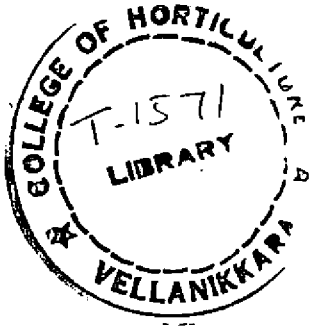
EVALUATION OF "LONG PEPPER" (*Piper longum* L.) GENOTYPES FOR GROWTH, FLOWERING AND YIELD



By

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(2012-12-112)

THESIS

Submitted in partial fulfillment of the requirement for the degree of

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Department of Plantation Crops and Spices

COLLEGE OF HORTICULTURE

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DECLARATION

I, **Maheswari R.S Nair** (2012-12-112) hereby declare that this thesis entitled **"Evaluation of "long pepper" (*Piper longum* L.) genotypes for growth, flowering and yield"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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Maheswari R.S Nair

Dedicated to the farming community

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Introduction

1. INTRODUCTION

Piper longum L. also known as 'long pepper' or 'pippali' belonging to the family Piperaceae and is one of the most extensively used medicinal plant in the ayurvedic system of medicine, particularly for diseases of respiratory tract. Four types of pippali namely 'pippali', 'vanapippali', 'saimhali' and 'gajapippali' are mentioned in ayurvedic literature Rajanighantu (Sivarajan and Balachandran, 1994)

Pippali is used in over 320 classical compound medicinal formulations and in many modern herbal formulations (Singh *et al.*, 2004). Several workers have investigated the species pharmacognostically, chemically and also pharmacologically in view of the commercial, economical and medicinal importance of *Piper longum* (Neelam and Krishnaswamy, 2001). Since it is one among the 14 medicinal plants, which has high demand in indigenous drug industry, it is prioritized for cultivation and development by National Medicinal Plant Board.

Piper longum is indigenous to South Asian countries including India. It is used as a spice in ancient India.

The plant is reported to be dioecious in nature. Long pepper of commerce is the dried mature female spikes. Till the formation of spikes, male and female plants are morphologically similar. Male plants can be identified by their long spikes and female plants by their short spikes. A new sex form (bisexual) has been reported in *Piper longum* by Sujatha and Nybe (2007). The new sex form has spike as long as male spike which were three to four times that of female spikes.

The only improved variety in *Piper longum* named as Viswam was released by Kerala Agricultural University in 1996 through clonal selection, from a few collections available under AICRP on Medicinal and Aromatic Plants in Kerala Agricultural University. The yield potential of Viswam was reported as 472 kg ha^{-1}.

Till date no new varieties were released in *Piper longum* after the release of the variety Viswam.

Piper longum is well adapted for cultivation as an intercrop in coconut, arecanut and rubber plantations of Kerala, but its cultivation is limited due to poor returns from the crop on account of high expenditure on harvesting due to staggered flowering and lack of high yielding varieties with high dry recovery. Being a semi domesticated crop, collection of diverse germplasm and selection appear to be the first and foremost method for developing high yielding varieties to suit different agro - climatic conditions and cropping systems.

Germplasm collection of long pepper was initiated at the Department of Plantation Crops and Spices and was further strengthened by KSCSTE funded project and 60 accessions were assembled. After an initial evaluation, 42 accessions were selected including check variety Viswam for the present study. The accessions were collected from Western Ghat regions of Kerala and also entries from NBPGR which includes the collections from different regions of Karnataka and Tirunelveli. Selection of superior accessions with high yield and quality can be looked into which enables augmenting production of quality drug.

Staggered flowering leading to non-synchronous harvesting is a labor intensive process and identification of types having seasonal flowering nature will help to overcome the problem.

In this background, the present study on "Evaluation of long pepper (*Piper longum* L.) genotypes for growth, flowering and yield" has been proposed with the following objectives.

- Catalogue the germplasm accessions of long pepper
- Study the flowering behavior and fruit set
- Identify superior long pepper genotypes with high yield and quality

Review of Literature

2. REVIEW OF LITERATURE

Piper longum Linn. popularly known as pippali, belonging to the family Piperaceae, is an important medicinal plant, used in traditional medicine in Asia and Pacific Islands. The family Piperaceae comprises 12 genera and about 1400 species, mainly found in tropical region (Barroso, 1978). *P. longum* has immense potential in medicines, as it is reported as a good remedy for treating gonorrhea, menstrual pain, tuberculosis, sleeping problems, respiratory tract infections, chronic gut-related pain and arthritic conditions (Singh, 1992). Almost all parts of it, namely roots, stems and fruits are medicinally important and used especially in the treatment of respiratory tract disorders like bronchitis, asthma, cough etc (Sivarajan and Balachandran, 1994). The principal pharmacological constituents are piperine and piplartine. The crude extract of *P. longum* contains 3-8 per cent of piperine (James, 1999). The plant is reported as endangered for Tamil Nadu and at lower risk for Kerala (Nair, 2000).

Collection of roots from wild habitats and deforestation has made this plant, a threatened species. As the plants are extracted from its natural habitat for drug formulations, the species has become very rare in the forests of Kerala (Nair, 2000). The genus *Piper* (L.) contain more than 700 species. They grow in tropical and subtropical rain forests. The Greek name "*Peperi*", the Latin "*Piper*" and the English "Pepper" were derived from the Sanskrit name "*Pippali*". It means the drug which gives protection from diseases, also nourish and restore health (Shastry, 2001). It is used in over 320 classical medicinal formulations and in many modern herbal formulations. The knowledge about cultivation practice of *P. longum* is necessary to overcome its requirement in pharmaceutics as it is a highly used plant in ayurvedic medicine.

Being a semi domesticated crop, collection of diverse germplasm from within and outside the country and selection appears to be the first and foremost method for developing high yielding varieties which suit to different agro-climatic conditions and

cropping systems. Pippali and Pippalimul are having high demand, in Indian market. *P. longum* is one of the highly trade oriented medicinal plant procured from cultivation. Approximate annual consumption of *P. longum* (fruits and roots) is 1737 MT, but maximum consumption is fulfilled through import. In the year, 2004-2005; about 9,067,191 kg Pippali including fruits and roots was imported (Ved and Goraya, 2008).

2.1 Origin and distribution

Piper longum is native of Indo-Malayan region. It was very early introduced to Europe and was highly regarded as a flavour ingredient by the Romans. *P. longum*, considered indigenous to the hotter parts of India was described by Krishnamurthy (1969). The distribution of long pepper in Calicut was recorded by Manilal and Sivarajan (1982). In India, it is widely distributed in low altitude evergreen forests, occurring in sub Himalayan hills, Assam, Khasi regions, Eastern Ghats and Western Ghats, and in low elevation of forest lands and lower hills of West Bengal. It was reported that from India, it has reached the rest of Asia and Mediterranean through the "spice route" and was used as a spice in all these regions (Ravindran and Balachandran, 2005).

Piper longum appears to be derived from two or three species that may include species from Malaysia and Indonesia. It was a product of either *P. longum* or *P.peepuloides*, while the java long pepper is from *P. officinarum* (Khushbu *et al.*, 2011).

2.2 Geographical races

A number of geographical races exist in the country based on different agro-climatic regions. The races found in Assam are called Asli (true) and Suvali (female in Assamese), from West Bengal are called Gol thippali and Pipal nan sori from Maharashtra. Viswam, released variety through selection from 'Cheemathippalli' bears female spikes, characterized by highest spike weight and total yield. It was released by Kerala Agricultural University for cultivation as an inter-crop in irrigated coconut plantations.

2.3 Taxonomy

According to Hooker (1890), order *Piperaceae* was divided into two tribes namely *Saurureae* and *Pipereae.* Pipereae tribe was further divided into genus *Piper* and *Peperomia. Piper* genus was again divided into six selections, they are *Muldera, Cubeba, Chavica, Pseudochavica, Eupiper* and *Heckeria. P. longum* is one among the fifteen species in the selection *Chavica.* They are *Piper peepuloides, Piper chaba* or *Piper officinarum* or *Piper retrofactum, Piper sylvaticum, Piper petiolatum, Piper betle, Piper miniatum, Piper boehmeriaefolium, Piper pothiformae, Piper anisotis, Piper aurantiacum, Piper hapinum, Piper bachystachyum, Piper thomsoni, Piper rostratum* and *Piper penangenese.* Other than *Piper longum* economic species in *Piper* genus was listed out by Purseglove *et al.* (1981). They are *Piper nigrum* (major spice), *Piper betle* (leaves masticatory) *Piper methysticum* (national beverage of Polynesians), *Piper cubeba, Piper retrofractum* or *Piper chaba* (Java long pepper), *Piper clusii, Piper guineense, Piper saigonense* and *Piper longifolium* species are also used as a spice.

Tepe *et al.* (2014) described a new species from the eastern Andes of Ecuador and Peru as *Piper kelleyi* sp. which was named in honor of Dr. Walter Almond Kelley. *Piper kelleyi* is a member of the *Macrostachys clade* of the genus *Piper*. Several insect species are entirely dependent on *Piper kelleyi* for survival.

2.4 Habit and external morphology

Piper longum is a slender, aromatic, perennial creeping shrub, spreading on the ground having erect branchlets, glabrous with swollen nodes and roots clasping at nodes. It grows and creeps over small shrubs, rock etc. Unlike, black pepper or other wild peppers it does not climb on other trees. *P. longum* has distinct dimorphic branching habit like orthotropic and plagiotropic branches. Leaves produced are simple, alternate and variable in size and shape. It is a dioecious plant with male and female spikes seen in different plants. Dried mature female spikes of thippali were commercially used.

Kirtikar and Basu (1935) reported that leaves of *P. longum* were numerous in number and its size ranging from 6.0 – 9.0 cm, were lower leaves, broadly ovate and vary with cordate to broad rounded lobes at base. Upper leaves were oblong- oval, cordate at base. All leaves were sub acute, entire, glabrous, thin, bullate with reticulate venation, sunken above and raised below, dark green and shiny above the leaf, and dull and pale beneath. The petiole of upper leaves was very short or without petioles, stipules are membraneous, lanceolate, obtuse and soon falling. The morphological and microscopical characters of *P. longum* fruits were described by Winton and Wintow (1939). According to them, a distinguishing character of fruits was endocarp, which are wavy in outline.

Joshi (1944) reported that in *P. longum*, female flowers were born in dense spikes about ½ - 1 inch long. Ovaries and the bracts of naked flowers were pressed very closely and they are fused with one another. Spikes contain a volatile oil, an acrid resin and piperine and commonly used in native and household medicine as a stimulant and carminative. Mathew (1958) suggested occurrence of a heteromorphic sex chromosome in *P. longum.*.

Mehra and Puri (1970) described spike of *Piper longum* as black, cylindrical, irregular, up to 2 to 5 cm long and compact. The fruits were one seeded with three layered pericarp. Dasgupta and Dutta (1980) has given a detailed anatomy of the fruits and described the fruitlet of *Piper longum* as thick walled with heavy brown contents in the outermost layer, mesocarp with thickened cells, endocarp and seed coat fused to form a deep zone with hyaline content in the outer layers, and orange-red pigment.

Chandy and Pillai (1979) observed that the drooping, horizontal or erect nature of plagiotropes varied between plant types in black pepper and this stem characters determined the photosynthetic efficiency and yield.

In black pepper, the pendant spikes were borne opposite to the leaves on plagiotropic branches and was 3 -5 cm long, bearing 50 – 150 minute flowers borne on the axils of ovate fleshy bract (Purseglove *et al.*, 1981). The flowers may be unisexual, with monoecious or dioecious or hermaphrodite but most of the cultivated types were bisexual. Report also showed that, there exist great variability in the per cent of bisexual or productive flowers on their spikes. Higher the per cent of bisexual flowers, greater will be the productivity. Most of the high yielding and popular cultivars produce as much as 70- 98 per cent bisexual flowers. They also observed

that under intense shade conditions the bisexual types produce more female flowers and less hermaphrodite flowers.

Significant variability in leaf characters like leaf length, leaf width, petiole and number of leaves per hill were reported by Manuel (1994) in four different accessions of long pepper and also found out that these leaf characters do not influence the dry spike yield.

. Leaves of *P.longum* types were 5-9 cm long, 3-5 cm wide, sub-acute, entire, glabrous, cordate with broad rounded lobes at base (Chatterjee and Pakrashi, 1997). Kumar (1998) observed that, according to the position on the plant, leaves in long pepper were numerous, simple, stipulate and petiolate or sessile. Shape of the leaf blade also varies in the same plant. The upper leaves were generally sessile, ovate or ovate oblong, acute and most often unequally sided or unequally cordate at base. He also reported that leaves were 6.5-9 cm long and 3-5 cm wide. Lower leaves were broadly ovate, pale dull beneath; cordate at base. In the case of lower leaves, petioles were 5- 7.5 cm long and stout but in that of upper leaves it was very short and absent. Stipules were about 1-3 cm, membraneous, lanceolate, obtuse and falling soon. According to CSIR report (1998), leaves of *Piper longum* were 5- 9 cm long, 3- 5 cm wide, ovate, cordate with broad rounded lobes at base, subacute, entire and glabrous.

. Kumar (1998) reported that in *Piper longum,* stems were numerous, ascending, cylindrical and globose. Those stems were swollen and irregular knotty with each piece quarter inch long, irregularly thick, hard and of a brownish colour. Branchlets were erect, prostrate or creeping, soft and grooved when dry. The whole stem was finely pubescent. The fruits were short, consists of multitude of minute buccate fruits closely packed among a common axis, whole forming a spike, one and half inch length and quarter inch thickness. Fruits were arranged with small peltate bracts

beneath each and were ovoid with crowned stigma. Ripe fruits were grayish green or nearly blackish and particularly sunk in fleshy axils. Fruiting season was November to March. Seeds were globose, testa thin, within the hardened periphery. *Piper longum* produce spikate inflorescence, whose flowers were sessile, usually unbranched, elongated, simple and indeterminate . Spikes were 5cm long, cylindrical, solitary, pedunculate and upright. Flowers were unisexual, minute and sessile. Male spikes were large, narrow and slender, narrow bracts, 1 - 3 inch long, peltate, stamens two in number. Female spikes were 1.3 - 2.5 cm long and 4 - 5 mm in diameter, bracts circulate, flat and peltate, stigma 3 - 4 very short and persisting. July – August was the flowering season. According to CSIR report (1998), spikes were cylindrical, pedunculate, male larger and slender, female 1.3 - 2.5cm long and 4-5 mm diameter.

Fruit spikes of *Piper longum* were cylindrical, oblong, berries red or black when ripe, globose with aromatic odour and pungent taste (Viswanathan, 1995; Banerjee *et al.*, 1999; Oommen *et al.*, 2000). Inflorescence type in *Piper* varies in position (axillary or terminal), length (from 2-3 cm to 150 cm long), presentation (erect or pendulous), color (cream to red), and number of spikes (single or umbellate) (Jaramillo and Manos, 2001). Also reported floral variation among *Piper* species which includes the number and position of parts (e.g., 3-4 carpels and 1-10 stamens), relative size of filament and anther aperture orientation. Variation also occurs in the structures associated with flowers such as floral bracts and presence or absence of pedicels. Flower structure in *Piper* appears to be influenced by the pack of flowers in the inflorescence. Loosely arranged flowers have an unstable number of carpels (varying from three to four) and tightly congested flowers always have three. In a similar manner, loosely arranged flowers have, in general, a higher number of stamens (e.g., *P. amalago* has six stamens), while flowers in tightly congested inflorescences may have as few as two (e.g., *P. umbellatum*).

Williamsons (2002) observed that the fruits of *Piper longum* were small, ovoid berries, shiny blackish green, embedded in fleshy spikes. Manoj *et al.* (2004) reported that male and female plants in *Piper longum* were morphologically very similar till the formation of spikes. Separate male, female and dioecious plants were in *P.longum* (Ravindran and Balachandran, 2005). Male spikes were much longer than female spikes and flowers arranged on a short cylindrical spike. Female spikes were short, stout and flowers fused laterally. Only one ovary in the female flower, that arises from axil of the bract.

Distinct dimorphic branches were reported in *P. longum* by Ravindran and Balachandran (2005). Main branches which creep on the ground were called orthotropes, it will give frame work to the plant. Those axillary branches which grew erect were called plagiotropes. Orthotropic shoots were vegetative and its growth was by the activity of terminal buds, while plagiotropes were fruiting branches which produces spike opposite to the leaves and growth was sympodial.

Fruits of *P.longum* were small and closely packed (Ravindran and Balachandran, 2005). Fruits were produced without pollination (Apomixis), so male plants are not required for pollination. Also reported that fruits of *Piper chaba* were larger, more conical and not cylindrical as in *Piper longum.* It become orange red on ripening and was more pungent with less flavor. But spikes of *Piper peepuliods* and *Piper longum* were similar. *Piper mollesua* spikes were globose with minute fruits and it was not fused laterally.

Orthotropes of *P.longum* have cordate leaves with long petioles and plagiotropes produce leaves that are sessile or with short petiole (Ravindran and Balachandran, 2005). Eight accessions of *P. longum* were studied by Jaleel (2006) and reported that length of leaves on vegetative branches and reproductive branches were differing

significantly. It was also reported that area of leaves on vegetative branches and reproductive branches differ significantly in between accessions. Petiole length of different accessions also showed significant variability. In all the eight accessions, shape of leaf lamina for the vegetative branch was cordate, where as for the reproductive branches it was lanceolate. Dark green coloured leaves in vegetative branches of all the accessions except Viswam, which had medium coloured leaves. Also recorded dark green colour leaves in the reproductive branches of all accessions except Odakkali (Medium green coloured leaves). Leaves were simple, alternate and variable in size and shape.

Jaleel (2006) studied eight accessions of *P. longum viz.* Assam, Kanjur, Maharashtra, NL -84-68, Viswam, Pattambi, Nilambur, Odakkali and reported that length of spike bearing branch and internodal length of different accessions differ significantly, but angle of insertion of reproductive branches of different accessions did not differ significantly. Joseph (2008) catalogued 20 accessions of long pepper and were observed erect and trailing growth habit with runner production varying from few to many.

Chaveerach *et al.* (2007) reported, the flowering season of *P. longum* to be May to September in Thailand. Sujatha and Nybe (2007) identified a bisexual variant (Acc. P 25) with spikes as long as male spikes. Joseph (2008) reported spike shape to be cylindrical and filiform. Colour of immature spike were found to change from green to yellow , while fruit ripening colour varied between green to black in female spikes.

Leaf lamina shape was found to be cordate and ovate lanceolate in different accessions of *P. longum* (Joseph, 2008). Mishra (2010) reported that the leaves in *P. longum* were alternate, spreading, without stipules and blade vary greatly in size. The

lowest leaves were about 5-7 cm long, whereas, the uppermost leaves about 2-3 cm long.

Inflorescence is a cylindrical, pedunculate spike, the female flower was up to 2.5 cm long and 4 - 5 mm in diameter but the male flower was larger and slender (Zaveri *et al.*, 2010). In all the three sex forms, spikes were cylindrical and erect. However, the colour of female spikes was different from that of male and bisexual types. The female spikes were creamy white until fruit set, then colour changed to green. In male and bisexual types, immature spikes were dark green which turned to light yellow and further to dull yellow on maturity (Kanimozhi, 2010). In around 22 days, female spikes attained full length (2.31 cm), where as male type attained full length in 43 days (7.76 cm) and bisexual type in 46 days (6.35 cm).

In female flowers, ovary and stigmatic lobes were subtended by bract. The male flowers were represented by anthers covered by peltate bract. Male, female and bisexual types did not possess perianth parts. Number of stigmatic lobes varied from 2-6 in bisexual flowers, two was the prominent number in the bisexual type (90 per cent). In the female type, four stigmatic lobes were common (74 per cent) followed by three lobes (20 per cent) (Kanimozhi, 2010).

