COMPARATIVE EVALUATION OF SELECTED TYPES OF *Piper longum* (Linn.) IN COCONUT PLANTATIONS

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "**Comparative evaluation of selected types of *Piper longum* (Linn.) in coconut plantations**" is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled "**Comparative evaluation of selected types of *Piper longum* (Linn.) in coconut plantations**" is a record of research work done independently by **Miss.Jaya Manuel** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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We the undersigned, members of the Advisory Committee of **Miss.Jaya Manuel**, a candidate for the degree of Master of Science in Agriculture with major in Agricultural Botany, agree that the thesis entitled "**Comparative evaluation of selected types of *Piper longum* (Linn.) in coconut plantations**" may be submitted by Miss.Jaya Manuel in partial fulfillment of the requirements for the degree.

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Dedicated to my parents

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Introduction

INTRODUCTION

Piper longum Linn. popularly known as 'Tippali' in Malayalam and 'Pippali' in Sanskrit is a slender aromatic climber of high medicinal value, with perennial woody roots. This occurs in the rain forests of Assam, lower hills of West Bengal and the evergreen forests of Western Ghats. Indian *Piper longum* is mostly derived from its wild growth in Assam, Sikkim, West Bengal and other North-East hill regions, Gujarat, Maharashtra and Andhra Pradesh.

The fruits (dry spikes of female types) as well as roots of *Piper longum* are attributed with numerous medicinal values and are extensively used in Ayurvedic and Unani systems of medicine for the treatment of diseases of the respiratory tract, cardiac and splenic disorders, chronic fever, loss of appetite, worm troubles, and all ailments of liver. It has also been used in vertigo, paralytic and arthritic disorders. The medicinal properties mainly depend on a pungent resin and volatile oil which is colourless turning yellow with age with a strong odour. The fruits contain alkaloids piperine, piperlongumine and piperlonguminine. The root contains the alkaloid piperidine. The root and thicker part of the stem are cut and used as an important drug 'Piplamul'. *Piper longum* is an important ingredient in over eighty ayurvedic preparations. It is a major constituent of ayurvedic drugs recommended for increasing immunity against AIDS (Acquired Immune Deficiency Syndrome) virus and acts as an immunostimulant.

India at present imports a large quantity of *Piper longum* from Java, Malaysia and Singapore. The main product of trade is the dried spikes of female types. A survey conducted by the State Government in 1987 had estimated the quantity of *Piper longum* required by the ayurvedic medicine manufacturing industry of

Kerala at 313 tonnes. By now the requirement is estimated to have gone upto about 700 tonnes, according to the Kerala Ayurvedic Medicine Manufacturers Association. Almost the entire quantity of dried *Piper longum* spikes required by the State is currently procured either from other States or through imports at an average price of Rs.90 per kilogram.

The dried spike is a costly medicine and organised cultivation for this crop is still not popular in this country. Since *Piper longum* prefers partial shade it can be a remunerative floor crop in irrigated coconut gardens. In Kerala, currently 6,90,000 hectares of land is under coconut cultivation. Of this nearly 1,72,500 hectares are irrigated and *Piper longum* could be a remunerative intercrop in a major portion of these coconut gardens. The possibility of growing *Piper longum* as an intercrop in coconut gardens - the major plantation crop of Kerala, and identification of best types suitable for cultivation was attempted in the present study.

The five types of *Piper longum* viz. Cheematippali, Panniyur, Mala, Pattambi and Kanjur chosen for comparative evaluation, are the five selections made from over forty germplasms collected from different districts of Kerala and maintained at AICRP on M & AP (All India Co-ordinated Research Project on Medicinal and Aromatic Plants) at the College of Horticulture, Vellanikkara. The present study was undertaken with the objective to select the best type of *Piper longum* in order to recommend for large scale cultivation after evaluating economic characters and active principles.

Review of Literature

REVIEW OF LITERATURE

A review of the available literature on taxonomy, distribution, external morphology of stem, leaf, spike and chemical composition of roots, stems and fruits of *Piper longum* is presented here. Literature relating to studies on comparative evaluation of different types of *Piper longum* based on vegetative and productive characters being scarce, examples from other crops belonging to the genus *Piper* of the family Piperaceae are drawn in order to give an overall dimension of the problem.

Piper longum L. is a dicotyledonous plant, belonging to the family Piperaceae of the order Piperales. Several workers (Kirtikar and Basu, 1935; Krishnamurthy, 1969; Biswas and Chopra, 1982 and Suseelappan, 1991) described the medicinal uses of *Piper longum* and its use in various medicinal formulations in Ayurvedic system of medicine. It is an indigenous drug widely used as a stimulant, carminative, vermifuge and emmenogogue. It is also a constituent of an ayurvedic drug recommended for increasing immunity against AIDS (Acquired Immune Deficiency Syndrome) virus by acting as an immunostimulant (Anon, 1993).

2.1 Taxonomy

Hooker (1890) divided the Order Piperaceae into two tribes namely Saurureae and Pipereae. The tribe Pipereae is further divided into genus Piper and Peperomia. The genus Piper is further divided into six sections namely Muldera, Cubeba, Chavica, Pseudochavica, Eupiper and Heckeria. *Piper longum* comes under the section Chavica. The section Chavica includes fifteen species other than *Piper* *longum*. They are *Piper peepuloides*, *P. chaba*, *P. sylvaticum*, *P. petiolatum*, *P. betle*, *P. miniatum*, *P. boehmeriaëfolium*, *P. pothiforme*, *P. anisotis*, *P. aurantiacum*, *P. hapinum*, *P. brachystachyum*, *P. thomsoni*, *P. rostratum* and *P. penangense*.

2.2 Distribution

Piper longum was found wild amongst bushes, on the banks of water-courses, uptowards the Circar mountains and is cultivated in West Bengal as recorded by Roxburgh (1832). Bentley (1880) gave an account of the habitat of *Piper longum*. According to him it is found wild on the borders of streams and grows amongst other bushes in many parts of Southern and Eastern India, especially the Malabar and Coromandel coasts, where it is also largely cultivated. It also grows in Ceylon, Timor and Philippine Islands and is cultivated in Bengal. Hooker (1890) has reported it to occur wild or cultivated in hotter provinces of India, from East Bengal to Assam, the Khasia mountains and Bengal, Westward to Bombay and Southward to Travancore, Ceylon and Malacca and is also found distributed in Malay Islands.

Rao (1914) located *P. longum* in the evergreen forests in Travancore, Arienkavu, Ponmudi and at elevations of 200-3000 feet. Kirtikar and Basu (1935) reported the distribution of *Piper longum* in hotter provinces of India, Ceylon and Malay Islands. Krishnamurthy (1969) described the occurrence of *Piper longum* in the hotter parts of India, from Central Himalayas to Assam, Khasi and Mikir hills, lower hills of Bengal and evergreen forests of Western Ghats from Konkan to Travancore and has been recorded from Car Nicobar Islands. Indian long pepper is mostly derived from the wild plants, the main sources of supply being Assam, West Bengal, Nepal and Uttar Pradesh. Small quantities are also available from evergreen forests of Kerala, West Bengal and certain parts of Andhra Pradesh. It is reported to be cultivated at low elevations in Anaimalai hills in Madras and parts of Assam, particularly in the Cherrapunji area. The habitat of *Piper longum* is Java, India, Phillippines, Batavia and Singapore as suggested by Grieve (1977).

A survey conducted by Rahiman *et al.* (1979) in the forests of Karnataka revealed the presence of *Piper longum* in the localities of Subrahmanya, Perla and Bantwal under Mangalore forest division in Dakshina Kannada District. The distribution of *Piper longum* in Calicut was recorded by Manilal and Sivarajan (1982).

Piper longum is a native of Bengal, Nepal, Assam, Khasiya and Southward to Travancore and is cultivated chiefly in the northern parts of India and has been occasionally found to be located in native gardens in Ceylon according to Ridley (1983). He also reported Bengal to be the chief source of long pepper of India.

2.3 Habit and External Morphology

2.3.1 Stem

Roxburgh (1832) opined that it is not a climbing plant but possesses a perennial rootstock from which are produced many creeping rounded stems, which are jointed with swollen joints. Young shoots are downy and branchlets bearing the fruit are erect. *P. longum* is a small shrub with a large woody root and numerous creeping, cylindrical, smooth, jointed stems, thickened at nodes, young shoots quite glabrous or slightly downy as suggested by Bentley (1880). Hooker (1890) described *P. longum* as creeping with jointed stems, thickened at nodes.

Piper longum L. has an erect rootstock which is thick, jointed and branched with numerous stems ranging in height from 0.6-0.9 m, ascending or prostrate (not climbing) and much branched, stout, cylindrical, thickened above nodes and finely pubescent according to Kirtikar and Basu (1935). *Piper longum* is a glabrous undershrub with erect or subscandent nodose stem and slender branches, the latter more often creeping or trailing or rooting below or rarely scandent to a few meters as explained by Aiyer (1966). It is a slender aromatic climber with perennial woody roots and creeping stems which are jointed and young shoots downy (Krishnamurthy, 1969). According to Ilyas (1976) *P. longum* is a perennial climber having jointed stem. Rahiman *et al.* (1979) described the stem characters of *Piper longum* as a creeper whose runners struck roots and branches at every node, the branches were erect and scandent, the stem smooth, green and comparatively very thin (about 1.5 cm in diameter). The habit of *Piper longum* is as a slender climber (Purseglove *et al.*, 1981). *Piper longum* is a scandent undershrub according to Nayar *et al.* (1986).

2.3.2 Leaf

Roxburgh (1832) described the leaf characters of *Piper longum.* The leaves on creeping branches are the largest, petioled, broad cordate, five nerved, smooth, somewhat wrinkled, pale green beneath and of various sizes. Stipules of the petioled leaves are two in number, joining lengthways to the petiole and lanceolate. In case of sessile leaves, it is within the leaf, single, spathiform. Branchlets bearing the fruit have sessile leaves.

The external morphology of leaves suggested by Bentley (1880) is that the leaves are alternate, without stipules, spreading, the lower ones stalked, petioles slender, the longest two inches long, the upper leaves are sessile or nearly so, blade varying greatly in size, the lowest three inches long and nearly as wide, the uppermost not more than one inch long and half as wide, cordate at base, acute and often somewhat attenuate at the apex, entire, smooth, somewhat flaccid, strongly five nerved, dark green and paler beneath. Hooker (1890) reported the leaves to be petiolated, cordate, quite glabrous, alternate, acute, entire and smooth.

Leaves are numerous ranging in size from 6.0-9.0 cm, lower leaves are broadly ovate and very cordate with broad rounded lobes at base. Upper leaves are oblong-oval, cordate at base. All leaves are subacute, entire, glabrous, thin, bullate with reticulate venation, sunk above and raised beneath, dark green and shining above and dull and pale beneath, petioles of lower leaves range in length from 5-7.5 cm and are stout, the petioles of upper leaves are very short or without petioles, stipules are membranous, lanceolate, obtuse, soon falling, having a size of about 1.3 cm according to Kirtikar and Basu (1935). Aiyer (1966) found the leaves of *Piper longum* to be simple, alternate, stipulate and petiolate or nearly sessile, entire, glabrous, seven nerved leaves, that vary in shape and mode of attachment even in the same plant. The leaves of *Piper longum* are 5-9 cm long, 3-5 cm wide, ovate, cordate with broad rounded lobes at base, subacute, entire and glabrous as reported by Krishnamurthy (1969). Leaves of *Piper longum* are cordate according to Ilyas (1976).

Rahiman *et al.* (1979) described the leaves as membranous ranging in size upto 13.0 x 6.5 cm^2, ovate or ovate oblong, young leaves downy, asymmetrically cordate, anteriormost pair of veins deviates from the leaf base, one of the two lobes of leaf base is large over the petiole, leaves on creeping stems are cordate with equal lobes. The leaves are ovate or ovate lanceolate, acuminate and deeply cordate at base as observed by Manilal and Sivarajan (1982).

According to Ridley (1983) creeping stems bear large broadly cordate leaves, somewhat polished and showing the nerves, the tip acuminate, the base with a broad and deep indentation. The erect fruiting branches have rather smaller oblong cordate leaves, with fine nerves, the upper ones of which have no petioles, but are stem clasping. The lower leaves were characterised as ovate, deeply cordate and upper leaves as ovate or ovate oblong by Nayar *et al.* (1986).

2.3.3 Spike

Bentley (1880) described the spikes as solid, cylindrical, somewhat tapering above, reddish brown, marked with superficial spirally arranged furrows, from an inch to an inch and a half in length and about a quarter of an inch in thickness. It has an aromatic odour and a pungent aromatic taste. It consists of number of minute sessile fruits, each being crowned with the remains of the stigma in the form of a small point, and the whole closely arranged around a common axis, and supported on a short stalk.

The spikes are solitary and pedunculate. The male spikes are slender and has narrow bracts, female spikes range in length from 1.3-2.5 cm, bracts are circular, flat peltate with two stamens and three or four stigmas that are short, spreading and persistent. The fruit is very small, ovoid, completely sunk in solid fleshy spike which is about 2.5-3.8 cm in length, ovoid-oblong, blunt, erect, blackish green and shining (Kirtikar and Basu, 1935). Aiyer (1966) reported the spikes as unisexual, with small or minute achlamydeous densely or closely packed flowers and very small clusters of small greyish green or darker grey berries. According to Ilyas (1976) the spikes of *Piper longum* are unisexual, cylindrical, pedunculate, with the female inflorescence measuring upto 6 cm long and 0.6 cm in diameter and is economically important while the male inflorescence is not useful, the fleshy spike consisting of yellowish orange ovoid fruits set compactly together. The inflorescence of *Piper longum* is erect and cylindrical as observed by Rahiman *et al.* (1979). Manilal and Sivarajan (1982) described the spikes as 1-2 cm long and yellow in colour.

Ridley (1983) observed spike characters and reported that the male spikes are slender and about 1-3 inches long. The female spikes are short sessile or nearly so, opposite to the leaf, cylindrical with a rounded base and blunt at the tips, 0.6 to 1.5 inch long and erect and red when ripe. The flowers are numerous, and closely packed as in the black pepper, but the bracts are orbicular and the fruit is a minute drupe embedded in the fleshy spike. The whole spike of fruits forms a cylindrical mass, broadest at the base, and when dry is of a grey colour and very pungent.

2.4 Characters to be considered for comparative evaluation

2.4.1 Vegetative characters

Shantamalliah (1973) described seven outstanding cultivated varieties of black pepper occuring in the North Kanara district in Mysore State based on several morphological characters. The vegetative characters described included the leaf characters namely leaf colour, shape and size of leaf, surface texture of leaves, length of petioles, the angle of lateral shoots to the climbing shoots and growth vigour.

Nambiar *et al.* (1978) reported the morphological descriptions of five cultivars of black pepper from Malabar region and twelve cultivars from Travancore region. Important morphological characters recorded were the length of the petiole, length of leaf lamina, maximum breadth of leaf lamina, colour of leaf, shape of leaf, angle of insertion of leaves and branching habits. It was found that Travancore cultivars have leaves with short petioles, oval or nearly circular lamina. The Malabar cultivars have generally long petioles and oblong leaves. The Malabar cultivars have drooping branches and leaves. The lateral branches and leaves of Travancore cultivars are horizontal and erect.

Pillai *et al.* (1978) compared eight varieties of black pepper based on the only vegetative character, the length of internode of bearing shoot. The eight varieties were found to differ significantly for this character i.e. the length of internode of bearing shoot.

Rahiman *et al.* (1979) gave an account of the morphology of nine species of family Piperaceae including *Piper longum* based on the following vegetative characters namely habit, size of leaf, shape of leaf, thickness of leaf, texture of leaf, leaf base and anteriormost part of veins.

Ponnuswami *et al.* (1983) evaluated eightysix open pollinated plants of black pepper for carrying out variability studies in pepper. The observations recorded were vine length, number of nodes, internodal length and vine girth. The vine length ranged from 0.6-5.5 m, the vine girth ranged from 0.6 to 2.8 cm in the population and the number of nodes ranged from 3-27. A wide range and coefficient of variability was recorded for the traits, number of nodes and vine length.

Ibrahim *et al.* (1984a) investigated the morphological affinity of the hybrid variety Panniyur-1 to Malabar and Travancore cultivars of black pepper. Various vegetative characters studied for the variety Panniyur-1 included the length of orthotrope internode, length of plageotrope internode, length of petiole and area of leaf lamina. The results showed that the hybrid variety Panniyur-1 shared more in common with Malabar group than Travancore group when vegetative characters alone were considered.

Ravindran and Nair (1984) gave a short description of some of the popular cultivars of black pepper. The cultivars were Karimunda, Narayakkodi, Kalluvally, Balancotta, Kottanadan, Kuthiravally, Kaniakkadan, Arakkulam Munda, Malligesara, Uddaghere, Neelamundi, Veluthanamban and Panniyur-1. The vegetative characters described included the leaf characters.

Kanakamany *et al.* (1985) prepared a key for the identification of the different cultivars of black pepper. Forty five *Piper nigrum* cultivars were grouped according to a key based on nine vegetative characters. The characters studied included internodal length in orthotrope, internodal length in plageotrope, thickness at node and internode, petiole length, leaf area, leaf shape and leaf tip. With respect to leaf shape the cultivars were grouped into three classes namely elliptic, ovate and cordate.

Analysis of variance of leaf and flower characters in male and female plants of *Piper argyrophyllum, Piper attenuatum, Piper galeatum, Piper hookeri, Piper longum, Piper mullesua (Piper brachystachyum), Piper nigrum* and *Piper trichostachyon*, occurring in the Western Ghat region of Southern India using Mahalanobis D^2 method was carried out by Rahiman *et al.* (1985).

A comparative study with open pollinated seedlings of six cultivars of pepper viz. Uthirankotta, Arakkulam Munda, Munda, Karimunda, Kalluvally (Pt 6) and Panniyur-1 was done by Ibrahim *et al.* (1986c). It was found that in general the internodal length varied between the varieties more than the other characters like number of leaves and plant height. Seedlings of Panniyur-1 showed very short internodes coupled with a high coefficient of variation whereas that of cultivar Munda was found to possess the least variability for internodal length.

Out of the various methods developed for various types of leaves, linear measurement of leaf area has been found more rapid and reliable according to

Spencer (1962) and Vivekanandan *et al.* (1972). Mohankumar and Prabhakaran (1980) reported that the product of maximum leaf length and breadth was found suitable for linear measurement to area conversion. The area of black pepper leaves can be determined rapidly and accurately by the use of the physiological constant K = 0.71. Ibrahim *et al.* (1985) measured leaf length, breadth, length:breadth ratio and leaf area for forty varieties of black pepper. The study revealed that the leaf area was rather a function of length:breadth ratio of the leaf rather than its breadth.

Chandy and Pillai (1979) found the actual angle of insertion of the plageotropes on the orthotrope to vary from variety to variety in black pepper and was identified as a varietal character. As a result some of the varieties possessed drooping branches while other semierect branches. As the intensity of light falling on the leaves varies according to their degree of horizontality the angle of insertion of plageotropes has a direct bearing on the photosynthetic efficiency and yield of the plant. Kanakamany *et al.* (1985) concluded that if the angle subtended by the lateral with the main stem was more than 80° the lateral was designated as drooping and if the angle was less than 80° it was designated as semierect in case of black pepper.

2.4.2 Productive characters

Rahiman *et al.* (1979) described the spike characters of *Piper longum*. The characters described included the average spike length, spike shape, spike surface, bract and number of stamens.

Comparative evaluation studies of four selected geographical races of *Piper longum* namely Cheematippali, Panniyur, Pattambi and Kaanjur, based on green spike yield and dry spike yield revealed that Cheematippali recorded the maximum green spike yield (624.92 kg/ha), followed by Pattambi (407.82 kg/ha), Kaanjur (401.34 kg/ha) and Panniyur (71.29 kg/ha). The maximum dry spike yield was recorded by Cheematippali (200.9 kg/ha) followed by Pattambi (157.6 kg/ha), Kaanjur (139.5 kg/ha) and Panniyur (28.7 kg/ha) (Progress Report, AICRP on M & AP, 1993).

Shantamalliah (1973) compared five outstanding cultivated varieties of pepper in North Kanara district on the basis of following spike characters namely spike length, dry weight of spike and percentage of developed and underdeveloped berries in each spike.

Ramankutty (1977) compared seven varieties of Pepper namely Panniyur-1, Karimunda, Kuthiravally, Balamcotta, Arakkulam Munda, Kalluvally and Uthirancotta, on the basis of economic characters of single spike based on a mean of 25 observations. The characters studied include length of spike, number of berries per spike, green weight of spike, weight of 1000 green berries, and percentage recovery of dry pepper. It was found that Panniyur-1 excels other varieties in all the spike characters.

Nambiar *et al.* (1978) compared six Malabar cultivars of black pepper and twelve Travancore cultivars of black pepper on the basis of following spike characters namely mean length of spike, mean number of developed berries on the spike, mean weight of 100 green berries, mean volume of 100 green berries in cc, percentage of dry to green weight of pepper and mean number of days taken for emergence of the spike. Pillai *et al.* (1978) compared eight varieties of black pepper based on biometric observations to arrive at useful results for improvement of its yield. The results showed that the number of spikes and yield are highly correlated.

The length of the spike had high influence on the number of berries per spike and the length of the internodes of the bearing shoot had positive influence on the weight of 1000 green berries.

Pillai and Balakrishnan (1979) compared the performance of eight varieties of black pepper namely Kottanadan, Karimunda, Valiyakaniakadan, Kuthiravally, Kalluvally, Karimunda, Narayakodi and Panniyur-1 on the basis of mean yield of green pepper (kg/vine). The results showed that Narayakodi outyielded all other cultivars in the first, third and fourth year. In the second year, Karimunda gave the highest yield per vine. The combined analysis showed that Narayakodi, Karimunda and Kuthiravally were significantly superior to other varieties tried. Kalluvally, a north Kerala cultivar gave the lowest yield.

Ravindran and Nair (1984) described some of the popular cultivars of black pepper. The productive characters described included the range of spike length, mean length of spikes, size of berries, colour of berries, driage percentage and yield of pepper.

Ibrahim *et al.* (1984a) while studying the morphological relationship of variety Panniyur-1 with Malabar and Travancore groups of black pepper compared the following reproductive characters namely length of spike, number of flowers per spike, number of developed berries per spike, 1000 berry weight and 1000 berry volume. The variety Panniyur-1 showed no tilt in either direction while reproductive characters alone were considered.

Kanakamany *et al.* (1985) while preparing a key for the identification of forty-five different cultivars of black pepper studied the following spike characters namely spike length, number of well developed berries, number of underdeveloped berries, 1000 berry weight in the fresh condition and in dry condition and 1000 berry volume in fresh condition and dry condition.

Mathai (1986) studied growth and yield analysis in black pepper varieties under different light conditions. It was found that Panniyur-1 bore more laterals, spikes and berries than other varieties and a higher mean berry weight and a higher rate of photosynthesis.

Chandy *et al.* (1979) reported that though the general acceptable rule is one spike for every leaf axil, it might not hold good uniformly. Some of the cultivars were superior in this aspect. They reported the occurrence of abortive spikes in pepper. Some of the spikes are retained only for a short period before being shed. A study of spike production in 39 varieties of black pepper cultivated in Kerala showed the percentage of the abortive spikes to be lowest in varieties giving highest yield such as Arakkulam Munda which sometimes produced two spikes in a leaf axil one of the spikes being abortive and the other normal.

