VARIABILITY,CORRELATION AND PATH ANALYSIS STUDIES IN LONG PEPPER (*Piper longum* L.)

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

MASTER OF SCIENCE IN AGRICULTURE
(VEGETABLE SCIENCE)

By

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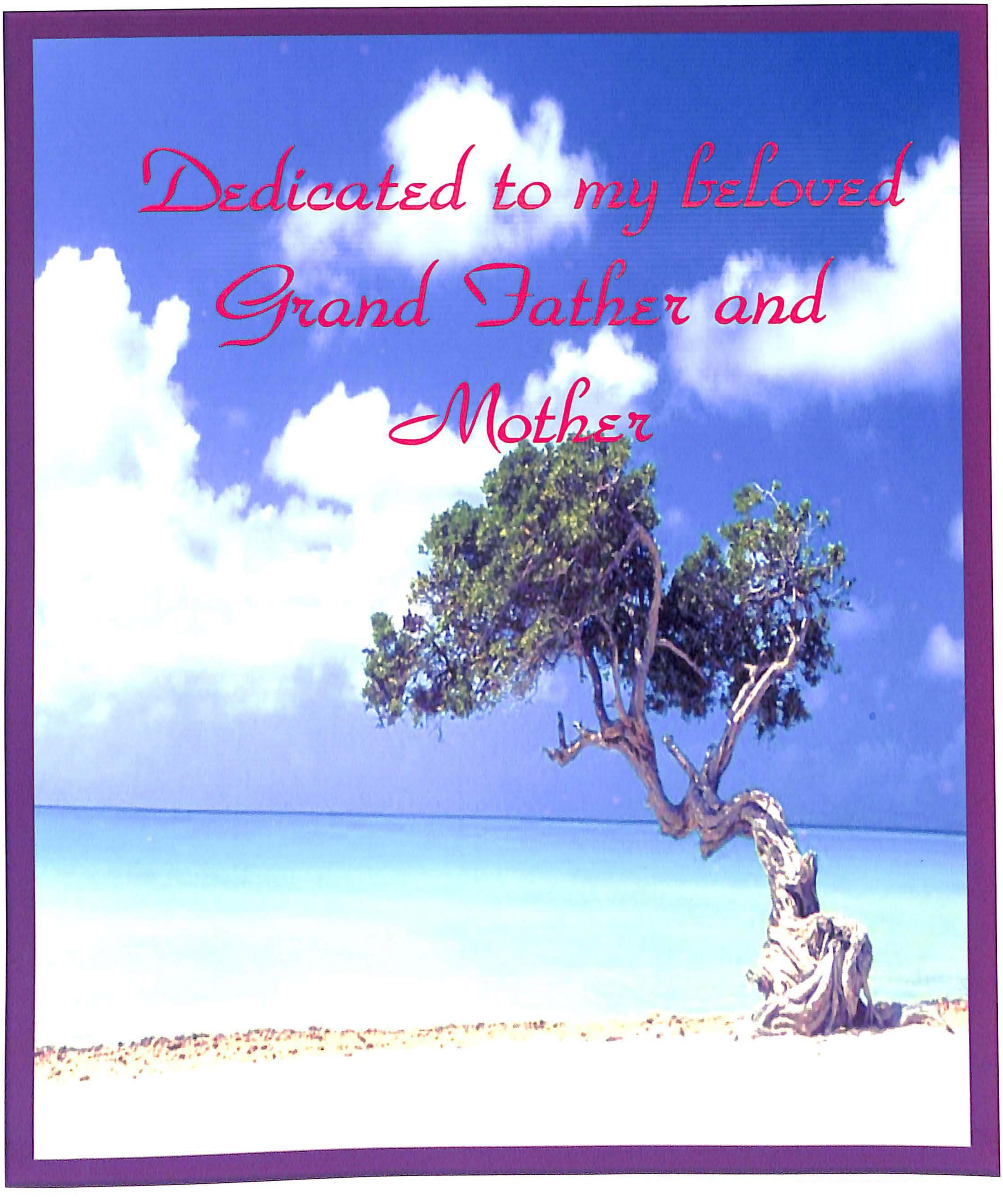
Dedicated to my beloved
Grand Father and
Mother

ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
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CERTIFICATE – I

This is to certify that the thesis entitled **"VARIABILITY, CORRELATION AND PATH ANALYSIS STUDIES IN LONG PEPPER** (*Piper longum* L.)" submitted for the award of degree of **MASTER OF SCIENCE (AGRICULTURE)** in the subject of **VEGETABLE SCIENCE** of the Orissa University of Agriculture and Technology, Bhubaneswar is a faithful record of bonafide and original research work carried out by **SATYAKI MANDAL** under my guidance and supervision. No part of the thesis has been submitted for any other degree or diploma or published in any other form.