Chandran (2012) studied the morphological characters of selected ten accessions and observed erect spike orientation in all accessions. Spike shape was either filiform, cylindrical or globular. Colour of immature spike was green, yellow or greenish yellow turning green, dark green or yellowish green on maturity. Spikes were mildly fragrant. Flowers on spikes were fused laterally. They were hirtellus in texture and had peltate orbicular bracts. Spikes were bitter and pungent in taste in all the accessions.

2.5 Reproductive biology of *Piper longum*

A shift in anther dehiscence was showed by the flowers of tightly congested inflorescences, from lateral slit towards an upward or apical opening (Burger, 1971). In *Piper longum*, pollination and dispersal biology have been influenced more by whole inflorescence structure rather than individual flower structure (Thies *et al.*, 1998).

Anther dehiscence in the bisexual variant was found to be between 9.00 am to 11.00 am which extended further in cloudy weather (Sujatha and Nybe, 2007). Time taken for attaining full length of spike was 22 days in female, 43 days in male and 46 days in bisexual types. Time taken for complete opening of flowers in an inflorescence was uniformly one week in all sex types (Kanimozhi, 2010).

Anthesis and anther dehiscence were between 7.30 am to 4.30 pm with a peak between 10.30 am to 12.30 pm (Kanimozhi, 2010). For complete opening of flowers male, female and bisexual types took seven days. Maximum flower opening was on 3rd and 4th day in the male types. Opening of flowers in female and bisexual types were noticed from second and sixth day. Complete anther dehiscence took one week in male and bisexual inflorescences.

Martin and Gregory (1962) observed that the anther dehiscence is controlled to a great extent by temperature and relative humidity in Piperaceae. Dewarrd and Zevan (1969) observed that in Sarawak, the flower opening usually takes place between 12.00 and 14.00 h on day where relative humidity of 60 per cent is attained and at a

temperature of 32^0C, combined with bright sunshine The flowers were almost perpendicular to the axis of the inflorescence and ovules were orthotropus. Serial transverse sections of the spikes were found to yield perfect longitudinal sections of the gynoecium and the ovule (Joshi, 1944).

2.6 Cytology

Wide variation in chromosome number was noticed by various workers in cytological studies of *P. longum.* Various chromosome numbers reported were 2n = 24 (Tijo, 1948); 2n = 52 (Mathew, 1958; Jose and Sharma, 1984); 2n = 96 (Sharma and Bhattacharya,1959); 2n = 48 (Dasgupta and Datta,1976); 2n = 44 (Sampath kumar and Navaneethan,1981); 2n = 53 (Samuel and Morawetz,1989); 2n = 32 (Anand *et al.*, 2000).

Investigations on Cyto-morphology in *Piper* sp. were done by Anand (1997). The somatic chromosome number in *P. longum* was observed as 2n = 32, and it was a new report. Procedure for mitotic studies was also standardized in *Piper* spp.

2.7 Cultivation practices

2.7.1 Climate and soil

Oommen *et al.* (2000) observed that, since it was a shade loving plant, for better fruiting 50 per cent shade was suitable. It grows well under the shade of trees in areas of abundant rainfall. It can also be grown as an inter- crop in coconut plantations in the plains, though altitude of 900 -1500 m above sea level.

Manoj *et al.* (2004) reported that *P. longum* was typically found in tropical humid climate and it prefers moist shady conditions. For its successful growth, areas with good rainfall and high relative humidity were suitable. Well drained sandy soil having a pH range of 5.5 to 8.5 with rich humus and laterite soils with organic matter and good water holding capacity were found to be the best.

Joshi *et al.* (2013) reported that plant requires a hot moist climate and an elevation between 100 and 1000 m for its cultivation. Also can be grown successfully even in areas which receive heavy rainfall with high relative humidity. Hence, recommended as an under crop in coconut and arecanut gardens with 20-25 per cent shade intensity. Laterite soils rich in organic matter content with good moisture holding capacity were also suitable.

2.7.2 Irrigation

During hot season the roots should be carefully covered with straw. During the hotter parts of year in Kerala starting from January crop can be irrigated once or twice in a week (Viswanathan, 1995). According to Joshi *et al.* (2013), *P. longum* crop should be irrigated once in a week, if it is grown as a pure crop. While as an intercrop the irrigation for main crop is ample. Sprinkler system of irrigation is better for economizing the irrigation water.

2.8 Crop management

Piper longum cuttings planted during June exhibited approximately 70 per cent rooting, while those planted in February recorded rooting per cent of almost zero. (Bhuse *et al.*, 2002). Also observed high values of rooting per cent (78.33), number

of roots (11.70), root length (13.59 cm) and vine length (22.47 cm) in cuttings with leaves than the cuttings without leaves.

Etampawala *et al.* (2002) conducted a study to develop simple and rapid propagation techniques, and to understand the variation in spike formation and optimum conditions for growth of *P. longum.* It was suggested that the vegetative stem cuttings comprising the two uppermost nodes and the cuttings obtained from vertically growing reproductive parts of the plant will be appropriate propagule types for propagation. *P. longum* plants grown under 50 per cent shade (maximum instantaneous light intensity 850 mol m" s ') performed well compared to plants grown under 25 per cent and 75 per cent shade respectively. Planting medium comprising sand, top soil and farmyard manure mixed in the ratio of 1:1:1 was found to be the best substratum for the growth of *P. longum* plants. Also observed that the plants raised from vertically grown branches produced fruits earlier than those from horizontally grown branches. However, nearly 50 per cent of fruits were shed from the mother plant about 22 days after their emergence.

For enhancing both total fresh and dry spike yield and total alkaloid production in long pepper under partial shade, an integrated nutrient management system involving incorporation of vermicompost @ 6.25 t/ha/yr and combined application of bioinoculants *viz*, Azospirillum, fluorescent pseudomonas and AMF was found favorable (Krishnan, 2003).

Manoj *et al.* (2004) reported that *P. longum* grows as a bushy runner and can be propagated using vegetative means by mature branches or by suckers planted at the beginning of the rainy season. Stem cuttings of 10 to 12 cm length with at least 3 nodes were rooted within 10 to 15 days with success of 60-70 per cent. Planting can be done in shaded nursery beds, with 12-15cm between each pair of cuttings.

Propagation also done through the tillers arising from the base of a mature plant, which can be separated and planted individually.

Pathiratna *et al.* (2005) made attempts to develop suitable cultural practices for obtaining higher yields in three locally available selections (Selections 1, 2 and 3) of *P. longum*. Effects of plant pruning and training methods, shade and the type of cutting on the production of reproductive branches and spikes. Pruning of runners in Selection - 1 produced more reproductive branches and spikes. In Selection - 2, restriction of the growth of runners by pruning them at a distance of 40 cm from the base of mother plant induced the formation of more number of reproductive branches and spikes. Training of runners to erect supports to encourage the production of reproductive branches was very successful with Selection - 3. In all the three selections, a shade level of around 50 per cent under field conditions, gave good growth and highest spike yields. Cuttings from reproductive branches of Selection - 3 kept on producing only reproductive branches during a period of one year observation.

2.9 Harvesting and yield

Davies (1992) showed that within six months vegetatively propagated crop established well. The first harvest could be made eight months after planting. During second year, two harvests could be taken. The crop grown in irrigated coconut gardens showed excellent performance. It will yield 500 kg dried spikes/ha during the first year, 750 kg during second year and 1000 kg during third year.

The first harvest from *P. longum* vines was available after six months of planting. Three to four pickings were made as and when spikes attained maturity for harvest. The yield of dry spikes during first year was around 400 kg/ha and increased up to

1000 kg in third year, after which the vines became less productive and had to be replanted (Viswanathan, 1995).

Marketed Pippalimool are cleaned stem and roots, cut into pieces of 2.5- 5 cm length and dried under shade. Pippalimool are of three grades, based on the thickness (Joy *et al.*, 1998). The grade I with thick roots and underground stem fetching higher price than grade II and or III which may comprises their roots, stem or broken fragments (Wealth of India, CSIR, 2003).

Chandran (2012) studied reproductive characters of selected ten accessions of *Piper longum* along with check variety Viswam. Out of total accessions seven including check flowered. Yield per plant of seven accessions including check will give a recordable yield. Fresh weight of the spikes varied from 0.27 g (Acc. No. 48) to 1.404 g (Viswam). Dry weight varied from 0.085 g (Acc. No.2) to 0.257 g (Viswam).

Joshi *et al.* (2013) reported that in three years of plantation, total yield of fruit and root may reach up to 2100 kg/ha and 500 kg/ha respectively. After three years, the productivity of the vines decreases and should be replanted. Besides the spike, the thicker parts of stems and roots which have medicinal value may also be harvested from 18 months after planting. The green to dry spike ratio is 10: 1.5 by weight. Drying is one of the most critical and fundamental unit operations in the post harvesting of medicinal plants. Muller and Heindl (2006) found that drying at a temperature of 50^0 C was found to be optimum, since quality reduction due to discoloration occurs at higher temperature.

2.10 Quality attributes

Atal *et al.* (1975) reported that spike of *P. longum* contains 4-5 per cent piperine, piplartin, piperolactam, N-isobutyl deca trans-2-trans-4-dienamide and piporadione alkaloids, besides 0.7 per cent essential oil. Roots gave the alkaloids piperine, piperlongumine (piplartine) and piperlonguminine, sesamine, methyl 3, 4, 5-trimethoxy cinnamate. Stem gave triacontane 22, 23- dihydrostigmasterol. Fruit essential oil also contains piperidine, caryophyllene and sesquiterpene alcohol. Sylvatine and dieudesmin were present in the seeds of *P. longum* (Dutta *et al.*, 1977). Fatty acids of crushed seeds were reported to be palmitic, hexadecenoic acids, stearic acids, linoleic acids , oleic acids , higher saturated acids, arachidic, and behenic acids

Dutta *et al.* (1977) reported that the spike of *P. longum* contains the alkaloids piperine (4-5 per cent) and piplartin, and 2 new alkaloids. One is designated as alkaloid A, which is having close relation with pellitorine and 3 more new alkaloids – Piperolactin A, Piperolactin B and Piporadione. Dasgupta and Dutta (1980) reported that the fruits of *P. longum* give positive tests for the presence of volatile oil, starch, protein alkaloids, saponins, carbohydrates and negative test for tannins.

The essential oil of the fruit of *P. longum* is a complex mixture of different components. The three major components are (excluding the volatile piperine) caryophyllene, pentadecane (both about 17.8 per cent) and bisaboline (11 per cent). Others include thujine, terpinoline, zingiberine, pcymene, p-methoxy acetophenone and dihydrocarveol (Handa *et al.*,1963; Nigam and Radhakrishnan,1968; Tabuneng *et al.*,1983; Sharma *et al.*,1983; Shankaracharya *et al.*,1997; Das *et al.*,1998; Madhusudan *et al.*, 2001).

When methanol extract of finely powdered black pepper was run in solvent system toluene - ethyl acetate (70: 30) the presence of piperine on TLC plate was observed. (Daniel, 1991). The developed chromatograms were seen in UV 360 nm and the major spot was fluorescent blue with Rf value 0.4 and it was reported as piperine. Two more spots were observed below piperine which was dipiperine and piperettine.

Total alkaloid content of five types of *P. longum* was studied by Manuel (1994) and found maximum per cent in Panniyur (2.91per cent) followed by Cheemathippali (2.87 per cent), Pattambi (2.85 per cent) and Kanjur (2.85 per cent) and minimum alkaloid content was recorded in Mala (2.80 per cent).

Piper longum fruits contain large number of alkaloids and related compounds, the most abundant of which is piperine, together with methyl piperine, piperonaline, piperettine, asarinine, pellitorine, piperundecalidine, piperlongumine, piperlonguminine, refractomide A, pregumidiene, brachystamide, brachystamide-A, brachystine, pipercide, piperderidine, longamide and tetrahydropiperine. Terahydro piperlongumine, dehydropipernonaline piperidine, piperine, terahydropiperlongumine and trimethoxy cinnamoyl-piperidine and piperlongumine have been found in the root of *P. longum* (Sharma *et al.*, 1983; Tabuneng *et al.*, 1983; Shoji *et al.*,1986; Koul *et al.*, 1988; Das *et al.*, 1996; Zhang *et al.*, 1996; Shankaracharya *et al.*, 1997; Das *et al.*, 1998; Parmar *et al.*, 1998; Lee *et al.*, 2001; Madhusudan *et al.*, 2001).

Piper longum contains essential oil, consisting of long chain hydrocarbon, mono and sesquiterpenes, caryophyllene being the main product (Chopra *et al.*, 1999). Neelam and Krishnaswamy (2001) reported piperine, piperlongumine or piplartine and dihydrostigmasterol from roots. Suthar *et al.* (2003) reported that among different chromatographic methods HPLC was reported to be the best for the quantification of piperine. Manoj *et al.* (2004) reported that fruits of *P. longum* contains 1 per cent

volatile oil, resin, alkaloids piperine and piperlonguminine, a waxy alkaloid N-isobutyldeca -trans -2 - trans - 4 - dienamide and a terpenoid substance. Also observed that the pungency of fruit is due to the piperidine alkaloid piperine. Steam distillation of long pepper yields 0.7 – 1.5 per cent of light green viscous essential oil with spicy odour (Ravindran and Balachandran, 2005)

Khare (2006) reported that the phytoconstituents of *P. longum* fruits include volatile oil, other minor alkaloids such as piplartin, piperlongumine, piperidine, starch, resin, and pungent alkaloid piperine. Piperine is the main therapeutically active compound.

From *Piper longum* forty five compounds were separated and identified. The main components were β - caryophyllene (33.44 per cent), 3 - careen (7.58 per cent), eugenol (7.39 per cent), D - limonene (6.70 per cent), zingiberene (6.68 per cent) and cubenol (3.64 per cent). Piperine was the major and active constituent and piperine content is 3-5 per cent (on dry weight basis) in *Piper longum* (Zaveri *et al.*, 2010). The essential oil and extracts derived from *Piper chaba* might be a potential source of natural preservatives in food industries as reported by Abbasi *et al.* (2010). The first amide isolated from piper species were Piperine.

Piperine, a characterizing compound present in fruits of *Piper nigrum* and *Piper longum* was used as a bioavailability enhancer. It can be isolated from the oleoresin of *Piper nigrum* and *Piper longum*. Using soxhlet and super critical fluid extraction technique an ingredient of antioxidant and anti-inflammatory activity has been extracted. Characterization of compound was done by spectroscopic technique (Hamrapurkar *et al.*, 2011). Rahman *et al.* (2011) analyzed the chemical composition of the essential oil of *Piper chaba* by GC –MS and identified fifty four compounds representing 95.4 per cent of the total oil, of which caryophyllene oxide, veridiferol,

globulol, selinine, linalool, 3 – pentanol, tricyclene and p –cymene were the major compounds. The oil and organic extracts revealed a great potential with anti – listerial effect.

On steam distillation of dry spike of *P. longum*, yielded 0.7 per cent essential oil with a spicy odour resembling that of pepper and ginger oil. Besides piperine, piper longuminine (0.2 – 0.25 per cent) and piper longumine (0.02 per cent) are the alkaloids present in roots (Khushbu *et al.*, 2011).

Kumar *et al.* (2011) carried out comparative evaluation of phytochemical and antioxidant assay of *Piper longum* and *Piper chaba* and reported that the leaf oil of *P. longum* was rich in phenyl propanoids apiole (50.0 per cent) and myristicin (26.9 per cent), whereas sesquiterpene hydrocarbons β-caryophyllene (28.6 per cent), α-humulene (22.8 per cent), and germacrene D (14.6 per cent) were the major constituents in *P. chaba* leaf oil. In the fruit oil of *P. longum*, aliphatic compounds predominated with n-pentadecane (15.8 per cent), whereas *P. chaba* fruit oil mainly had sesquiterpene hydrocarbons such as germacrene D (21.5 per cent), β-caryophyllene (18.5 per cent), and α-humulene (11.4 per cent). In *P. longum* fruits, piperine content was lower (0.03 per cent) compared to *P. chaba* fruits (1.32 per cent). In *P. chaba*, the piperamides were mainly piperine, whereas other piperamides were predominant in *P. longum*. Antioxidant activity was higher for *P. longum* fruits as compared to *P. chaba* fruits.

Essential oil in *P. longum* was less than its relatives (about 1per cent), which consists of sesquiterpene hydrocarbons and ethers (bisabolene, β-caryophyllene, β-caryophyllene oxide, each 10 to 20 per cent; α-zingiberene, 5 per cent), and saturated aliphatic hydrocarbons such as 18 per cent pentadecane, 7 per cent tridecane, 6 per cent heptadecane.

Volatile constituents and microbiological studies on *Kaempferia galangal, Hibiscus abelmoschus* and *Piper longum* revealed the presence of over 15 components which were further identified by GC – MS.

2.10.1. Isolation and extraction of piperine from *Piper* species:

Piperine can be isolated from the oleoresin of *P. nigrum* or *P. longum.* The powdered fruits of the plant were extracted with dichloromethane at room temperature with stirring for 12 hours. The extract was filtered, concentrated in vacuum, and then the residue was purified on an alumina column. Pure piperine can also be obtained by crystallization from ethanol, which may be required for food and/or medicinal usages. Piperine obtained directly from the crude residue in lesser amounts by extraction in alcohol, filtration and successive crystallization.
(Zaveri *et al.*, 2010).

2.11 Characters for evaluation of genotypes

2.11.1 Correlation studies related to morphological characters

Chandy and Pillai (1979) reported that length of leaf, length of internodes of plagiotrope, thickness of node of plagiotrope showed non significant and positive correlation with yield, while length of petiole, breadth of leaf, area of leaf and thickness of internode of plagiotrope showed negative and non significant correlation with yield.

Mathai (1983) reported that in black pepper upper part of the canopy having relatively higher leaf area during the spike development period and also had higher

photosynthetic rate. It promotes growth and development of productive laterals and sustains relatively large number of spikes.

Ibrahim *et al.*, 1985 reported that in black pepper more than any other morphological character internodal length varied within the varieties. Shorter internodes tend to increase total number of spike. Variety Panniyur 1 showed most variability for internodal length.

Study on the influence of vegetative characters on yield of black pepper (*Piper nigrum*) observed that characters like thickness of node of orthotrope, thickness of internode of orthotrope and angle of insertion of plagiotrope influenced the yield positively.(Sujatha and Namboodiri, 1995). Study utilized data on 580 genotypes of black pepper to estimate correlation between yield and 20 quantitative characters. Thickness of internodes showed high inter correlation with reproductive characters and thickness of main stem influenced the yield.

Sujatha and Namboodiri (1995) also reported the significant positive correlation of angle of insertion of plagiotrope with yield. Reason behind the process was, as the angle increases the plagiotrope will be more or less horizontal and this will enable the vine to hold most of leaves on these fruiting branches directly against sunlight, thus increasing photosynthetic efficiency and there by increases the yield in black pepper.

Joseph (2008) carried out a preliminary evaluation trial in long pepper accessions. Correlations of the various vegetative and reproductive characters were worked out with dry spike yield and significant positive correlations were observed for nine characters like number of vegetative branches per stem, total number of leaves per hill, number of spikes per spike bearing branch, length of spike, girth of spike, fresh weight of spike, dry weight of spike and fresh yield per plant.

Krishnamurthy *et al.* (2010) made an attempt to describe crop ideotype of black pepper and reported that ideotype should have acute branch angles (45^0) at the top and wider angles (60^0) at the bottom. The fruiting branches should be well spread from top to bottom of the canopy. To harvest maximum light, the leaf angle should be more at the bottom ($130\text{-}140^0$) compared to the top ($100\text{-}110^0$) and also within a branch, the bottom leaves have lengthier petioles than the top leaves. The vine should have a high photosynthetic rate (minimum of 3.0–3.5 μ moles), more than 90 per cent bisexual flowers with greater than 95 per cent self pollination, increased spike length (≥12 cm) and more number of berries/spike (≥70). Fruit set should be ≥80 per cent and should yield at least 2.5–3.0 kg dry berries/ vine. Among the cultivars/varieties studied, Panniyur 1 was found to possess more number of traits for the proposed ideotype compared to other cultivars/varieties.