2.5 Component characters of yield, their correlations and path analysis

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, to carry out selection. 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.

Pillai *et al.* (1978) conducted a study on eight popular varieties of pepper to understand the association between various pairs of component characters as well as component characters and yield. The number of spikes and the yield were found to be highly correlated, as can be seen from the genotypic correlation coefficient of 0.93. The length of spike had high influence on number of berries per spike. The length of the internodes exhibited a negative influence on the number of spikes and a positive influence on number of berries per spike. The spike length, the number of berries per spike and the length of the internodes of the bearing shoot had positive influence on the weight of 1000 green berries.

Ibrahim *et al.* (1985c) have conducted a study on 28 genotypes of pepper to understand the intercorrelation between various pairs of component characters as well as the correlation of 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 soyabean (Johnson *et al.*, 1955a), Pearlmillet (Pokhriyal *et al.*, 1967) and mungbean (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.

In pepper, 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 importance 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. Correlation studies carried out in Turmeric by Philip (1983) to screen the superior types with higher yield revealed that height of the plant, petiole length, length and breadth of leaf, leaf area index and number of leaves per tiller were positively correlated with yield whereas the number of tillers per plant and number of leaves per plant showed no correlation with yield.

A background information on the relative contribution of each 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 through number of developed berries per spike whereas it was small and negative through 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. While 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 spike length on yield was negative (-0.0887) while its indirect effect through 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 with 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.

2.6 Chemical composition

Atal and Banga (1962) carried out phytochemical studies on stems of *P. longum* and reported the isolation of an alkaloid piplartine (m.p. 124–125°C) from the stems of this species.

Atal and Banga (1963) reported the structure of piplartine an alkaloid isolated from stems of *Piper longum*. They suggested that piplartine is a piperidine amide of 3,4,5-trimethoxycinnamic acid.

Chatterjee and Dutta (1963) investigated the roots of *Piper longum* and a new alkaloid piperlongumine was isolated and its structure was established. The petroleum ether extract of the dried roots of *Piper longum* contained 0.3% of total basic material from which the alkaloid piperlongumine, $C_{17}H_{19}O_5N$ (Mass number, 317), m.p.124°C, $[\alpha]_D^{30} \pm O$ (in ethanol) was isolated in a yield of 0.2-0.25% based on dry roots.

Atal *et al.* (1966) reported the occurrence of sesamin in *Piper longum.* N-isobutyldeca-trans-2-trans-4-dienamide is found to occur in *Piper longum* according to Dhar and Atal (1967).

Nigam and Radhakrishnan (1968) carried out the chemical examination of the essential oil derived from the berries of *Piper longum* L. The essential oil of *Piper longum* has been obtained in a yield of 0.6% as a greenish yellow mobile liquid. Caryophyllene has been found to be the major constituent of the oil on chemical analysis. A sesquiterpene hydrocarbon has been isolated and the presence of a sesquiterpene alcohol and a carbonyl compound has been established.

Krishnamurthy (1969) elaborated on the chemical constituents of the fruits and drug obtained from the dried roots and thicker parts of the stem of *Piper longum*. The fruit of *Piper longum* has shown the presence of the alkaloids piperine (4-5%) and piplartine (m.p.124-125°C) and two liquid alkaloids, one of which is designated as alkaloid A. Alkaloid A showed significant *in vitro* antitubercular activity against *Mycobacterium tuberculosis* $H_{-37}Rv$ strain. Sesamin ($C_{20}H_{18}O_6$ m.p.122°C), dihydrostigmasterol, and a new sterol piplasterol are also present. Piplamul an important drug obtained from the dried roots and thicker part of stem contains piperine (0.15-0.18%), piplartine (0.13-0.20%) and traces of a yellow crystalline pungent alkaloid (m.p.116-117°C). Other constituents found in the drug include triacontane, dihydrostigmasterol, an unidentified steroid (m.p.122-123°C) reducing sugars and glycosides.

Atal *et al.* (1975) gave an account of the chemical compounds isolated from *Piper longum*. 1-Undecyl-3,4-methylenedioxy benzene, a hydrocarbon derivative ($C_{18}H_{26}O_2$), m.p.37-38°C was isolated from the steam distilled residue of the ether extract of the fruits of *Piper longum*. Sesamin ($C_{20}H_{20}O_6$, m.p.122°C), a lignan has been isolated from the petroleum ether extract of the fruits and stems of *Piper longum* by chromatography over alumina. Piperlonguminine ($C_{16}H_{19}NO_3$, m.p.166-168°C) an isobutylamide, a white crystalline compound has been isolated from the petroleum ether extract of the roots of *Piper longum*. Piperine ($C_{17}H_{19}NO_3$, m.p.128-129°C) the most commonly occurring alkaloid in *Piper species* has been isolated from *Piper longum*. Another alkaloid piplartine was isolated, from stems of *Piper longum*.

Hentriacontane, hentriacontanone-16, triacontanol and B-sistosterol have been chemically isolated and identified in the leaves of *P. longum* by Manavalan and Singh (1979).

Sharma *et al.* (1983) chemically examined the dried fruits of *Piper longum* and have reported the presence of L-tyrosine, L-cysteine hydrochloride, dl-serine and L-aspartic acid as free amino acids.

Tabuneng *et al.* (1983) isolated two new piperidine alkaloids, pipernonaline and piperundecalidine from the fruits of *Piper longum*. Their structures were determined to be (2E, 8E)-N-[9-(3,4-methylenedioxyphenyl)-2,8-nonadienoyl] piperidine and (2E, 4E, 10E)-N-[11-(3,4-methylenedioxyphenyl)-2,4,10-undecatrienoyl] piperidine, respectively on the basis of spectral data.

According to Prabhu and Mulchandani (1985) an alkamide piperlongumine is the major constituent of *Piper longum*.

Shoji *et al.* (1986) reported the isolation of dehydropipernonaline, an amide possessing coronary vasodilating activity from the fruits of *P. longum*. The structure of this compound is also described.

Banerjee *et al.* (1986) described the crystal and molecular structure of Piperlongumine, N-(3,4,5-trimethoxycinnamoyl)-Δ^3-piperidine-2-one, isolated from the roots of *Piper longum*. This amide alkaloid is used in the treatment of asthma and chronic bronchitis.

Three new alkaloids, piperolactam A, piperolactam B and piperadione, have been isolated from the cold ethanol extract of *P. longum* by Desai *et al.* (1988).

Five types of *Piper longum* namely Cheematippali, Panniyur, Mala, Pattambi and Kaanjur were evaluated for total alkaloidal content in the dried spikes of each of the five types. The study revealed that Panniyur possessed the maximum alkaloidal content (3.00%) followed by Pattambi and Kaanjur each of which recorded (2.90%), Cheematippali (2.83%) and Mala (2.80%) in that order (Annual Report, AICRP on M & AP, 1993).

Chemical studies on the fruits of *Piper longum* showed the presence of three alkaloids namely piperine, piperlongumine and piplerlonguminine. The fruits on extraction with petroleum ether gave sylvatin, sesamin and dieudesmin (Anon, 1991).

2.7 *Piper longum* as an intercrop

Many workers (Lahiri. 1972; Singh *et al.* 1985; Singh *et al.* 1990) have reported successful intercropping of medicinal and cash crops.

Successful intercropping of *Piper longum* in coconut gardens was reported in the trials conducted at AICRP on M&AP Project in order to evaluate the performance of selected geographical races of *Piper longum* in coconut gardens (Annual Report, AICRP on M & AP, 1990).

Jha and Gupta (1991) studied the suitability of *Piper longum* as an intercrop with poplar. The performance was recorded in the form of survival percentage. *Piper longum* showed cent per cent survival as a short rotation intercrop with poplar.

Materials and Methods

MATERIALS AND METHODS

The experiment was conducted in the Department of Agricultural Botany, College of Horticulture, Vellanikkara during the period 1990-92 using five types of *Piper longum* (Linn.) selected from forty germplasms maintained at the All India Co-ordinated Research Project on Medicinal and Aromatic Plants (AICRP on M&AP). The experiment was laid out as an intercrop in coconut plantations. The selections are Cheematippali, Panniyur, Mala, Pattambi and Kaanjur.

The location of the experiment was the coconut plantations in the Instructional Farm attached to the College of Horticulture, Vellanikkara in the P Block at 10° 32' North latitude and 76° 11' East longitude with an altitude of 22.3 m above MSL.

The details of the meteorological observations recorded during the crop period are presented in Appendix-I.

The details of materials and techniques adopted during the course of investigation are presented here.

3.1 Experimental Material

The experimental material consisted of five selections of *Piper longum* (Linn.) namely Cheematippali, Panniyur, Mala, Pattambi and Kaanjur. The details of types selected for study are given in Table 1.

Table 1. Details of *Piper longum* types selected for study

Sl.No.	Accession No.	Local name	Place of origin
1	PL-7	Cheematippali	Pepper Research Station, Panniyur
2	PL-6	Panniyur	Panniyur (Thaliparamba)
3	PL-23	Mala	Mala Local
4	PL-4	Pattambi	Regional Agricul-ural Research Station, Pattambi
5	PL-17	Kaanjur	Near Kalady

3.2 Methods

Experiment was laid out in Randomised Block Design with five replications which formed the experimental area. The layout of the experiment in the field in Randomised Block Design is depicted in Appendix II. The gross area of each plot was 3.6 m x 3.0 m, the net area was 3.0 m x 2.4 m. The spacing adopted was 60 cm x 60 cm. Three noded cuttings of the five types were raised in polybags and later transferred to the main field and planted at the rate of three rooted cuttings per hole.

Gap filling was carried out three weeks after planting in the main field. Weeding was done at regular intervals to keep away unwanted plants. Earthing up was taken up at regular intervals. Irrigation was carried out at fortnightly intervals. Farmyard manure was applied at the rate of ten to twelve tonnes per hectare. This was applied in three split doses, one at the time of planting and consequent ones at three months interval. Staking was done two months after planting to provide support to the plant for climbing.

3.2.1 Characters studied

Observations on vegetative and productive characters were recorded from six randomly chosen hills from each plot for all the five types of *Piper longum*.

Leaving a border row on all sides, a total of six hills were selected at random from each plot and tagged for recording observations.

3.2.1.1 Vegetative characters

3.2.1.1.1 Length of the longest stem

The length of the longest stem was measured in cm from ground level to the tip of the stem using a metre scale and was recorded from six hills per plot and mean arrived at, at monthly intervals.

3.2.1.1.2 Number of stems per hill

The number of stems per hill from each of the six hills per plot was counted and mean arrived at, at monthly intervals.

3.2.1.1.3 Number of vegetative branches per stem

The number of vegetative branches per stem was recorded for two stems chosen at random from each of the six hills per plot and mean arrived at based on twelve observations per plot, at monthly intervals.

3.2.1.1.4 Internodal length of main stem

The length in cm of two internodes of main stem selected at random from each of the six hills per plot was measured using a metre scale and mean arrived at based on twelve observations per plot, at monthly intervals.

3.2.1.1.5 Diameter at node of main stem

The diameter at node of main stem was measured in cm with the help of a long strip of paper calibrated in mms and cms and wound over the node. Observations were recorded for twelve nodes chosen at random from six hills per plot and the mean arrived at.

3.2.1.1.6 Diameter at internode of main stem

A long strip of paper calibrated in mms and cms was wound over the internode of the main stem was used to measure the diameter in cm at the internode of main stem. Observations were recorded for twelve internodes chosen at random from six hills per plot and mean arrived at.

3.2.1.1.7 Shape of leaf lamina

Shape of leaf lamina in all the five types was recorded by visual observation. The shape of leaf lamina was compared with the different types of leaf shapes as suggested by Shukla and Misra (1979).

3.2.1.1.8 Nature of leaf tip

The type of leaf tip in all five types was recorded by visual observation. The leaf tip in the five types was compared with different types of leaf tips depicted by Shukla and Misra (1979).

3.2.1.1.9 Shape of leaf base

The type of leaf base in all five types was recorded by visually observing the leaf base of each type and comparing it with the different types of leaf base recorded by Shukla and Misra (1979).

3.2.1.1.10 Margin of leaf

The type of leaf margin in all five types was described as either entire or undulating.

3.2.1.1.11 Leaf surface

The leaf surface in all five types was described by feel of touch as glabrous or rough.

3.2.1.1.12 Leaf characters

Leaf characters namely leaf length, leaf width and length of petiole were recorded for the same twelve leaves chosen at random from six hills per plot.

3.2.1.1.12.1 Length of leaf

The length of each of the twelve leaves chosen at random from six hills per plot was measured in cm using a metre scale and mean arrived at, at monthly intervals.

3.2.1.1.12.2 Width of leaf

The width of each of the twelve leaves chosen at random from six hills per plot was measured in cm using a metre scale and mean arrived at, at monthly intervals.

3.2.1.1.12.3 Length of petiole

The length of petiole was measured in cm using a metre scale for each of the twelve leaves chosen at random from six hills per plot and mean arrived at, at monthly intervals.

3.2.1.1.13 Area of leaf lamina

The leaf area was determined using graph paper method. The leaf boundaries were drawn on the graph paper and the area determined by counting the number of squares and expressed in cm^2. The observations were recorded for each of the thirty leaves chosen at random from six hills per plot and mean arrived at from each plot.

3.2.1.1.14 Number of leaves per hill

The number of leaves from each of the six hills per plot was counted and mean arrived at, at monthly intervals.

3.2.1.1.15 Spread of the plant

Spread of the plant towards both sides was measured in cm using a metre scale, for six hills per plot and mean arrived at, at monthly intervals.

3.2.1.1.16 Nature of spike apex

The nature of spike apex was recorded for all the five types by visual observation.

3.2.1.1.17 Number of spike bearing branches per stem

The number of spike bearing branches per stem was recorded for twelve stems chosen at random from six hills per plot and mean arrived at, at monthly intervals.

3.2.1.1.18 Angle of insertion of spike bearing branch

The angle subtended by the spike bearing branch with the main stem was measured in degrees with the help of a protractor. Observations were recorded for twelve spike bearing branches chosen at random from six hills per plot and mean arrived at.

3.2.1.1.19 Internodal length of spike bearing branch

The length of two internodes of spike bearing branch selected at random from each of the six hills per plot was measured in cm using a metre scale and mean arrived at based on twelve observations per plot at monthly intervals.

3.2.1.1.20 Diameter at node of spike bearing branch

The diameter at node of spike bearing branch was measured in cm with the help of a long strip of paper calibrated in mms and cms and wound over the node. Observations were recorded for twelve nodes chosen at random from six hills per plot and mean arrived at.

3.2.1.1.21 Diameter at internode of spike bearing branch

The diameter at internode of spike bearing branch was measured in cm with the help of a long strip of paper calibrated in mms and cms and wound over the internode. Observations were recorded for twelve internodes chosen at random from six hills per plot and mean arrived at.

3.2.1.2 Productive characters

3.2.1.2.1 Spike characters

Spike characters namely length of spike, diameter of spike and length peduncle were recorded for the same twenty spikes chosen at random from six hills per plot.

3.2.1.2.1.1 Length of spike

Length of spike was measured in cm immediately after harvest for twenty spikes chosen at random from six hills per plot with the help of a metre scale, and mean arrived at. The observations were recorded both after first and second harvest.

3.2.1.2.1.2 Diameter of spike

The maximum diameter of the spike was measured in cm with the help of a long strip of paper calibrated in mms and cms and wound over the spike. Observations were recorded for twenty spikes chosen at random from six hills per plot after first harvest and second harvest.

3.2.1.2.1.3 Length of peduncle

The length of peduncle was measured in cm with the help of a metre scale for twenty spikes chosen at random from six hills per plot and mean arrived at after first harvest and second harvest.

3.2.1.2.2 Number of spikes per spike bearing branch

The number of spikes per spike bearing branch was recorded for twelve spike bearing branches chosen at random from six hills per plot and mean arrived at, at monthly intervals.

3.2.1.2.3 Days from planting to emergence of spike

The number of days required from planting to emergence of spike was recorded for twenty spikes per plot and mean arrived at based on twenty observations per plot.

3.2.1.2.4 Days from emergence to maturity of spike

The fruits after emergence, when attained a bright cream colour were tagged with papertags bearing the date of tagging. When the fruits attained maturity ie. when the fruits attained a blackish green colour with a shining surface they were harvested and the number of days required for the maturity of spike was recorded. The observations were taken for twenty spikes chosen at random from six hills per plot and mean arrived at.

3.2.1.2.5 Yield of green spike

Yield of green spike was recorded from each of the six hills per plot and the total plot yield obtained by multiplying the average green spike yield per hill by the number of hills per plot ie. twenty. The yield in kg per hectare of green spike was then worked out.

3.2.1.2.6 Yield of dry spike

The green spikes were sundried for a period of three days and the dry spike yield from each of the six hills was recorded. The average dry spike yield per hill thus obtained was multiplied by twenty to obtain the total dry spike yield per plot. The yield in kg per hectare of dry spike was then worked out.

3.2.1.2.7 Ratio of weight of green spike to the weight of dry spike

Twenty mature green spikes were selected at random from each plot and weighed. The same twenty spikes were then sundried and again weighed and the ratio of weight of green spike to weight of dry spike was worked out for each of the spike and mean arrived at based on twenty observations per plot at both first and second harvest.

3.2.2 Statistical Analysis

The details of the statistical analysis followed are given below.

3.2.2.1 Analysis of variance

The data pertaining to the different vegetative and productive characters were recorded and tabulated. The data were subjected to analysis of variance, to test the significance of treatments, according to the procedure of Panse and Sukhatme (1978).

ANOVA

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio (F)
Replication	(r-1)	SSR	S^2R	S^2R/S^2E
Treatment	(v-1)	SSV	S^2V	S^2V/S^2E
Error	(r-1) (v-1)	SSE	S^2E	

r = Number of replications
v = Number of varieties

SSR = Replication sum of squares

SSV = Varietal sum of squares

SSE = Error sum of squares

S^2R = Replication mean square

S^2V = Varietal mean square

S^2E = Error mean square

The significance of computed values of 'F' was tested with reference to the 'F' table (Panse and Sukhatme, 1978).

3.2.2.2 Estimation of correlation

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

$$r = \frac{Cov}{\sigma x \ \sigma y}$$

where r = Correlation coefficient

Cov = Covariance for the two characters x and y

σx = Standard deviation of the character x

σy = Standard deviation of the character y

3.2.2.3 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. Seven characters showing maximum correlation with dry spike yield 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

$$y = a_1x_1 + a_2x_2 \ldots\ldots\ldots + a_7x_7$$

where, y and x's are standardised variates corresponding to yield and the 7 attributes, respectively. The following set of simultaneous equations were formed and solved for estimating the various direct and indirect effects.

$$r_{iy} = \sum_{j=1}^{7} P_{iy} \, r_{ij} \quad i = 1, \ldots\ldots\ldots 7$$

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

$$A = \begin{bmatrix} r_{1y} \\ r_{2y} \\ \vdots \\ r_{7y} \end{bmatrix} \quad B = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{17} \\ r_{21} & r_{22} & \cdots & r_{27} \\ \vdots & & & \\ r_{71} & r_{72} & \cdots & r_{77} \end{bmatrix} \quad C = \begin{bmatrix} P_{1y} \\ P_{2y} \\ \vdots \\ P_{7y} \end{bmatrix}$$

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,

$$R^2 = \sum_{i=1}^{7} P^2_{iy} + 2 \sum_{i} \sum_{j} P_{iy} P_{jy} r_{ij}, \; i < j$$

3.3 Total alkaloidal content in dried spikes of *Piper longum*

The total alkaloids in percentage of dried spikes of *Piper longum* was determined using the Soxhlet extraction method. Five grams of dried and finely ground spikes of *Piper longum* was accurately weighed into the filter paper to hold the sample and the weight of the sample together with the filter paper was recorded. The sample packet was then dropped into the extraction tube of the Soxhlet apparatus. The bottom of the extraction tube was then attached to the previously weighed Soxhlet flask. One hundred ml of Petroleum benzine (40-60°C b.p) was used as the solvent and poured through the sample in the tube into the flask. The top of the extraction tube was then attached to the condenser. Extraction of the sample was carried out for eight hours without interruption by gentle heating. The temperature of water bath was regulated so that the solvent which volatilizes condenses and drops continously upon the sample without any appreciable loss.

At the end of the extraction period ie. when the previously colourless solvent in the flask turns green coloured and the solvent in the extraction tube turns colourless the sample packet was removed from the extractor and most of the solvent was distilled off by allowing it to collect in the Soxhlet tube. The solvent was poured off into the Soxhlet flask when the tube was nearly full. The Soxhlet flask was dismantled, allowed to cool and the solvent was evaporated over a waterbath. The Soxhlet flask along with the residue was weighed. The residue left in the Soxhlet flask after complete evaporation of the solvent is the total alkaloid extracted.

Total alkaloid content (grms) = Weight of the Soxhlet flask along with the residue (grms) - Weight of the empty Soxhlet flask (grms)

$$\text{Total alkaloids in percentage} = \frac{\text{Weight of the residue (grms)}}{\text{Weight of the dried sample (grms) used for extraction}} \times 100$$

Results

RESULTS

Results of observations on important vegetative and productive characters collected from five types of *Piper longum* namely Cheematippali, Panniyur, Mala, Pattambi and Kaanjur are presented in this chapter.

4.1 Vegetative characters

Observations recorded on the vegetative characters and the results of their analysis are presented below.

4.1.1 Length of the longest stem

Length in cm of the longest stem of the five *Piper longum* types from one month after planting to nine month after planting at intervals of one month are given in Table 2 and the analysis of variance in Appendix III. These types did not differ significantly with respect to this character at these stages except for one month and seven month after planting. Cheematippali (9.40 cm) had the maximum height at one month after planting which was on par statistically with Kaanjur (9.12 cm). The minimum height at one month after planting was observed for Mala (7.78 cm). Cheematippali (152.52 cm) which had the maximum height at one month after planting maintained the position of the tallest type at seven month after planting. This type was significantly taller than the remaining four types. Similarly Mala (75.23 cm) had the minimum height at this stage and did not differ significantly from Kaanjur (91.55 cm) and Pattambi (81.08 cm).

The mean height varied from 10.72 cm in Mala to 13.75 cm in Cheematippali at two month after planting, 29.03 cm in Pattambi to 35.08 cm in Panniyur at

Table 2. Length of the longest stem in cm of the five *Piper longum* types (one month after planting to nine month after planting)

Types	Length of the longest stem (cm)								
	Month after planting								
	1	2	3	4	5	6	7	8	9
Cheematippali	9.40	13.75	34.33	42.92	70.01	91.35	152.52	129.17	56.53
Panniyur	8.70	10.92	35.08	48.66	60.60	67.69	112.36	82.92	63.89
Mala	7.78	10.72	31.90	34.64	54.87	77.01	75.23	90.11	51.03
Pattambi	8.38	11.21	29.03	37.22	56.40	77.74	81.08	80.80	55.64
Kaanjur	9.12	12.32	30.07	33.34	65.33	81.17	91.55	95.65	68.32
SEm±	0.20	0.86	3.76	3.99	4.54	6.44	8.18	12.57	7.79
CD (0.05)	0.43	NS	NS	NS	NS	NS	17.33	NS	NS

three month after planting, 33.34 cm in Kaanjur to 48.66 cm in Panniyur at four month after planting, 54.87 cm in Mala to 70.01 cm in Cheematippali at five month after planting, 67.69 cm in Panniyur to 91.35 cm in Cheematippali at six month after planting, 80.80 cm in Pattambi to 129.17 cm in Cheematippali at eight month after planting and from 51.03 cm in Mala to 68.32 cm in Kaanjur at nine month after planting.