The assistance and help received during the course of investigation has been fully acknowledged.

Forwarded
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CERTIFICATE – II

This is to certify that the thesis entitled **"VARIABILITY, CORRELATION AND PATH ANALYSIS STUDIES IN LONG PEPPER (*Piper longum* L.)"** submitted by **SATYAKI MANDAL** to the Orissa University of Agriculture and Technology, Bhubaneswar in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE (AGRICULTURE)** in the subject **VEGETABLE SCIENCE** has been approved by the student's Advisory Committee after an oral examination on the same in collaboration with an External Examiner.

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Satyaki Mandal.

Bhubaneswar
Date: 19.09.2011

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ABSTRACT

Title of the thesis	:	**VARIABILITY, CORRELATION AND PATH ANALYSIS STUDIES IN LONG PEPPER** ***(Piper longum*** **L.)**
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Sixteen genotypes of long pepper were assessed for variability, correlation and path analysis for yield and its attributes. The differences among genotypes were statistically significant for all the fifteen quantitative characters. High estimates of genotypic coefficient of variation, heritability and genetic advance were shown by number of spikes/plant, number of spike bearing branches and internodal length of spike bearing branch, respectively. This is an indication that selection based on the above spikes will be more effective for crop improvement programme. Correlation studies among the fruits indicated that number of spike bearing branch/plant had high significant positive association with fruit yield at both phenotypic and genotypic levels followed by spike length. Path analysis of fruit yield revealed that number of spikes/plant, number of primary branches, leaf area, vine length, days of first emergence of spike, spike girth and fruit weight had high to moderate direct effect on yield which indicated their better prospects for further crop improvement.

ABBREVIATION

%	-	Percentage.
L.	–	Linius.
cm.	–	Centimeter.
mm.	–	Millimeter.
e.g.	–	Example.
kg	–	Kilogram.
ha	–	Hectare.
gm	–	Gram.
km	–	Kilometer.
m.	–	Meter.
i.e.	-	That is.
Max.	-	Maximum.
Min	-	Minimum.
Mn.	-	Morning.
An.	-	Afternoon.
FYM	–	Farm yard manure.
SSP	–	Single super phosphate.
MOP	–	Murate of potash.
Fig.	–	Figure.
d.f.	–	Degree of freedom.
S.S.	-	Sum of square.
M.S.	–	Mean square.
E(MS)	–	Expected mean square.
RBD	–	Randomized Block Design.
M.P.	–	Mean product.
E(MP)	–	Expected mean product.
S.E.	–	Standard error.
C.D.	-	Critical difference.
C.V.	-	Coefficient of variation.
AC	–	Accession.
KAU	–	Kerala Agriculture University.
BBSR	–	Bhubaneswar.
@	-	At the rate of.
wt.	–	Weight.
no.	–	Number.
DAP	-	Days after planting.
BSH	-	Bright sunshine hour.

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INTRODUCTION

INTRODUCTION

Medicinal and Aromatic plants have become important in last two decades for their commercial uses, although their use in India has ancient history. It is estimated that 80% of the population in developing countries still rely on traditional medicines. With growing awareness globally for health, there is an increasing consciousness for the use of herbs for healthcare (Singh *et al.*, 2009).

Medicinal plants form the major resource base of our indigenous healthcare traditions. Outreach and acceptability of Ayurvedic, Unani, Siddha, Homeopathy (AYUSH) systems, both nationally as well as globally, is dependent on uninterrupted availability of quality plant based raw material. More than 90% of the species used in trade continue to be sourced from the wild of which about 2/3rd are harvested by destructive means.