Chandran (2012) studied the morphological characters of selected ten accessions along with check variety Viswam and observed that the accessions showed high variability in the number of main branches which ranged from 0.78 (Acc. No.77) to 9.01 (Viswam). Length of longest stem ranged from 15.90 cm (Acc.no.77) to 88.75 cm (Viswam) at seven months after planting. Total number of leaves produced per plant at seven months after planting ranged from 16.3 (Acc.no. 77) to 176.4 (Viswam).

2.11.2 Correlation studies related to spike characters

In *Piper nigrum*, the green spike yield per vine, green berry yield per vine, number of spikes per vine and number of under developed berries per spike as well as vegetative characters like thickness of node and internodes of orthotrope and angle of insertion were positively and significantly correlated with yield (Ibrahim *et al.*, 1985).

The inter correlation among these characters was alo reported to be positive and significant.

Manuel (1994) carried out comparative evaluation of five selected types of *Piper longum* namely Cheematippali, Panniyur, Mala, Pattambi and Kanjur at Vellanikkara. The study revealed that the five types of *P.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 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 were recorded. Correlation studies and path analysis showed that angle of insertion of spike bearing branch, number of stems per hill, number of spikes per spike bearing branch, number of spike bearing branches per stem and yield of green spike were the most important characters influencing dry spike yield. Superior performance was consistently showed by Cheemathippali for all the important characters at all stages.

A study conducted by Sujatha and Namboodiri (1995) on heterosis in black pepper (*Piper nigrum* L.) reported that the reproductive characters viz. number of spikes per vine, number of developed berries per spike and length of spike influenced the dry berry yield per vine. Also reported that in black pepper reproductive characters *viz.* green spike yield per vine, green berry yield per vine and number of under developed berries per spike were positively and significantly correlated with yield.

Jaleel (2006) evaluated eight accessions of *Piper longum viz.* Assam, Kanjur, Maharashtra, NL – 84 -68, Viswam, Pattambi and two male accessions Nilambur and Odakkali. For the spike initiation, the male accessions Nilambur took minimum days

(132) and the female accession NL – 84 – 68 took the maximum number of days (178). NL – 84 – 68 recorded maximum number of days for the maturity of spike (69.6). Male accessions took 56 days for the maturity recorded the minimum (56 days). Male accessions Nilambur and Odakkali produce longest spikes with mean length of 7.55 cm and 7.31 cm respectively. In the case of female accessions the longest spike length was recorded for NL-84-68 (4.23 cm) and shortest spike length for the KAU variety Viswam (2.4 cm). Maximum spike diameter was recorded in NL- 84 - 68 as 3.59 cm and the minimum spike diameter for male accessions Nilambur and Odakkali 1.31 cm and 1.40 cm respectively. Viswam recorded spike diameter of 1.53 cm which was near to male accessions. Bold spikes were recorded in accession NL- 84- 68 in terms of spike length and spike diameter. Jaleel (2006) also reported a maximum of four spikes per spike bearing branch for Assam followed by Viswam. Minimum number of spike per spike bearing branch were reported in NL-84-68 (2.6). Variation was also noticed in spike weight for all the accessions. NL-84-68 recorded maximum mean spike weight (1.639 g) followed by Maharashtra (1.58 g). Viswam recorded minimum fresh weight as 0.36 g per spike.

Correlation studies conducted by Suma *et al.* (2012) revealed that fresh yield of spike per plant showed significant and positive association with leaf number, number of spikes per spike bearing branch, number of spike bearing branches per stem, spike length and spike girth, fresh weight and dry weight of spike. Spike yield was highly and significantly associated with dry weight of spike followed by spike girth, spike length, fresh weight of spike, number of spike bearing branches per stem, number of spikes per spike bearing branches and leaf number. The yield per plant exhibited negative association with petiole length, length of longest stem and leaf area.

2.11.3 Biochemical characters

Sawangjaroen *et al.* (2004) reported that the fruits of *P. longum* contain 1.0 – 2.5 per cent volatile oil and 5-9 per cent alkaloids. Among them the major ones were piperine, chavicine, piperidine, piperitine and a resin.

Joseph (2008) reported maximum oil content in Viswam (1.50 per cent).The accessions PL5, PL 18 and PL 21 recorded an oil content of one per cent. Minimum oil content was recorded in accessions PL 2, PL3, PL8 and PL20. Piperine content was recorded maximum in PL 11 (3.08 per cent), Viswam recorded piperine content of 1.23 per cent and PL 10 recorded the minimum piperine content of 0.92 per cent.

Chandran (2012) estimated essential oil, oleoresin and piperine in three accessions. Viswam recorded maximum oil content of 1.25 per cent followed by Acc. No.9 (0.75 per cent) and pure female (0.60 per cent). Oleoresin content was maximum in Acc.no.9 (11.75 per cent) followed by Viswam (11.4 per cent) and female check (9.8 per cent).The maximum piperine content was observed in Viswam (4.1 per cent) followed by acc no.9 (2.0 per cent) and pure female (1.2 per cent).

2.12 Cluster analysis

Cluster analysis is a genetic tool used for crop improvement in different crops. It demonstrate genetic relationship of accessions based on cluster grouping. In banana, due to crop inherent problem like sterility, parthenocarpy and polyploidy genetic improvement is quite difficult. To overcome the problem, Durai *et al.* (2013) carried out Multivariate Hierarchical Cluster Analysis based on morphotaxonomic data of 107 traits of 14 accessions including four exotic potential diploids of banana using NTSYS Software. Study helped to facilitate the selection of genetically closer parents with desired trait combination in banana breeding programmes. Geleta *et al.*

(2005) carried out study to group pepper (*Capsicum annuum* L.) genotypes into clusters according to their distance as estimated by morphological traits and amplified fragment length polymorphism (AFLP) markers, to assess the relationships between two. Assessment of genetic diversity based on cluster and principal component (PC) analysis for yield and eleven contributing traits in 32 bittergourd genotypes including two checks (Pusa Do Mausami and Kalyanpur Sona)was carried out. Categorization of 32 bittergourd genotypes into 6 major clusters and proportionate contribution of different characters for genetic divergence was done. Extreme genetic divergence was estimated among clusters. Highest cluster mean values for fruits/plant, fruit weight (g) and fruit yield/plant was found in cluster V followed by cluster II. Promising diverse parents identified based on cluster and PC analysis were selected for future hybridization programme (Singh *et al.*, 2014). Thapa *et al.*, 2014 carried out genetic divergence analysis and grouped thirty two tomato genotypes into five clusters based on nineteen characters for utilizing them for developing variety/ hybrid having higher yield and better quality.

Materials and Methods

3. MATERIALS AND METHODS

The study on "Evaluation of long pepper (*Piper longum* L.) genotypes for growth, flowering and yield" was carried out at the Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara during December 2012 to May 2014. The details about experimental materials and methodology adopted for the study are presented in this chapter.

3.1 Field evaluation

The experimental materials included 41 accessions of long pepper (*Piper longum* L.) and the released variety Viswam.

Design	- CRD
No. of treatments	- 42
Replications	- 6
No. of bags/treatment	- 6

Two node rooted cuttings @ of one cutting / bag was planted in black polythene bags of size 13"x 9" filled with potting mixture.

Treatments	Replications					
Viswam	R1	R2	R3	R4	R5	R6
PL 2	R1	R2		R4		
PL 3	R1	R2		R4		
PL 4	R1	R2		R4	R5	R6
PL 5	R1	R2		R4	R5	R6
PL 8	R1	R2	R3	R4	R5	
PL 9	R1	R2	R3	R4	R5	R6
PL 10	R1	R2	R3	R4	R5	R6
PL 11	R1	R2	R3	R4	R5	R6
	R1	R2	R3	R4	R5	R6
	R1	R2	R3	R4	R5	R6
PL 15	R1	R2	R3		R5	R6
PL 17	R1	R2	R3		R5	R6
PL 18	R1	R2	R3	R4	R5	R6
PL 19	R1		R3	R4		R6
PL 20	R1	R2	R3	R4		R6
PL 21	R1	R2		R4	R5	
PL 22	R1	R2		R4	R5	R6
PL 23	R1	R2		R4	R5	R6
PL 24	R1	R2	R3	R4	R5	
PL 25	R1	R2	R3	R4	R5	

Treatments	Replications					
PL 26	R1	R2	R3	R4	R5	R6
PL 30	R1	R2	R3	R4	R5	R6
PL 34	R1	R2	R3	R4	R5	R6
PL 35	R1	R2	R3	R4	R5	R6
PL 36	R1	R2	R3	R4	R5	R6
PL 39	R1	R2	R3	R4	R5	R6
PL 41	R1	R2			R5	R6
PL 42	R1	R2	R3	R4	R5	R6
PL 43	R1	R2				
PL 44	R1	R2	R3	R4	R5	R6
PL 47	R1	R2	R3	R4	R5	R6
PL 49	R1	R2	R3	R4	R5	R6
PL 50	R1	R2	R3	R4		R6
PL 51		R2	R3	R4	R5	R6
PL 52		R2	R3	R4	R5	
PL 53	R1	R2	R3		R5	R6
PL 54	R1	R2	R3	R4	R5	R6
PL 56	R1	R2				R6
PL 57	R1	R2	R3	R4	R5	R6
PL 58	R1	R2	R3	R4	R5	R6
PL 69	R1	R2	R3	R4	R5	R6

Fig 1. Layout of the experimental plot

Plate 1. Experimental plot

Plate 2. Experimental plot at maximum vegetative phase

Table 1. Details of long pepper accessions included in the study

Sl No.	Accession No:	Source of collection	Sl No.	Accession No:	Source of collection
1	PL 1	Viswam	22	PL 26	Vellanikkara
2	PL 2	IC 85299 – Malappuram	23	PL 30	Vellanikkara
3	PL 3	IC85301 – Kasaragod	24	PL 34	Mananthavady
4	PL 4	IC85247 – Kollam	25	PL 35	MSSRF
5	PL 5	IC85278 – Tirunelveli	26	PL 36	Pulpally
6	PL 8	Mananthody big type	27	PL 39	Wayanad
7	PL 9	Mananthody	28	PL 41	Chanthanathode
8	PL10	IC 85277 – Tirunelveli	29	PL 42	Chanthanathode
9	PL 11	IC 85285 – Karnataka	30	PL 43	Chanthanathode
10	PL 12	IC 85298 – Malappuram	31	PL 44	Chanthanathode
11	PL 13	IC 266468 - Tirunelveli	32	PL 47	Kottakkal
12	PL 15	Yercaud	33	PL 49	Kottakkal
13	PL 17	Marotichal big	34	PL 50	Wayanad
14	PL 18	Oushadhi	35	PL 51	Wayanad
15	PL 19	Vydyarathnam	36	PL 52	Wayanad
16	PL 20	Mala	37	PL 53	Wayanad
17	PL 21	Bathery range	38	PL 54	Wayanad
18	PL 22	Thiruvanathapuram	39	PL 56	Pattikkad
19	PL 23	Ambalavayal	40	PL 57	Vazhachal
20	PL 24	Ambalavayal	41	PL 58	Malakkapara
21	PL 25	Ambalavayal	42	PL 69	Thenmala

3.2 Cataloguing of germplasm accessions of long pepper (*Piper longum* L.)

42 germplasm accessions of long pepper were catalogued based on the descriptor developed for *Piper nigrum* by IPGRI

3.2.1. Vegetative characters

1. Growth habit - climbing/ trailing/ erect
2. Branching type - dimorphic/ polymorphic/ others
3. Runner shoot production - few/ many
4. Pubescence on stem - absent/ present
5. Lateral branch habit - erect/ horizontal/ hanging
6. Leaf lamina shape - ovate/ ovate eliptic/ ovate lanceolate/ eliptic lanceolate/ cordate
7. Leaf base shape - round/ cordate/ acute / oblique
8. Leaf margin - even/ wavy
9. Leaf texture - glabrous coriaceous/ glabrous membraneous/ glabrous sarcous /downy membraneous/ downy along the veins
10. Types of veining - acrodromous/ camphylodromous/ eucamptodromous
11. Leaf scales - absent/ present

3.2.2. Inflorescence and fruit characters

1 Spike orientation - erect/ prostrate

2. Spike Shape - filiform /cylindrical /globular/conical

3. Immature spike color - green/ greenish yellow/ light yellow/ light purple/ others.

4. Color change while fruit ripening - green to black/ green to yellow, orange and then to red

5. Spike fragrance - not fragrant/ fragrant

6. Flower arrangement on spike - free/ fused laterally

7. Spike texture - glabrous/ hirtellous

8. Bract type - sessile oblong and adnate to the rachis/ cupular with decurrent base/ fleshy, connate, transformed in to a cup/ deeply cupular with decurrent base/ others

9. Flower nature - sessile/ shortly stipitate/ pedicillate

10. Fruit shape - round/ ovate/ oblong/ others

11. Fruit taste - bitter/ pungent/ spicy.

3.3 Details of experiment

3.3.1 Observation based on qualitative and quantitative characters

Observations were recorded during maximum vegetative phase of the crop.

3.3.1.1 Qualitative characters

1. Leaf shape

Leaf shape was recorded by visual observation and comparison was made with leaf shapes noted in the descriptor of *Piper nigrum* by IPGRI (1995).

2. Leaf colour

Leaf colour was assessed through visual observation.

3. Nature of spike

Nature of spike was assessed through visual observation

4. Colour of mature and immature spike

Colour of mature and immature spike was recorded through visual observation based on the descriptor of *Piper nigrum* by IPGRI (1995).

5. Year round observation on flowering

Mean number of inflorescence produced per replications per treatment were recorded monthly over a period of one year.

6. Anthesis (stigma receptivity and anther dehiscence)

Anthesis including stigma receptivity and anther dehiscence was recorded. Flower opening were recorded at hourly intervals during 24 h cycle of the day for one week. Five inflorescence per treatment were tagged to find out number of days and time taken for anthesis. Detailed observations were recorded at the time of anthesis.

To find out stigma receptivity, the colour change on stigmatic surface was noted. Flowers of five inflorescence per treatment were observed for stigmatic receptivity. Anther dehiscence in male accessions was also recorded based on colour and appearance of anthers of five spikes per treatment using a hand lens over a period of one week.

3.3.1.2 Quantitative characters

1. Height of the plant (cm)

Height of erect branches per plant was recorded by using meter scale.

2. Number of primary branches per plant

The number of primary branches per plant was recorded.

3. Number of spike bearing branches per primary branch per plant

Number of spike bearing branches per primary branch per plant was recorded by counting spike bearing branches in each of primary branch.

4. Petiole length (cm)

The length of petiole was measured by using a meter scale from five leaves chosen at random from each replication and average was noted.

5. Internodal length of spike bearing branch (cm)

The length of internodes between third and fourth leaf of randomly selected spike bearing branches from each replication was recorded, using a meter scale and average was noted.

6. Number of leaves per plant

Total number of leaves produced per replications per treatment was counted.

7. Leaf area (cm^2)

Leaf area per plant was measured using leaf area meter. Observations were recorded from ten leaves chosen randomly from each replication per treatment and average was noted.

8. Days from planting to emergence of spike

The number of days required from planting to first emergence of spikes was recorded for 42 accessions.

9. Days from emergence to maturity of spike

Spikes which emerged were tagged with paper tags marked with date (five spikes/ treatment) and number of days taken from emergence date up to the day in which spike changes to yellow and green or black were counted.

10. Number of spikes per spike bearing branch

The number of spikes per spike bearing branch was recorded by counting spikes in spike bearing branches in each of the replication per treatment and mean was noted.

11. Length of spike (cm)

Length of ten spikes was taken randomly from each of the replication per treatment immediately after harvest with the help of meter scale and mean was noted.

12. Girth of spike (mm)

The girth of ten spikes was measured randomly from each of the replication per treatment with the help of vernier caliper.

13. Yield of spikes/ plant (fresh and dry) (g)

The number and fresh weight of harvested spikes were recorded from each replications per treatment. The green spike was oven dried for a period of four days at 60^0C until the weight was constant and the dry weight of spikes was recorded from replications per treatment and took its average.

14. Spike set (per cent)

Number of inflorescence produced per month per treatment and the number of mature spikes harvested was recorded and the spike set percentage was calculated.

15. Driage (per cent)

Ratio of dry weight to the fresh weight of spike was worked out for the harvested spikes and expressed as per cent.

3.3.1.3 Biochemical attributes

1. Volatile oil

Extraction of oil was done by using Clevenger apparatus (AOAC, 1980) for twenty acessions.Two samples per treatment were analysed. Minimum of 20 g dry and ground thippali spikes was taken in a round bottomed flask; added 200ml distilled water and distilled. Being lighter than water, the volatile oil condensed and collected as top layer of graduated tube. The volume of essential oil collected was noted and expressed in per cent.

2. Oleoresin

The oleoresin content in the spikes of *Piper longum* was estimated using Soxhlet apparatus [AOAC, 1980] with acetone for thirty accessions and expressed in per cent. Two samples per treatment were used for analysis.

2 g sample (ground dry) packed in filter paper, tied it tightly and kept in Soxhlet flask. Placed soxhlet above round bottom flask. Add 150 ml of acetone (solvent) to it and kept distillation unit in water bath. Four to five siphoning were done. After 3 – 4 hrs, acetone was collected from Soxhlet apparatus periodically. At last minute quantity of solution collected in the round bottom flask should be transferred to already weighed beaker. Kept the collected solution for overnight. Next day took the weight of beaker. Difference between these two weights was taken as quantity of oleoresin and is expressed in percentage.

3. Piperine

Piperine content in the dried spikes of thirty three accessions were estimated spectroscopically by the method of Sowbhagya *et al.* (1990). Two samples per treatment were used for analysis.10 mg freshly powdered samples of thippali was taken in a volumetric flask and extracted with 10 ml of acetone. Kept the flask at room temperature and shaken well for 2.5

hours. From the flask, took 0.25 ml of clear solution in a cuvette. The absorbance of the solution was read at 337 nm in a UV Spectrophotometer with acetone as blank.

Preparation of the standard curve

For the preparation of standard curve, stock solution of pure piperine was prepared by taking 10 mg piperine in 10 ml acetone. Then prepared working standard, by taking 0.5 ml stock solution and added 9.5 ml acetone into it. From working standard, 1µg/ml (1ml solution + 49 ml acetone), 2.5µg/ml (1ml solution + 19 ml acetone), 5µg/ml (1ml solution + 9 ml acetone), 10µg/ml (1ml solution + 4 ml acetone) and 25µg/ml (5ml solution + 5 ml acetone) solutions were prepared. The absorbance was measured at 337 nm

3.3.2 Statistical analysis of data

Data based on different characters were subjected to statistical analysis, using MSTATC package. The analysis of variance technique suggested by Fisher (1954) was used for the estimation of analysis of variation. Ranking was done by using Duncan's Multiple Range Test.

3.3.3 Cluster analysis

Data based on qualitative and quantitative characters were compared with Euclidean co-efficient and was clustered by the Unweighed Pair Group Average Method (UPGAM) devised by Sneath and Sokal (1973) using NTSYS pc 2.02 software. Similarity matrix was computed and the dendrogram was constructed accordingly.

Results

4. RESULT

Evaluation of forty one accessions of long pepper along with check variety 'Viswam' was undertaken, to study the vegetative, flowering behavior, fruit set, yield, quality and to identify superior long pepper genotypes having high yield and quality. The present study was undertaken at the Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara during December 2012 to May 2014. Planting was done on 31/12/2014. The results obtained are presented below.

4.1 Cataloguing of germplasm accessions of long pepper

Based on the descriptor developed for *Piper nigrum* by IPGRI. Forty one accessions of long pepper along with check variety 'Viswam' were catalogued for vegetative, inflorescence and fruit characters (Table 2 & 3).

All the accessions included in the study were having erect and trailing growth habit, except PL 52 and PL 53, having erect growth habit (Plate 11). *Piper longum* accessions had dimorphic branching habit and had few to many runner shoots except in PL 52 and PL 53. Pubescence was present for stem and had erect branching habit. Leaf base shapes observed were cordate and round. Lamina shapes cordate and ovate lanceolate were observed among the accessions. Cordate is the predominant shape for leaf base and lamina among accessions.