4.1.2 Number of stems per hill

The number of stems per hill of the five *Piper longum* types from three month after planting to nine month after planting at intervals of one month are presented in Table 3 and the analysis of variance in Appendix IV. These five types differed significantly with respect to this character at all of these stages. Cheematippali (4.63) had the highest number of stems per hill at three month after planting and was on par statistically with Kaanjur (4.46) at this stage. However Cheematippali was significantly superior to Pattambi (3.13), Mala (3.06) and Panniyur (2.70). Panniyur (2.70) recorded the minimum number of stems per hill at three month after planting. Cheematippali (7.10) maintained the position of highest number of stems per hill at four month after planting. Cheematippali was on par statistically with Kaanjur (6.70) and significantly superior to Panniyur (4.80), Mala (4.26) and Pattambi (4.03) at this stage. Pattambi (4.03) recorded the minimum number of stems per hill at four month after planting which was on par statistically with Panniyur (4.80) and Mala (4.26). Cheematippali (10.26) occupied the position of highest number of stems per hill at five month after planting and was on par statistically with Kaanjur (9.73) and Panniyur (9.07). Cheematippali was significantly superior to Mala (7.96) and Pattambi (7.33) at five month after planting. The minimum number of stems per hill was recorded in Pattambi (7.33) at this stage. Cheematippali (13.16) which recorded the highest number of stems per hill at six month after

Table 3. Number of stems per hill of the five *Piper longum* types (three month after planting to nine month after planting)

Types	Number of stems per hill						
	Month after planting						
	3	4	5	6	7	8	9
Cheematippali	4.63	7.10	10.26	13.16	19.03	11.72	10.76
Panniyur	2.70	4.80	9.07	11.40	13.93	9.87	5.82
Mala	3.06	4.26	7.96	10.40	11.40	6.86	5.82
Pattambi	3.13	4.03	7.33	9.70	12.33	8.40	5.08
Kaanjur	4.46	6.70	9.73	13.03	18.03	13.03	11.35
SEm ±	0.23	0.50	0.53	0.48	1.12	0.82	0.78
CD (0.05)	0.48	1.05	1.13	1.01	2.36	1.74	1.66

planting was on par statistically with Kaanjur (13.03). However Cheematippali was found to be significantly superior to Panniyur (11.40), Mala (10.40) and Pattambi (9.70) at this stage. The minimum number of stems per hill was recorded in Pattambi (9.70) at six month after planting which was on par statistically with Mala (10.40). Cheematippali (19.03) recorded the highest number of stems per hill at seven month after planting which was on par statistically with Kaanjur (18.03). Cheematippali was significantly superior to Panniyur (13.93), Pattambi (12.33) and Mala (11.40) at seven month after planting. The minimum number of stems per hill was recorded in Mala (11.40) at this stage which was statistically on par with Panniyur and Pattambi. Kaanjur (13.03) had the highest number of stems per hill at eight month after planting which was on par statistically with Cheematippali (11.72). Kaanjur was significantly superior to Panniyur (9.87), Pattambi (8.40) and Mala (6.86) at eight month after planting. The minimum number of stems per hill was recorded in Mala (6.86) at this stage which was on par statistically with Pattambi. Kaanjur (11.35) which had the maximum number of stems per hill at eight month after planting maintained its position even at nine month after planting. Kaanjur was found to be significantly superior to Panniyur (5.82), Mala (5.82) and Pattambi (5.08) but was on par statistically with Cheematippali (10.76) at this stage. The minimum number of stems was recorded in Pattambi (5.08) which was on par statistically with Mala and Panniyur at nine month after planting.

4.1.3 Number of vegetative branches per stem

Number of vegetative branches per stem of the five types of *Piper longum* from five month after planting to nine month after planting at intervals of one month are presented in Table 4 and the analysis of variance in Appendix V. The five types of *P. longum* did not differ significantly for this character at any of these stages except at five month after planting. At five month after planting

Table 4. Number of vegetative branches per stem of the five *Piper longum* types (five month after planting to nine month after planting)

Types	Number of vegetative branches per stem				
	Month after planting				
	5	6	7	8	9
Cheematippali	1.50	2.80	3.53	3.26	2.94
Panniyur	1.43	2.46	3.28	3.09	2.40
Mala	1.16	2.06	2.63	3.00	2.30
Pattambi	1.23	2.21	3.19	3.07	2.31
Kaanjur	1.46	2.53	3.40	3.13	2.68
SEm ±	0.08	0.18	0.21	0.36	0.28
CD (0.05)	0.17	NS	NS	NS	NS

Cheematippali (1.50) recorded the maximum number of vegetative branches per stem which was on par statistically with Kaanjur (1.46) and Panniyur (1.43), but it was significantly superior to Pattambi (1.23) and Mala (1.16) at this stage. The lowest number of vegetative branches per stem was recorded in Mala (1.16) at five month after planting.

The number of vegetative branches per stem varied from 2.06 in Mala to 2.80 in Cheematippali at six month after planting, 2.63 in Mala to 3.53 in Cheematippali at seven month after planting, 3.00 in Mala to 3.26 in Cheematippali at eight month after planting and 2.30 in Mala to 2.94 in Cheematippali at nine month after planting. Cheematippali consistently recorded the maximum number of vegetative branches per stem at all these stages whereas Mala consistently recorded the minimum number of vegetative branches per stem at all these stages.

4.1.4 Internodal length of main stem

The internodal length of main stem of the five types of *Piper longum* from four month after planting to nine month after planting at intervals of one month are presented in Table 5 and the analysis of variance in Appendix VI. The five types did not differ significantly with respect to this character at any of these stages except at four month after planting. Kaanjur (4.90 cm) recorded the maximum internodal length at four month after planting and was significantly superior to Cheematippali (4.05 cm) and Panniyur (4.03 cm) but was on par statistically with Mala (4.49 cm) and Pattambi (4.47 cm). Panniyur (4.03 cm) recorded the minimum internodal length at four month after planting.

The internodal length of main stem varied from 4.82 cm in Mala to 4.93 cm in Pattambi at five month after planting, 4.76 cm in Mala to 5.80 cm in Cheematippali at six month after planting, 4.40 cm in Cheematippali to 4.94 cm in Pattambi

Table 5. Internodal length of main stem in cm of the five *Piper longum* types (four month after planting to nine month after planting)

Types	Internodal length of main stem (cm)					
	Month after planting					
	4	5	6	7	8	9
Cheematippali	4.05	4.83	5.80	4.40	5.11	4.63
Panniyur	4.03	4.84	5.58	4.57	5.35	4.48
Mala	4.49	4.82	4.76	4.78	5.31	4.36
Pattambi	4.47	4.93	5.62	4.94	4.67	4.79
Kaanjur	4.90	4.84	5.01	4.58	5.12	4.64
SEm ±	0.20	0.25	0.39	0.29	0.29	0.25
CD (0.05)	0.42	NS	NS	NS	NS	NS

at seven month after planting, 4.67 cm in Pattambi to 5.35 cm in Panniyur at eight month after planting, 4.36 cm in Mala to 4.79 cm in Pattambi at nine month after planting.

4.1.5 Diameter at node of main stem

The diameter at node of main stem of the five types of *Piper longum* is presented in Table 6 and the analysis of variance in Appendix VII. The five types did not differ significantly with respect to this character. The diameter at node of main stem varied from 1.90 cm in Pattambi to 2.05 cm in Mala.

4.1.6 Diameter at internode of main stem

The diameter at internode of main stem of the five types of *Piper longum* is presented in Table 7 and the analysis of variance in Appendix VIII. The five types did not differ significantly with respect to this character. The diameter at internode of main stem varied from 1.18 cm in Panniyur to 1.21 cm in Pattambi.

4.1.7 Shape of leaf lamina

The shape of leaf lamina in all the five types was recorded as cordate.

4.1.8 Nature of leaf tip

The leaf tip in all the five types was described as acuminate.

4.1.9 Shape of leaf base

The leaf base in all the five types was cordate.

4.1.10 Margin of leaf

The margin of leaf in all the five types was described as undulating.

Table 6. Diameter at node of main stem in cm of the five *Piper longum* types

Types	Diameter at node of main stem (cm)
Cheematippali	1.97
Panniyur	1.95
Mala	2.05
Pattambi	1.90
Kaanjur	1.94
SEm ±	0.05
CD (0.05)	NS

Table 7. Diameter at internode of main stem in cm of the five *Piper longum* types

Types	Diameter at internode of main stem (cm)
Cheematippali	1.19
Panniyur	1.18
Mala	1.20
Pattambi	1.21
Kaanjur	1.20
SEm ±	0.03
CD (0.05)	NS

4.1.11 Surface of leaf lamina

The leaf surface in all the five types was described as glabrous.

4.1.12 Leaf characters

4.1.12.1 Length of leaf

Length of leaf in cm of five *Piper longum* types from four month after planting to nine month after planting at monthly intervals is presented in Table 8 and the analysis of variance in Appendix IX. These five types did not differ significantly with respect to this character at these stages except at four month after planting. Cheematippali (7.15 cm) recorded the maximum leaf length at four month after planting which was on par statistically with Kaanjur (6.56 cm) but was significantly superior to Pattambi (5.90 cm), Panniyur (5.42 cm) and Mala (5.28 cm). The minimum length of leaf was recorded in Mala (5.28 cm) which was on par statistically with Pattambi and Panniyur at four month after planting.

The length of leaf varied from 5.93 cm in Panniyur to 7.26 cm in Cheematippali at five month after planting, 6.27 cm in Mala to 7.32 cm in Cheematippali at six month after planting, 7.22 cm in Pattambi to 7.62 cm in Cheematippali at seven month after planting, 7.91 cm in Kaanjur to 8.45 cm in Cheematippali at eight month after planting and 7.99 cm in Pattambi to 8.66 cm in Kaanjur at nine month after planting.

4.1.12.2 Width of leaf

Width of leaf in cm of five *Piper longum* types from four month after planting to nine month after planting at monthly intervals is presented in Table 9 and the analysis of variance in Appendix X. These five types did not differ significantly

Table 8. Length of leaf in cm of the five *Piper longum* types (four month after planting to nine month after planting)

Types	Length of leaf (cm)					
	Month after planting					
	4	5	6	7	8	9
Cheematippali	7.15	7.26	7.32	7.62	8.45	8.62
Panniyur*	5.42	5.93	6.94	7.29	8.09	8.15
Mala	5.28	6.93	6.27	7.24	8.42	8.50
Pattambi	5.90	6.80	7.08	7.22	7.97	7.99
Kaanjur	6.56	6.66	7.15	7.55	7.91	8.66
SEm ±	0.72	0.52	0.49	0.20	0.49	0.59
CD (0.05)	0.34	NS	NS	NS	NS	NS

Table 9. Width of leaf in cm of the five *Piper longum* types (four month after planting to nine month after planting)

Types	Width of leaf (cm)					
	Month after planting					
	4	5	6	7	8	9
Cheematippali	7.19	7.25	7.60	7.77	7.80	7.84
Panniyur	6.14	6.28	6.62	7.10	7.28	7.66
Mala	5.48	6.43	7.04	7.46	7.57	7.63
Pattambi	5.83	6.76	6.83	7.00	7.15	7.45
Kaanjur	6.74	6.94	7.02	7.30	7.51	7.59
SEm ±	0.39	0.38	0.47	0.53	0.45	0.34
CD (0.05)	0.83	NS	NS	NS	NS	NS

with respect to this character at these stages except at four month after planting. Cheematippali (7.19 cm) had the maximum width of leaf at four month after planting which was on par statistically with Kaanjur (6.74 cm) and Panniyur (6.14 cm). Cheematippali was significantly superior to Pattambi (5.83 cm) and Mala (5.48 cm). The minimum width of leaf was recorded in Mala (5.48 cm) which was on par statistically with Pattambi (5.83 cm) at four month after planting.

The width of leaf varied from 6.28 cm in Panniyur to 7.25 cm in Cheematippali at five month after planting, 6.62 cm in Panniyur to 7.60 cm in Cheematippali at six month after planting, 7.00 cm in Pattambi to 7.77 cm in Cheematippali at seven month after planting, 7.15 cm in Pattambi to 7.80 cm in Cheematippali at eight month after planting and 7.45 cm in Pattambi to 7.84 cm in Cheematippali at nine month after planting.

4.1.12.3 Length of petiole

Length of petiole in cm of the five *Piper longum* types from four month after planting to nine month after planting at intervals of one month are presented in Table 10 and the analysis of variance in Appendix XI. The five types did not differ significantly with respect to this character at these stages except at eight month after planting. At eight month after planting, Panniyur (5.00 cm) with the maximum length of petiole was on par statistically with Mala (4.98 cm), Cheematippali (4.92 cm) and Pattambi (4.32 cm). However Panniyur was significantly superior to Kaanjur (4.25 cm) at this stage. The minimum length of petiole was recorded in Kaanjur (4.25 cm) at eight month after planting.

The length of petiole varied from 4.12 cm in Cheematippali to 5.03 cm in Mala at four month after planting, 3.70 cm in Panniyur to 4.35 cm in Kaanjur at five month after planting, 5.25 cm in Cheematippali to 5.68 cm in Panniyur at six

Table 10. Length of petiole in cm of the five *Piper longum* types (four month after planting to nine month after planting)

Types	Length of petiole (cm)					
	Month after planting					
	4	5	6	7	8	9
Cheematippali	4.12	3.86	5.25	4.49	4.92	4.78
Panniyur	4.37	3.70	5.68	4.84	5.00	5.01
Mala	5.03	4.13	5.31	4.80	4.98	4.64
Pattambi	4.42	4.11	5.47	5.22	4.32	4.52
Kaanjur	4.46	4.35	5.61	4.73	4.25	4.71
SEm ±	0.45	0.26	0.33	0.30	0.21	0.36
CD (0.05)	NS	NS	NS	NS	0.45	NS

month after planting, 4.49 cm in Cheematippali to 5.22 cm in Pattambi at seven month after planting and 4.52 cm in Pattambi to 5.01 cm in Panniyur at nine month after planting.

4.1.13 Area of leaf lamina

Area of leaf lamina in cm^2 of the five *Piper longum* types is presented in Table 11 and the analysis of variance in Appendix XII. The leaf area did not differ significantly in the five types. The area of leaf lamina recorded in Cheematippali was 58.97 cm^2, in Pattambi was 55.10 cm^2, in Kaanjur was 54.96 cm^2, in Panniyur was 54.29 cm^2 and Mala was 53.41 cm^2.

4.1.14 Number of leaves per hill

Number of leaves per hill of the five types of *Piper longum* from one month after planting to nine month after planting at an interval of one month are given in Table 12 and the analysis of variance in Appendix XIII. The five types differed significantly with respect to this character at one, two,five, six, seven, eight and nine month after planting. Cheematippali (8.76) recorded the maximum number of leaves per hill at one month after planting and was significantly superior to the remaining four types. The minimum number of leaves per hill at one month after planting was recorded for Pattambi (5.88). However Kaanjur (6.93), Panniyur (6.86) and Mala (6.73) were on par statistically with each other at one month after planting. Cheematippali (12.76) which had the maximum number of leaves per hill at one month after planting maintained the position of highest number of leaves per hill at two month after planting. Cheematippali was found to be on par statistically with Kaanjur (11.76) and Mala (11.46) at this stage but was significantly superior to Pattambi (9.90) and Panniyur (8.13). The minimum number of leaves per hill was recorded in Panniyur (8.13) at two month after planting. Cheematippali (72.03) was

Table 11. Area of leaf lamina in cm^2 of the five *Piper longum* types

Types	Leaf area (cm^2)
Cheematippali	58.97
Panniyur	54.29
Mala	53.41
Pattambi	55.10
Kaanjur	54.96
SEm ±	3.74
CD (0.05)	NS

Table 12. Number of leaves per hill of the five Piper longum types (one month after planting to nine month after planting)

Types	Number of leaves per hill								
	Month after planting								
	1	2	3	4	5	6	7	8	9
Cheeaatippali	8.76	12.76	33.58	53.16	72.03	170.73	249.00	162.26	57.10
Panniyur	6.86	8.13	36.03	50.60	53.13	152.46	214.47	102.83	47.06
Mala	6.73	11.46	29.00	43.96	63.33	112.19	130.03	97.65	58.23
Pattambi	5.88	9.90	27.50	40.26	52.03	121.03	162.26	95.36	56.74
Kaanjur	6.93	11.76	29.36	42.86	64.63	184.73	226.35	123.79	88.13
SEm±	0.54	0.66	2.94	4.61	3.71	10.35	11.97	13.44	4.97
CD (0.05)	1.15	1.39	NS	NS	7.86	21.95	25.37	28.49	10.53

found to occupy the position of maximum number of leaves per hill at five month after planting. Cheematippali was found to be on par statistically with Kaanjur (64.63) and Mala (63.33) but was significantly superior to Pattambi (52.03) and Panniyur (53.13) at this stage. The minimum number of leaves per hill was observed in Pattambi (52.03) at five month after planting. At six month after planting Kaanjur (184.73) recorded the maximum number of leaves per hill which was on par statistically with Cheematippali (170.73) and Panniyur (152.46) and significantly superior to Pattambi (121.03) and Mala (112.19). The minimum number of leaves per hill was recorded in Mala (112.19) at this stage. Cheematippali (249.00) recorded the maximum number of leaves per hill at seven month after planting which was on par statistically with Kaanjur (226.35) and Panniyur (214.47) and significantly superior to Pattambi (162.26) and Mala (130.03). The minimum number of leaves per hill was recorded in Mala (130.03) at seven month after planting. At eight month after planting the maximum number of leaves per hill was recorded in Cheematippali (162.26) which was on par statistically with Kaanjur (123.79) and significantly superior to Panniyur (102.83), Mala (97.65) and Pattambi (95.36). The minimum number of leaves per hill was recorded in Pattambi (95.36) at eight month after planting. Nine month after planting the maximum number of leaves per hill was recorded in Kaanjur (88.13) which was significantly superior to Mala (58.23), Cheematippali (57.10), Pattambi (56.74) and Panniyur (47.06). The minimum number of leaves per hill was recorded in Panniyur (47.06) which was on par statistically with Pattambi, Cheematippali and Mala at nine month after planting.

The number of leaves per hill varied from 27.50 in Pattambi to 36.03 in Panniyur at three month after planting and from 40.26 in Pattambi to 53.16 in Cheematippali at four month after planting.

4.1.15 Spread of the plant

The spread of the plant of the five types of *Piper longum* from four month after planting to nine month after planting at an interval of one month are presented in Table 13 and the analysis of variance in Appendix XIV. The five types did not differ significantly with respect to this character at any of these stages except at five month after planting. Kaanjur (39.98 cm) recorded the maximum spread at five month after planting which was on par statistically with Cheematippali (37.44 cm) but significnatly superior to Pattambi (29.83 cm), Panniyur (29.82 cm) and Mala (28.39 cm). The minimum spread of the plant was recorded in Mala (28.39 cm) which was on par statistically with Panniyur and Pattambi at five month after planting.

The spread of the plant varied from 24.09 cm in Kaanjur to 27.83 cm in Mala at four month after planting, 38.30 cm in Mala to 49.85 cm in Kaanjur at six month after planting, 47.40 cm in Mala to 53.16 cm in Cheematippali at seven month after planting, 64.49 cm in Mala to 66.37 cm in Pattambi at eight month after planting, 49.39 cm in Mala to 55.93 cm in Cheematippali at nine month after planting.

4.1.16 Nature of spike apex

The spike apex in all the five types was recorded as oblong and blunt.

4.1.17 Number of spike bearing branches per stem

The number of spike bearing branches per stem of the five types of *Piper longum* from seven month after planting to nine month after planting at an interval

Table 13. Spread of the plant in cm of the five *Piper longum* types (four month after planting to nine month after planting)

Types	Spread of the plant (cm)					
	Month after planting					
	4	5	6	7	8	9
Cheematippali	25.46	37.44	49.00	53.16	65.97	55.93
Panniyur	26.44	29.82	48.33	52.90	65.63	51.94
Mala	27.83	28.39	38.30	47.40	64.49	49.39
Pattambi	25.80	29.83	39.10	52.54	66.37	51.21
Kaanjur	24.09	39.98	49.85	50.34	65.89	52.03
SEm±	1.82	2.01	4.71	3.41	3.62	2.93
CD (0.05)	NS	4.25	NS	NS	NS	NS

Table 14. Number of spike bearing branches per stem of the five *Piper longum* types (seven month after planting to nine month after planting)

Types	Number of spike bearing branches per stem		
	Month after planting		
	7	8	9
Cheematippali	4.08	2.30	1.81
Panniyur	2.65	2.26	1.55
Mala	2.46	1.60	1.33
Pattambi	2.68	1.83	1.38
Kaanjur	3.03	2.30	1.55
SEm ±	0.27	0.16	0.14
CD (0.05)	0.58	0.33	NS

of one month are presented in Table 14 and the analysis of variance in Appendix XV. The five types differed significantly with respect to this character at seven and eight month after planting. Cheematippali (4.08) recorded the maximum number of spike bearing branches per stem at seven month after planting and was significantly superior to all the remaining four types. The minimum number of spike bearing branches per stem was recorded in Mala (2.46) which was on par statistically with Kaanjur (3.03), Pattambi (2.68) and Panniyur (2.65) at seven month after planting. At eight month after planting, Cheematippali (2.30) maintained the position of maximum number of spike bearing branches per stem and was on par statistically with Kaanjur (2.30) and Panniyur (2.26) and was significantly superior to Pattambi (1.83) and Mala (1.60). The minimum number of spike bearing branches per stem was recorded in Mala (1.60) which was on par statistically with Pattambi (1.83) at eight month after planting.

The number of spike bearing branches per stem varied from 1.33 in Mala to 1.81 in Cheematippali at nine month after planting.

4.1.18 Angle of insertion of spike bearing branch

The angle of insertion of spike bearing branch in degrees of the five types of *Piper longum* are presented in Table 15 and the analysis of variance in Appendix XVI. The five types differed significantly with respect to this character at first harvest and second harvest. At first harvest Cheematippali (73.33°) recorded the highest angle of insertion which was on par statistically with Kaanjur (72.90°) and was significantly superior to Panniyur (54.50°), Pattambi (51.74°) and Mala (48.61°). The minimum angle of insertion was recorded in Mala (48.61°) which was on par statistically with Panniyur (54.50°) and Pattambi (51.74°) at first harvest. Cheematippali (97.03°) recorded the highest angle of insertion at second

Table 15. Angle of insertion of spike bearing branch in degrees of the five *Piper longum* types (at first harvest and second harvest)

	Angle of insertion of spike bearing branch (degree)	
Types	First harvest	Second harvest
Cheematippali	73.33	97.03
Panniyur	54.50	80.96
Mala	48.61	67.15
Pattambi	51.74	74.93
Kaanjur	72.90	90.63
SEm ±	3.46	3.37
CD (0.05)	7.34	7.15

harvest which was on par statistically with Kaanjur (90.63°) and significantly superior to Panniyur (80.96°), Pattambi (74.93°) and Mala (67.15°). The minimum angle of insertion was recorded in Mala (67.15°) which was on par statistically with Pattambi (74.93°) at second harvest.

