	-	3530.00	-	1153.00
15	Sullia	2	2795 - 3100	2947.50	2305 - 2610	2457.50	378 - 715	546.50
16	Mundi	3	595 - 3155	2276.67	495 - 2630	1890.00	195 - 970	671.67
17	Panniyur-1	6	61 - 3825	1196.50	55 - 3330	990.00	24 - 1065	324.33
18	Perumkodi	6	70 - 2660	1227.50	60 - 2350	1074.17	25 - 938	393.17
19	Poonjarmunda	10	55 - 4350	908.43	41 - 3500	756.00	20 - 1485	316.71
20	TMB II	1	-	3260.00	-	2915.00	-	1070.00
21	TMB IV	1	-	1325.00	-	1120.00	-	438.00
22	TMB V	2	950 - 1140	1045.00	845 - 970	907.50	270 - 305	287.50
23	Uthirenkotta	92	32 - 12200	1348.99	18 - 10820	1167.04	9 - 3600	443.48
24	Vally	1	-	3200.00	-	2790.00	-	890.00
25	Culture-94	4	130 - 1420	693.25	105 - 1290	620.75	45 - 460	224.25
26	Culture-120	1	-	390.00	-	330.00	-	130.00
27	Culture-141	1	-	1120.00	-	955.00	-	305.00
28	Culture-239	26	62 - 2440	835.15	51 - 2290	715.38	22 - 862	258.27
29	Culture-292	2	110 - 642	376.00	101 - 555	328.00	35 - 226	130.50
30	Culture-331	6	1150 - 3695	2290.00	990 - 3360	1977.50	323 - 1230	738.83
31	Culture-341	9	17 - 2765	666.11	13 - 2070	532.78	5 - 795	207.56
32	Culture-498	2	585 - 1160	872.50	502 - 990	746.00	175 - 354	264.50
33	Culture-527	9	54 - 3820	666.78	46 - 3077	543.33	20 - 1182	205.67
34	Culture-774	2	55 - 90	72.50	39 - 77	58.00	20 - 27	23.50
35	Culture-1297	2	110 - 355	232.50	90 - 280	185.00	41 - 115	78.00

VARIABILITY IN INTERVARIETAL F_1 HYBRIDS AND OPEN POLLINATED SEED PROGENIES OF BLACK PEPPER *(Piper nigrum L.)*

By

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Abstract of a Thesis

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ABSTRACT

The experiment was conducted at Pepper Research Station, Panniyur and College of Horticulture, Vellanikkara during 1989-90 to study the variability in F_1 hybrids and open pollinated seed progenies of black pepper (*Piper nigrum* L.).

Fourty five intervarietal F_1 hybrids and 492 open pollinated seed progenies of 1982-83 plantings maintained at the Pepper Research Station, Panniyur were included in the study. Observations on four qualitative and 21 quantitative characters were made from all the available hybrids and open pollinated seed progenies for one season. The data thus obtained were interpretted suitably, after subjecting them to appropriate statistical analyses.

Considerable variation was present for both vegetative and reproductive characters in parents, F_1 hybrids and open pollinated seed progenies. However, variability did not follow a uniform pattern in these three groups for the various characters.

High positive correlation with yield was shown by several characters viz., green spike yield per vine, green berry yield per vine, number of spikes per vine, length of spike, developed berries per spike and thickness of orthotrope node and internode. The path analysis identified number of spikes per vine, length of spike and developed berries per spike as the most important characters influencing yield in the crop.

Significant heterosis for important yield related characters viz., number of spikes per vine, length of spike and developed berries for spike was shown by certain hybrids.