Spike shape was found cylindrical to filiform with glabrous texture . In PL 52, PL 57 and PL 58 spikes had hirtellous texture (Plate 10). Colour of immature spike be yellow and mature green or black in female types. PL 53 were having the shortest spikes. In male accession spike colour is green during immature stage and yellow during maturity. Forty two accessions include thirty eight female, three male and one non - flowering type. Flowers were fused laterally in the inflorescence and having sessile nature.

4.2 Field evaluation

The experimental material included 41 accessions along with check variety 'Viswam' were observed for qualitative and quantitative characters. All the observations were taken during maximum vegetative phase of the crop.

4.2.1 Qualitative characters

1. Leaf shape

All the accessions had cordate leaf base shape except PL 8, PL12, PL13, PL 30, PL 42, PL 50 and PL 56 had round shape (Plate 3). Leaf lamina was cordate in most accessions except the accessions PL 8, PL12, PL13, PL 30, PL 42, PL 50 and PL 56 where it was ovate lanceolate (Plate 4). Leaf margins in most of the accessions were wavy except in PL 52 and PL 53, which had entire leaf margin (Plate 5) (Table 2).

2. Leaf colour

Most of the accessions recorded light green color for immature leaves and dark green colour for mature leaves which were presented in Table 2.

3. Nature of spike

The male accessions exhibited filiform shaped spike and female accessions had acuminate shaped spike (Plate 6). In PL 53 it was globular shaped.

4. Colour of mature and immature spike

In male accessions immature spike was having green colour and colour changed to yellow on maturity (Plate 9). In female accessions, at immature stage, spike colour was light yellow and at mature stage it changed to green or black. Apart from this, PL 52 spike had pure white colour at immature stage and on maturity it changes to green. In PL 53 it was green colour during immature and mature stage (Plate 7 & 8).

5. Year round observation on flowering

Month wise observation on production of inflorescence was studied in detail. Mean number of inflorescence produced per accessions from April 2013 – March 2014 were recorded. Among the accessions thirty eight were female, three male and PL 47 was observed as non – flowering type during study.

Maximum inflorescence was observed during June, July and August in all the accessions (more than 55 per cent) and minimum during December, January (less than 5 per cent). In PL 42, PL 53 and PL 57, 100 per cent flowering extend was observed during May to October. (Table 4).

6. Anthesis (stigma receptivity and anther dehiscence)

Flower opening in both male and female inflorescence started from 7.30 am and continued up to 4.30 pm in a day. Flower opening was completed in both male and female inflorescence within seventh or eighth day in both accessions.

In female accessions, peak time of flower opening was observed between 10.30 am to 12.30 pm. Opening take place from bottom to top portion of spike. Flower opening in female types were observed abundant from second to seventh day. It remains white for two days after opening of flowers. After 3rd or 4th day of flower opening, colour of stigmatic lobe changed to brown around 12.00 pm to 1.00 pm indicating the end of stigmatic receptivity (Plate 12).

In male accessions, flower opening and anther dehiscence having a peak time period of 10.30 am to 12.30 pm. Maximum flower opening was noticed in 3rd and 4th day in male accessions, while anther dehiscence took place profusely during second to fourth day. Anther dehiscence started from 7.30 am and continued up to 4.30 pm in a day from bottom to top portion of spike like flower opening. For complete dehiscence of anthers it took around seven days. The white two lobed anthers were changed to black indicating the end of anther dehiscence (Plate 13).

Table 2: Cataloguing of long pepper accessions based on vegetative characters

Sl. No.	Acc. No.	Growth habit	Branching type	Runner shoot production	Pubescence on stem	Lateral branch habit	Leaf lamina shape	Leaf base shape	Leaf margin	Types of veining	Leaf texture	Leaf scale	Leaf colour	
													Immature	Mature
1	Viswam	Erect and trailing	Dimorphic	Few	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
2	PL 2	Erect and trailing	Dimorphic	Few	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
3	PL 3	Erect and trailing	Dimorphic	Few	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
4	PL 4	Erect and trailing	Dimorphic	Few	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
5	PL 5	Erect and trailing	Dimorphic	Few	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
6	PL 8	Erect and trailing	Dimorphic	Many	Present	Erect	Ovate lanceolate	Round	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
7	PL 9	Erect and trailing	Dimorphic	Few	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
8	PL 10	Erect and trailing	Dimorphic	Many	Present	Erect	Cordate	Cordate	Wavy	acrodromous	Glabrous coriaceous	Absent	Light green	Green
9	PL 11	Erect and trailing	Dimorphic	Few	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
10	PL 12	Erect and trailing	Dimorphic	Few	Present	Erect	Ovate lanceolate	Round	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green

11	PL 13	Erect and trailing	Dimorphic	Many	Present	Erect	Ovate lanceolate	Round	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
12	PL 15	Erect and trailing	Dimorphic	Few	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
13	PL 17	Erect and trailing	Dimorphic	Few	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
14	PL 18	Erect and trailing	Dimorphic	Few	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
15	PL 19	Erect and trailing	Dimorphic	Few	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
16	PL 20	Erect and trailing	Dimorphic	Few	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
17	PL 21	Erect and trailing	Dimorphic	Few	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
18	PL 22	Erect and trailing	Dimorphic	Few	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
19	PL 23	Erect and trailing	Dimorphic	Few	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
20	PL 24	Erect and trailing	Dimorphic	Few	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
21	PL 25	Erect and trailing	Dimorphic	Few	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
22	PL 26	Erect and trailing	Dimorphic	Few	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green

23	PL 30	Erect and trailing	Dimorphic	Few	Present	Erect	Ovate lanceolate	Round	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
24	PL 34	Erect and trailing	Dimorphic	Few	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
25	PL 35	Erect and trailing	Dimorphic	Few	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
26	PL 36	Erect and trailing	Dimorphic	Few	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
27	PL 39	Erect and trailing	Dimorphic	Many	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
28	PL 41	Erect and trailing	Dimorphic	Few	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
29	PL 42	Erect and trailing	Dimorphic	Few	Present	Erect	Ovate lanceolate	Round	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
30	PL 43	Erect and trailing	Dimorphic	Few	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
31	PL 44	Erect and trailing	Dimorphic	Few	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
32	PL 47	Erect and trailing	Dimorphic	Many	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
33	PL 49	Erect and trailing	Dimorphic	Few	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green

34	PL 50	Erect and trailing	Dimorphic	Few	Present	Erect	Ovate lanceolate	Round	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
35	PL 51	Erect and trailing	Dimorphic	Few	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
36	PL 52	Erect	Dimorphic	-	Present	Erect	Cordate	Cordate	Even	Acrodromous	Glabrous coriaceous	Absent	Light Green	Green
37	PL 53	Erect	Dimorphic	-	Present	Erect	Cordate	Cordate	Even	Acrodromous	Glabrous coriaceous	Absent	Light Green	Green
38	PL 54	Erect and trailing	Dimorphic	Few	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
39	PL 56	Erect and trailing	Dimorphic	Many	Present	Erect	Ovate lanceolate	Round	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
40	PL 57	Erect and trailing	Dimorphic	Few	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
41	PL 58	Erect and trailing	Dimorphic	Few	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green
42	PL 69	Erect and trailing	Dimorphic	Few	Present	Erect	Cordate	Cordate	Wavy	Acrodromous	Glabrous coriaceous	Absent	Light green	Green

Table 3: Cataloguing of long pepper accessions based on inflorescence and spike characters

Sl. No.	Acc. No.	Spike Orientation	Spike Shape	Spike texture	Immature Spike colour	Colour change while fruit ripening	Spike fragrance	Flower arrangement on spike	Bract type	Flower nature	Fruit shape	Fruit flavor
1	Viswam	Erect	Cylindrical	Glabrous	Yellow	Green to Black	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
2	PL 2	Erect	Cylindrical	Glabrous	Yellow	Green to Green	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
3	PL 3	Erect	Cylindrical	Glabrous	Yellow	Green to Black	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
4	PL 4	Erect	Cylindrical	Glabrous	Yellow	Green to Black	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
5	PL 5	Erect	Cylindrical	Glabrous	Yellow	Green to Green	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
6	PL 8	Erect	Cylindrical	Glabrous	Yellow	Green to Green	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
7	PL 9	Erect	Cylindrical	Glabrous	Yellow	Green to Green	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
8	PL 10	Erect	Cylindrical	Glabrous	Yellow	Green to Black	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
9	PL 11	Erect	Cylindrical	Glabrous	Yellow	Green to Black	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
10	PL 12	Erect	Cylindrical	Glabrous	Yellow	Green to Black	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
11	PL 13	Erect	Cylindrical	Glabrous	Yellow	Green to Black	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
12	PL 15	Erect	Cylindrical	Glabrous	Yellow	Green to Green	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
13	PL 17	Erect	Cylindrical	Glabrous	Yellow	Green to Black	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
14	PL 18	Erect	Cylindrical	Glabrous	Yellow	Green to Black	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
15	PL 19	Erect	Cylindrical	Glabrous	Yellow	Green to Black	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
16	PL 20	Erect	Cylindrical	Glabrous	Yellow	Green to Black	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
17	PL 21	Erect	Cylindrical	Glabrous	Yellow	Green to Black	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
18	PL 22	Erect	Cylindrical	Glabrous	Yellow	Green to Black	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
19	PL 23	Erect	Cylindrical	Glabrous	Yellow	Green to Black	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
20	PL 24	Erect	Cylindrical	Glabrous	Yellow	Green to Black	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy

21	PL 25	Erect	Cylindrical	Glabrous	Yellow	Green to Black	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
22	PL 26	Erect	Filiform	Glabrous	Green	Green to Yellow	Fragrant	Fused laterally	Peltate orbicular	Sessile	-	-
23	PL 30	Erect	Filiform	Glabrous	Green	Green to Yellow	Fragrant	Fused laterally	Peltate orbicular	Sessile	-	-
24	PL 34	Erect	Cylindrical	Glabrous	Yellow	Green to Black	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
25	PL 35	Erect	Cylindrical	Glabrous	Yellow	Green to Black	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
26	PL 36	Erect	Cylindrical	Glabrous	Yellow	Green to Black	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
27	PL 39	Erect	Filiform	Glabrous	Green	Green to Yellow	Fragrant	Fused laterally	Peltate orbicular	Sessile	-	-
28	PL 41	Erect	Cylindrical	Glabrous	Yellow	Green to Black	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
29	PL 42	Erect	Cylindrical	Glabrous	Yellow	Green to Black	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
30	PL 43	Erect	Cylindrical	Glabrous	Yellow	Green to Black	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
31	PL 44	Erect	Cylindrical	Glabrous	Yellow	Green to Black	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
32	*PL 47	-	-	-	-	-	-	-	-	-	-	-
33	PL 49	Erect	Cylindrical	Glabrous	Yellow	Green to Black	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
34	PL 50	Erect	Cylindrical	Glabrous	Yellow	Green to Black	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
35	PL 51	Erect	Cylindrical	Glabrous	Yellow	Green to Black	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
36	PL 52	Erect	Cylindrical	Hirtellous	White	Green to Green	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
37	PL 53	Erect	Globular	Glabrous	Green	Green to Green	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Sweet and Spicy
38	PL 54	Erect	Cylindrical	Glabrous	Yellow	Green to Black	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
39	PL 56	Erect	Cylindrical	Glabrous	Yellow	Green to Black	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
40	PL 57	Erect	Cylindrical	Hirtellous	Yellow	Green to Green	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
41	PL 58	Erect	Cylindrical	Hirtellous	Yellow	Green to Green	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy
42	PL 69	Erect	Cylindrical	Glabrous	Yellow	Green to Green	Fragrant	Fused laterally	Peltate orbicular	Sessile	Ovate	Spicy

*PL47 - non flowering type

Table 4: Year round observation on flowering of long pepper accessions

Accession	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March
Viswam	8.67	16.67	40.50	46.33	32.67	19.67	14.83	10.83	5.17	5.83	6.33	7.83
PL 2	2.00	3.83	9.50	10.67	7.83	4.50	3.33	2.50	1.17	1.33	1.50	1.83
PL 3	2.67	5.33	12.67	14.50	10.17	6.17	4.50	3.50	1.67	1.83	2.00	2.50
PL 4	3.83	7.50	18.33	20.83	14.67	8.83	6.50	4.83	2.33	2.67	2.83	3.50
PL 5	6.50	12.67	30.67	34.67	24.33	14.67	10.83	8.17	3.83	4.50	4.67	5.83
PL 8	10.33	20.17	48.50	54.83	38.67	23.17	17.17	13.00	6.17	7.17	7.33	9.33
PL 9	9.83	19.17	46.33	52.50	37.17	22.33	16.33	12.33	5.83	6.67	7.00	9.00
PL 10	0.50	1.00	2.17	2.67	1.83	1.00	0.67	0.50	0.33	0.33	0.33	0.50
PL 11	3.00	5.83	14.50	16.33	11.50	7.00	5.00	3.83	1.83	2.17	2.33	2.83
PL 12	3.83	7.50	18.17	20.67	14.50	8.83	6.50	4.83	2.17	2.67	2.83	3.50
PL 13	0.33	0.67	1.83	2.00	1.33	0.67	0.50	0.17	0.33	0.33	0.33	0.50
PL 15	6.17	11.83	28.83	32.67	23.00	13.83	10.17	7.67	3.83	4.33	4.50	5.67
PL 17	3.67	7.33	17.50	20.33	14.33	8.50	6.33	4.67	2.33	2.67	2.83	3.50
PL 18	0.67	1.17	2.67	3.00	2.17	1.33	1.00	0.67	0.33	0.33	0.50	0.50
PL 19	0.50	0.83	2.33	2.67	1.83	1.00	0.67	0.67	0.17	0.33	0.33	0.50
PL 20	3.83	7.67	18.50	21.00	14.67	8.83	6.50	4.83	2.33	2.67	2.83	3.50
PL 21	6.50	12.50	30.50	34.50	24.33	14.67	10.83	8.17	3.83	4.50	4.67	5.83
PL 22	3.67	7.17	17.50	19.83	14.00	8.33	6.17	4.67	2.17	2.50	2.67	3.33
PL 23	8.33	16.17	38.83	44.17	31.00	18.67	13.83	10.33	5.00	5.67	5.83	7.50
PL 24	8.33	16.33	39.33	44.50	31.33	19.00	13.83	10.50	5.00	5.67	6.00	8.00
PL 25	7.00	13.67	33.00	37.67	26.50	16.00	11.67	8.83	4.17	5.33	5.00	6.17
PL 26	0.33	0.33	1.17	1.33	0.83	0.50	0.33	0.33	0.17	0.17	0.17	0.33
PL 30	0.17	0.33	0.67	0.83	0.50	0.33	0.33	0.17	0.00	0.17	0.17	0.17
PL 34	2.17	4.00	9.83	11.33	7.83	4.67	3.50	2.67	1.33	1.50	1.50	2.00
PL 35	0.00	0.17	0.50	0.83	0.33	0.16	0.17	0.17	0.00	0.00	0.00	0.00
PL 36	1.33	2.50	6.33	7.17	5.00	3.00	2.17	1.67	0.67	0.83	1.00	0.17
PL 39	0.33	0.67	1.67	1.83	1.00	0.83	0.50	0.33	0.17	0.33	0.33	0.33
PL 41	0.17	0.50	1.17	1.33	1.00	0.50	0.33	0.33	0.17	0.17	0.17	0.33
PL 42	0.00	0.17	0.33	0.33	0.17	0.17	0.17	0.00	0.00	0.00	0.00	0.00
PL 43	2.50	4.67	11.17	12.83	9.00	5.33	4.00	3.00	1.33	1.67	1.67	2.17
PL 44	0.33	0.67	1.67	1.83	1.33	0.67	0.50	0.33	0.17	0.33	0.33	0.33

PL 47	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
PL 49	0.83	1.50	3.50	4.00	2.67	1.67	1.33	1.00	0.33	0.50	0.50	0.67
PL 50	3.83	7.67	18.33	20.67	14.67	8.67	6.67	5.00	2.33	2.67	2.83	3.50
PL 51	3.00	5.67	13.83	15.67	11.00	6.67	4.83	3.67	1.67	2.00	2.00	2.67
PL 52	0.83	1.50	3.67	4.33	3.00	1.83	1.33	1.00	0.33	0.50	0.67	0.83
PL 53	0.00	0.17	0.33	0.33	0.17	0.17	0.178	0.00	0.00	0.00	0.00	0.00
Pl 54	0.00	0.17	0.50	0.50	0.33	0.33	0.17	0.17	0.00	0.00	0.00	0.00
PL 56	0.33	0.50	1.33	1.50	1.00	0.67	0.50	0.33	0.17	0.17	0.17	0.33
PL 57	0.00	1.00	0.33	0.33	0.17	0.17	0.17	0.00	0.00	0.00	0.00	0.00
PL 58	0.50	0.83	2.33	2.67	1.83	1.00	0.83	0.67	0.17	0.33	0.33	0.33
PL 69	0.33	0.67	1.83	1.83	1.33	0.83	0.67	0.50	0.17	0.17	0.33	0.33
Mean	2.79	5.44	13.16	14.94	10.51	6.31	4.66	3.59	1.65	1.93	2.00	2.53
CD (0.05)	1.14	1.39	1.50	1.25	1.41	1.28	1.16	1.00	0.80	0.89	1.05	0.91
CV(%)	35.69	22.35	9.97	7.34	11.95	18.01	22.16	25.03	42.84	40.59	46.32	31.93

4.2.2 Cluster analysis

Cluster analysis on qualitative data of 42 accessions was subjected to Multivariate Hierrarchial Cluster Analysis using NTSYS. The dendrogram derived through qualitative characteristics showed high degree of similarity varying from 26 to 100 per cent (Fig. 2).

4.2.2.1 Clustering based on qualitative characters

Based on data, at 81 per cent similarity long pepper accessions were grouped into seven clusters. (Table 5).

Cluster I, include thirty accessions, PL 1, PL 3, PL 4, PL 5, PL 8, PL 9, PL10, PL 11, PL 12, PL 13, PL 18, PL 19, PL 20, PL 21, PL 22, PL 23, PL 24, PL 25, PL 34, PL 35, PL 36, PL 41, PL 42, PL 43, PL 44, PL 50, PL 51, PL 54, PL 56 and PL 69. Among them PL 1, PL 3, PL 4, PL 11, PL 18, PL 19, PL 20, PL 21, PL 22, PL 23, PL 24, PL 25, PL 34, PL 35, PL 36, PL 41, PL 43, PL 44, PL 51, and PL 54 shares 100 per cent similarity, PL 5, PL 9 and PL 69 shares 100 per cent similarity, PL 12, PL 42 and PL 50 shares 100 per cent similarity and PL 13 and PL 56 also shares 100 per cent similarity.

Cluster II, includes PL 57 and PL 58 shares nearly 90 per cent similarity. Cluster III includes PL 2, PL 15, PL 17 and PL 49, among them PL 2, PL 15 and PL 17, PL 49 shares 100 per cent similarity. Cluster IV includes PL 52 and Cluster V contain PL 53. Cluster VI consists of PL 26, PL 30 and PL 39. Among them PL 26 and PL 39 shares nearly 90 per cent similarty. Cluster 7 include PL 47.