4.1.19 Internodal length of spike bearing branch

The internodal length of spike bearing branch of the five *Piper longum* types at seven and eight month after planting is presented in Table 16 and the analysis of variance in Appendix XVII. The five types did not differ significantly with respect to this character at these stages. The internodal length of spike bearing branch varied from 5.31 cm in Cheematippali to 5.51 cm in Mala at seven month after planting and 5.30 cm in Cheematippali to 5.54 cm in Panniyur at eight month after planting.

4.1.20 Diameter at node of spike bearing branch

The diameter at node of spike bearing branch in cm of the five *Piper longum* types is presented in Table 17 and the analysis of variance presented in Appendix XVIII. The five types did not differ significantly with respect to this character. The diameter at node of spike bearing branch varied from 1.42 cm in Mala to 1.53 cm in Kaanjur.

4.1.21 Diameter at internode of spike bearing branch

The diameter at internode of spike bearing branch in cm of the five *Piper longum* types in presented in Table 18 and the analysis of variance in Appendix XIX. The five types did not differ significantly with respect to this character. The diameter at internode of spike bearing branch varied from 0.83 cm in Mala to 0.92 cm in Kaanjur.

Table 16. Internodal length of spike bearing branch in cm of the five *Piper longum* types

Types	Internodal length of spike bearing branch (cm)	
	Months after planting	
	7	8
Cheematippali	5.31	5.30
Panniyur	5.42	5.54
Mala	5.51	5.51
Pattambi	5.50	5.51
Kaanjur	5.32	5.42
SEm ±	0.25	0.17
CD (0.05)	NS	NS

Table 17. Diameter at node of spike bearing branch in cm of the five *Piper longum* types

Types	Diameter at node of spike bearing branch (cm)
Cheematippali	1.46
Panniyur	1.43
Mala	1.42
Pattambi	1.42
Kaanjur	1.53
SEm ±	0.04
CD (0.05)	NS

Table 18. Diameter at internode of spike bearing branch in cm of the five *Piper longum* types

Types	Diameter at internode of spike bearing branch (cm)
Cheematippali	0.89
Panniyur	0.88
Mala	0.83
Pattambi	0.84
Kaanjur	0.92
SEm ±	0.03
CD (0.05)	NS

4.2 Productive characters

4.2.1 Spike characters

4.2.1.1 Length of spike

The length of spike in cm recorded at the first and second harvest is presented in Table 19 and the analysis of variance in Appendix XX. The length of spike did not differ significantly for the five types of *Piper longum* at the first and second harvest. The length of spike varied from 4.00 cm in Pattambi to 4.33 cm in Cheematippali at first harvest and from 4.06 cm in Pattambi to 4.37 cm in Cheematippali at second harvest.

4.2.1.2 Diameter of spike

The diameter of spike in cm recorded at the first and second harvest is presented in Table 20 and the analysis of variance in Appendix XXI. The diameter of spike did not differ significantly for the five types of *Piper longum* at the first and second harvest. The diameter of spike varied from 2.22 cm in Pattambi to 2.33 cm in Mala at first harvest and from 2.44 cm in Pattambi to 2.54 cm in Mala at second harvest.

4.2.1.3 Length of peduncle

The length of peduncle in cm recorded at the first and second harvest is presented in Table 21 and the analysis of variance in Appendix XXII. The length of peduncle did not differ significantly for the five types of *Piper longum* at the first and second harvest. The length of penduncle varied from 1.17 cm in Mala to 1.33 cm in Kaanjur at first harvest and 1.48 cm in Pattambi to 1.69 cm in Cheematippali at second harvest.

Table 19. Length of spike in cm of the five *Piper longum* types (at first harvest and second harvest)

Types	Length of spike (cm)	
	First harvest	Second harvest
Cheematippali	4.33	4.37
Panniyur	4.28	4.31
Mala	4.09	4.14
Pattambi	4.00	4.06
Kaanjur	4.24	4.25
SEm ±	0.15	0.11
CD (0.05)	NS	NS

Table 20. Diameter of spike in cm of the five *Piper longum* types (at first harvest and second harvest)

Types	Diameter of spike (cm)	
	First harvest	Second harvest
Cheematippali	2.23	2.45
Panniyur	2.25	2.47
Mala	2.33	2.54
Pattambi	2.22	2.44
Kaanjur	2.30	2.51
SEm ±	0.08	0.09
CD (0.05)	NS	NS

Table 21. Length of peduncle in cm of the five *Piper longum* types (at first harvest and second harvest)

Types	Length of peduncle (cm)	
	First harvest	Second harvest
Cheematippali	1.32	1.69
Panniyur	1.23	1.63
Mala	1.17	1.50
Pattambi	1.21	1.48
Kaanjur	1.33	1.67
SEm ±	0.06	0.09
CD (0.05)	NS	NS

4.2.2 Number of spikes per spike bearing branch

Number of spikes per spike bearing branch of the five types of *Piper longum* from five month after planting to nine month after planting at an interval of one month are recorded in Table 22 and the analysis of variance in Appendix XXIII. The five types of *Piper longum* differed significantly for this character only at five, six and seven month after planting. Cheematippali (2.23) recorded the maximum number of spikes per spike bearing branch at five month after planting and was on par statistically with Kaanjur (2.03) and Mala (1.33). Mala (1.33) recorded the minimum number of spikes per spike bearing branch and was on par statistically with Pattambi at five month after planting. At six month after planting Cheematippali (2.31) recorded the maximum number of spikes per spike bearing branch which was on par statistically with Kaanjur (2.25) and Panniyur (2.06) and significantly superior to Mala (1.48) and Pattambi (1.79). The minimum number of spikes per spike bearing branch was recorded in Mala (1.48) at six month after planting. Cheematippali (3.93) recorded the maximum number of spikes per spike bearing branch at seven month after planting which was significantly superior to the remaining four types. Mala (2.43) recorded the minimum number of spikes per spike bearing branch which was on par statistically with Pattambi (2.56) at seven month after planting.

The number of spikes per spike bearing branch varied from 2.03 in Mala to 2.66 in Cheematippali at eight month after planting and 1.46 in Mala to 1.86 in Cheematippali at nine month after planting.

4.2.3 Days from planting to emergence of spike

The days from planting to emergence of spike for the five types of *Piper*

Table 22. Number of spikes per spike bearing branch of the five *Piper longum* types (five month after planting to nine month after planting)

Types	Number of spikes per spike bearing branch				
	Month after planting				
	5	6	7	8	9
Cheematippali	2.23	2.31	3.93	2.66	1.86
Panniyur	1.49	2.06	3.13	2.36	1.58
Mala	1.33	1.48	2.43	2.03	1.46
Pattambi	1.40	1.80	2.56	2.10	1.48
Kaanjur	2.03	2.25	3.23	2.43	1.80
SEm ±	0.22	0.12	0.15	0.18	0.11
CD (0.05)	0.46	0.24	0.32	NS	NS

Table 23. Days from planting to emergence of spike of the five *Piper longum* types

Types	Days from planting to emergence of spike
Cheematippali	172.02
Panniyur	180.56
Mala	163.70
Pattambi	167.76
Kaanjur	170.70
SEm ±	6.57
CD (0.05)	NS

longum are presented in Table 23 and the analysis of variance in Appendix XXIV. The five types of *Piper longum* did not differ significantly with respect to this character. The maximum number of days from planting to emergence of spike was required by Panniyur (180.56) and minimum number of days was required by Mala (163.70). The days required from planting to emergence of spike by Cheematippali, Pattambi and Kaanjur are 172.02, 167.76 and 170.70 respectively.

4.2.4 Days from emergence to maturity of spike

The days required from emergence to maturity of spike at first harvest and second harvest are presented in Table 24 for the five types of *Piper longum* and the analysis of variance in Appendix XXV. The five types of *P. longum* did not differ significantly with respect to this character at first and second harvest. At first harvest the maximum number of days required from emergence to maturity of spike was recorded in Cheematippali (68.82) and minimum number of days required from emergence to maturity of spike was recorded in Panniyur (60.66). At second harvest the maximum number of days required from emergence to maturity of spike was recorded in Cheematippali (64.48) and minimum number of days required from emergence to maturity of spike was recorded in Pattambi (60.87).

4.2.5 Yield of green spike

The yield of green spike in kg per hectare of the five types of *Piper longum* at first and second harvest are presented in Table 25 and the analysis of variance in Appendix XXVI. The five types of *Piper longum* differed significantly for this character at first and second harvest. At first harvest the maximum yield of green spike was recorded in Cheematippali (2229.50 kg/ha) which was on par statistically with Kaanjur (2221.11 kg/ha). Cheematippali which recorded the maximum green spike yield was significantly superior to Pattambi (1372.81 kg/ha), Panniyur

Table 24. Days from emergence to maturity of spike of the five *Piper longum* types (at first harvest and second harvest)

Types	Days from emergence to maturity of spike	
	First harvest	Second harvest
Cheematippali	68.82	64.48
Panniyur	60.66	62.14
Mala	64.20	63.93
Pattambi	64.48	60.87
Kaanjur	61.29	63.39
SEm ±	3.39	2.88
CD (0.05)	NS	NS

Table 25. Yield of green spike in kg per hectare of the five *Piper longum* types (at first harvest and second harvest)

Types	Yield of green spike (kg/ha)	
	First harvest	Second harvest
Cheematippali	2295.00	2621.94
Panniyur	1310.34	1813.33
Mala	815.38	1530.55
Pattambi	1372.81	2233.06
Kaanjur	2221.11	2499.44
SEm ±	31.23	79.43
CD (0.05)	66.21	168.39

(1310.34 kg/ha) and Mala (815.38 kg/ha) at first harvest. The maximum yield of green spike was recorded in Cheematippali (2621.94 kg/ha) at second harvest which was on par statistically with Kaanjur (2499.44 kg/ha) and significantly superior to Pattambi (2233.06 kg/ha), Panniyur (1813.33 kg/ha) and Mala (1530.55 kg/ha). The minimum yield of green spike was recorded in Mala at both first harvest (815.38 kg/ha) and second harvest (1530.55 kg/ha).

4.2.6 Yield of dry spike

The yield of dry spike in kg per hectare of the five types of *Piper longum* at first and second harvest are presented in Table 26 and the analysis of variance in Appendix XXVII. The five types of *Piper longum* were found to differ significantly for this character at first harvest and second harvest. At first harvest the maximum yield of dry spike was recorded in Cheematippali (580.83 kg/ha) which was on par statistically with Kaanjur (562.50 kg/ha) and was significantly superior to Pattambi (355.28 kg/ha), Panniyur (312.25 kg/ha) and Mala (201.95 kg/ha) at first harvest. Mala (201.95 kg/ha) recorded the minimum dry spike yield per hectare at first harvest. Cheematippali (651.39 kg/ha) recorded the maximum dry spike yield at second harvest which was on par statistically with Kaanjur (638.61 kg/ha) and significantly superior to Pattambi (552.22 kg/ha), Panniyur (466.38 kg/ha) and Mala (382.22 kg/ha). Mala (382.22 kg/ha) recorded the minimum dry spike yield per hectare at second harvest.

4.2.7 Ratio of weight of green spike to the weight of dry spike

The ratio of weight of green spike to the weight of dry spike at first harvest and second harvest are presented in Table 27 and its analysis of variance in Appendix XXVIII. The five types did not differ significantly for this character at both first and second harvest. The ratio of weight of green spike to the weight of dry

Table 26. Yield of dry spike in kg per hectare of the five *Piper longum* types (at first harvest and second harvest)

Types	First harvest	Second harvest
Cheematippali	580.83	651.39
Panniyur	312.25	466.38
Mala	201.95	382.22
Pattambi	355.28	552.22
Kaanjur	562.50	638.61
SEm ±	11.59	18.01
CD (0.05)	24.57	38.19

Table 27. Ratio of weight of green spike to weight of dry spike of the five *Piper longum* types (at first harvest and second harvest)

Types	Ratio of weight of green spike to weight of dry spike	
	First harvest	Second harvest
Cheematippali	3.96 : 1	4.01 : 1
Panniyur	4.19 : 1	3.90 : 1
Mala	3.96 : 1	4.01 : 1
Pattambi	3.86 : 1	4.04 : 1
Kaanjur	3.91 : 1	3.92 : 1
SEm ±	0.024	0.154
CD (0.05)	NS	NS

spike varied from 3.86:1 in Pattambi to 4.19:1 in Cheematippali at first harvest and from 3.90:1 in Panniyur to 4.04:1 in Pattambi at second harvest.

4.3 Correlation studies

Correlation coefficients among dry spike yield and the various vegetative and productive characters were worked out and are presented in Table 28.

4.3.1 Basis of selection of vegetative and productive characters for correlation studies and path analysis

From Table 28 it can be seen that the character length of the longest stem was significantly correlated to dry spike yield at one (0.663), two (0.456) and seven month (0.559) after planting. Number of stems per hill was found to be significantly correlated to dry spike yield at all the stages i.e., three (0.767), four (0.734), five (0.547), six (0.679), seven (0.763), eight (0.795) and nine (0.640) month after planting. The number of vegetative branches per stem exhibited significant correlation with dry spike yield at five (0.480), six (0.509) and seven (0.465) month after planting. The presence of significant correlation between length of leaf and dry spike yield was observed at four (0.726) and six (0.400) month after planting. At four month after planting width of leaf (0.585) was found to be significantly correlated to dry spike yield. Significant correlation was found between number of leaves per hill and dry spike yield at two (0.435), six (0.409) and seven (0.444) and eight month (0.524) after planting. The spread of plant was found to have significant correlation with dry spike yield at five (0.697) month after planting. The correlation of number of spike bearing branches per stem to dry spike yield was significant at seven (0.581) and eight (0.575) months after planting. At seven (0.800) and eight (0.762) month after planting the angle of insertion of spike bearing branch was found to be significantly correlated to dry spike yield. The length of peduncle was found to be

Table 28. Correlation coefficient between dry spike yield and the various vegetative and productive characters

Sl. No.	Character	Correlation coefficient with dry spike yield
1	2	3
A. VEGETATIVE CHARACTERS		
1. Length of the longest stem		
	a. First month after planting	0.663**
	b. Second month after planting	0.456*
	c. Third month after planting	0.007
	d. Fourth month after planting	-0.020
	e. Fifth month after planting	0.329
	f. Sixth month after planting	0.360
	g. Seventh month after planting	0.559**
	h. Eighth month after planting	0.369
	i. Ninth month after planting	0.187
2. Number of stems per hill		
	a. Third month after planting	0.767**
	b. Fourth month after planting	0.734**
	c. Fifth month after planting	0.547**
	d. Sixth month after planting	0.679**
	e. Seventh month after planting	0.763**
	f. Eighth month after planting	0.795**
	g. Ninth month after planting	0.640**
3. Number of vegetative branches per stem		
	a. Fifth month after planting	0.480*
	b. Sixth month after planting	0.509**
	c. Seventh month after planting	0.465*
	d. Eighth month after planting	0.098
	e. Ninth month after planting	0.387
4. Internodal length of main stem		
	a. Fourth month after planting	0.018
	b. Fifth month after planting	0.047
	c. Sixth month after planting	0.210
	d. Seventh month after planting	-0.210
	e. Eighth month after planting	-0.034
	f. Ninth month after planting	0.175

Contd.

Table 28. Continued

1	2	3
5.	Diameter at node of main stem	-0.217
6.	Diameter at internode of main stem	-0.137
7.	Length of leaf	
	a. Fourth month after planting	0.726**
	b. Fifth month after planting	0.153
	c. Sixth month after planting	0.400*
	d. Seventh month after planting	0.142
	e. Eighth month after planting	-0.081
	f. Ninth month after planting	0.156
8.	Width of leaf	
	a. Fourth month after planting	0.585**
	b. Fifth month after planting	0.362
	c. Sixth month after planting	0.193
	d. Seventh month after planting	0.062
	e. Eighth month after planting	0.153
	f. Ninth month after planting	0.073
9.	Length of petiole	
	a. Fourth month after planting	-0.243
	b. Fifth month after planting	0.204
	c. Sixth month after planting	0.053
	d. Seventh month after planting	-0.204
	e. Eighth month after planting	-0.280
	f. Ninth month after planting	0.047
10.	Area of leaf lamina	0.183
11.	Number of leaves per hill	
	a. First month after planting	0.363
	b. Second month after planting	0.435*
	c. Third month after planting	0.105
	d. Fourth month after planting	0.107
	e. Fifth month after planting	0.335
	f. Sixth month after planting	0.409*
	g. Seventh month after planting	0.444*
	h. Eighth month after planting	0.524**
	i. Ninth month after planting	0.335

Contd.

significantly correlated to dry spike yield at the first harvest (0.473). The number of spikes per spike bearing branch showed significant correlation with dry spike yield at five (0.477), six (0.742), seven (0.689) and nine (0.608) month after planting. The green spike yield showed positive significant correlation with dry spike yield at first harvest (0.991) and second harvest (0.982).

The internodal length of main stem, diameter at node of main stem, diameter at internode of main stem, length of petiole, area of leaf lamina, internodal length of spike bearing branch, diameter at node of spike bearing branch, diameter at internode of spike bearing branch, length of spike, diameter of spike, days from planting to emergence of spike, days from emergence to maturity of spike and the ratio of weight of green spike to the weight of dry spike showed no significant correlation with dry spike yield at any of these stages.

Of the above mentioned characters that showed significant correlation with dry spike yield eight characters exhibiting high and significant correlation with dry spike yield at first harvest i.e., seven month after planting were chosen for determining the intercorrelation among yield components and for doing path analysis. The character green spike yield was not included in path analysis since the ratio of weight of green spike to weight of dry spike showed no significant difference for the five types and hence the dry spike yield was a direct reflection of green spike yield.

The length of the longest stem was chosen as a character for further analysis since being a contributor to the plant size it showed significant correlation with dry spike yield at seven month after planting i.e., at first harvest. Significant correlation was seen between the number of stems per hill and dry spike yield at all

Table 28. Continued

1	2	3
12.	Spread of the plant	
	a. Fourth month after planting	-0.289
	b. Fifth month after planting	0.697**
	c. Sixth month after planting	0.308
	d. Seventh month after planting	0.107
	e. Eighth month after planting	0.095
	f. Ninth month after planting	0.317
13.	Number of spike bearing branches per stem	
	a. Seventh month after planting	0.581**
	b. Eighth month after planting	0.575**
	c. Ninth month after planting	0.383
14.	Angle of insertion of spike bearing branch	
	a. Seventh month after planting	0.800**
	b. Eighth month after planting	0.762**
15.	Internodal length of spike bearing branch	
	a. Eighth month after planting	-0.115
	b. Ninth month after planting	-0.163
16.	Diameter at node of spike bearing branch	0.286
17.	Diameter at internode of spike bearing branch	0.368
B.	PRODUCTIVE CHARACTERS	
1.	Length of spike	
	a. First harvest	0.160
	b. Second harvest	0.222
2.	Diameter of spike	
	a. First harvest	-0.025
	b. Second harvest	-0.071

Contd.

Table 28. Continued

1	2	3
3. Length of peduncle		
	a. First harvest	0.473*
	b. Second harvest	0.203
4. Number of spikes per spike bearing branch		
	a. Fifth month after planting	0.477*
	b. Sixth month after planting	0.742**
	c. Seventh month after planting	0.689**
	d. Eighth month after planting	0.299
	e. Ninth month after planting	0.608**
5. Days from planting to emergence of spike		0.076
6. Days from emergence to maturity of spike		
	a. First harvest	0.127
	b. Second harvest	0.053
7. Yield of green spike		
	a. First harvest	0.991**
	b. Second harvest	0.982**
8. Ratio of weight of green spike to weight of dry spike		
	a. First harvest	-0.249
	b. Second harvest	-0.243

these stages and hence formed a component character contributing to yield and was chosen for further analytical studies. Significant correlation was found to exist between number of vegetative branches per stem and dry spike yield and was chosen as a character for further analysis. Leaf area exhibited very low and non-significant correlation with yield. This could be due to the absence of any significant correlation shown by leaf length and leaf width with dry spike yield at this stage. But significant correlation was found to exist between the number of leaves per hill and dry spike yield. The leaf area remaining constant the number of leaves per hill could be the determining factor contributing to dry spike yield and hence was chosen as a character for further analytical studies. Though significant correlation was found to exist between spread of the plant and dry spike yield at five month after planting no significant correlation was found to exist at seven month after planting i.e., towards the first harvest and hence was not taken up for further analytical studies. The number of spike bearing branches per stem was found to be significantly correlated to dry spike yield at all the stages and hence was obviously a significant contributor to dry spike yield. Angle of insertion of spike bearing branch and number of spikes per spike bearing branch were significantly correlated to yield at all the stages and hence both characters were important contributors to the dry spike yield and were chosen for further analytical studies. Green spike yield exhibited the highest and significant correlation the dry spike yield and was obviously a choice as a yield component for intercorrelation studies and path analysis.

Thus length of the longest stem, number of stems per hill, the number vegetative branches per stem, number of leaves per hill, number of spike bearing branches per stem, angle of insertion of spike bearing branch, number of spikes per spike bearing branch and green spike yield were selected for further analytical studies.

4.3.2 Correlation among yield and its components

Correlation coefficients among dry spike yield and eight vegetative and productive characters selected for further analysis are presented in Table 28.

Green spike yield showed the highest positive and significant correlation with dry spike yield (0.991) followed by angle of insertion of spike bearing branch (0.800) and number of stems per hill (0.736). The characters such as number of spikes per spike bearing branch (0.689), number of spike bearing branches per stem (0.581), length of the longest stem (0.559), number of vegetative branches per stem (0.465) and number of leaves per hill (0.444) showed significant positive correlations with dry spike yield.

4.3.3 Intercorrelation among yield components

The intercorrelation among yield components were worked out and the results are presented in Table 29 and diagramatically depicted in Fig. 1.

Highest positive and significant correlation was found between green spike yield and angle of insertion of spike bearing branch (0.825). The angle of insertion of spike bearing branch also showed significant correlation with number of stems per hill (0.791), number of spike bearing branches per stem (0.652), number of spikes per spike bearing branch (0.634) and length of the longest stem (0.463) The correlation of this character with number of vegetative branches per stem and number of leaves per hill was not significant.

Green spike yield showed relatively high significant and positive correlation with number of stems per hill (0.743), number of spikes per spike bearing branch (0.718), number of spike bearing branches per stem (0.592), length of the longest stem (0.581), number of vegetative branches per stem (0.442) and number

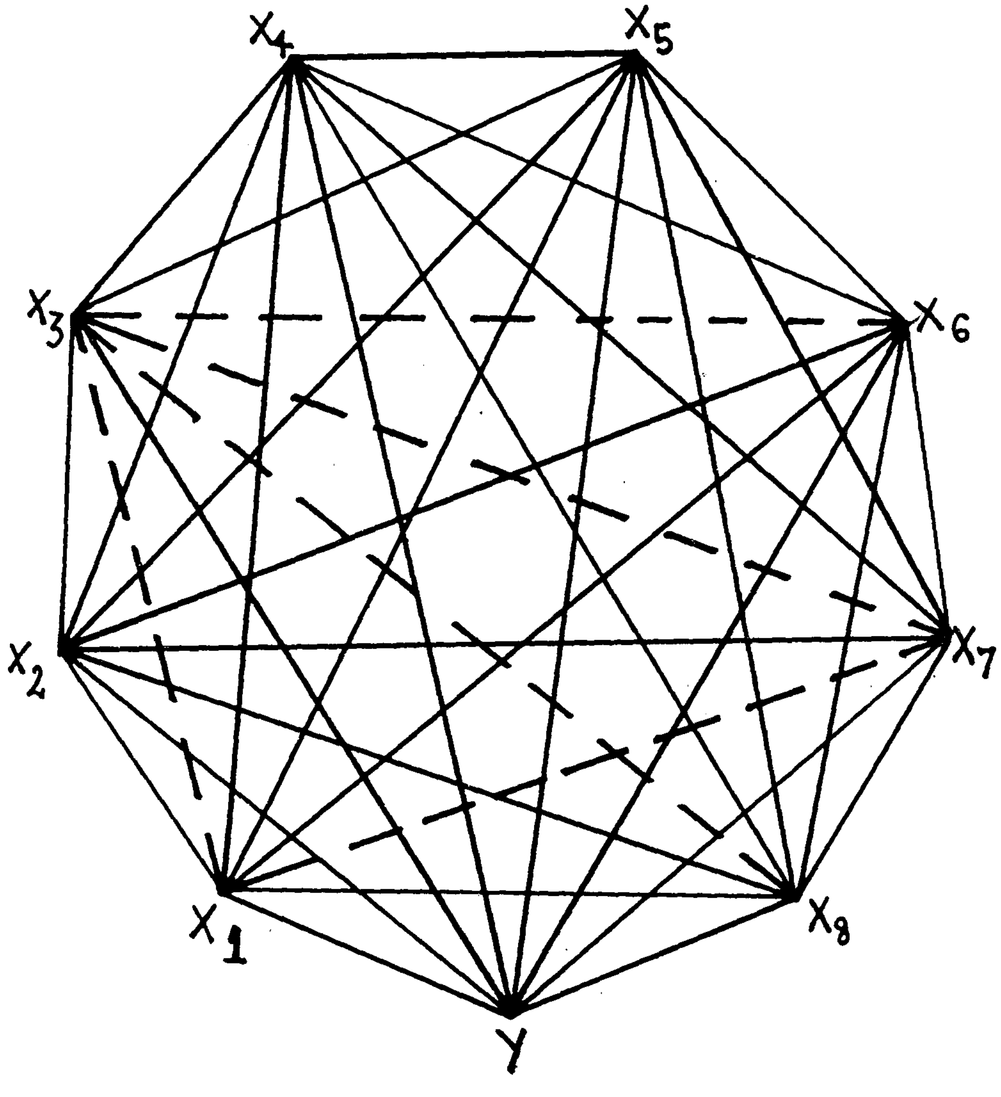
Table 29. Intercorrelation matrix of dry spike yield and plant characters

Characters	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
Y	x	0.991**	0.559**	0.736**	0.465*	0.444*	0.581**	0.800**	0.689**
X_1			0.581**	0.743**	0.442*	0.476*	0.592**	0.825**	0.718**
X_2				0.539**	0.391	0.546**	0.632**	0.463*	0.771**
X_3					0.379	0.416*	0.618**	0.791**	0.579**
X_4						0.321	0.404*	0.391	0.554**
X_5							0.429*	0.281	0.564**
X_6								0.652**	0.561**
X_7									0.634**

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

Y - Dry spike yield in kg per hectare
X_1 - Green spike yield in kg per hectare
X_2 - Length of the longest stem
X_3 - Number of stems per hill
X_4 - Number of vegetative branches per stem
X_5 - Number of leaves per hill
X_6 - Number of spike bearing branches per stem
X_7 - Angle of insertion of spike bearing branch
X_8 - Number of spikes per spike bearing branch

Fig. 1. Correlation diagram of yield and eight yield components in *Piper longum*



Significant positive ————

Nonsignificant positive — — —

of leaves per hill (0.476). High positive and significant correlation was found between number of spikes per spike bearing branch and length of the longest stem (0.771).

4.5 Path analysis

Path coefficient analysis was done with seven characters in order to study the association of these characters with dry spike yield by isolating the direct as well as indirect effects of the causative factors on the dry spike yield and is presented in Table 30.

The path analysis revealed that angle of insertion exerted the maximum positive direct effect (0.5460) followed by number of stems per hill (0.1582), number of leaves per hill (0.1202), number of spikes per spike bearing branch (0.1144), number of vegetative branches per stem (0.0881) and length of the longest stem (0.0806). Negative direct effect (-0.0757) was observed in case of number of spike bearing branches per stem.

The indirect effect of angle of insertion through number of stems per hill was positive and high (0.1251) whereas the indirect effect through all other characters though negligibly low, was positive and increased the total effect to 0.800. It has a negligibly low and negative indirect effect through number of spike bearing branches per stem (-0.0493).

Number of stems per hill had a low positive direct effect (0.1582) but its indirect effect through angle of insertion of spike bearing branch (0.4317) was high and positive. The indirect effect through length of the longest stem (0.0435), number of vegetative branches per stem (0.0334), number of leaves per hill (0.0501)

Table 30. Direct and indirect effects of component characters on yield

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	Correlation with yield
X_1	0.0806	0.0854	0.0345	0.0657	-0.0478	0.2527	0.0883	0.559
X_2	0.0435	0.1582	0.0334	0.0501	-0.0468	0.4317	0.0663	0.736
X_3	0.0315	0.0600	0.0881	0.0386	-0.0306	0.2136	0.0634	0.465
X_4	0.0440	0.0659	0.0283	0.1202	-0.0325	0.1535	0.0646	0.444
X_5	0.0510	0.0979	0.0356	0.0516	-0.0757	0.3560	0.0642	0.581
X_6	0.0373	0.1251	0.0345	0.0338	-0.0493	0.5460	0.0726	0.800
X_7	0.0622	0.0917	0.0488	0.0679	-0.0425	0.3462	0.1144	0.689

Residual effect = 0.2725

X_1 - Length of longest stem
X_2 - Number of stems per hill
X_3 - Number of vegetative branches per stem
X_4 - Number of leaves per hill
X_5 - Number of spike bearing branches per stem
X_6 - Angle of insertion of spike bearing branch
X_7 - Number of spikes per spike bearing branch

and number of spikes per spike bearing branch (0.0663) was positive thereby elevating the total effect to 0.736. The number of stems per hill had negligibly low indirect effect (-0.0468) through number of spike bearing branches per stem.

Number of leaves per hill had a positive direct effect (0.1202) and its indirect effect through angle of insertion of spike bearing branch (0.1535) was slightly higher than the direct effect. The indirect affect through length of the longest stem (0.0440), number of stems per hill (0.0659), number of vegetative branches per stem (0.0283) and number of spikes per spike bearing branch (0.0646) was positive thereby increasing the total effect to 0.444. The indirect effect of number of leaves per hill through number of spike bearing branches per stem was negative and negligibly low (-0.0325).

Number of spikes per spike bearing branch had a positive direct effect (0.1144) and its indirect effect through angle of insertion of spike bearing branch was high and positive (0.3462). It exerted a positive indirect effect through length of the longest stem (0.0622), number of stems per hill (0.0917), number of vegetative branches per stem (0.0488) and number of leaves per hill (0.0679), thereby increasing the total effect to 0.689. The indirect effect of number of spikes per spike bearing branch through number of spike bearing branches per stem was low and negative (-0.0425).

Number of vegetative branches per stem had a low positive direct effect (0.0881) but its indirect effect through angle of insertion of spike bearing branch was high and positive (0.2136). The indirect effect of number of vegetative branches per stem through length of the longest stem (0.0315), number of stems per hill (0.6000), number of leaves per hill (0.0386) and number spikes per spike bearing branch (0.0634) was low but positive thereby increasing the total effect to 0.465.

Table 31. Total alkaloidal content in percentage in dried spikes of the five *Piper longum* types

Types	Total alkaloidal content (%)
Cheematippali	2.87
Panniyur	2.91
Mala	2.80
Pattambi	2.85
Kaanjur	2.85

Length of the longest stem exerted a low positive and direct effect (0.0806) but its indirect effect through angle of insertion of spike bearing branch was high and positive (0.2527). The indirect effect through number of stems per hill (0.0854), number of vegetative branches per stem (0.0345), number of leaves per hill (0.0657) and number of spikes per spike bearing branch (0.0883) was positive and negligibly low but increased the total effecet to 0.559. The indirect effect through number of spike bearing branches per stem was negative (-0.0478) and negligibly low.

The direct effect of number of spike bearing branches per stem was negative and negligibly low but its indirect effect through angle of insertion of spike bearing branch was high and positive. Its indirect effect through length of the longest stem (0.0510), number of stems per hill (0.0979), number of vegetative branches per stem (0.0356), number of leaves per hill (0.0561) and number of spikes per spike bearing branch (0.0516) was high and positive thereby making the total effect positive and high (0.581). The seven characters alone and in combination contributed nearly 72.7275 per cent of the variability in dry spike yield. The residual effect (0.2725) obtained was low.

4.6 Total alkaloidal content in dried spikes of *Piper longum*

The total alkaloidal content in percentage obtained from the dried spikes of the five types of *Piper longum* is presented in Table 31. Panniyur (2.91%) recorded the maximum percentage of alkaloids followed by Cheematippali (2.87%), Pattambi (2.85%) and Kaanjur (2.85%). The minimum alkaloidal content of 2.80% was recorded in Mala.

Discussion

DISCUSSION

The result of the evaluation of five *Piper longum* types based on twenty three vegetative characters, nine productive characters and total alkaloidal content in the dried spikes are briefly discussed in the following pages. Analysis of variance carried out for all the characters studied helped in identifying those characters in which the five types were found to differ inherently. This was followed by correlation studies and path coefficient analysis to identify the characters on which selection can be made for further improvement of the crop.

Piper longum is a perennial climber possessing numerous stems which are jointed, branched, ascending or prostrate, stout, cylindrical, thickened above nodes and finely pubescent. The runners strike roots and branches at every node. The branches are erect or scandent. The five types of *Piper longum* evaluated were found to possess simple, alternate and cordate leaf lamina; undulating leaf margin; a glabrous leaf surface; bullate with reticulate venation; dark green and shining above, pale and dull beneath; acuminate leaf tip and a cordate leaf base; with stipules which are membranous, lanceolate, obtuse and soon falling. The leaves varied in shape and mode of attachment even in the same plant. The upper leaves are generally sessile, amplexicaul ie. stem clasping while the lower ones are petiolated.

The inflorescence is cylindrical in *Piper longum*. Flowers are unisexual, minute, sessile, bracteate without perianth, very densely packed in spikate inflorescences, the male and female on separate plants. Female spikes possess circular, flat and peltate bracts with two stamens and three stigmas which are short, spreading and persistent. Fruit is very small, ovoid, completely sunk in solid fleshy spike, which is cylindrical, pedunculate, erect, blunt, blackish green and shining.

5.1 Analysis of variance

5.1.1 Vegetative characters

The five types of *Piper longum* did not differ significantly for the following vegetative characters namely diameter at node of main stem, diameter at internode of main stem, area of leaf lamina, internodal length of spike bearing branch, diameter at node of spike bearing branch and diameter at internode of spike bearing branch. However the five types were found to differ significantly for length of the longest stem, number of stems per hill, number of vegetative branches per stem, internodal length of main stem, length of leaf, width of leaf, length of petiole, number of leaves per hill, spread of the plant, number of spike bearing branches per stem and angle of insertion of spike bearing branch.

Plant size is mainly contributed by length of the stem. Longer the stem, higher will be the number of leaves. Increase in number of leaves will enhance the photosynthetic activity which has a direct bearing on yield. Cheematippali consistently maintained the position of maximum length of the longest stem at all these stages except at three, four and nine month after planting. However the five types of *P. longum* were found to differ significantly with respect to the length of the longest stem only at one and seven month after planting. At one month after planting Cheematippali with maximum length of the stem was on par statistically with Kaanjur but significantly superior to the remaining three types and at seven month after planting Cheematippali with maximum length of the longest stem was significantly superior to the remaining four types. There was found to be a steady increase in the length of the longest stem in case of Cheematippali, Panniyur and Pattambi upto seven month after planting after which it showed a continous decline, whereas there was a continous increase in the length of the longest stem in Mala and Kaanjur upto eight month after planting after which it showed a decline (Fig.2). Since same amount of irrigation was given for all the five types in all the months, except the monsoon months during which no irrigation was given, the increase in length of the longest stem seen in Mala and Kaanjur upto eight month after planting may be due to its ability to withstand water stress. The effect of water stress in reducing plant height and consequently the crop yield has been reported by Kramer (1983). Ponnuswami *et al.* (1983) reported considerable variability in vine length in the evaluation of eighty six open pollinated plants of black pepper.

Number of stems per hill is another important factor contributing to the plant size. The higher the number of stems per hill more will be the number of leaves and hence the photosynthetic activity is enhanced which has a direct bearing on yield. The five types of *Piper longum* differed significantly for this character at all these stages. Cheematippali consistently maintained the position of highest number of stems per hill at all these stages except at eight and nine month after planting. At three, four, six, seven, eight and nine month after planting Cheematippali was on par statistically with Kaanjur but significantly superior to Panniyur, Mala and Pattambi. At five month after planting Cheematippali was on par statistically with Kaanjur and Panniyur but significantly superior to Mala and Pattambi. All the five types of *P. longum* showed a steady increase in number of stems per hill upto seven month after planting after which it showed a steady decline (Fig.3).

Number of vegetative branches per stem is an important character since higher the number of vegetative branches per stem higher will be the number of leaves and hence the photosynthetic activity is more. The five types of *Piper longum* differed significantly for this character only at five month after planting. At this stage Cheematippali with the maximum number of vegetative branches per stem was on par statistically with Kaanjur but significantly superior to Panniyur, Pattambi and

Fig.2. Trend in average length of the longest stem for the five *Piper longum* types (one month to nine month after planting)

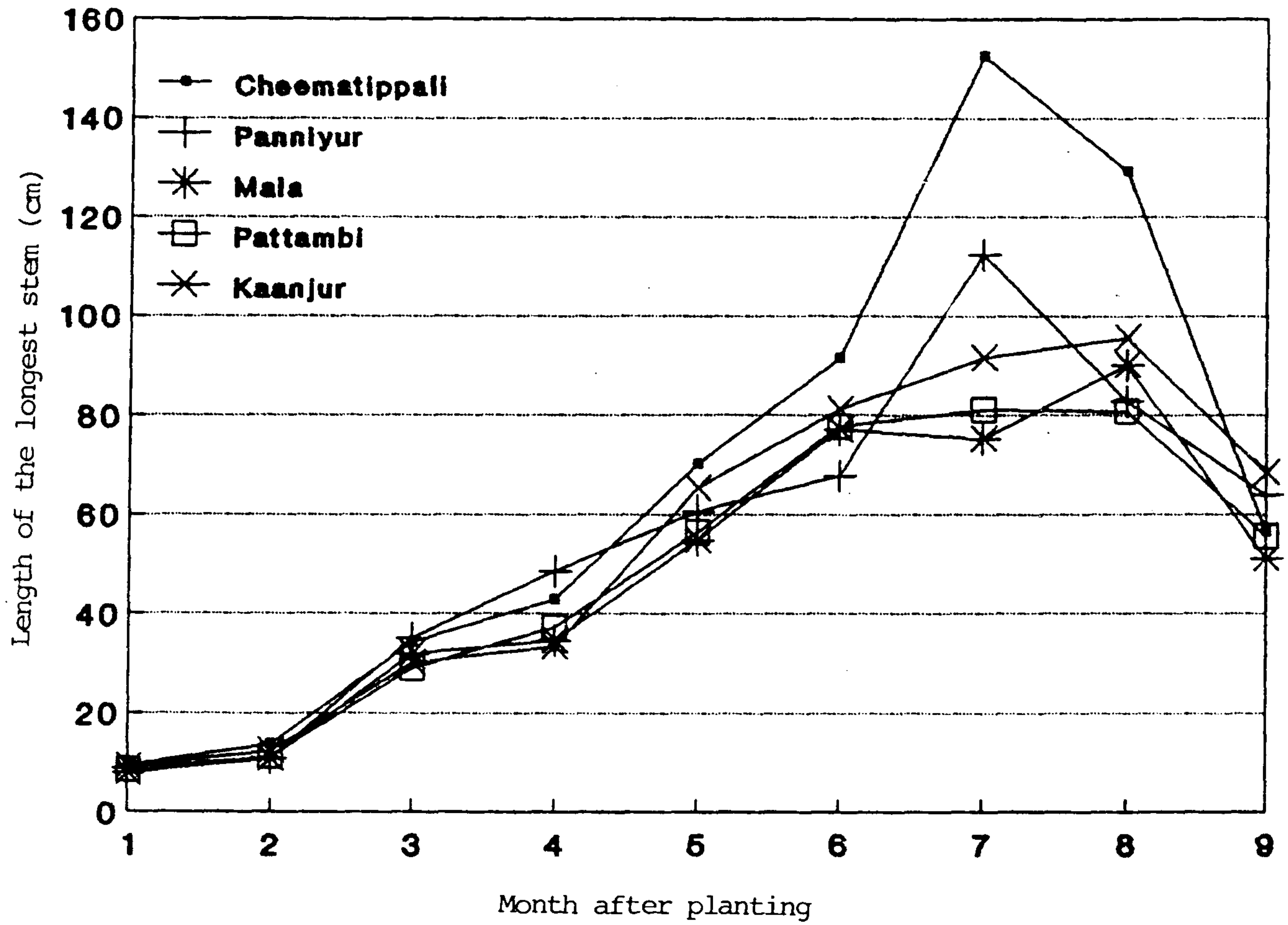
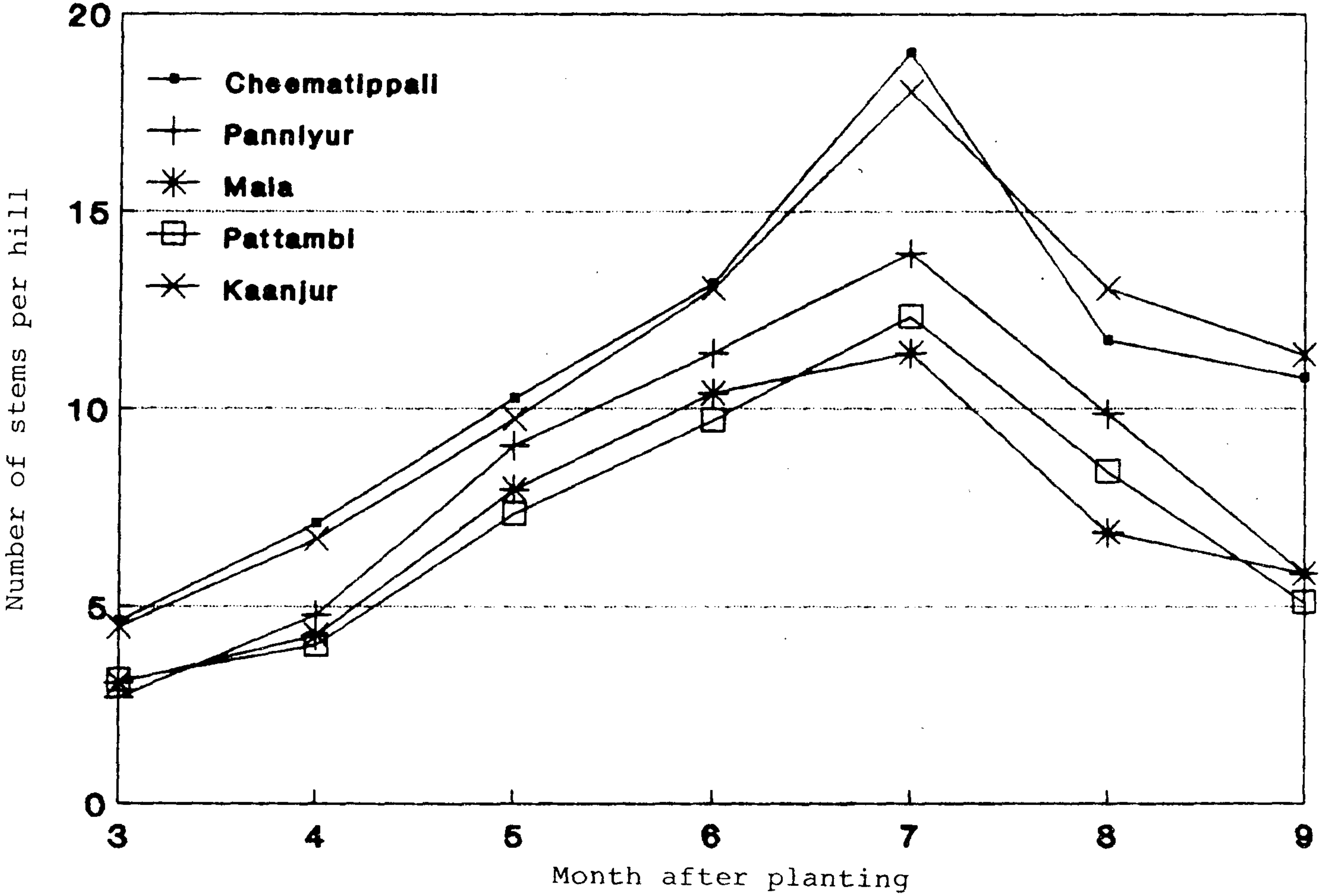


Fig. 3. Trend in the average number of stems per hill for the five *Piper longum* types (three month to nine month after planting)

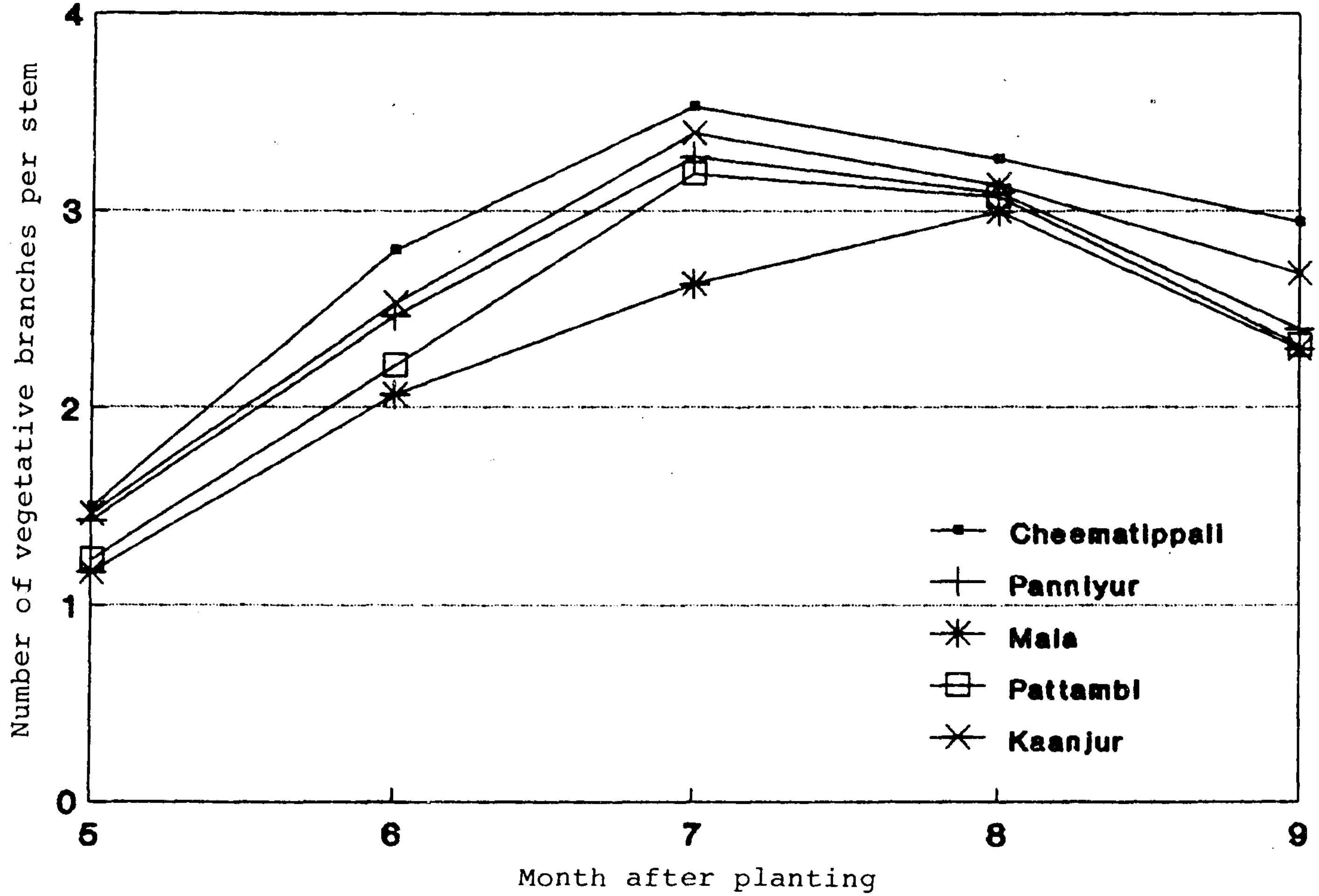


Mala. There was an increase in the number of vegetative branches per stem upto seven month after planting after which it showed a decline in all the four types except Mala which showed an increase upto eight month after planting (Fig. 4).