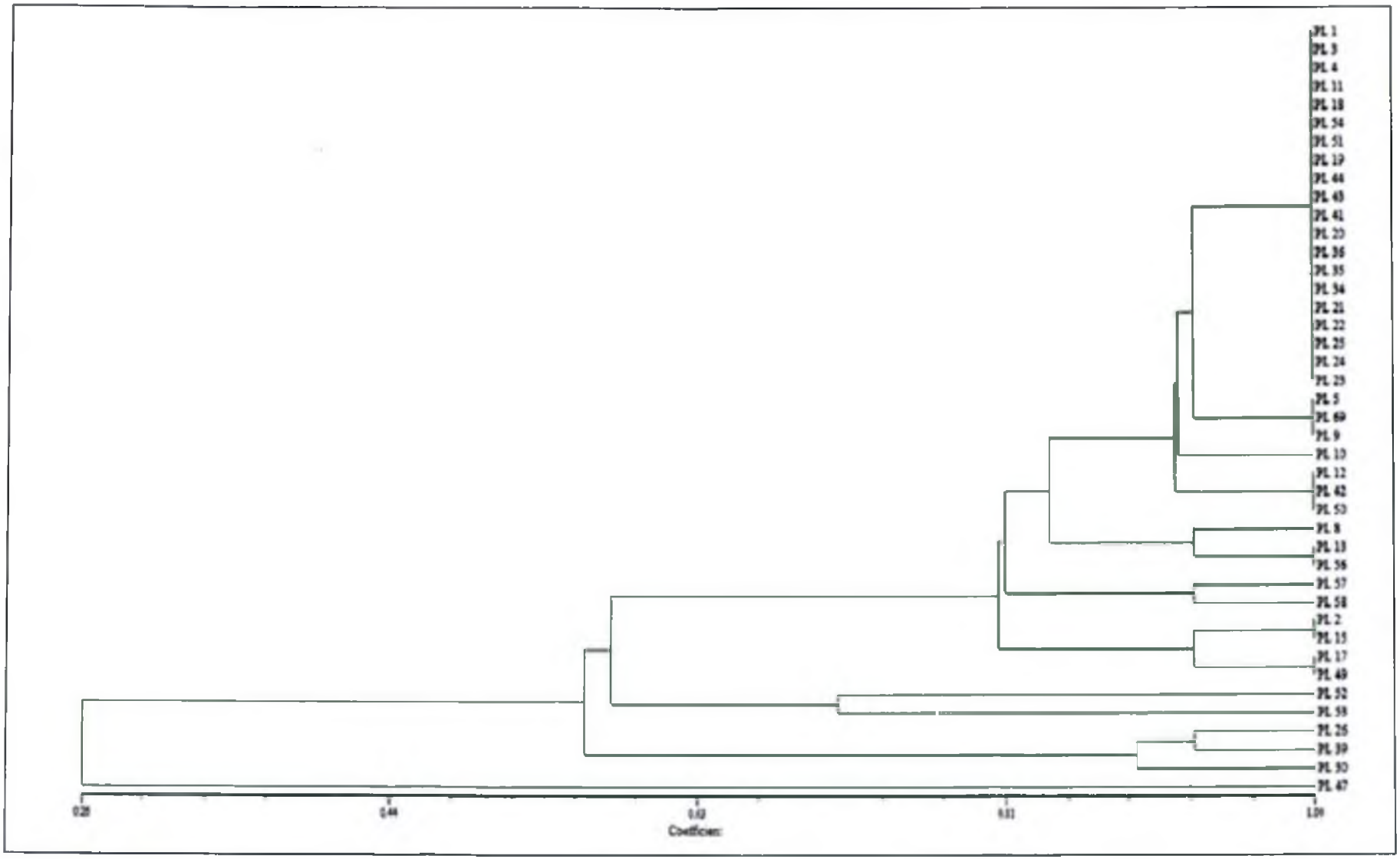


Fig 2. Dendrogram based on qualitative characters

Table 5. Cluster composition based on qualitative characters

Cluster	Accessions
I	PL 1, PL 3, PL 4, PL 5, PL 8, PL 9, PL10, PL 11, PL 12, PL 13, PL 18, PL 19, PL 20, PL 21, PL 22, PL 23, PL 24, PL 25, PL 34, PL 35, PL 36, PL 41, PL 42, PL 43, PL 44, PL 50, PL 51, PL 54, PL 56, PL 69
II	PL 57, PL 58
III	PL 2, PL 15, PL 17, PL 49
IV	PL 52
V	PL 53
VI	PL 26, PL 30, PL 39
VII	PL 47

Cordate

Round

Plate 3. Variabilty in leaf base of long pepper accessions

Cordate

Ovate lanceolate

Plate 4. Variability in leaf lamina of long pepper accessions

Wavy

Even

Plate 5. Variability in leaf margin of long pepper accessions

Female - cylindrical

Male - filiform

Plate 6. Variability in spike of male and female types in long pepper

Common PL 52 PL 53

Plate 7. Variability in immature spikes of female types in long pepper accessions

Black Green

Plate 8. Variability in mature spikes of female types in long pepper accessions

Immature Mature

Plate 9. Immature and mature spikes of male types in long pepper accessions

Glabrous

Hirtellous

Plate 10. Variability in spike texture of long pepper accessions

Erect and trailing

Erect

Plate 11. Variability in growth habit of long pepper accessions

Opened inflorescence

PL 52 - opened inflorescence

Inflorescence after stigma receptivity

Plate 12. Stages of anthesis in female types of long pepper accessions

Unopened inflorescence

Opened inflorescence

Inflorescence after anther dehiscence

Plate 13. Stages of anthesis in male types of long pepper accessions

Initial stage

Started flower opening from base

Colour changes from light green to yellow

Fully opened inflorescence

Closed flowers

End of stigma receptivity

Plate 14. Flowering phases in female types of long pepper accessions

4.2.3 Quantitative characters

Observations were carried out during maximum vegetative phase of the crop.

1. Height of the plant

Plant height differed significantly in most of the accessions. The accession PL 35 (88.33cm) recorded maximum plant height which was on par with PL 22 (83.02 cm), PL 44 (82.48 cm), PL 11 (82.42 cm) and PL 15 (82.23 cm) respectively. Minimum height was recorded in PL 54 (39.67 cm) (Table 6).

2. Number of primary branches per plant

The number of primary branches per plant in forty two accessions was recorded and presented in Table 6. The forty two accessions differed significantly in the number of primary branches.

The accessions PL 23 (8.00), PL 24 (8.00) and PL 34 (8.00) showed highest number of primary branches which was on par with check variety Viswam (7.67), PL 43 (7.83), PL 25 (7.33), PL 30 (6.83), PL 2 (6.67), PL 21 (6.67), PL 44 (6.50), PL 42 (6.17), PL 50(6.17), PL 36 (6.00), PL 8 (5.83) and PL 15 (5.67) respectively. The accession PL 54 (1.00) showed the lowest position at maximum vegetative phase.

3. Number of spike bearing branches per primary branch

Number of spike bearing branches per primary branch ranged from 1.00 to 6.71. The highest number of spike bearing branches was recorded in PL 8 (6.71) which was statistically on par with PL 9 (5.70) and the lowest in PL 53 (1.00). The accession PL 47 produced no spike bearing branches. The check variety Viswam had 3.85 spike bearing branches which was on par with PL 25 (Table 6).

4. Petiole length

The forty two accessions differed significantly with respect to petiole length. The maximum petiole length was recorded by PL 20 (7.56cm) which was on par with PL 19 (7.43cm), PL 18 (6.85 cm) and PL 49 (6.81 cm) compared with check variety Viswam (4.33cm) respectively. Minimum value was recorded by PL 53 (1.11cm) (Table 6).

5. Internodal length of spike bearing branch

Accessions differed significantly for the internodal length of spike bearing branches. At peak vegetative growth of plant, PL 58 (7.38 cm) recorded the highest inter nodal length which was on par with PL 13 (7.36 cm), PL 10 (7.11 cm), PL 69 (7.08 cm), PL 47 (7.08 cm), PL 56 (7.01 cm), PL 49 (6.93 cm), PL 57 (6.91 cm) and PL 17 (6.88 cm) respectively. Minimum internodal length was recorded by PL 53 (1.86 cm). Check variety recorded an internodal length of 5.01cm (Table 6).

6. Number of leaves

Number of leaves varied significantly among the accessions (Table 6). The highest number of leaves were recorded in PL 24 (166.0) which was on par with check variety Viswam (144.80), PL 23 (151.30), PL 44 (148.80), PL 47 (143.30), PL 10 (143.20), PL 25 (142.00), PL 42 (141.30), PL 9 (140.50), PL 26 (140.20), PL 34 (135.20), PL 8 (133.70), PL 43 (131.30), PL 49 (127.20), PL 13 (124.50) and PL 56 (119.00) respectively. The lowest value was in accession PL 54 (21.67) (Table 6).

7. Leaf area

The leaf area of accessions differed significantly (Table 6). Maximum leaf area was recorded by PL 52 (63.87cm^2) and the minimum leaf area was recorded by PL 54 (25.98 cm^2).

8. Days from planting to emergence of spike

The number of days for spike emergence from planting was presented in Table 7. PL 53 (146 days) took maximum number of days in comparison with check variety Viswam (104 days) for spike emergence. Lowest number of days was taken by PL 23 (77 days). The accession PL 47 was a non - flowering type observed during the study period.

9. Days from emergence to maturity of spike

The accessions PL 2 (60 days) and PL 5 (60 days) took minimum days to reach maturity compared with check variety (61 days). Maximum days for maturity were taken by PL 10 (80 days). In accessions PL 35, PL 42, PL 53, PL 54 and PL 57 spike shedding was observed before reaching maturity (Table 7).

10. Number of spikes per spike bearing branch

The maximum number of spikes/ spike bearing branch was seen in PL 8 (3.21) and PL 9 (3.21) which was statistically on par with check variety Viswam (2.25), PL 15 (2.33) and PL 58 (2.25) respectively. Minimum number of spikes per spike bearing branch was in PL 53 (1.00) and PL 10 (1.00) (Table 8).

11. Length of spike

Spike length of different accessions are presented in Table 8. Among accessions, male types like PL 39 (8.18 cm), PL 30 (8.10 cm) and PL 26 (8.10 cm) recorded longest spike. In female accessions PL 8 (3.10 cm) recorded longest spike which was on par with PL 9 (2.93 cm) and PL 23 (2.90 cm) respectively. The check variety recorded a spike length of 2.25 cm. Shortest spike length was observed in PL 56 (0.90 cm).

12. Girth of spike

The girth of spike in male accessions PL 26, PL 39 and PL 30 were 4.03 mm, 4.03 mm and 4.00 mm respectively. Among female accessions PL 8 (8.86 mm) and PL 19 (3.75 mm) had maximum and minimum girth of spike respectively. Check variety Viswam recorded a spike girth of about 6.83 mm (Table 8).

13. Yield of spikes/plant (Fresh and dry)

Fresh and dry weights per spike was recorded. Maximum fresh weight per spike was noticed in PL 8 (1.06 g) which was on par with PL 5 (1.05 g), PL 12 (1.03 g), PL 9 (1.00 g) and PL 58 (0.98 g) compared with check variety Viswam (0.68 g). Least weight per spike was noticed in PL 69 (0.46 g). Dry weight per spike was maximum in PL 12 (0.20 g) which was on par with PL 5 (0.19 g) and PL 58 (0.19 g). Check variety reported dry weight per spike as 0.12 g and minimum weight was recorded in PL 13 (0.08 g) (Table 8).

The fresh and dry spike yield per plant were recorded and presented in Table 8. Maximum fresh yield per plant was noticed in PL 8 (58.32 g) which was on par with check variety Viswam (42.72 g) and PL 9 (50.61 g). Lowest fresh yield per plant was noticed in PL 41 (0.29 g). The dry spike yield per plant was noticed maximum in PL 8 (9.20 g) which was on par with Viswam (8.36 g) and PL 9 (8.59 g) respectively. Minimum dry yield of spikes per plant was noticed in PL 19 (0.05 g) and PL 41(0.05 g) respectively. There is no spike yield from male accessions since the spikes just reaches maturity and fell down.

14. Spike set

Spike set of forty two accessions are represented as per cent (Table 8). Maximum spike set was noticed in accession PL 8 (97.42 per cent) followed by PL 9 (97.21 per cent) and PL 23 (96.72 per cent) compared with check variety Viswam which had a spike set of 96.85 per cent. The lowest percentage of spike set was

noticed in PL 41 (25 per cent). The accession PL 35, PL 42, PL 53, PL 54 and PL 57 having zero percent spike set.

15. Driage

Maximum percent of driage was observed in PL49 (20.66 per cent) compared with check variety Viswam (19.56 per cent) and least driage was noticed in PL 19 (11.62 per cent) (Table 8).

Table 6.Variability in plant characteristics among long pepper accessions

Accessions	Plant height (cm)	No: of primary branches	No: of spike bearing branch/primarybranch	Petiole length (cm)	Internodal length (cm)	Leaf number	Leaf area (cm^2)
Viswam	61.62	7.67	3.85	4.33	5.01	144.80	49.65
PL 2	56.38	6.67	2.86	6.30	5.91	118.70	49.13
PL 3	42.65	5.17	2.16	3.61	5.63	49.33	45.25
PL 4	78.32	4.33	2.96	4.21	5.08	90.17	53.03
PL 5	70.52	4.33	3.66	4.41	5.96	95.50	41.53
PL 8	77.67	5.83	6.71	3.11	6.70	133.70	49.78
PL 9	68.83	3.83	5.70	4.48	6.50	140.50	47.83
PL 10	78.73	4.67	1.75	4.78	7.11	143.20	41.85
PL 11	82.42	4.17	2.58	2.76	3.55	73.67	46.17
PL 12	58.60	4.83	2.45	4.48	6.65	89.17	39.13
PL 13	78.58	5.33	1.20	3.65	7.36	124.50	41.07
PL 15	82.23	5.67	2.95	6.60	6.08	116.70	48.17
PL 17	72.17	3.17	3.53	3.28	6.88	109.00	40.22
PL 18	73.77	4.17	1.58	6.85	6.03	78.50	51.43
PL 19	73.42	4.33	2.00	7.43	6.45	95.67	50.07
PL 20	56.78	5.33	2.63	7.56	5.06	73.50	50.48
PL 21	50.42	6.67	3.25	3.83	4.95	93.33	34.88

PL 22	83.02	4.83	4.48	4.13	5.80	89.50	47.10
PL 23	79.25	8.00	4.56	3.45	4.90	151.30	48.72
PL 24	74.55	8.00	4.88	4.50	4.91	166.00	50.83
PL 25	58.17	7.33	3.85	3.78	6.03	142.00	43.25
PL 26	76.67	6.83	1.66	5.15	5.71	140.20	50.32
PL 30	78.27	6.83	1.80	4.11	6.36	78.17	49.38
PL 34	68.92	8.00	3.11	4.48	6.68	135.20	48.02
PL 35	88.33	3.33	1.66	3.60	6.43	97.83	46.60
PL 36	62.50	6.00	2.46	3.86	5.71	89.00	58.48
PL 39	64.65	4.33	3.08	5.08	6.53	94.83	47.98
PL 41	77.30	4.83	2.81	4.05	6.73	116.70	48.62
PL 42	75.25	6.17	1.41	5.93	6.25	141.30	50.18
PL 43	49.67	7.83	3.58	5.76	5.16	131.30	45.23
PL 44	82.48	6.50	1.33	4.88	6.31	148.80	48.10
PL 47	60.00	5.33	Nil	6.21	7.08	143.30	45.23
PL 49	79.28	4.67	3.13	6.81	6.93	127.20	48.50
PL 50	63.73	6.17	3.21	2.73	5.56	106.00	44.57
PL 51	70.10	3.17	2.35	5.08	5.95	66.33	39.58
PL 52	80.70	4.50	1.50	4.83	5.50	103.00	63.87
PL 53	49.15	1.33	1.00	1.11	1.86	31.83	39.93
Pl 54	39.67	1.00	1.33	2.21	3.01	21.67	25.98

PL 56	79.50	3.67	3.23	5.85	7.01	119.00	38.55
PL 57	61.15	3.00	2.00	3.03	6.91	47.00	42.30
PL 58	69.22	2.33	1.50	4.43	7.38	73.83	35.83
PL 69	79.12	3.83	2.16	5.10	7.08	73.17	34.30
CD (0.05)	6.61	2.34	1.74	0.78	0.59	46.64	3.860
CV (%)	9.13	40.37	56.51	15.04	8.01	39.08	7.42

Table 7: Days from planting to emergence and emergence of spike to maturity in long pepper accessions

Accessions	Days from planting to emergence	Days from emergence to maturity
Viswam	104	61
PL 2	114	60
PL 3	82	62
PL 4	79	66
PL 5	116	60
PL 8	113	63
PL 9	111	69
PL10	126	80
PL11	88	66
PL12	79	64
PL13	81	62
PL15	79	64
PL17	121	64
PL18	120	64
PL19	122	64
PL20	108	69
PL21	80	65
PL22	78	67
PL23	77	66
PL24	80	63
PL25	83	74
PL26	141	61
PL30	135	64
PL34	80	66
PL35	136	0
PL36	126	61
PL39	141	61
PL41	85	68
PL42	82	0
PL43	83	63
PL44	85	63
PL47	Non – flowering	Non – flowering
PL49	142	76
PL50	79	76
PL51	128	77
PL52	98	74
PL53	146	0
PL54	99	0
PL56	144	74
PL57	143	0
PL58	129	65
PL69	126	79

Table 8: Variability in yield characteristics among long pepper accessions

Accessions	No: of spikes/spike bearing branch	Spike length (cm)	Spike girth (mm)	Fresh wt/spike (g)	Dry wt/spike(g)	Fresh yield/ plant(g)	Dry yield/ plant (g)	Spike set (percent)	Driage (per cent)
Viswam	2.25	2.25	6.83	0.68	0.12	42.72	8.36	96.85	19.56
PL 2	1.70	2.70	4.40	0.76	0.14	11.66	2.12	77.77	18.18
PL 3	1.68	1.68	6.30	0.52	0.09	10.10	1.89	71.76	18.71
PL 4	1.91	2.41	5.06	0.83	0.13	24.20	4.11	90.98	16.98
PL 5	2.08	2.16	6.08	1.05	0.19	26.56	4.88	92.64	18.37
PL 8	3.21	3.10	8.86	1.06	0.15	58.32	9.20	97.42	15.77
PL 9	3.21	2.93	7.88	1.00	0.16	50.61	8.59	97.21	16.97
PL 10	1.00	2.38	3.98	0.54	0.10	1.01	0.19	80	18.81
PL 11	1.91	1.60	6.80	0.50	0.09	9.45	1.78	92.70	18.83
PL 12	1.15	2.38	5.16	1.03	0.20	16.79	3.21	90.90	19.11
PL 13	1.03	2.15	4.05	0.47	0.08	0.63	0.10	66.66	15.87
PL 15	2.33	2.86	5.10	0.96	0.17	29.19	5.28	96.05	18.08
PL 17	1.05	1.93	5.21	0.84	0.16	14.32	2.03	94.11	14.17
PL 18	1.25	2.43	6.61	0.49	0.09	1.45	0.24	72.22	16.55
PL 19	1.16	2.65	3.75	0.79	0.15	0.43	0.05	33.33	11.62
PL 20	1.60	2.03	7.38	0.80	0.15	10.42	2.15	82.11	20.63
PL 21	1.48	2.10	6.93	0.50	0.08	19.74	3.95	95.92	20.01
PL 22	1.66	2.00	6.86	0.54	0.10	14.40	2.73	90.51	18.95

PL 23	1.11	2.90	5.43	0.60	0.09	32.68	4.67	96.72	14.29
PL 24	1.66	2.20	6.61	0.52	0.10	27.26	4.82	93.89	17.68
PL 25	1.40	2.01	6.65	0.68	0.11	29.43	4.75	95.14	16.14
*PL 26	1.50	8.10	4.03	-	-	-	-	-	-
*PL 30	1.66	8.10	4.00	-	-	-	-	-	-
PL 34	1.01	2.78	6.11	0.73	0.14	5.28	1.08	77.27	20.45
PL 35	1.21	0.00	0.00	0.00	0.00	0.00	0.00	0	0
PL 36	1.33	2.63	7.05	0.64	0.12	3.33	0.68	85.71	20.42
*PL 39	1.66	8.18	4.03	-	-	-	-	-	-
PL 41	1.08	2.16	4.51	0.80	0.15	0.29	0.05	25	17.24
PL 42	1.41	0.00	0.00	0.00	0.00	0.00	0.00	0	0
PL 43	1.23	2.61	3.93	0.59	0.10	6.53	1.26	89.33	19.29
PL 44	1.50	2.15	6.55	0.59	0.11	0.53	0.08	45.45	15.09
*PL 47	-	-	-	-	-	-	-	-	-
PL 49	1.25	2.73	5.66	0.69	0.13	3.05	0.63	78.26	20.66
PL 50	1.23	2.58	6.33	0.62	0.11	13.91	2.67	95.92	19.19
PL 51	2.21	2.11	6.00	0.84	0.16	9.68	1.73	95.65	17.87
PL 52	2.21	2.13	7.33	0.79	0.15	2.64	0.51	72.00	19.31
PL 53	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0

PL 54	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0	0
PL 56	1.33	0.90	6.00	0.81	0.16	1.45	0.290	55.55	20
PL 57	1.16	0.00	0.00	0.00	0.00	0.00	0.00	0	0
PL 58	2.25	2.51	7.38	0.98	0.19	1.80	0.27	66.66	15
PL 69	1.66	1.46	6.40	0.46	0.08	0.33	0.058	41.66	17.57
CD (0.05)	0.97	0.21	0.39	0.09	0.02	15.94	2.75		
CV (per cent)	54.81	7.87	6.83	14.13	16.78	122.45	120.44		

*PL 26, PL 30 and PL 39 were male accessions

*PL 47 was non flowering type

4.2.4 Biochemical characters

1. Volatile oil

The volatile oil content of 20 accessions of long pepper were estimated (Table 9). The accession PL8 and PL 12 recorded maximum oil content of 1.60 per cent. Check variety Viswam recorded an oil content of 1.50 per cent. Accessions PL9, PL 17 and PL 50 recorded 1.00 per cent oil content. Minimum percentage of oil was recorded in PL3, PL 4, PL 11 and PL 20 (0.50 per cent). Volatile oil content in accessions ranged from 0.50 per cent to 1.60 per cent.