Internodal length of main stem is another important economic character for which the five types of *P. longum* were found to differ significantly. As internodal length increases the leaves will be well spread and light interception will be more which increases photosynthesis and hence the yield. Significant difference in internodal length of main stem of five *Piper longum* types was recorded only at four month after planting. Kaanjur which recorded the maximum internodal length of the stem at this stage was found to be on par statistically with Mala and Pattambi but significantly superior to Cheematippali and Panniyur for this character. As the internodal length increases, the plant height increases. However the above fact was not found to hold true at any of these stages. For instance at seven month after planting when Cheematippali recorded the maximum length of the longest stem ie. maximum height, the maximum internodal length was not recorded in Cheematippali but Pattambi, this could be probably due to the fact that though Cheematippali has less internodal length than Pattambi it may have more number of nodes than Pattambi. Many workers (Chandy *et al.*, 1984; Kanakamany *et al.* 1985; Ibrahim *et al.* 1986c) reported wide variation in internodal length for different genotypes of black pepper. In a study of 86 open pollinated plants of pepper the character number of nodes exhibited significant variation (Ponnuswami *et al.* 1983).

Leaf length has frequently been used in studies of plant development. It represents an important dimension of morphological change associated with growth. Leaf length has a direct bearing on the leaf area which in turn has direct bearing on the photosynthetic activity. Leaf length showed a substantial but steady increase in all the five types of *Piper longum* at all these stages upto nine month after planting.

Fig. 4. Trend in the average number of vegetative branches per stem for the five *Piper longum* types (five month to nine month after planting)



No significant difference in leaf length was recorded at any of these stages except at four month after planting. At this stage Cheematippali recorded the maximum leaf length and was on par statistically with Kaanjur and significantly superior to all other three types.

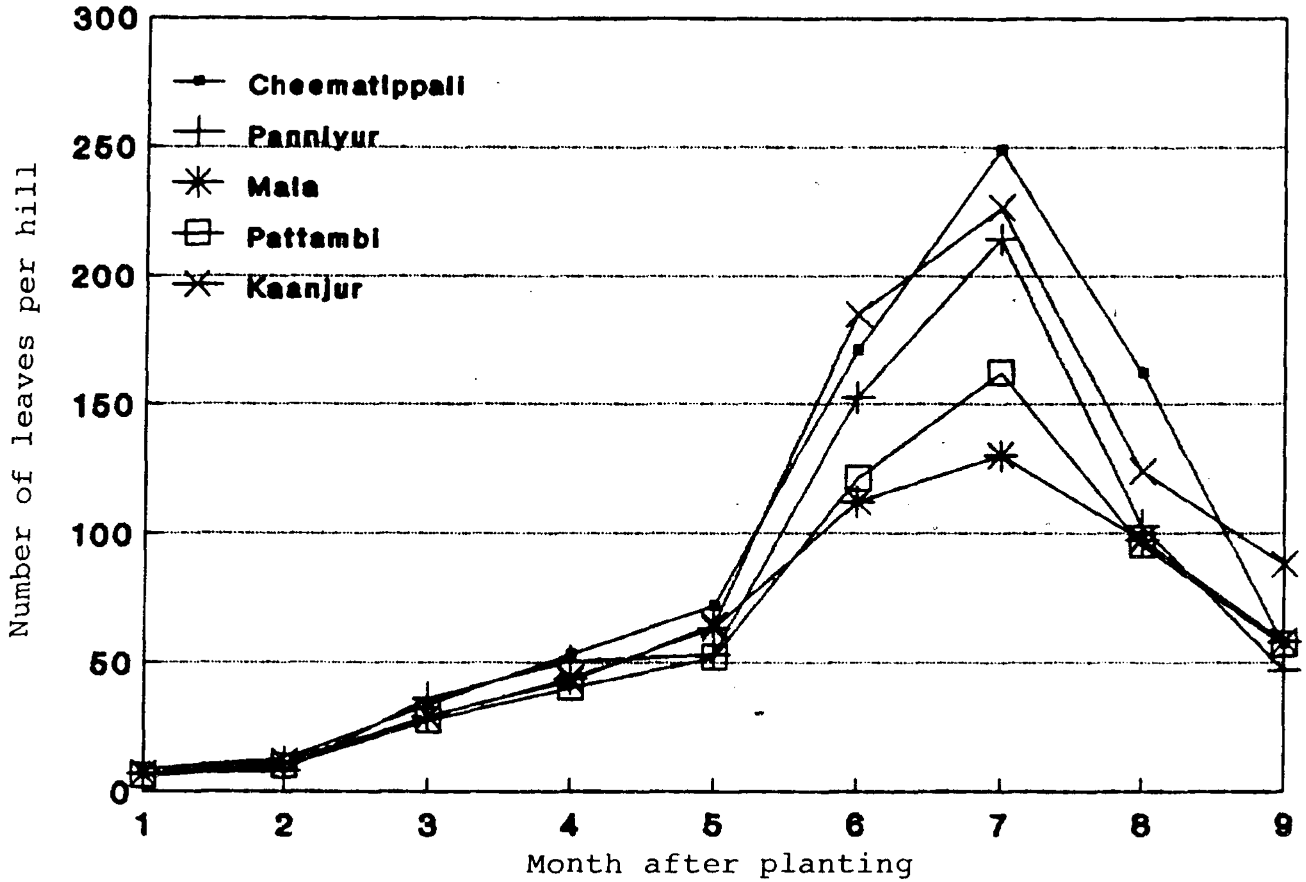
Leaf width is another important character which influences leaf area and hence the photosynthetic area and consequently the yield. Leaf width showed a substantial but steady increase in all the five types of *Piper longum* upto nine month after planting. Significant difference in leaf width for five *Piper longum* types was observed at four month after planting. Cheematippali which recorded the maximum leaf width at this stage was found to be on par statistically with Kaanjur and Panniyur but was significantly superior to Pattambi and Mala.

Higher the length of petiole, the better will be the exposure of the leaf to the sunlight. The five types of *Piper longum* were found to differ significantly for this character only at eight month after planting. At eight month after planting Panniyur which recorded the maximum length of petiole was found to be on par statistically with Mala, Cheematippali and Pattambi, but was significantly superior to Kaanjur.

Though Cheematippali and Kaanjur showed superiority in leaf length and leaf width at four month after planting, Panniyur which also showed superiority in leaf width was inferior in leaf length at this stage. Moreover at eight month after planting when no significant difference was observed for leaf length and leaf width at this stage in case of the length of petiole the types Panniyur, Mala, Cheematippali and Kaanjur were significantly superior to Pattambi. Thus from the above observations it can be seen that the type which showed superiority in one of the leaf character did not necessarily show superiority in other two characters thereby suggesting that the three characters namely leaf length, leaf width and length of petiole are independent of one another. Nambiar *et al.* (1978) reported the results of observations on three morphological attributes namely leaf length, leaf width and length of petiole in 24 cultivars of black pepper and found that they exhibited wide variability. Their observations also showed that all the three characters are independent and were not necessarily related to each other.

Number of leaves per hill is an important economic character since higher the number of leaves, higher will be the leaf area exposed and hence photosynthetic activity will be more which has a direct effect on yield. Cheematippali maintained the position of highest number of leaves per hill at all these stages except at three, six and nine month after planting. However the five types of *Piper longum* were found to differ significantly for this character at one, two, five, six, seven, eight and nine month after planting. At one month after planting, Cheematippali was significantly superior to the remaining four types. At two and five month after planting Cheematippali, Kaanjur and Mala were on par statistically with each other whereas at six and seven month after planting. Cheematippali, Panniyur and Kaanjur were on par statistically with each other and significantly superior to the remaining types. Cheematippali and Kaanjur were on par statistically with each other at eight month after planting and significantly superior to the remaining types whereas at nine month after planting Kaanjur was significantly superior to the remaining four types. All the five types of *Piper longum* showed a steady increase in number of leaves per hill upto seven month after planting after which it showed a decline (Fig. 5). Kaanjur recorded more number of leaves than Panniyur at seven month after planting though Panniyur had greater height than Kaanjur at this stage. This could be due to the more number of stems per hill and vegetative branches per stem recorded in Kaanjur than Panniyur since higher the number of stems per hill and vegetative

Fig. 5. Trend in the average number of leaves per hill for the five *Piper longum* types (one month to nine month after planting)



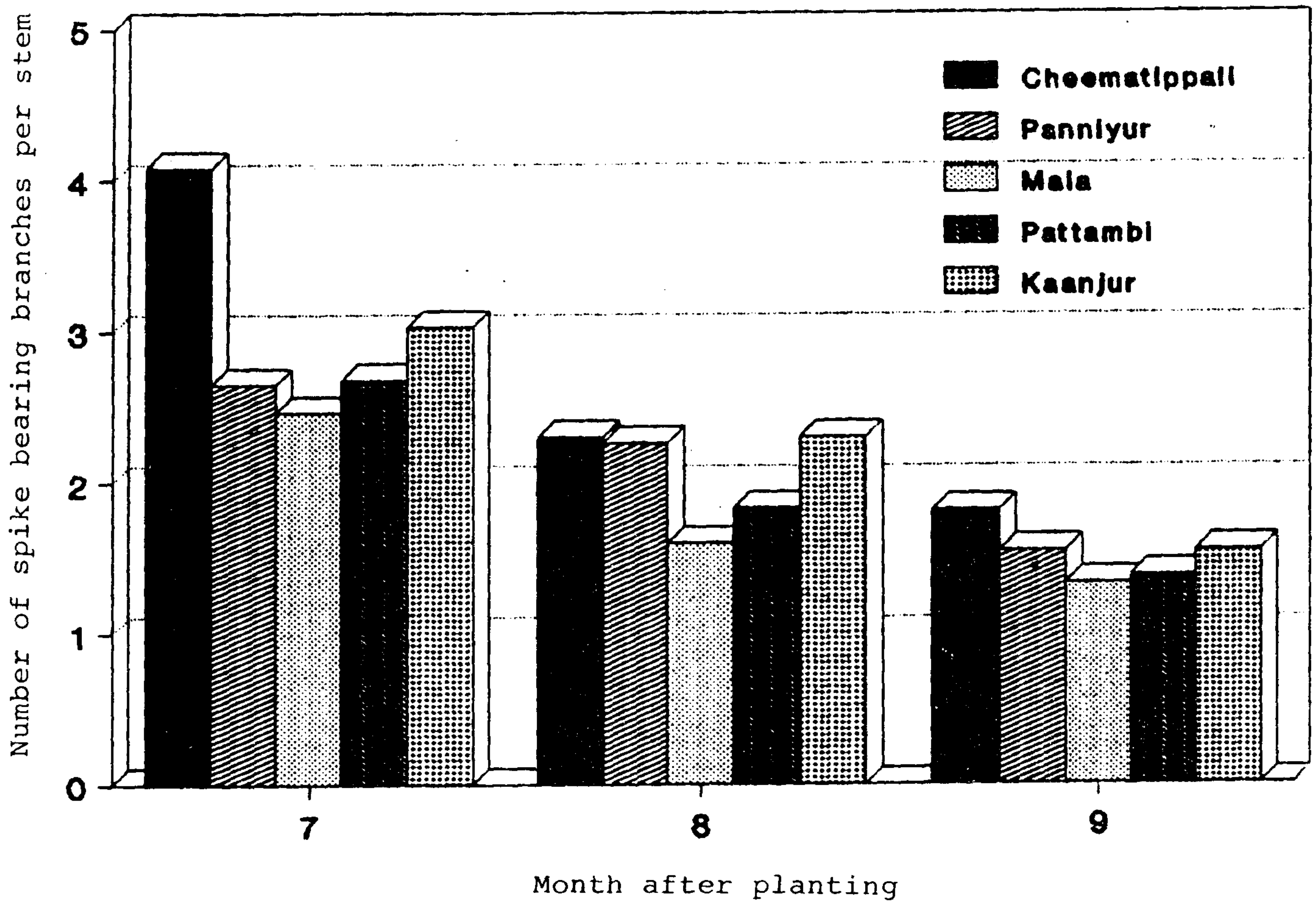
branches per stem higher will be the number of leaves. Pattambi and Kaanjur showed a decline in number of leaves per hill at eight month after planting though they both showed an increase in height at the same stage. This could be due to the decrease in number of stems per hill and number of vegetative branches per stem at eight month after planting.

Increased spread of the plant increases the leaf area exposed to sunlight which enhances the photosynthetic activity which has a direct bearing on yield. The five types of *Piper longum* were found to differ significantly for this character only at five month after planting. At this stage Kaanjur and Cheematippali were on par statistically with each other and significantly superior to Pattambi, Panniyur and Mala.

Number of spike bearing branches per stem is an important economic character contributing to the output of the crop. The more the number of spike bearing branches per stem greater will be the number of spikes which consequently increases the final yield of the crop. Significant difference in number of spike bearing branches per stem was observed only at seven and eight month after planting. At seven month after planting Cheematippali was found to be significantly superior to all other four types whereas at eight month after planting Cheematippali, Kaanjur and Panniyur were found to be on par statistically with each other but significantly superior to Pattambi and Mala. The number of spike bearing branches per stem showed a continous decline in all the five types of *Piper longum* after seven month after planting (Fig.6). This was obviously due to the harvest of mature spike at seven month after planting thereby decreasing the average number of spike bearing branches per stem at eight and nine month after planting.

Increased angle of insertion of spike bearing branch with main stem will

Fig. 6. Comparison of the average number of spike bearing branches per stem of the five *Piper longum* types (at seven, eight and nine month after planting)



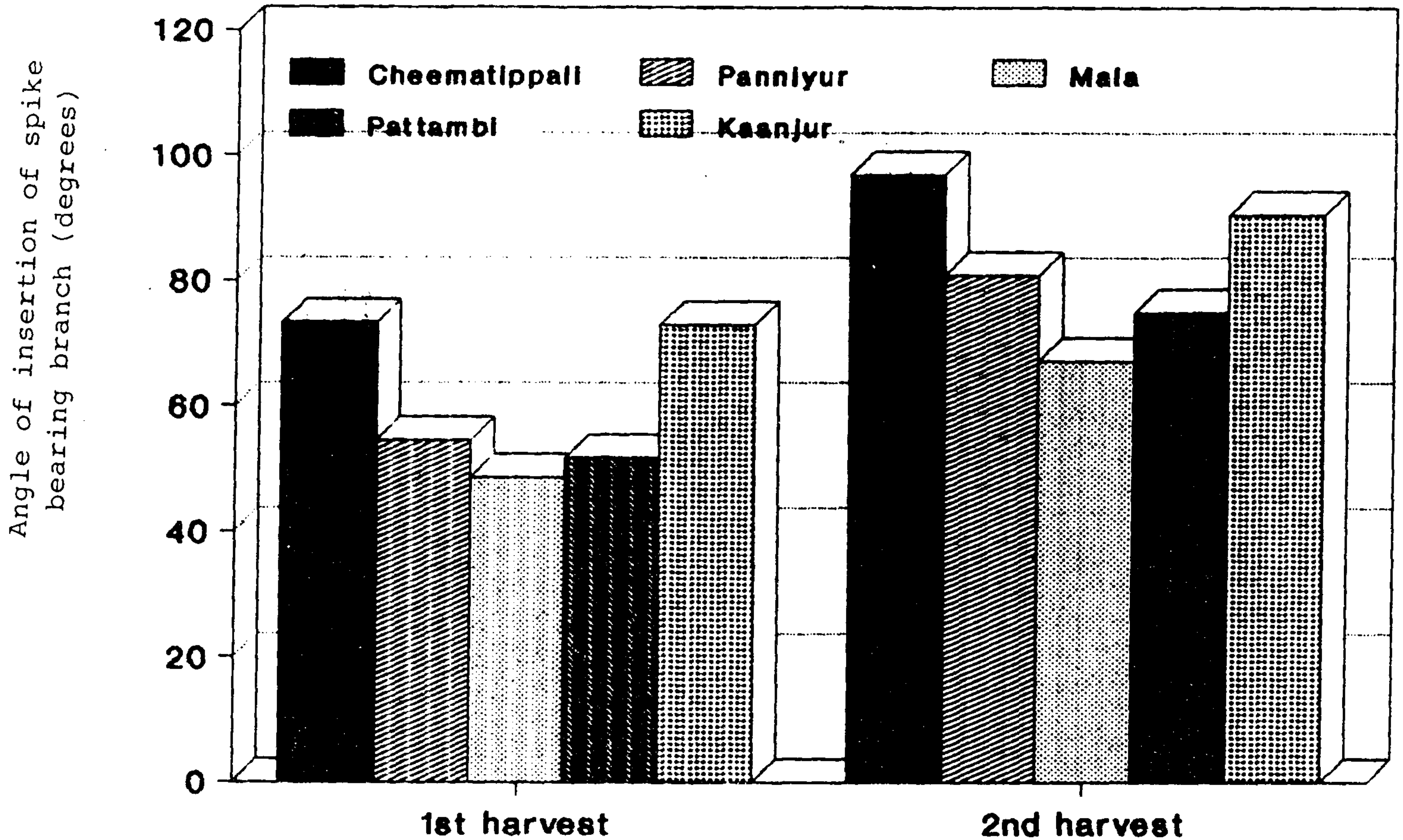
result in well spread laterals by which light interception will be more which has a direct bearing on yield since photosynthetic activity is enhanced. Significant difference in the angle of insertion was recorded at first harvest and second harvest. At first harvest and second harvest Cheematippali with maximum angle of insertion was found to be on par statistically with Kaanjur but was significantly superior to the remaining three types. 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 in black pepper. There was an increase in the angle of insertion of spike bearing branch at second harvest compared to the first harvest in all the five types (Fig.7). It may also be noted that there was an increase in dry spike yield at second harvest as compared to the first harvest in all the five types. Thus the increase in dry spike yield could be due to the increase in angle of insertion of spike bearing branch. The increased angle could be due to the increased number of spikes per spike bearing branch which is reflected in the increased yield.

5.1.2 Productive characters

The five types of *Piper longum* did not differ significantly for the following productive characters namely length of spike, diameter of spike, length of peduncle, days from planting to emergence of spike, days from emergence to maturity of spike and ratio of weight of green spike to weight of dry spike. They were however found to differ significantly for the following productive characters namely number of spikes per spike bearing branch, yield of green spike in kg per hectare and yield of dry spike in kg per hectare.

Number of spikes per spike bearing branch is another important character which influences the yield. Higher the number of spikes per spike bearing branch higher will be the final output of the crop. Significant difference in the number of

Fig.7. Comparison of the average angle of insertion of spike bearing branch of five *Piper longum* types (at first harvest and second harvest)



spikes per spike bearing branch was recorded at five, six and seven month after planting. Cheematippali which recorded the maximum number of spikes per spike bearing branch was on par statistically with Kaanjur but significantly superior to Panniyur, Mala and Pattambi at five month after planting. Cheematippali, Kaanjur and Panniyur were on par statistically with each other and significantly superior to Pattambi and Mala at six month after planting. At seven month after planting Cheematippali was significantly superior to the remaining four types. Number of spikes per spike bearing branch showed an increase upto seven month after planting in all the five types after which it showed a decline (Fig. 8).

Cheematippali and Kaanjur were statistically on par with each other with respect to green spike yield and dry spike yield and significantly superior to all other types with respect to these characters. Mala recorded the minimum green spike yield and dry spike yield at both first harvest and second harvest. The superiority in yield shown by Cheematippali and Kaanjur could be due to the reason that they were superior to the other types at most of the stages for most of the vegetative and productive characters influencing yield namely length of the longest stem, number of stems per hill, number of vegetative branches per stem, internodal length of main stem, spread of the plant, leaf length, leaf width, number of leaves per hill, number of spike bearing branches per stem and angle of insertion of spike bearing branch. There was found to be an increase in dry spike yield at second harvest as compared to first harvest in all the five types of *Piper longum* (Fig.9). This could be due to the reason that being a perennial crop it requires a longer period to achieve stability in yield.

5.2 Correlation studies

Yield is a complex quantitative character and many other metric traits

Fig.8. Trend in the average number of spikes per spike bearing branch for five *Piper longum* types (five month to nine month after planting)

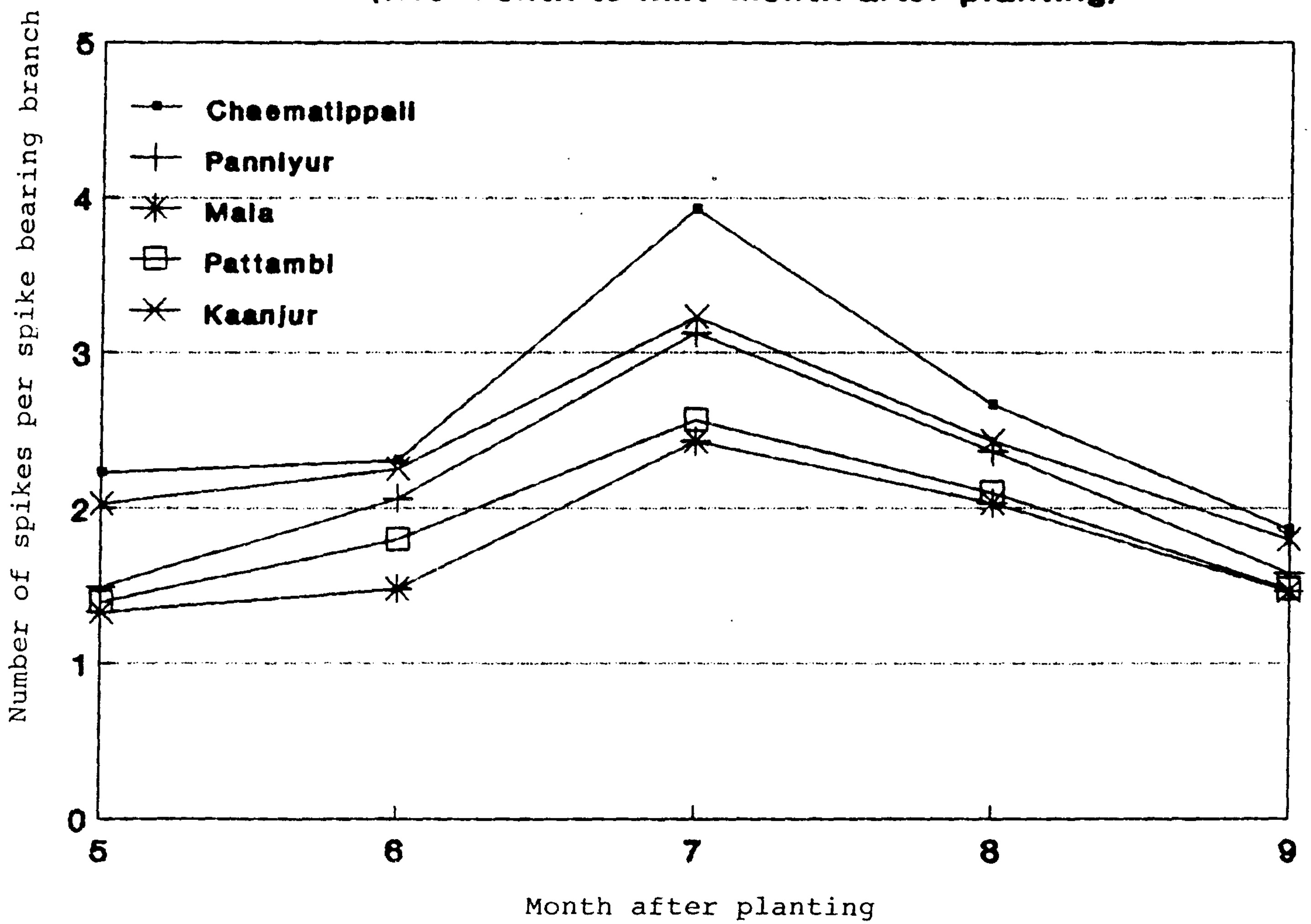
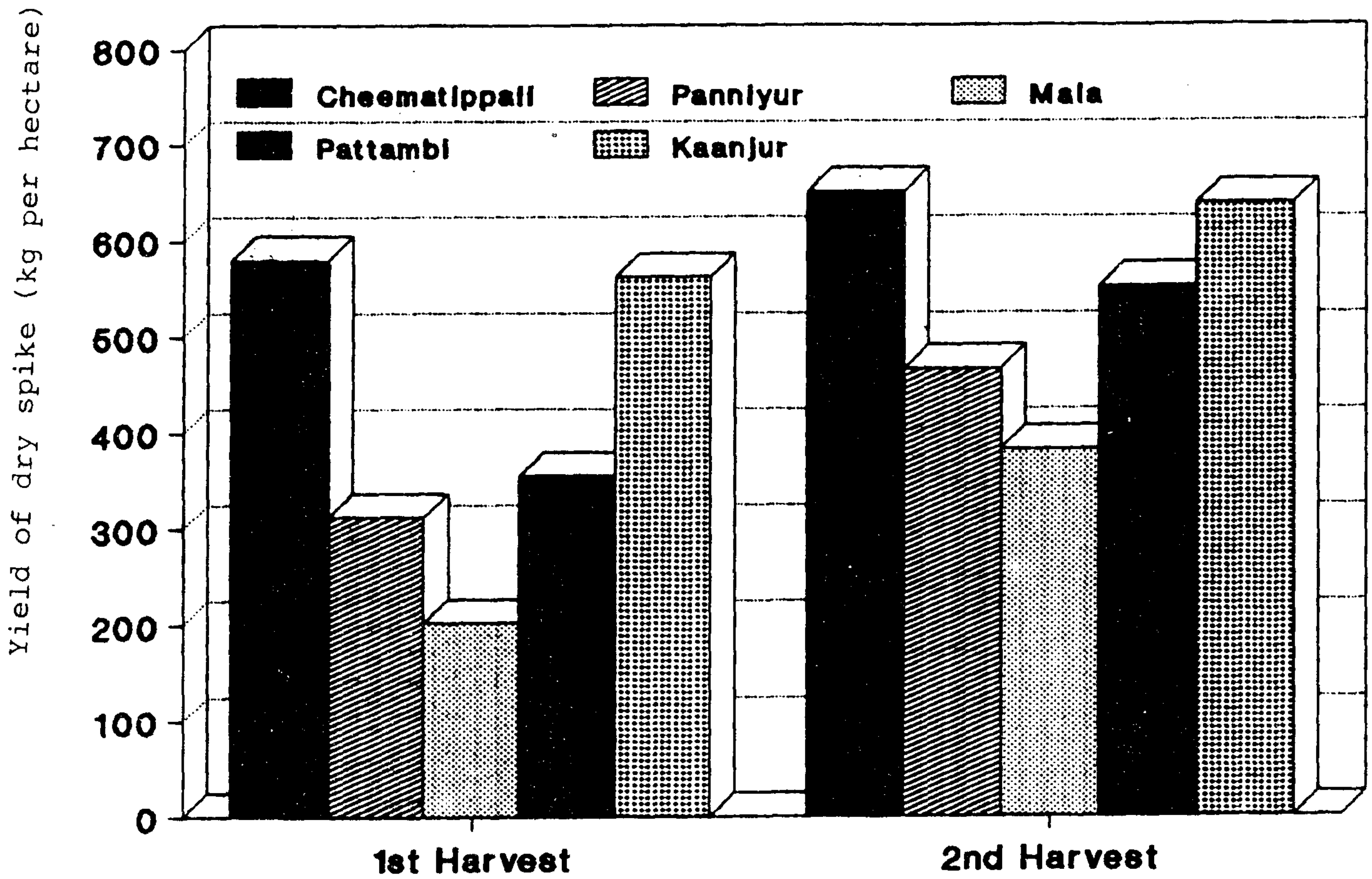


Fig. 9. **Comparison of the average dry spike yield of five *Piper longum* types (at first harvest and second harvest)**



which are interrelated 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 prerequisite for making effective selection especially when two or more characters are simultaneously considered in the selection programme.

In the present study, green spike yield showed the highest positive correlation with dry spike yield followed by angle of insertion of spike bearing branch and number of stems per hill. Data on interrelationship among yield components give a more reliable information rather than a knowledge of association between yield and its components. High, significant and positive correlation of dry spike yield with angle of insertion of spike bearing branch was due to the positive and significant correlation of angle of insertion of spike bearing branch with green spike yield, number of spikes per spike bearing branch, number of spike bearing branches per stem, length of the longest stem and number of stems per hill. The high positive and significant correlation of angle of insertion of spike bearing branch with yield agrees with the reports of Chandy and Pillai (1979) in case of black pepper.

Similarly number of stems per hill showed a significant and positive correlation with dry spike yield. This could be due to the positive and significant intercorrelation of number of stems per hill with angle of insertion of spike bearing branch, number of spikes per spike bearing branch and number of spike bearing branches per stem, length of the longest stem and number of leaves per hill.

Number of spikes per spike bearing branch also showed significant and positive correlation with yield. This was in conformity with the reports of Ibrahim *et al.* (1985c) who reported a high correlation of spike number with yield in case of black pepper.

Number of spike bearing branches per stem also recorded a significant and positive correlation with yield. This could be due to the intercorrelation of number of spike bearing branches per stem with angle of insertion of spike bearing branch and number of spikes per spike bearing branch. Significant and positive correlation was observed between length of the longest stem and the dry spike yield. Number of leaves per hill also showed positive correlation with yield since as the number of leaves increases the photosynthesis is enhanced which has a direct effect on the output of the crop. Number of vegetative branches per stem was also found to have a positive and significant correlation with dry spike yield. This could be due to the reason that as the number of vegetative branches increases there is a consequent increase in the number of leaves which enhances the photosynthetic activity and consequently the yield.

In the present study interrelations among angle of insertion of spike bearing branch, green spike yield, number of spikes per spike bearing branch, number of spike bearing branches per stem, length of the longest stem and number of stems per hill were high and positive suggesting the 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 interrelationships among themselves, selection can perhaps be based on these characters for improving yield in *Piper longum*.

5.3 Path analysis

Path analysis suggested by Dewey and Lu (1959) provides a method for separating the correlation coefficient of a causative factor with its effects into direct and indirect effects and it measures the relative importance of 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 the values of the associated characters and finally these together affect the yield. To determine the relative contribution of different characters towards yield and to measure the co-ordinated relationship existing among these traits, seven characters in *P. longum* were subjected to path analysis. Out of these seven characters angle of insertion of spike bearing branch, number of vegetative branches per stem, number of spikes per spike bearing branch, length of the longest stem, number of leaves per hill and number of stems per hill showed positive direct effect.

The maximum contribution to dry spike yield is through angle of insertion of spike bearing branch. The increased angle will result in well spread laterals by which light interception will be more which has a direct bearing on yield since photosynthetic activity is enhanced.

Number of stems per hill had a positive direct effect as well as high indirect effect through angle of insertion of spike bearing branch. This could be due to the fact that as number of stems per hill increase crowding may occur and hence for increased light interception the laterals spread thereby increasing the angle of insertion of spike bearing branch since spikes are produced on laterals.

Number of spikes per spike bearing branch had a small direct effect but its significant correlation with yield could be due to the high indirect effect through angle of insertion of spike bearing branch.

The number of spike bearing branches per stem had a high and positive correlation with yield mainly due to the positive indirect effect through angle of insertion of spike bearing branch.

From the above findings it can be concluded that selection for improvement of dry spike yield can be efficient if it is based on angle of insertion of spike bearing branch, number of stems per hill, number of spikes per spike bearing branch and number of spike bearing branches per stem as evidenced from their simple correlation with yield as well as by the path analysis.

5.4 Total alkaloidal content in dried spikes of *Piper longum*

Though Panniyur possessed high alkaloidal content in the dried spikes its total dry spike yield from per hectare area was low compared to Cheematippali, thereby decreasing the total alkaloidal output from per hectare of land. Hence Cheematippali is preferable to Panniyur with respect to this character though Panniyur possessed higher alkaloid content than Cheematippali.

Based on correlation studies and path analysis it has been concluded that the characters, angle of insertion of spike bearing branch, number of stems per hill, number of spikes per spike bearing branch and number of spike bearing branches per stem are the major characters influencing dry spike yield. Hence in order to recommend the best type of *Piper longum* suitable for cultivation as an intercrop in coconut gardens it may be advisable to select a type which shows superiority for the above mentioned characters based on analysis of variance studies and consequently in the dry spike yield.

As regards angle of insertion of spike bearing branch Cheematippali and Kaanjur were statistically on par and significantly superior to the remaining three types at both first and second harvest. With regard to number of stems per hill Chemmatippali and Kaanjur were on par statistically with each other and significantly superior to all the remaining types at all these stages except at three month after planting when Cheematippali was found to be superior to all other four types. As regards the number of spikes per spike bearing branch at six month after planting, when the five types differed significantly for this character Cheematippali was on par statistically with Kaanjur and Panniyur but significantly superior to the remaining two types. At seven month after planting Cheematippali was significantly superior to the remaining four types. With respect to number of spike bearing branches per stem Cheematippali was significantly superior to all other four types at seven month after planting and Cheematippali with the maximum number of spike bearing branches per stem at eight month after planting was significantly superior only to Mala and on par statistically with Kaanjur, Panniyur and Pattambi. As regards dry spike yield Cheematippali and Kaanjur were statistically on par with each other at both first and second harvest and significantly superior to the remaining three types. Considering the above facts it could be seen that with respect to the above characters, in most of the stages where the five types differed significantly, Cheematippali was on par statistically with Kaanjur except in case of number of stems per hill at three month after planting and number of spike bearing branches per stem at seven month after planting when Cheematippali was significantly superior to the remaining four types. With respect to total alkaloidal content in percentage of the five *Piper longum* types though Panniyur possessed a substantially higher alkaloidal content in percentage over Cheematippali, dry spike yield per hectare was very low compared to Cheematippali hence Cheematippali was preferable to Panniyur with respect to this character since it could give higher alkaloidal output from per hectare of land area. Hence Cheematippali which showed consistently superior performance with respect to all of the characters could be definitely recommended for large scale cultivation after multilocational trials. However Kaanjur can also be considered as a promising type since only in a very few characters it failed to establish its superiority over Cheematippali.

Summary

SUMMARY

The investigations reported herein were undertaken in the Department of Agricultural Botany, College of Horticulture, Vellanikkara during 1990-92. The objective was to select the best type of *Piper longum* suitable as an intercrop in coconut gardens.

Five types of *Piper longum* namely Cheematippali, Panniyur, Mala, Pattambi and Kaanjur were evaluated for economic characters and active principles in the 16 year aged coconut garden of the Instructional Farm, Vellanikkara.

Six plants were randomly selected for taking observations on twenty three vegetative characters and nine productive characters. The data obtained were subjected to suitable statistical analysis so as to estimate the variability in the five types with respect to vegetative characters and productive characters, and also to estimate the correlation of these characters with the dry spike yield. A path coefficient analysis was also attempted to partition the cause and effect relationship among the characters.

The salient findings could be summarised as follows:

The five types of *Piper longum* differed significantly for only eleven of the twenty three vegetative characters studied. These were length of the longest stem, number of stems per hill, number of vegetative branches per stem, leaf length, leaf width, length of petiole, number of leaves per hill, spread of the plant, internodal length of main stem, number of spike bearing branches per stem and angle of insertion of spike bearing branch.

Only three of the nine productive characters studied were found to differ

significantly in the five *P. longum* types namely number of spikes per spike bearing branch, yield of green spike and yield of dry spike.

High, positive and significant correlation was observed for green spike yield, angle of insertion of spike bearing branch and number of stems per hill with dry spike yield. Significant and positive correlation was observed for number of spikes per spike bearing branch, number of spike bearing branches per stem, number of leaves per hill, length of the longest stem and number of vegetative branches per stem with dry spike yield.

Intercorrelations among angle of insertion of spike bearing branch, green spike yield, number of spikes per spike bearing branch, number of spike bearing branches per stem, length of the longest stem and number of stems per hill were high and positive suggesting the simultaneous improvement of these characters in a selection programme involving any one of these traits.

The path analysis revealed that angle of insertion of spike bearing branch, number of stems per hill, number of spikes per spike bearing branch and number of spike bearing branches per stem were the most important characters influencing dry spike yield.

The selection for improvement of dry spike yield can be efficient if it is based on angle of insertion of spike bearing branch, number of stems per hill, number of spikes per spike bearing branch and number of spike bearing branching per stem from their simple correlation with yield as well as path analysis.

With respect to total alkaloids in percentage in the dried spikes of *Piper longum*, Panniyur recorded the maximum percentage of alkaloids and Mala recorded the minimum percentage of alkaloid. But with respect to total alkaloid output from unit area, Cheematippali was found to be superior to Panniyur since dry spike yield of Panniyur differed significantly with Cheematippali and was inferior to Cheematippali with respect to this character.

In respect of the most important characters influencing dry spike yield Cheematippali showed consistently superior performance for all these characters at all these stages in which the five types of *P. longum* were found to differ significantly and could definitely be recommended for large scale cultivation after multilocational trials.

Kaanjur can also be considered as a promising type since only in a very few characters it failed to establish its superiority over Cheematippali.

The type Mala was found to be consistently inferior in all the vegetative and productive characters studied and in total alkaloidal content.

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Plates

Plate 1a. General view of the experimental plot

Plate 1b. General view of the experimental plot

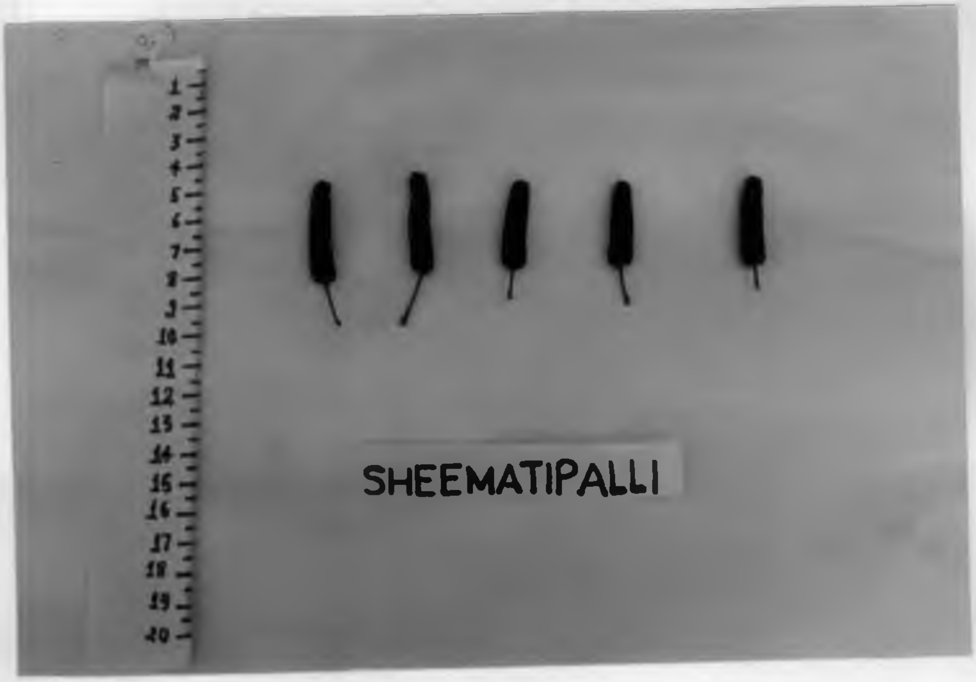
Plate 2. Cheematippali - A. Individual spike

B. Bearing habit of spike


SHEEMATIPALLI

Plate 3. Panniyur - A. Individual spike

B. Bearing habit of spike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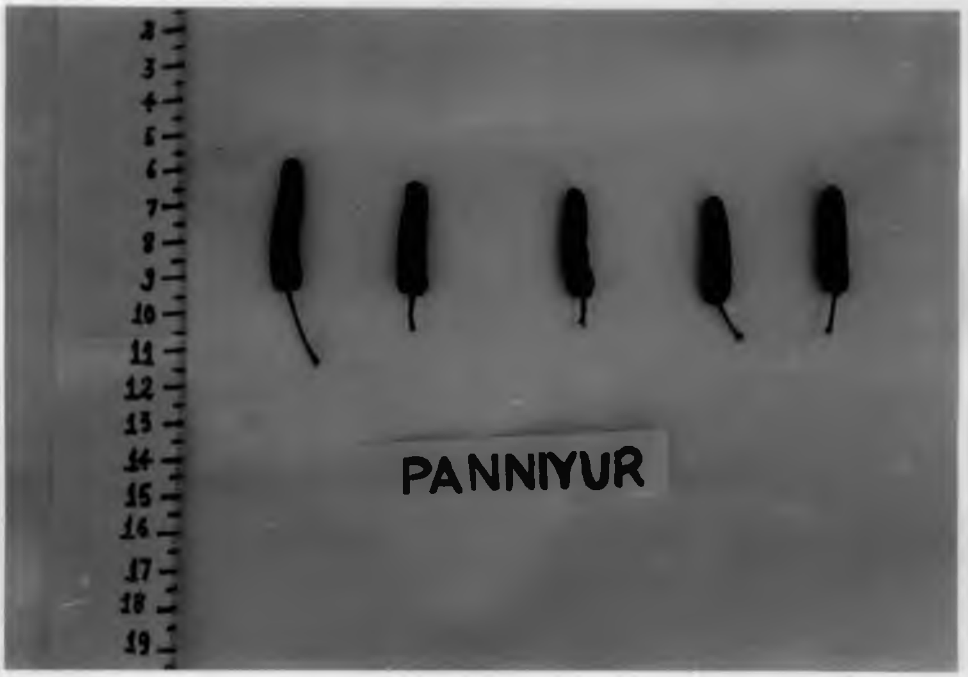
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PANNIYUR

Plate 4. Mala - A. Individual spike

B. Bearing habit of spike

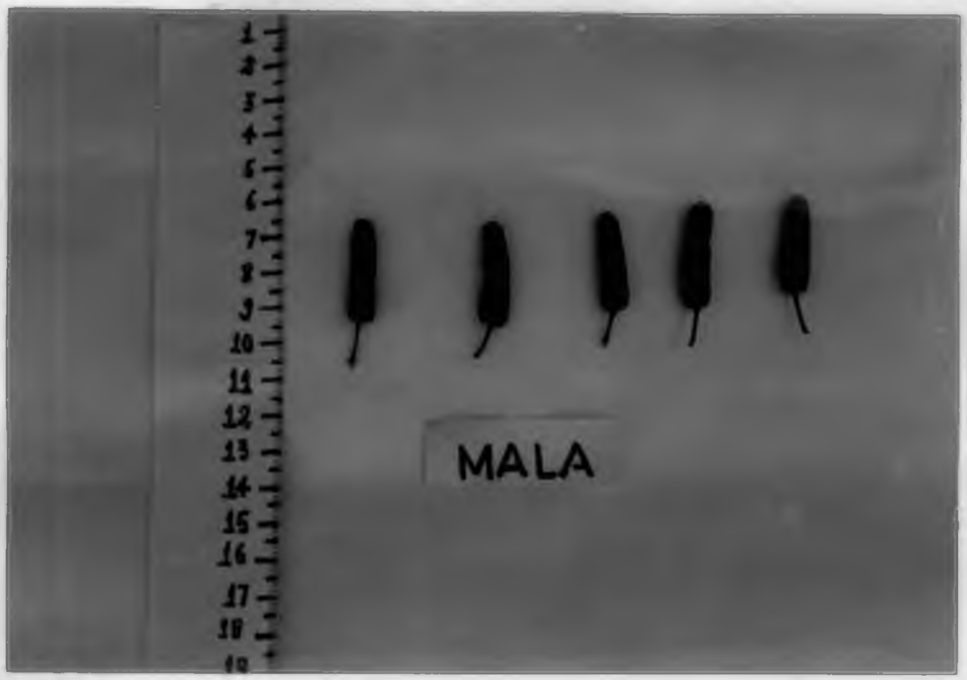

MALA

Plate 5. Pattambi - A. Individual spike

B. Bearing habit of spike

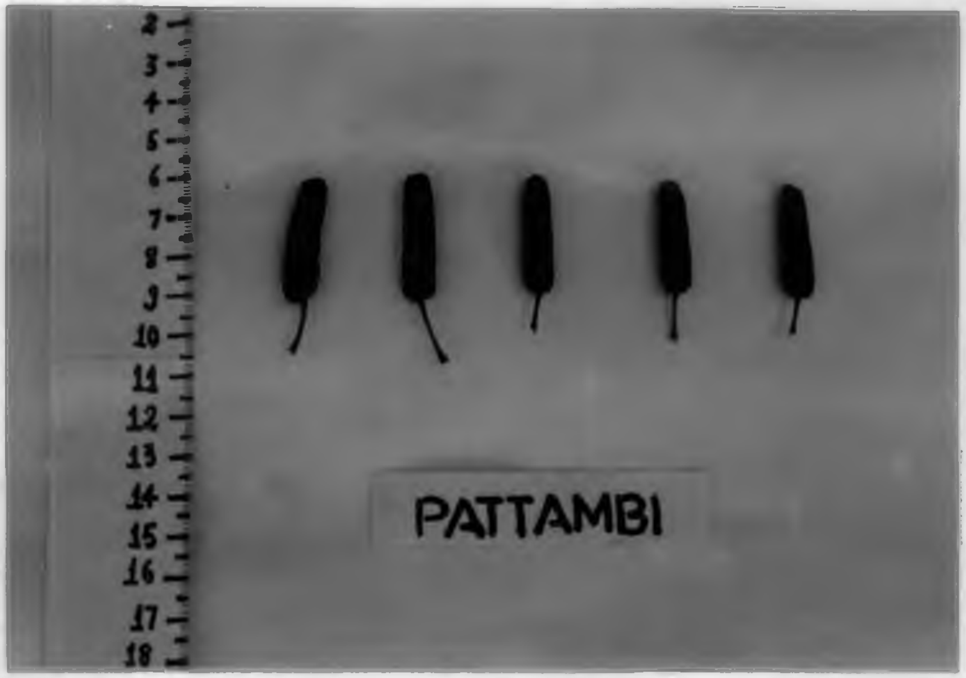
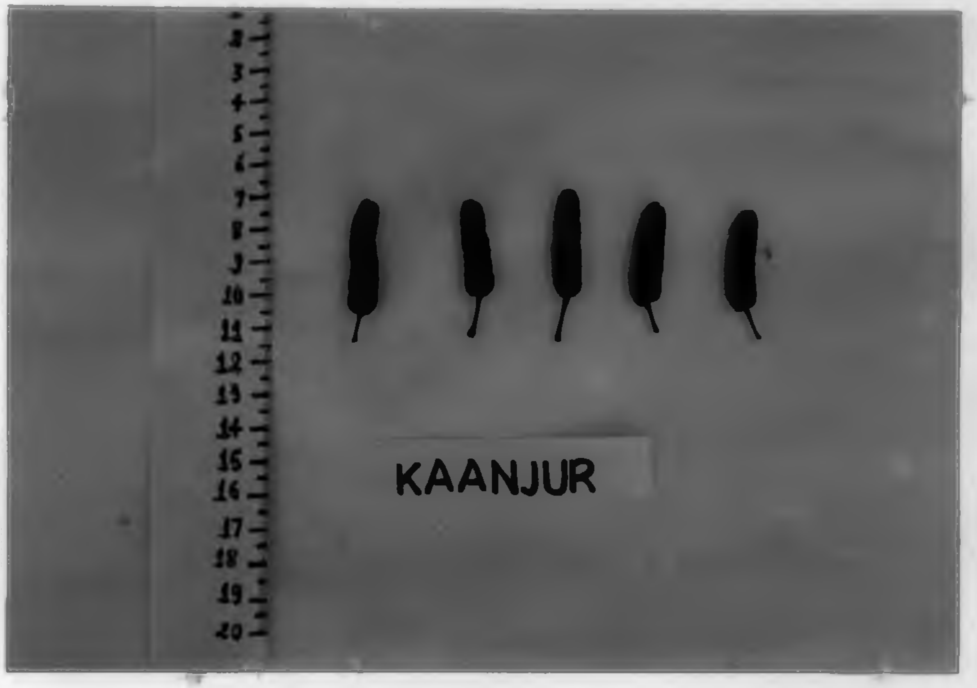