2. Oleoresin content

The oleoresin content of 30 accessions were recorded and presented in Table 9. The maximum content was recorded in PL 5 (20.21 per cent) compared with check variety (14.21 per cent) and minimum oleoresin content was recorded in PL 43 (3.21 per cent). Oleoresin content among accessions ranged from 3.21 percent to 20.21 percent.

3. Piperine content

The piperine content of 33 accessions are tabulated in Table 9. The maximum piperine content was recorded in PL 50 (1.10 per cent). The accessions PL 2 recorded a piperine content of 1.08 per cent. Minimum content was recorded in PL 4 (0.24 per cent). Check variety Viswam recorded 0.79 per cent piperine content. Piperine content among accessions ranged from 0.24 per cent to 1.10 per cent.

4.2.5 Comparison of quantitative and biochemical attributes of promising accessions along with check variety

Quantitative and biochemical attributes of promising accessions were carried out along with check variety and were presented in Table 10. From the table it was observed that the accessions PL 8 and PL 9 having highest value in the case of spikes per spike bearing branch, spike length, spike girth, fresh and dry yield per plant and spike set.

Table 9. Variability in biochemical characteristics among long pepper accessions

Accessions	Volatile oil content (per cent)	Oleoresin content (per cent)	Piperine content (per cent)
PL 1 (Viswam)	1.50	14.21	0.79
PL 2	0.60	18.00	1.08
PL 3	0.50	17.00	0.56
PL 4	0.50	10.70	0.24
PL 5	0.80	20.21	0.61
PL 8	1.60	9.72	0.85
PL 9	1.00	9.00	0.76
PL 10	-	10.20	0.90
PL 11	0.50	11.71	0.97
PL 12	1.60	20.00	0.87
PL 13	-	-	0.40
PL 15	1.32	11.20	0.96
PL 17	1.00	11.00	0.47
PL 18	-	-	0.70
PL 19	-	-	0.34
PL 20	0.50	9.22	1.01
PL 21	0.71	13.70	0.65
PL 22	1.20	15.20	0.68
PL 23	0.80	10.71	0.73
PL 24	0.80	9.50	0.92
PL 25	0.50	19.70	0.78
*PL 26	-	-	-
*PL 30	-	-	-
PL 34	-	14.70	0.82
PL 35	-	-	-
PL 36	-	12	0.75
*PL 39	-	-	-
PL 41	-	5.71	0.58
PL 42	-	-	-
PL 43	1.22	3.21	0.30
PL 44	-	4.70	0.98
*PL 47	-	-	-
PL 49	-	5.50	0.69
PL 50	1.00	11.51	1.10
PL 51	0.60	20.00	0.73
PL 52	-	10.52	0.30
PL 53	-	-	-
PL 54	-	-	-
PL 56	-	12.00	0.32
PL 57	-	-	-
PL 58	-	10.70	0.47
PL 69	-	15.50	0.53

*PL 26, PL 30 and PL 39 were male accessions , PL 47 was non flowering type

Table 10. Quantitative and biochemical attributes of promising accessions along with check variety (Viswam)

Characters	Viswam	PL 5	PL 8	PL 9	PL 15	PL 23	PL 24	PL 25
Spikes/spike bearing branch	2.25	2.08	3.21	3.21	2.33	1.11	1.66	1.40
Spike length (cm)	2.25	2.16	3.10	2.93	2.86	2.90	2.20	2.01
Spike girth (mm)	6.83	6.08	8.86	7.88	5.10	5.43	6.61	6.65
Fresh wt/spike (g)	0.68	1.05	1.06	1.00	0.96	0.60	0.52	0.68
Dry wt/ spike (g)	0.12	0.19	0.15	0.16	0.17	0.09	0.10	0.11
Fresh yield/plant (g)	42.72	26.56	58.32	50.61	29.19	32.68	27.26	29.43
Dry yield/plant (g)	8.36	4.88	9.20	8.59	5.28	4.67	4.82	4.75
Spike set (per cent)	96.85	92.64	97.42	97.21	96.05	96.72	93.89	95.14
Driage (per cent)	19.56	18.37	15.77	16.97	18.08	14.29	17.68	16.14
Oil (per cent)	1.50	0.80	1.60	1.00	1.32	0.80	0.80	0.50
Oleoresin (per cent)	14.21	20.21	9.72	9.00	11.20	10.71	9.50	19.70
Piperine (per cent)	0.79	0.61	0.85	0.76	0.96	0.73	0.92	0.78

4.2.6. Cluster analysis based on quantitative characters

Cluster analysis on quantitative data of 20 accessions was subjected to Multivariate Hierrarchial Cluster Analysis using NTSYS. The accessions showed only 14 per cent similarity. Among them PL 4, PL 11 PL 17 and PL 51 showed 100 per cent similarity. Since high variability was seen among accessions they can be utilized in future breeding programmes (Fig.3).

4.2.7 Problems observed in the field

Major problems noticed in the field were yellowing during February, March, might be due to low nutrient content and the presence of root knot nematode. Applied 2g/litre of pseudomonas and micro-rich at the rate of one teaspoon per plant controlled yellowing. Mealy bug attack during September – October month were prevented by using ekalux 2ml/litre.

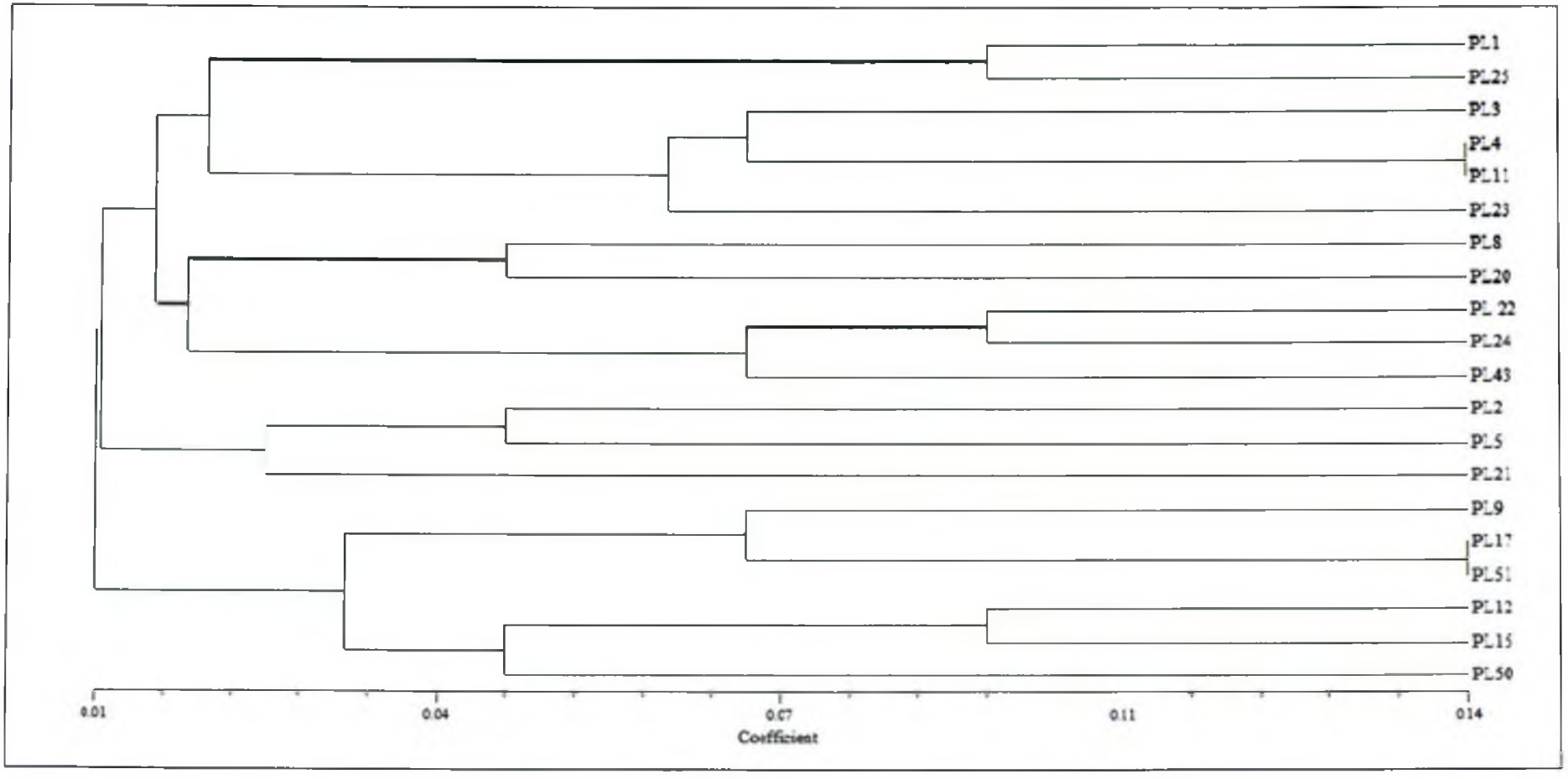


Fig 3. Dendrogram based on quantitative characters of 20 accessions

Common- for female types

PL 52

PL 53

Male type

Plate 15. Developmental stages of spikes in long pepper accessions

Viswam

PL 5

PL 8

PL 9

Plate 16 a. Promising accessions in long pepper

PL 15

PL 23

PL 24

PL 25

Plate 16 b. Promising accessions in long pepper

Yellowing

Mealy bug attack

Plate 17. Yellowing and mealy bug attack in the plot

Discussion

5. DISCUSSION

Piper longum is a slender and aromatic perennial creeping shrub, spreading on the ground, rooting at the node and have numerous wide, ovate, cordate leaves. It creeps over the surface but does not climb on the trees as in black pepper or other wild peppers. It has distinct dimorphic branching habit with orthotropic and plagiotropic branches and produce simple and alternate leaves which are variable in size and shape. *Piper longum* is reported to be dioecious with male and female spikes seen in different plants. Male spikes are much longer than female spikes.

Long pepper is indigenous to South Asian countries and The Western Ghats, one of the two hot spots of biodiversity in India represents wide variability in the crop. Long pepper is well adapted for cultivation as an intercrop in coconut, arecanut and rubber plantations of Kerala. It's cultivation is limited due to poor returns from the crop on account of high expenditure on harvesting due to staggered flowering and lack of high yielding varieties with high dry recovery. The only improved variety released is a clonal selection, Viswam in 1996. Being a semi domesticated crop, collection of diverse germplasm and selection appears to be the first and foremost method for developing high yielding varieties which suit to different agro-climatic conditions and cropping systems. This investigation was taken up with an objective to evaluate the forty two accessions of long pepper including check variety 'Viswam' assembled at the Department of Plantation Crops and Spices, COH, Vellanikkara for their vegetative characters, flowering behavior, fruit set, yield and quality. The results obtained are briefly discussed in this chapter.

5.1 Genetic cataloguing in *Piper longum*

Forty one accessions collected from different locations along with check variety 'Viswam' were catalogued based on IPGRI descriptor for *Piper nigrum*. Variations were observed among different accessions of *Piper longum*. Most of the accessions

included in the study are having erect, trailing and dimorphic branching habit with few to many runner shoot production. Stems were pubescent and lamina shape was cordate and ovate lanceolate.

Spike shape varied from cylindrical to filiform with glabrous texture. In PL 52, PL 57 and PL 58 spikes had hirtellous texture. Immature spike colour was yellow and when mature were green or black in female accessions. In male accessions, spike colour was green during immature stage and yellow during maturity. In accession PL 52, spikes had pure white colour at immature stage and at maturity it changed to green. PL 53 have short spikes which were green during all the stages.

5.2 Variability among qualitative characters

In the present study significant differences was noticed among the accessions for the qualitative characters such as leaf shape, leaf colour, nature of spike apex, colour of mature and immature spike, year round observation on flowering and anthesis (anther dehiscence and stigma receptivity).

Accessions included in the study had a leaf base of cordate shape except PL 8, PL12, PL13, PL 30, PL 42, PL 50 and PL 56 had round shape. Leaf margins were wavy except the accessions PL 52 and PL 53 which had entire leaf margin. Leaf lamina shape was recorded as cordate, ovate lanceolate and reported acrodromous types of veining.These types of variations may be due to the genotypic characters of accessions.

These findings were supported by CSIR report (1998), Chatterjee and Pakrashi (1997), Ravindran and Balachandran (2005) and Chandran (2012).

Immature and mature stages of both male and female spikes were identified due to colour change. Colour change was noticed from green to yellow in male accessions and from light yellow to green or black in female accessions. Pure white coloured inflorescence at immature stage was a special character of accession PL 52. Green in

all stages is a character for accession PL 53. This might be due to genotypic characters of particular accessions.

Similar colour changes with maturity of spike was also reported by Kanimozhi, 2010 ; Kumar, 1998 ; Joseph, 2008 and Chandran, 2012 in long pepper.

In the present study, out of 42 accessions, 38 accessions were female, three male and one non – flowering type (PL 47) were observed during the study. Observations based on mean number of inflorescence produced per accession per month from April 2013 – March 2014 indicated that maximum production of inflorescence were observed during June, July and August in all the male and female accessions. 100 percent flowering in accessions PL 42, PL 53, PL 57 were extended during May to October. This may be the character of particular accession or may be due to the effect of geographic location from where it is collected.. Kanimozhi (2010) and Kumar (1998) supported results of the present study who reported that the maximum flowering season in *Piper longum* accessions as May – July and July – August respectively.

Flower opening time in both male and female inflorescence and the mean number of inflorescence opened per month in each accession were recorded. Flower opening were started from 7.30 am and continued upto 4.30 pm in all the accessions. Opening of flowers in an inflorescence was completed within seventh to eighth day in both male and female accessions.

In female accessions, peak time of flower opening was observed between 10.30 am to 12.30 pm from bottom to top portion of the inflorescence and observed abundantly from second to seventh day. It remains white for two days after opening of flowers. After 3rd or 4th day of flower opening, colour of stigmatic lobe changed to brown at around 12.00 pm to 1.00 pm indicating the end of stigmatic receptivity.

In the case of male accessions, both flower opening and anther dehiscence took place from bottom to top portion of spike and peak time of anther dehiscence was from 10.30 am to 12.30 pm. Maximum flower opening was noticed in 3rd and 4th day in male accessions, while anther dehiscence took place profusely during second to fourth day. The white two lobed anthers were changed to black indicating the end of anther dehiscence.

Anthesis and anther dehiscence in accessions might be greatly influenced by temperature, relative humidity and sunshine. Earlier report of Kanimozhi (2010) on anthesis is in agreement with present result. Martin and Gregory (1962) also supported the results by explaining about the control of temperature and relative humidity towards anther dehiscence in Piperaceae.

5.3 Variability in quantitative characters

During maximum vegetative phase, mean number of primary branches ranged from 1.00 to 8.00, plant height ranged from 39.67 cm to 88.33cm, number of spike bearing branches per primary branch ranged from 1.00 to 6.71, leaf area from 25.98 cm^2 to 63.87 cm^2, petiole length from 1.11 cm to 7.56 cm, internodal length of spike bearing branches from 1.86 cm to 7.38 cm and mean number of leaves from 21.67 to 166.0. Significant differences among accessions might be due to genetic characters or environmental conditions. Number of spike bearing branches per primary branch in promising accessions were represented in Fig.4.

Variation in characters among different accessions was supported by the comparative evaluation study of five selected types of *Piper longum* by Manuel (1994). Results of the present study are also in agreement with the variability studied by Jaleel (2006) and Chandran (2012).

Number of days from planting to emergence of spike and emergence to maturity varied among accessions. Number of days from planting to emergence

ranged from 77 to 146 days and for emergence to maturity from 60 to 80 days in female accessions. For spike initiation, male accessions took maximum of 141 days and minimum of 135 days and to reach maturity male accessions took maximum of 64 days and minimum of 61 days. These type of variability for emergence and maturity of spike was also reported by Jaleel (2006) [Female : 178 days, male : 132 days for spike initiation; Female : 69.6 days, Male : 56 days for spike maturity] and Suma *et al.*, (2012) (66 – 97 days from emergence to maturity of spikes).

Length and girth of female spikes showed wide variation among accessions, but for male spikes variation was less and between male and female accessions wide variation was observed. In female accessions, length of spikes varied from 0.90 cm to 3.10 cm and girth ranged from 3.75 mm to 8.86 mm. In the case of male accessions spike length varied from 8.10 cm to 8.18 cm, spike girth varied from 4 mm to 4.03 mm. The study revealed that female spikes were shorter than male spikes, but in the case of girth, female spikes were broader than male spikes (Fig 6).

Observations on relative size of female and male spikes are in agreement with Jaleel (2006) [length of female spikes: 2.4 cm – 4.23 cm ; male spikes : 7.51 cm – 7.55 cm] and Manuel (1994) [spike length : 4.00 – 4.33 cm].

Among accessions, spike set ranged from 25 per cent to 97.42 per cent among female accessions. Per cent of spike set and mean number of inflorescence of promising accessions shown in Fig. 9&10. It was noticed that mean number of inflorescence produced has no direct effect on per cent spike set, probably due to the fact that all the inflorescence produced didn't reach up to maturity in all accessions.

Among accessions, number of spikes per spike bearing branch ranged from 1.00 to 3.21, fresh weight per spike ranges from 0.46 g to 1.06 g, dry weight per spike ranges from 0.08 g to 0.20 g ,fresh yield per plant ranges from 0.29 g to 58.32 g, dry yield from 0.05g to 9.20 g and driage from 11.62 per cent to 20.66 per cent. The number of

spikes per spike bearing branch, fresh weight and dry weight per spike, fresh and dry yield per plant and driage of promising accesiions were represented in Fig.5,7&8, respectively . Observations revealed that, higher yield was observed in accession PL 8 and PL 9 and these two accessions also had maximum number of spike bearing branches per primary branch, maximum number of spikes per spike bearing branch, spike length and girth, fresh and dry yield per plant. Also showed negative correlation of yield with petiole length, leaf area and number of leaves per hill.

These observations were greatly supported by correlation studies on yield and quantitative characters in *Piper longum* accessions. Manual (1994) reported that number of spikes per spike bearing branch, number of spike bearing branches per stem and yield of green spike were the most important characters influencing dry spike yield. Correlation of above characters with yield has also been reported by Suma *et al.* (2012) in *Piper longum* and also found negative association of yield per plant with petiole length and leaf area. Same correlation of yield with above *Piper nigrum* was also reported by Nair *et al.* (1984).