PATTAMBI

Plate 6. Kaanjur - A. Individual spike

B. Bearing harbit of spike


KAANJUR


R5 V5

Plate 7. A general view of the arrangement of the five types of *Piper longum* in the first replication (R_1)

Plate 8. A general view of the arrangement of the five types of *Piper longum* in the second replication (R_2)

Plate 9. A general view of the arrangement of the five types of *Piper longum* in the third replication (R_3)

Plate 10. A general view of the arrangement of the five types of *Piper longum* in the fourth replication (R_4)

Plate 11. A general view of the arrangement of the five types of *Piper longum* in the fifth replication (R_5)

Plate 12. Individual spikes of the five types of *Piper longum*

V_1 - Cheematippali

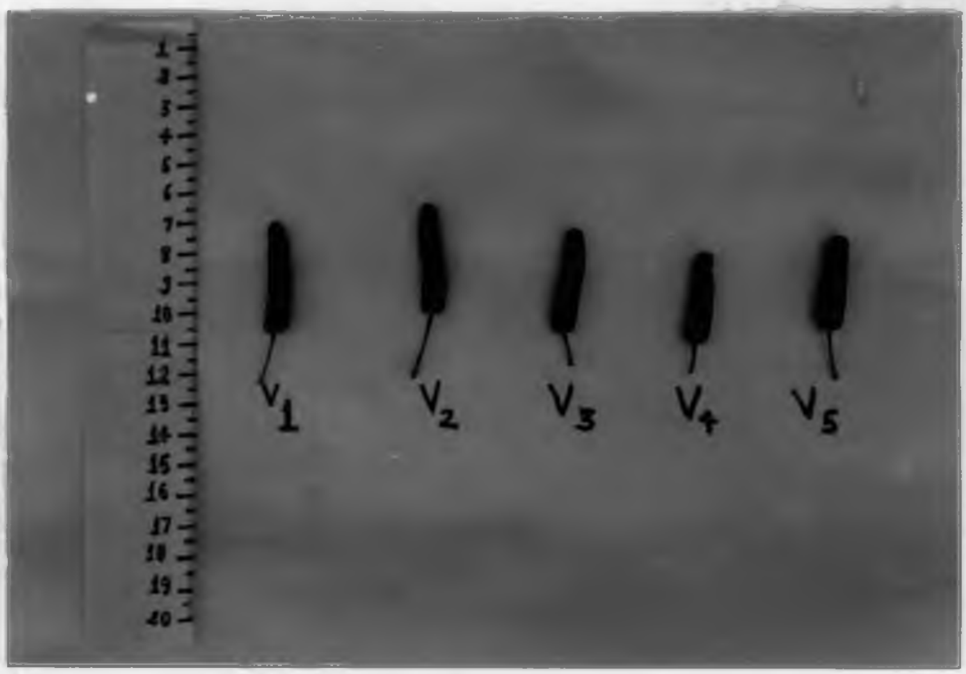
V_2 - Panniyur

V_3 - Mala

V_4 - Pattambi

V_5 - Kaanjur


R5V5


V1
V2
V3
V4
V5

Appendices

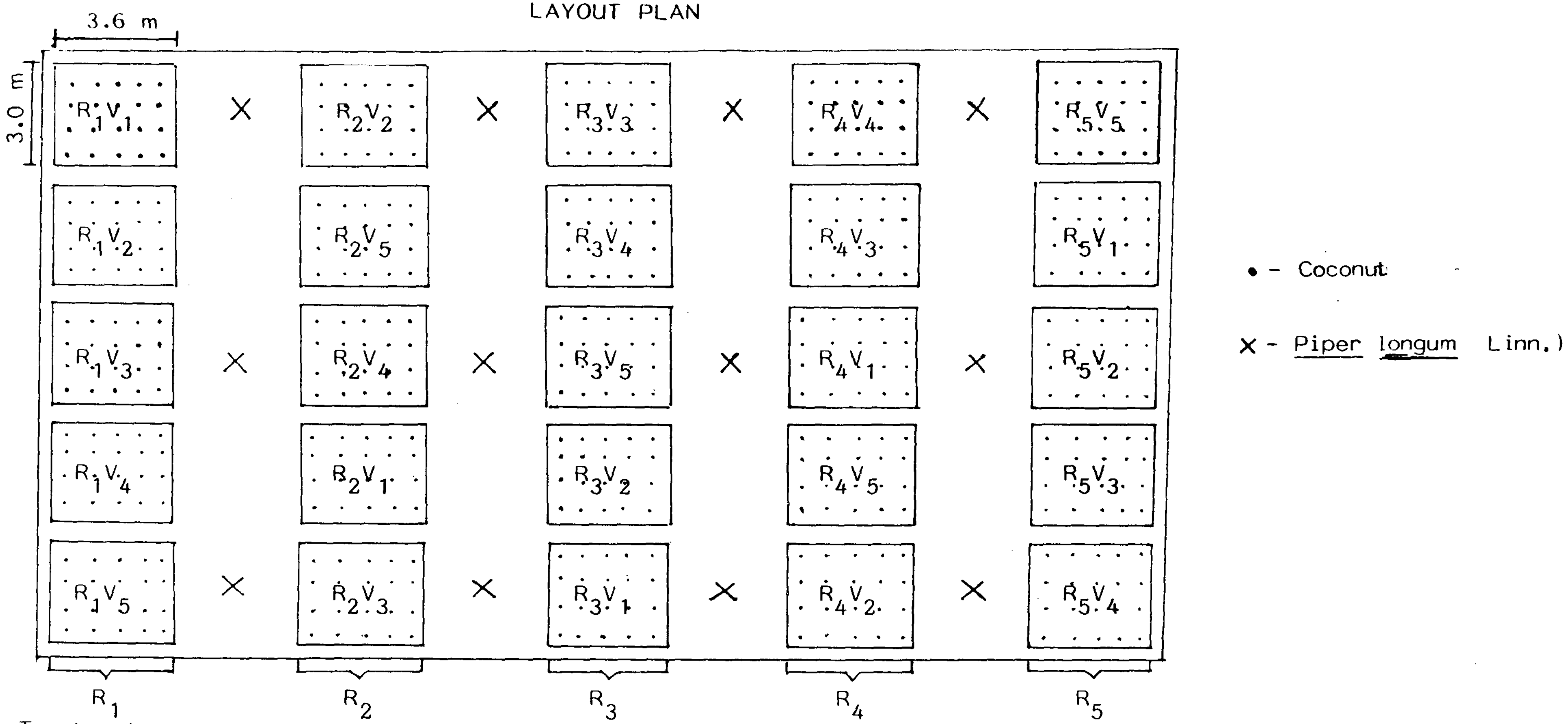
APPENDIX-I

Mean monthly weather parameters for the crop growth

Month	Air temperature mean C		Total rainfall (mm)	Rainy days	Total evaporation (mm)	Mean sunshine hours
	Maximum	Minimum				
			1991			
June	29.7	23.8	993.1	28	66.8	4.8
July	29.1	22.8	975.6	27	74.9	2.5
August	29.0	22.7	533.3	24	78.2	2.8
September	31.5	23.6	61.5	7	110.2	7.3
October	30.9	23.2	281.7	14	78.7	4.3
November	31.5	25.0	191.3	9	120.7	7.1
December	31.9	21.7	0.2	0	190.1	8.6
			1992			
January	32.6	20.9	0.0	0	229.6	9.0
February	34.5	21.8	0.0	0	150.4	9.2

APPENDIX - II

LAYOUT PLAN



Treatment

V_1 - Cheematippali

V_2 - Panniyur

V_3 - Mala

V_4 - Pattambi

V_5 - Kaanjur

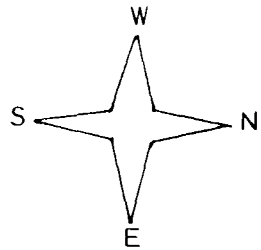
R_1 - First Replication

R_2 - Second Replication

R_3 - Third Replication

R_4 - Fourth Replication

R_5 - Fifth Replication



APPENDIX-III

Analysis of variance of length of the longest stem in cm of the five *Piper longum* types (one month to nine month after planting

Source	df	Mean squares								
		Length of the longest stem (cm)								
		Month after planting								
		1	2	3	4	5	6	7	8	9
Replication	4	1.43**	2.38	43.33	66.33	567.77	455.76	238.67	1766.99	190.92
Type	4	2.03**	7.94	34.33	202.83	197.19	363.17	4901.88**	1921.22	239.43
Error	16	0.21	3.67	70.72	79.63	168.82	207.39	334.21	789.53	303.28

* Significant at 5% level
** Significant at 1% level

APPENDIX-IV

Analysis of variance of number of stems per hill of the five *Piper longum* types (three month to nine month after planting)

Source	df	Mean squares						
		Number of stems per hill						
		Month after planting						
		3	4	5	6	7	8	9
Replication	4	0.81*	1.72	1.57	0.90	19.14*	2.45	2.09
Type	4	3.92**	10.12**	7.39**	11.99**	58.35**	30.69**	45.74**
Error	16	0.25	1.23	1.42	1.14	6.22	3.39	3.07

* Significant at 5% level
** Significant at 1% level

APPENDIX-V

Analysis of variance of number of vegetative branches per stem of the five *Piper longum* types (five month to nine month after planting)

Source	df	Mean squares				
		Number of vegetative branches per stem				
		Month after planting				
		5	6	7	8	9
Replication	4	0.04	0.28	1.15**	0.29	0.21
Type	4	0.11*	0.41	0.61	0.05	0.39
Error	16	0.03	0.16	0.22	0.65	0.39

* Significant at 5%

** Significant at 1%

APPENDIX-VI

Analysis of variance of internodal length of main stem in cm of the five *Piper longum* type (four month to nine month after planting)

Source	df	Mean square Internodal length of main stem, cm Month after planting 4	5	6	7	8	9
Replication	4	3.51**	0.06	2.20	0.64	1.97*	0.40
Type	4	0.64*	0.01	1.00	0.22	0.35	0.14
Error	16	0.19	0.32	0.74	0.43	0.43	0.31

* Significant at 5% level

** Significant at 1% level

APPENDIX-VII

Analysis of variance of diameter at node of main stem in cm of the five *Piper longum* types

Source	df	Mean squares
		Diameter at node of main stem
Replication	4	0.014
Type	4	0.016
Error	16	0.011

APPENDIX-VIII

Analysis of variance of diameter at internode of main stem of the five *Piper longum* types

Source	df	Mean squares
		Diameter at internode of main stem
Replication	4	0.010
Type	4	0.001
Error	16	0.005

APPENDIX-IX

Analysis of variance of the length of leaf in cm of the five *Piper longum* types (four month to nine month after planting)

Source	df	Mean square					
		Length of leaf, cm					
		Month after planting					
		4	5	6	7	8	9
Replication	4	0.92	1.18	1.48	0.26	0.32	1.61
Type	4	3.11**	0.92	0.81	3.34	0.32	0.45
Error	16	0.57	1.38	1.19	0.21	1.22	1.75

* Significant at 5% level

** Significant at 1% level

APPENDIX-X

Analysis of variance of the width of leaf in cm of the five *Piper longum* types (four month to nine month after planting)

Source	df	Mean square					
		Width of leaf, cm					
		Month after planting					
		4	5	6	7	8	9
Replication	4	1.06	0.27	3.71*	3.97	0.89	0.98
Type	4	2.36*	0.75	0.67	0.46	0.32	0.10
Error	16	0.76	0.72	1.12	1.39	1.03	0.56

* Significant at 5% level
** Significant at 1% level

APPENDIX-XI

Analysis of variance of the length of petiole in cm of the five *Piper longum* types (four month to nine month after planting)

Source	df	Mean squares					
		Length of petiole, cm					
		Month after planting					
		4	5	6	7	8	9
Replication	4	1.70	0.36	1.03	1.81*	0.21	1.95
Type	4	0.56	0.32	0.18	0.35	0.70*	0.17
Error	16	1.03	0.33	0.54	0.45	0.23	0.66

* Significant at 5% level

APPENDIX-XII

Analysis of variance of the area of leaf lamina in cm^2 of the five *Piper longum* types

Source	df	Mean squares
		Area of leaf lamina
Replication	4	123.80
Type	4	22.78
Error	16	69.76

APPENDIX-XIII

Analysis of variance of number of leaves per hill of the five *Piper longum* types (one month to nine month after planting)

Source	df	Mean square								
		Number of leaves per hill								
		Month after planting								
		1	2	3	4	5	6	7	8	9
Replication	4	7.06*	2.92	89.24	326.21*	261.48*	591.41	1977.74	1939.62	72.961
Treatment	4	5.55*	16.45**	63.65	148.98	353.29**	4869.72**	11950.88**	3918.15*	1212.706**
Error	16	1.48	2.16	43.08	106.28	68.68	536.11	716.26	903.02	123.261

* Significant at 5% level
** Significant at 1% level

APPENDIX-XIV

Analysis of variance of the spread of the plant in cm of the five *Piper longum* types (four month to nine month after planting)

Source	df	Mean squares — Spread of the plant — Month after planting: 4	5	6	7	8	9
Replication	4	26.37	18.05	450.14*	271.62*	129.59	19.33
Treatment	4	9.40	137.28**	162.52	29.18	2.51	28.49
Error	16	16.54	20.13	111.03	58.05	65.38	42.82

* Significant at 5% level
** Significant at 1% level

APPENDIX-XV

Analysis of variance of the number of spike bearing branches per stem of the five *Piper longum* types (seven month to nine month after planting)

Source	df	Mean squares		
		Number of spike bearing branches per stem		
		Month after planging		
		7	8	9
Replication	4	1.86**	0.05	0.28
Type	4	2.11**	0.52*	0.18
Error	16	0.38	0.12	0.10

* Significant at 5% level
** Significant at 1% level

APPENDIX-XVI

Analysis of variance of the angle of insertion of spike bearing branch in degrees of the five *Piper longum* types (at first harvest and second harvest)

Source	df	Mean squares	
		Angle of insertion of spike bearing branch (degrees)	
		Month after planting	
		First harvest	Second harvest
Replication	4	145.22	96.91
Type	4	714.89**	714.83**
Error	16	59.91	56.84

** Significant at 1% level

APPENDIX-XVII

Analysis of variance of the internodal length of spike bearing branch in cm of the five *Piper longum* types (seven and eight month after planting)

Source	df	Mean squares	
		Internodal length of spike bearing branch	
		Month after planting	
		7	8
Replication	4	0.82	0.16
Type	4	0.05	0.05
Error	16	0.32	0.14

APPENDIX-XVIII

Analysis of variance of the diameter at node of spike bearing branch in cm of the five *Piper longum* types

Source	df	Mean squares
		Diameter at node of spike bearing branch
Replication	4	0.033**
Type	4	0.010
Error	16	0.006

** Significant at 1% level

APPENDIX-XIX

Analysis of variance of the diameter at internodal spike bearing branch in cm of the five *Piper longum* types

Source	df	Mean squares
		Diameter at internode of spike bearing branch
Replication	4	0.004
Type	4	0.007
Error	16	0.005

APPENDIX-XX

Analysis of variance of the length of spike in cm of the five *Piper longum* types (at first harvest and second harvest)

Source	df	Mean squares	
		Length of spike (cm)	
		First harvest	Second harvest
Replication	4	40.433*	0.077
Type	4	40.094	0.082
Error	16	160.107	0.058

* Significant at 5% level

APPENDIX-XXI

Analysis of variance of the diameter of spike in cm of the five *Piper longum* types (at first harvest and second harvest)

Source	df	Mean squares	
		Diameter of spike (cm)	
		First harvest	Second harvest
Replication	4	0.341**	0.119*
Type	4	0.011	0.009
Error	16	0.030	0.036

* Significant at 5% level
** Significant at 1% level

APPENDIX-XXII

Analysis of variance of the length of peduncle in cm of the five *Piper longum* types (at first harvest and second harvest)

Source	df	Mean squares	
		Length of penduncle (cm)	
		First harvest	Second harvest
Replication	4	0.011	0.423**
Type	4	0.024	0.047
Error	16	0.018	0.038

** Significant at 1% level

APPENDIX-XXIII

Analysis of variance of the number of spikes per spike bearing branch of the five *Piper longum* types (five month to nine month after planting

Source	df	Mean squares				
		Number of spikes per spike bearing branch				
		Month after planting				
		5	6	7	8	9
Replication	4	1.88*	2.99*	0.30	2.991**	0.14
Type	4	0.82*	0.33	1.79**	0.331	0.17
Error	16	0.56	0.19	0.11	0.156	0.06

* Significant at 5% level
** Significant at 1% level

APPENDIX-XXIV

Analysis of variance of the days from planting to emergence of spike of the five *Piper longum* types

Source	df	Mean squares
		Days from planting to emergence of spike
Replication	4	113.11
Type	4	195.37
Error	16	215.82

APPENDIX-XXV

Analysis of variance of the days from emergence to maturity of spike of the five *Piper longum* types (at first harvest and second harvest)

Source	df	Mean squares	
		Days from emergence to maturity of spike	
		First harvest	Second harvest
Replication	4	42.51	21.13
Type	4	52.48	10.61
Error	16	57.49	41.37

APPENDIX-XXVI

Analysis of variance of the yield of green spike in kg per hectare of the five *Piper longum* types (at first harvest and second harvest)

Source	df	Mean squares	
		Yield of green spike in kg/ha	
		First harvest	Second harvest
Replication	4	14024.50	29680.06
Type	4	2024860.70*	1060331.67*
Error	16	4883.87	31545.26

* Significant at 5% level

APPENDIX-XXVII

Analysis of variance of the yield of dry spike in kg per hectare of the five *Piper longum* types (at first harvest and second harvest)

Source	df	Mean squares: Yield of dry spike in kg/ha	
		First harvest	Second harvest
Replication	4	434.51	1691.36
Type	4	134964.32*	65734.57*
Error	16	686.60	1619.21

* Significant at 5% level

APPENDIX-XXVIII

Analysis of variance of the ratio of weight of green spike to the weight of dry spike (at first harvest and second harvest)

Source	df	Mean squares: Ratio of weight of green spike to the weight of dry spike	
		First harvest	Second harvest
Replication	4	0.024	0.023
Type	4	0.078	0.020
Error	16	0.032	0.069

COMPARATIVE EVALUATION OF SELECTED TYPES OF *Piper longum* (Linn.) IN COCONUT PLANTATIONS

By

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ABSTRACT OF A THESIS

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ABSTRACT

Comparative evaluation of five selected types of *Piper longum* (Linn.) namely Cheematippali, Panniyur, Mala, Pattambi and Kaanjur was carried out in the Department of Agricultural Botany, College of Horticulture, Vellanikkara during the year 1990-92 with the objective to select the best type of *Piper longum* in order to recommend for large scale cultivation after evaluating economic characters and active principles. Experiment was laid out in Randomised Block Design with five replications.

Observations were recorded for twenty three vegetative characters, nine productive characters and total alkaloidal content in dried spikes of *Piper longum* for all the five types.

The study revealed that the five types of *Piper longum* differed for eleven vegetative characters namely length of the longest stem, number of leaves per hill, number of stems per hill, number of vegetative branches per stem, length of leaf, width of leaf, length of petiole, spread of the plant, internodal length of main stem, number of spike bearing branches per stem and angle of insertion of spike bearing branch and for three productive characters namely number of spikes per spike bearing branch, yield of green spike and yield of dry spike at one or all of the stages for which observations were recorded.

Of the above characters for which the five types differed significantly eight characters showing high and significant correlation with yield were chosen for carrying out studies on intercorrelation among yield components and path analysis. Correlation studies and path analysis revealed that angle of insertion of spike bearing branch, number of stems per hill, number of spikes per spike bearing branch and

number of spike bearing branches per stem and yield green spike were the most important characters influencing dry spike yield.

The studies on the total alkaloidal content in dried spikes of *Piper longum* revealed that though Panniyur recorded the maximum alkaloidal content in percentage, with respect to total alkaloidal out put from an unit area of land Cheematippali was found to be superior to Panniyur since dry spike yield per hectare of Cheematippali was significantly superior to Panniyur. Mala recorded the minimum alkaloidal content in the dried spikes.

Cheematippali showed consistently superior performance for all the important characters at all the stages and could be recommended for large scale cultivation after multilocational trials. Kaanjur can also be considered as a promising type since only in a very few characters it failed to establish its superiority over Cheematippali. The type Mala was found to be consistently inferior to all other five types of *Piper longum* for all the vegetative and productive characters studied.