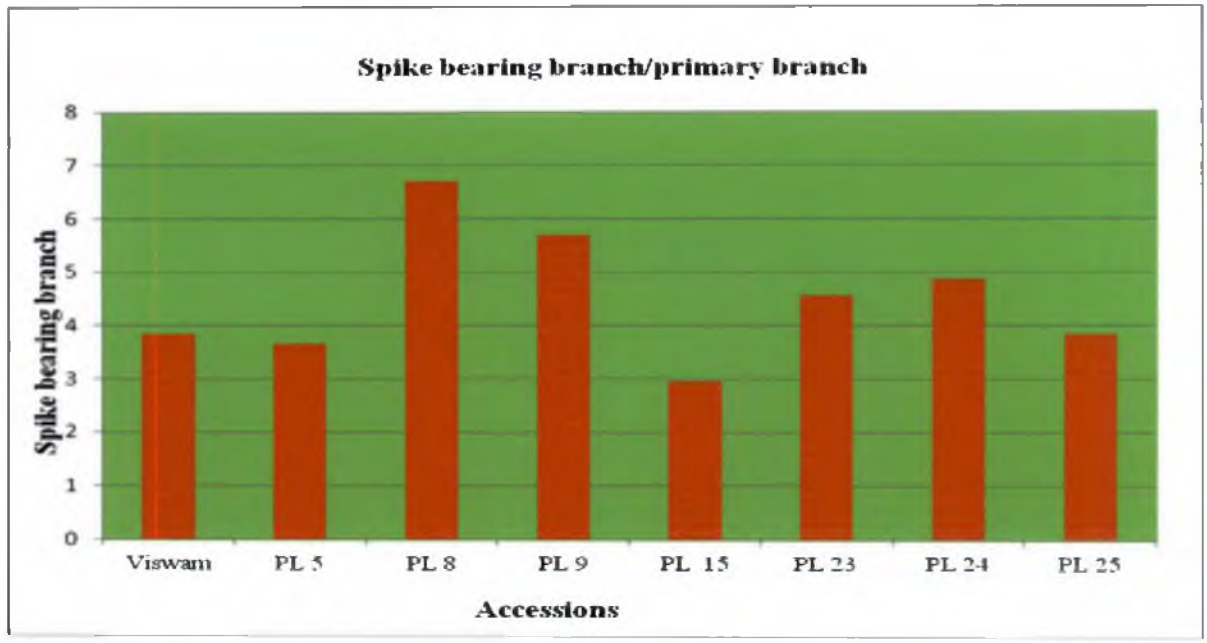


Fig. 4. Number of spike bearing branches per primary branch in promising accessions of long pepper

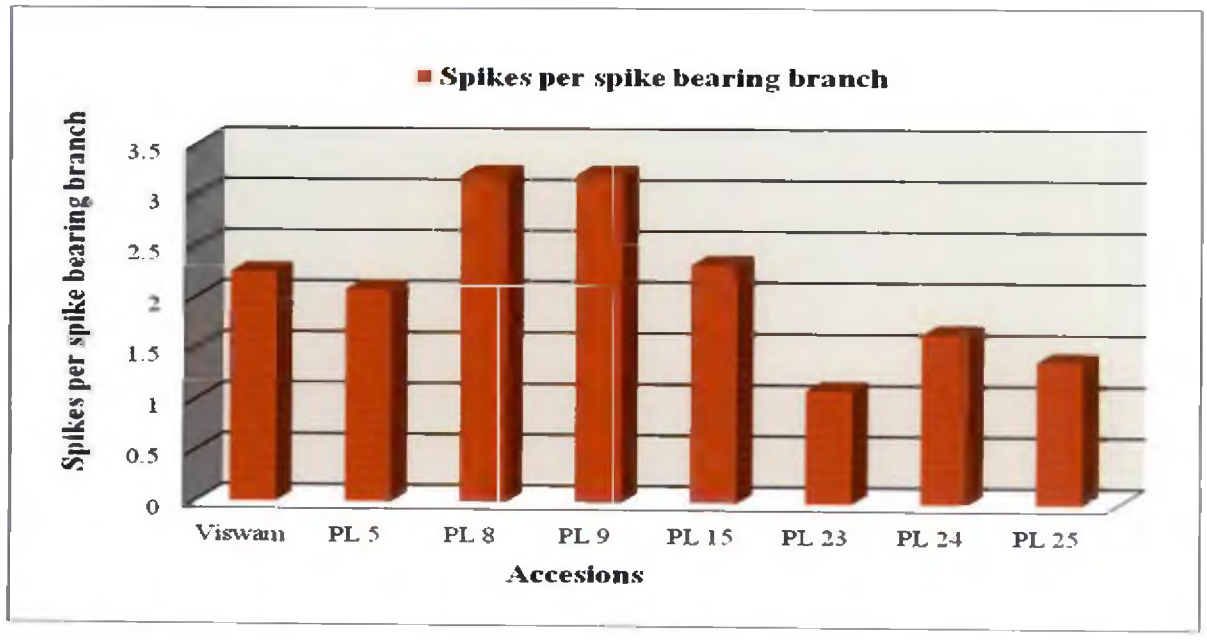


Fig. 5.Number of spikes per spike bearing branches in promising accessions of long pepper

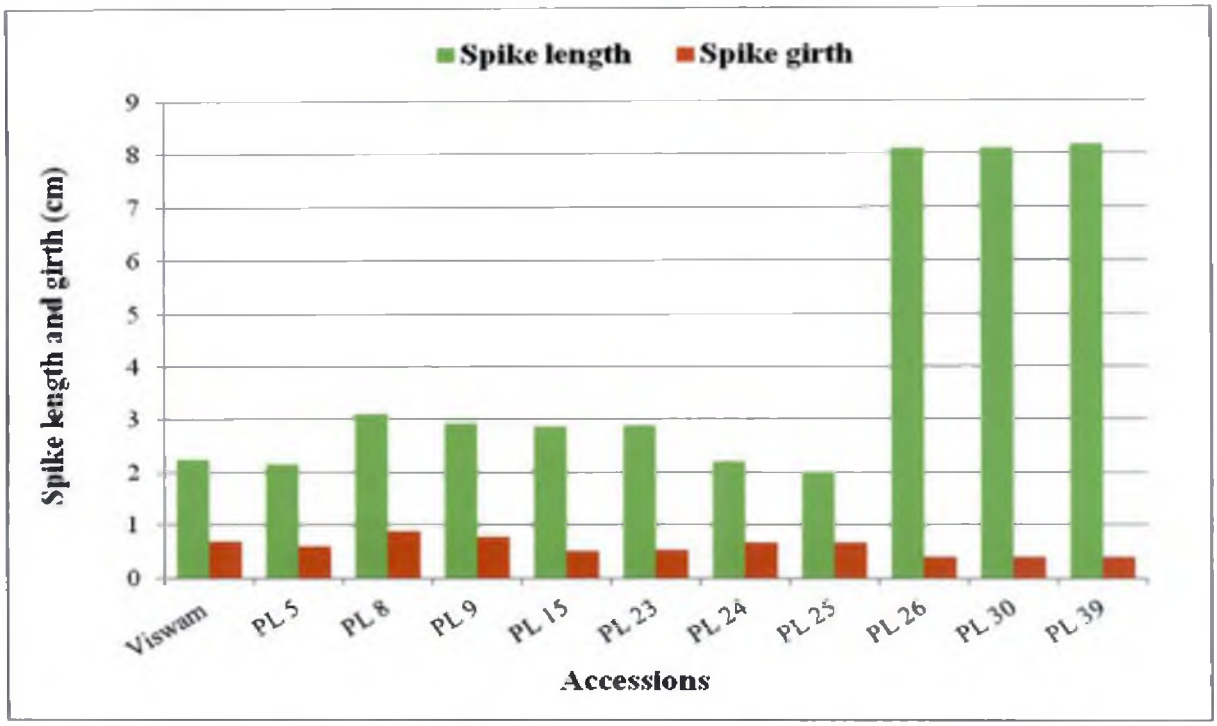


Fig.6. Spike length and girth of promising female and male accessions of long pepper

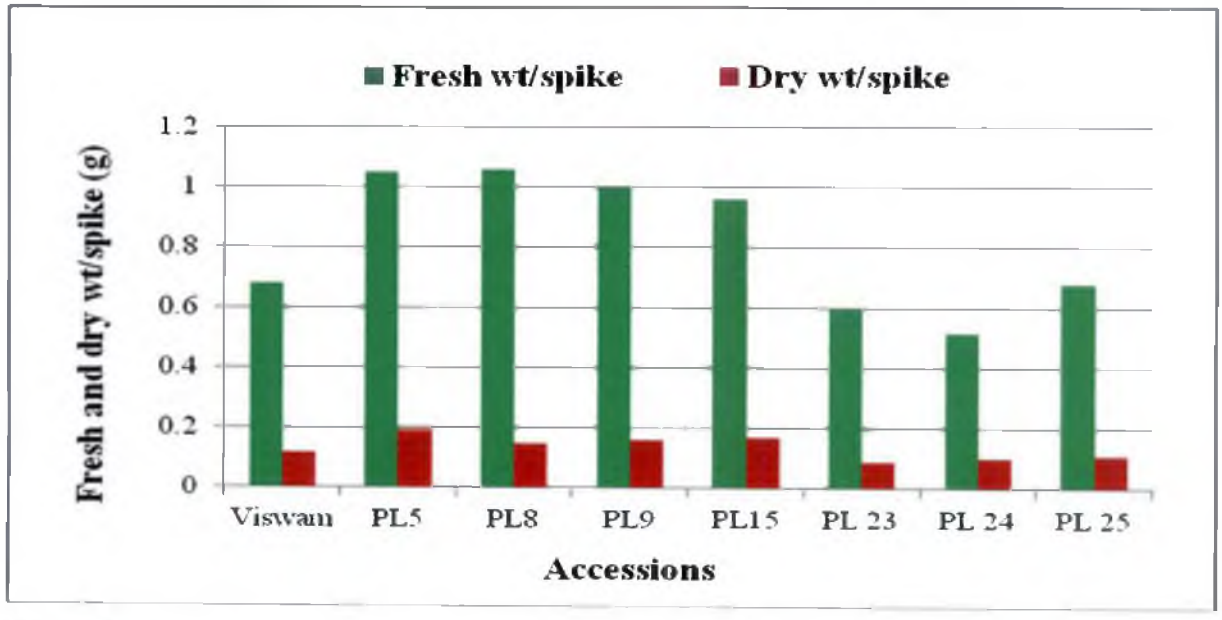


Fig.7. Fresh and dry weight per spike of promising accessions of long pepper

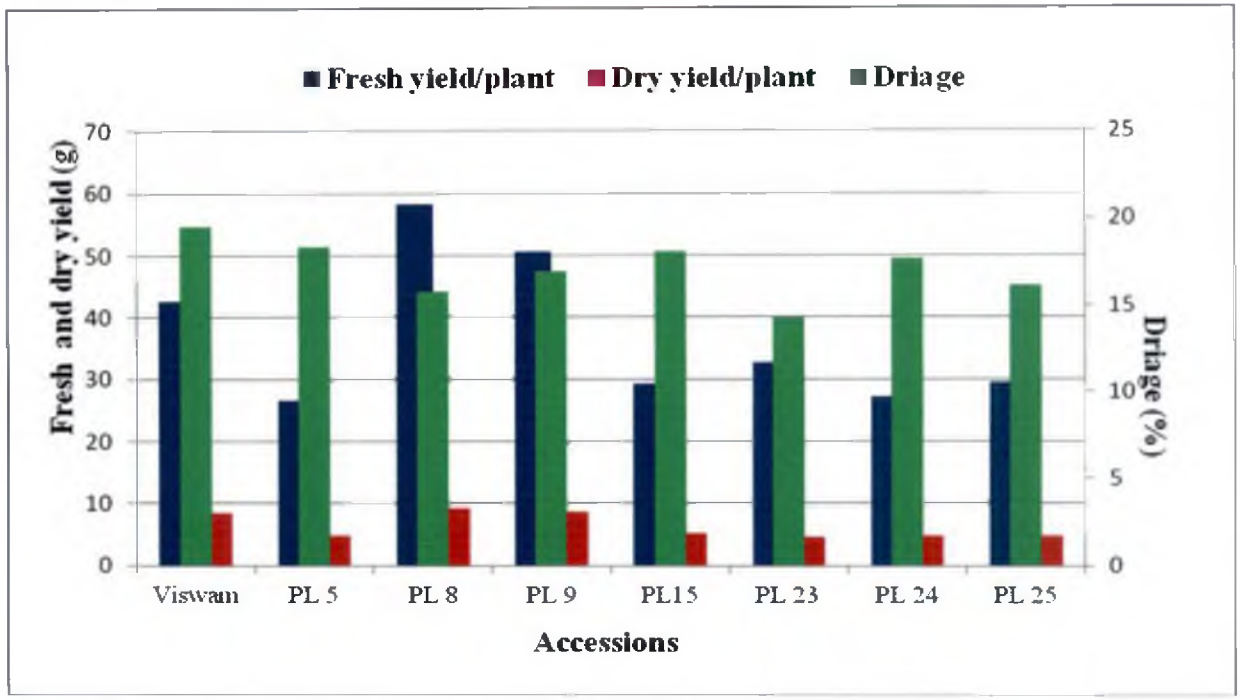


Fig 8. Fresh and dry yield per plant and driage of promising accessions of long pepper

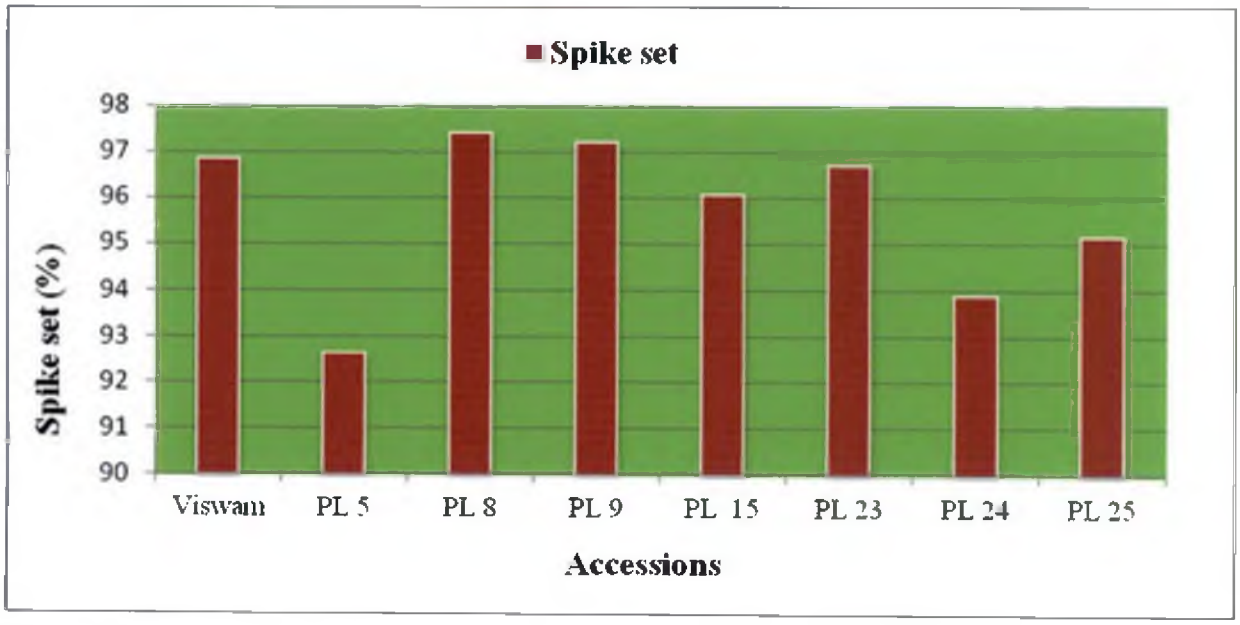


Fig 9. Spike set in promising accessions of long pepper

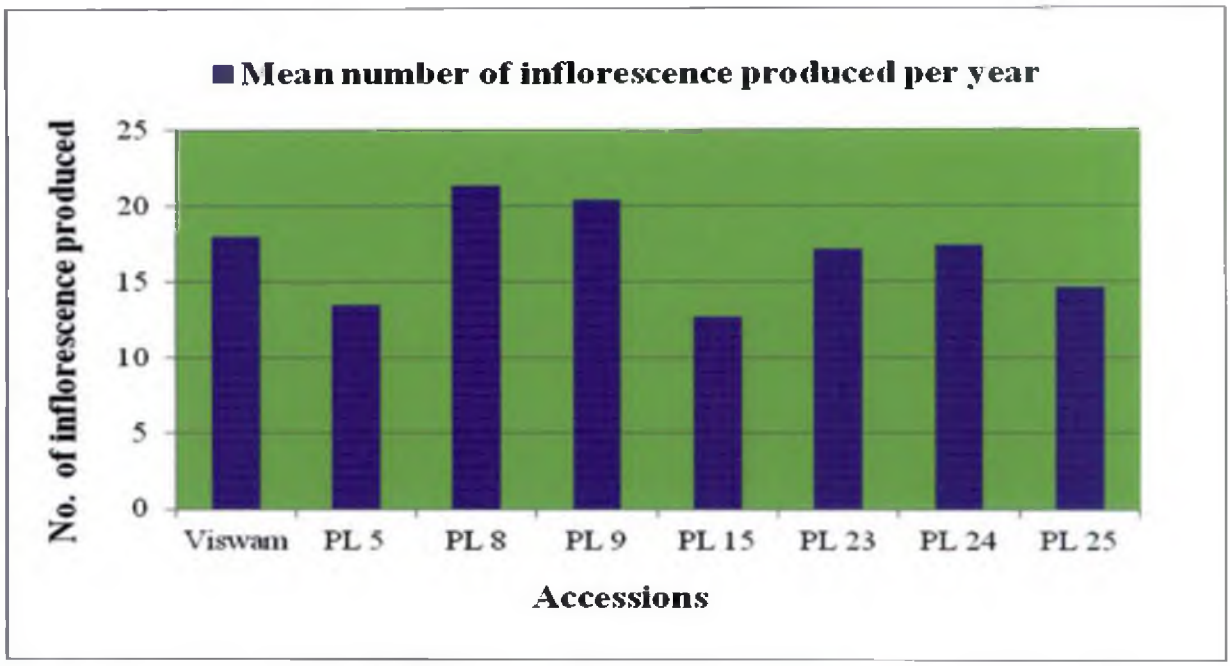


Fig 10. Mean number of inflorescence produced in promising accessions of long pepper

5.4 Biochemical attributes

The accessions showed wide variation for the qualitative parameters such as volatile oil, oleoresin and piperine contents. Oleoresin content varied from 3.21 per cent to 20.21 percent, the highest value being with PL 5 and lowest being with PL 43. Such kind of variation in oleoresin content due to genotypes was also observed by Chandran (2012). Volatile oil content showed variation which ranging from 0.50 per cent to 1.60 per cent. The lowest content was in PL 3, PL 11 and PL 20 and highest content in PL 8 and PL 12. Piperine, the pungent principle of long pepper was found to vary from 0.24 per cent to 1.10 per cent. The lowest piperine content was obtained with PL 4 and highest with PL 50. Similar variations for oil and piperine contents were also reported by Manuel (1994), Sawangjaroen *et al*, (2004), Ravindran and Balachandran (2005) and Jaleel (2006) in *Piper longum* accessions. The variation observed in the piperine content of genotypes could probably be due to the presence of gene modifying factors for pungency (Sreelathakumary, 2000). Varietal variation in pungency was reported by Anu *et al* (2002), in paprika and paprika alike chillies, Manju and Sreelathakumary (2002) and by Kumar *et al*, (2012) in chillies. The oil, oleoresin and piperine content in promising accessions were shown in Fig. 11,12 & 13.

5.5 Cluster analysis

Cluster analysis among 42 accessions based on qualitative characters and 20 accessions based on quantitative characters were done by using NTSYS software.

Observed that the pattern of distribution of genotypes into different clusters was at random based on qualitative characters. Genotypes belonging to same geographic origin were included in different clusters. Differences in genetic constitution and presence of unabated influence of environmental factors might be responsible for this type of clustering pattern (Rahman *et al*., 1997). In addition, the clustering pattern in the present study indicated that genetic diversity was not necessarily related to

geographical distribution. This might be due to the free exchange of propagating materials from one place to another. This was also reported by Rahman *et al*, (1997).

Based on quantitative characters among 20 accessions, whose all the quantitative observations were taken and dendrogram were constructed. They showed only 14 per cent similarity and the germplasm collections are highly variable with respect to the various quantitative characters.

5.6 Selection parameters

Selection of accessions can be based mainly on yield contributing characters like spike length, spike girth, fresh weight per spike, dry weight per spike, fresh yield per plant, dry yield per plant, driage per plant, spike set and biochemical characters like oil, oleoresin and piperine content. The accessions PL 5, PL 8, PL 9 PL 15, PL 23, PL 24 and PL 25 were found to be promising types along with check variety can carried forward to advanced variety trials. Considering the biochemical aspects alone, like volatile oil, oleoresin and piperine content accessions PL 8, PL 12, PL 5, PL 50 along with check variety were found to be promising.

Cluster analysis, based on qualitative and quantitaive characters the accessions showed wide variability and can be utilized in future breeding programmes

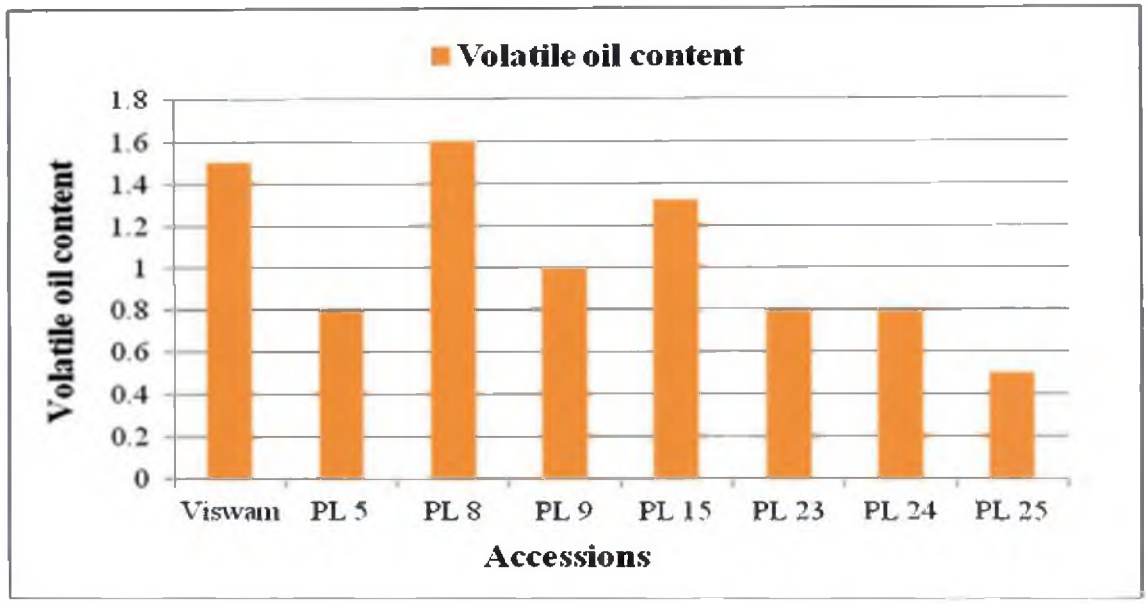


Fig 11. Volatile oil content of promising accessions of long pepper

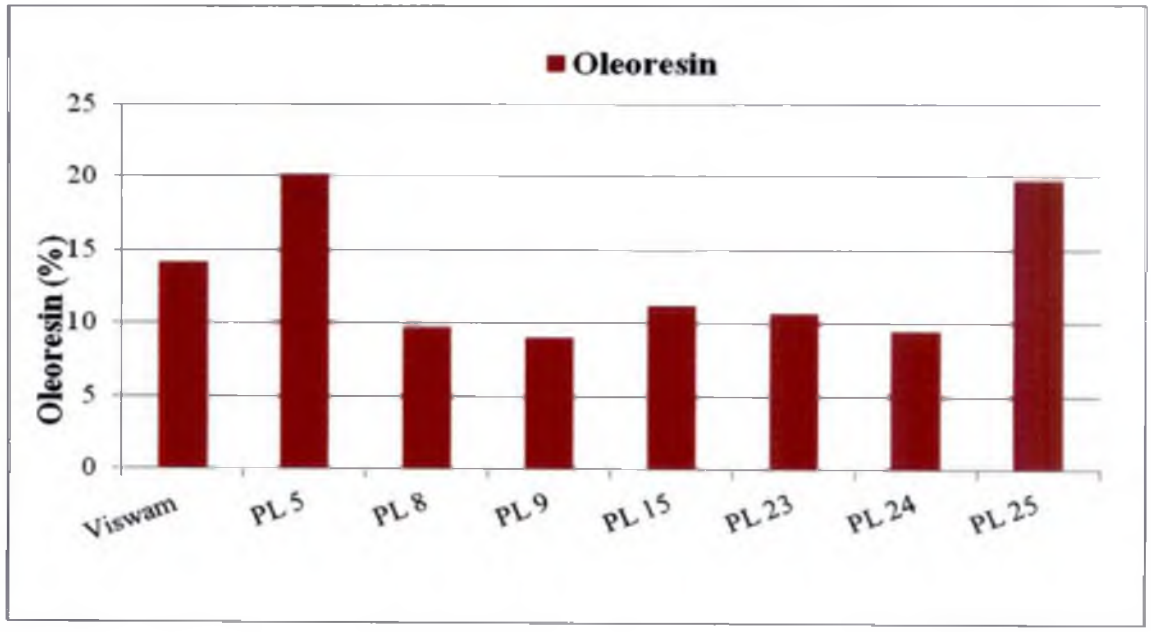


Fig 12. Oleoresin content of promising accessions of long pepper

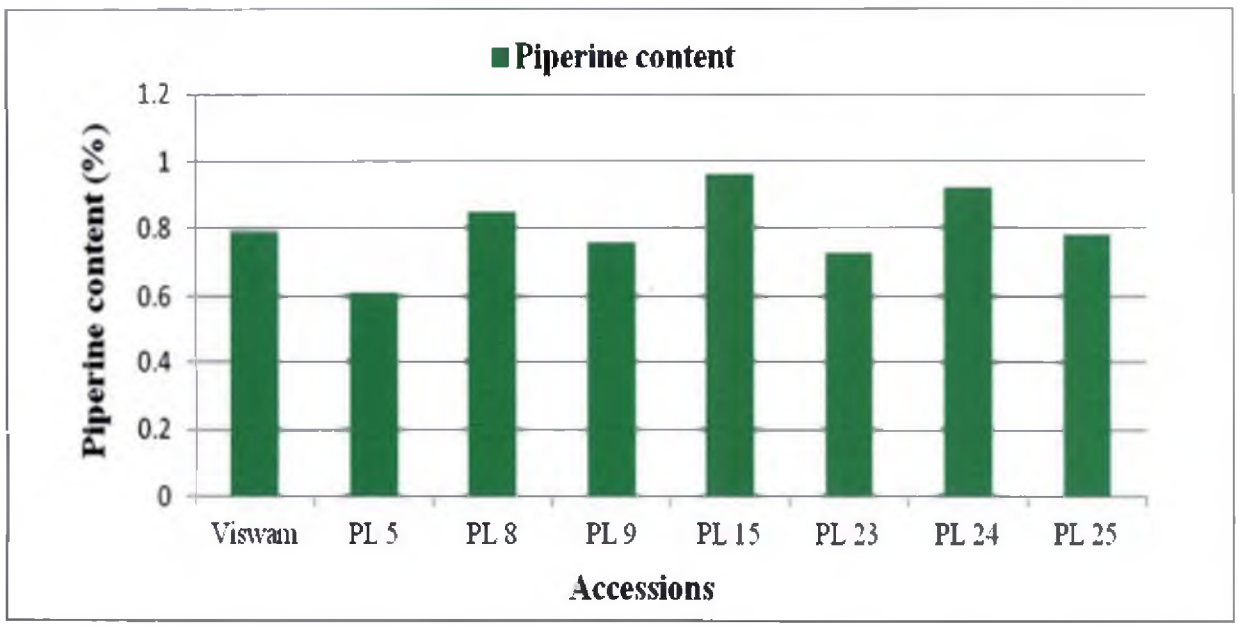


Fig 13. Piperine content of promising accessions of long pepper

Future line of work

- The superior accessions PL 5, PL 8, PL 9, PL 15, PL 23, PL 24 and PL 25 along with check variety identified from the study need to be evaluated under field situations to study the stability in performance.

- Based on cluster analysis on quantitative data, accessions showed wide variability and could be utilized as parental lines in future breeding programmes.

Summary

6. SUMMARY

The present study entitled "Evaluation of long pepper (*Piper longum* L.) genotypes for growth, flowering and yield" was carried out at the Department of Plantation Crops and Spices at College of Horticulture, Vellanikkara during the period December 2012 to May 2014. Forty one genotypes gathered from various sources along with check variety Viswam were evaluated for their growth, flowering, yield and quality. Out of forty two genotypes, thirty eight were females, three males and one non - flowering type during present study. Salient findings of the study are summarized below.

1. The forty two accessions were catalogued for qualitative characters using the IPGRI descriptor for *Piper nigrum* and variation was observed among different accessions of *Piper longum*. Most of the accessions included in the study showed erect, trailing and dimorphic branching habit. Stems were pubescent and lamina shape was cordate and ovate lanceolate.

2. The shape of leaf base was cordate in all the accessions except PL8, PL12, PL 13, PL30, PL42, PL50 and PL56 which possessed round leaf base shape. Leaf lamina shape was observed as cordate, ovate lanceolate and venation was acrodromous. Leaf margins were wavy except in accessions PL 52 and PL 53 which had entire leaf margin.

3. Irrespective of the accessions immature leaves were light green and mature leaves were dark green coloured leaves.

4. Spike shape was found to vary from cylindrical to filiform with predominantly glabrous texture. Accessions PL 52, PL 57 and PL 58 had hirtellous textured spikes.

5. Immature spike colour was found to be yellow and on maturity the colour turned to green or black in female accessions. In male accessions, spike colour was green during immature stage and yellow during mature stage. In accession PL 52 spikes having pure white colour at immature stage and green colour during mature stage. Spike was filiform in male accessions and cylindrical in female accessions.

6. Significant variation was noticed for quantitative characters in 42 accessions. During maximum vegetative phase, mean number of primary branches ranged from 1.00 to 8.00, plant height from 39.67 cm to 88.33cm, number of spike bearing branches per primary branch from 1.00 to 6.71, leaf area from 25.98 cm^2 to 63.87 cm^2, petiole length from 1.11 cm to 7.56 cm, internodal length of spike bearing branches from 1.86 cm to 7.38 cm and mean number of leaves from 21.67 to 166.0 respectively.

7. The days from planting to emergence of spikes ranged from 77 to 146 days and for emergence to maturity ranged from 60 to 80 days in female accessions. For spike emergence, male accessions took 135 – 141 days and to reach maturity it took 61- 64 days.

8. Variations were observed among accessions for length and girth of spikes. Length of spikes varied from 0.90 cm to 3.10 cm and girth ranged from 3.75 mm to 8.86 mm in female accessions. In the case of male accessions spike length varied from 8.10 cm to 8.18 cm and girth varied from 4mm to 4.03 mm respectively.

9. Monthly observations of flowering for a period of one year indicate that maximum production of inflorescence were observed during June, July and August in all the male and female accessions. Production of inflorescence was noticed highest per cent during July in all the accessions. PL 47 was found to be non – flowering type during the study.

10. Flower opening in both male and female inflorescence were started from 7.30 am and continued up to 4.30 pm.

11. In female accessions, peak time of flowering was observed between 10.30 am to 12.30 pm. After 3rd or 4th day of flower opening, colour of stigmatic lobe changed to brown around 12.00 pm to 1.00 pm indicating the end of stigmatic receptivity.

12. Anther dehiscence also started from 7.30 am and continued up to 4.30 pm with a peak time period between 10.30 am to 12.30 pm. The white two lobed anthers were changed to green indicating the end of anther dehiscence.

13. It was noticed that mean number of inflorescence produced had no direct effect on spike set, since all the spikes were not carried to maturity in all accessions. Accessions PL 35, PL 42, PL 53 and PL 54 showed no spike set.

14. During May to October 100 per cent flowering extend was observed in PL 42, PL 53 and PL 57.

15. Higher yield was observed in accession PL 8 and PL 9 and these two accessions also exhibited maximum number of spike bearing branches per primary branch, maximum number of spikes per spike bearing branch, highest spike length and girth, fresh and dry spike yield per plant.

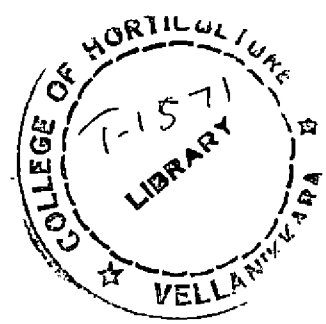
16. With respect to quality attributes, PL 5 was identified to be highest in oleoresin content, PL 8 and PL 12 in volatile oil content and PL 50 in piperine content.

17. With respect to selection based on yield contributing characters, revealed that accessions PL 5, PL 8, PL 9 PL 15, PL 23, PL 24 and PL 25 were promising types along with check variety.

18. Considering the quality aspects volatile oil, oleoresin and piperine content accessions PL 5, PL 8, PL 12 and PL 50 along with check variety were found to be promising.

19. Cluster analysis based on qualitative characters, accessions were grouped into seven clusters and based on quantitative characters, wide variability was shown between accessions.

20. Genotypes belonging to same geographic origin were included in different clusters. In addition, the clustering pattern in the present study indicated that genetic diversity was not necessarily related to geographical distribution.



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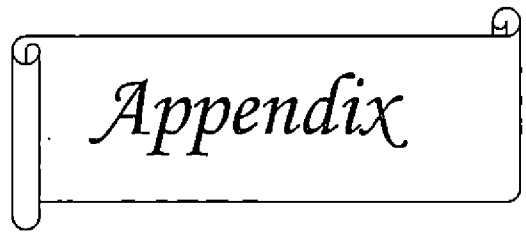
Appendix

Appendix I

Mean monthly parameters for crop growth

January 2013 – May 2014

Month	Mean max temp (^{0}c)	Mean min temp (^{0}c)	Mean RH (per cent)	Rainfall (mm)
Jan 2013	34.1	22.3	52	0.0
Feb 2013	34.7	23.3	57	84.4
Mar 2013	35.4	24.4	64	14.6
Apr 2013	34.9	25.1	71	0.0
May 2013	33.6	25.2	77	99.1
June 2013	28.5	22.7	90	1031.8
July 2013	28.4	22.7	91	932.3
Aug 2013	29.9	22.9	84	305.9
Sep 2013	30.0	22.2	85	344.1
Oct 2013	30.8	22.6	83	369.8
Nov 2013	32.6	23.9	73	82.0
Dec 2013	31.9	22.3	61	0.5
Jan 2014	32.9	23.0	51	0.0
Feb 2014	34.7	22.9	56	0.0
Mar 2014	36.7	24.2	55	0.0
Apr 2014	35.3	25.7	73	61.0
May 2014	33.2	24.2	77	323.6
Average	**32.8**	**23.50**	**70.5**	**214.6**

EVALUATION OF "LONG PEPPER" (*Piper longum* L.) GENOTYPES FOR GROWTH, FLOWERING AND YIELD

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ABSTRACT OF THE THESIS

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ABSTRACT

Long pepper (*Piper longum* L.) belonging to the family Piperaceae is one among the 14 medicinal plants which has high demand in indigenous drug industry and is also prioritized for cultivation and development by National Medicinal Plant Board. Even though long pepper is well adapted for cultivation as an intercrop in coconut, arecanut and rubber plantations of Kerala, its cultivation is limited due to poor returns from the crop on account of high expenditure on harvesting due to staggered flowering and lack of high yielding varieties with high dry recovery.

Germplasm collection of long pepper was initiated at the Department of Plantation Crops and Spices and was further strengthened by KSCSTE funded project and 60 types were assembled. After an initial evaluation, 42 types were selected including check variety 'Viswam' for the present study. The present investigations on "Evaluation of "long pepper" (*Piper longum* L.) genotypes for growth, flowering and yield" was carried out in Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara during December 2012 to May 2014. The objectives of the study were to catalogue the germplasm accessions of long pepper, to study the flowering behavior fruit set and quality and to identify superior long pepper genotypes with high yield and quality. The experiment was laid out in completely randomized design, comprised of 42 treatments and six replications.

The accessions studied were collected from Western Ghat regions of Kerala and also entries from NBPGR which includes the collections from different regions of Karnataka and Tirunelveli. Characters studied include six qualitative and eighteen quantitative characters including biochemical attributes. Cataloguing of accessions for qualitative characters using IPGRI descriptor for *Piper nigrum* revealed wide variation among accessions in growth habit, runner shoot production, leaf shape (base, lamina, margin), spike shape and spike colour.

Among the forty two accessions studied, it was noticed that thirty eight accessions were found to be female, three found to be male and one non-flowering type. Maximum inflorescence (more than 55 per cent) was produced during June, July and August and minimum (less than 5 per cent) during December and January. In PL 42, PL 53 and PL 57 flowering was extended during May to October. Coefficient of variation for year round flowering ranged from 7.34 per cent to 46.32 per cent.

Among accessions, number of primary branches, spike bearing branches per primary branch and leaves per plant ranged from 1.00 to 8.00, 1.00 to 6.71 and 21.67 to 166.0, respectively. The plant height, petiole length, internodal length of spike bearing branches and leaf area ranged from 39.67 cm to 88.33cm, 1.11 cm to 7.56 cm, 1.86 cm to 7.38 cm and 25.98 cm^2 to 63.87 cm^2, respectively. The days from planting to emergence and emergence to maturity of spike in female types ranged from 77 to 146 days and 60 to 80 days whereas, male accessions took 135-141 days and 61-64 days, respectively.

Number of spikes/spike bearing branch ranged from 1.00 to 3.21 and coefficient of variation observed were 54.81%. Spike length and girth varied from 0.90 cm to 3.10 cm and 3.75 mm to 8.86 mm in female accessions and male accessions from 8.10 cm to 8.18 cm, and 4mm to 4.03 mm respectively. Coefficient of variation for spike length and girth were 7.87 per cent and 6.83 per cent , respectively. Fresh weight per spike recorded highest in PL8 (1.06 g) and dry weight per spike recorded maximum in PL 12(0.20 g). Fresh and dry yield per plant was recorded highest in PL8 which was on par with PL9 along with check variety Viswam. Coefficient of variation observed for fresh and dry yield per plant as 122.45 per cent and 120.44 per cent, respectively. Spike set percent was shown maximum by PL 8 (97.42 per cent) and driage by PL 49 (20.66 per cent).

Based on yield parameters, PL 5, PL 8, PL 9, PL 15, PL 23, PL 24 and PL 25 along with check variety were selected as superior accessions. For volatile oil,

oleoresin and piperine content, accessions PL 5, PL 8, PL 12 and PL 50 were promising.

Cluster analysis among 42 accessions based on qualitative characters and 20 accessions based on quantitative characters were done by using Multivariate Hierrarchial Cluster Analysis using NTSYS software. The dendrogram derived through qualitative characteristics showed degree of similarity varying from 26 to 100 and at 81 per cent similarity long pepper accessions were grouped into seven clusters. Based on quantitative data, the accessions showed only 14 per cent similarity. Since the accessions showed wide variability it can be utilized in future breeding programmes.