Cultivation of medicinal plants, therefore, is key to meet the raw material needs of the AYUSH industry besides offering opportunities for higher levels of income, crop diversification and growth of exports. Indian exports of medicinal plants and herbs are mostly in the form of raw herbs and extracts and account for almost 60-70% of the current exports of herbal/AYUSH products. Export of value added item requires product development, setting up of processing facilities, quality assurance and brand promotion. Increasing concerns of unsustainable collection from the wild, disappearance of certain species on the one hand and concerns of quality and standardization on the other make it imperative to promote cultivation of species critical to AYUSH systems of medicine.

India has richest biodiversity, where in more than 9,500 plant species have been identified and documented, which have importance in pharmaceutical industries. With rising awareness globally for health, there is an increasing consciousness for the use of herbs for healthcare. This emerging trend provides opportunity to harness traditional knowledge and power of herbs. A rapid stride has been made to exploit medicinal and aromatic plants through research and developmental strategies. The Indian Council of Agricultural Research through the network of research programmes and National Research Centers has provided a focused attention for the technological upscaling of medicinal and aromatic plants. Initiatives taken by the Government of India have also helped in enhancing the production of medicinal and aromatic plants (Singh *et al.*, 2009).

Long pepper or Pippali (*Piper longum* L.) is an important medicinal plant belonging to the family Piperaceae. Vedas and almost all Samhitas have described this plant in detail. In Charaksamhita, pippali has been mentioned for 264 times, Susruta also referred this plant with at most importance. Long pepper was well known in ancient India and was mainly used as source of pungency and for flavouring various beverages and dishes. Ravindran *et al.* (2005) reported that it was from India long pepper reached the rest of Asia and Mediterranean region through 'Spice Route' and it was used as spice in this entire region.

It is native of Indo-Malaya region. It was probably an earlier introduction into Europe and was highly regarded as a flavour ingredient by the Romans. The Greek name 'Peperi', the Latin 'Piper' and the English 'Pepper' all came from the Sanskrit name 'Pippali' for this long pepper. *Piper longum* has now disappeared from markets of Europe. It is growing wild in the Tropical rain forests of India, Nepal, Indonesia, Malaysia, Sri Lanka, Rhio, Timar and the Philippines. In India, it grows in small scattered plots mainly in Assam, Khasi hills, lower hills of West Bengal, Eastern Uttar Pradesh, Madhya Pradesh, Maharashtra and evergreen forests of Western Ghats in Kerala, Karnataka and Tamil Nadu (The Wealth of India, 1969). Its occurrence in wild has also been reported from Andhra Pradesh and Andaman and Nicobar island.

Records of its cultivation are available from Bengal and lower elevations of Assam, particularly Cherapunji area. In Akola-Amravati region of Maharashtra, farmers cultivate a particular race of *Piper longum*. Reports are also available on its cultivation at lower elevations of Annamalai hills of Tamil Nadu, parts of lower Assam and Orissa. Homestead cultivation of *Piper longum* is in practice in

Uduppi and Mangalore regions of Karnataka (Velayudhan, personal communication). But even today, the bulk of Indian long pepper for market is derived from its wild growth in Assam, Shillong and West Bengal and supplemented by imports from Sri Lanka and Indonesia. Organized commercial cultivation is still not popular in this crop.

Piper longum Linn. is a glabrous under-shrub with erect or sub scandent nodose stem and slender branches, the latter are more often creeping or trailing and rooting below or rarely scandent reaching a few meters height. Leaves are simple, alternate, stipulate and petiolate or nearly sessile according to their position on the plant. The leaf lamina varies in shape over the same plant. The upper leaves are generally sessile, amplexicaul or stemclasping. Ovate or ovate-oblong acute and most often unequal sided or unequally cordate at base while the lower ones are usually cordate. All the leaves are entire glabrous, membranous or slightly succulent and 5-7 ribbed from the base. Flowering is nearly throughout the years; inflorescence is spike with unisexual (dioecious) small or minute achlamydeous densely or closely packed flowers and form very close clusters of small greyish green or darker grey berries. Female spikes with short thick stock vary from 1.5 to 2.5 cm in length and 0.5 to 0.7 cm in thickness. The male spikes also are stalked but longer, 2.5 to 7.5 cm and slender; they slightly elongate during maturation. The nearly ripened fruiting female spike is collected and dried in sunlight which forms the long pepper of commerce for use in medicine. The male spikes are not of much economic value.

Male flowers are minute, no perianth, stamens are two, with short broad filaments and anther cells separated below. Female flowers have perianth none, stamens none, ovary sunk in the substance of the spike with a single erect ovule, style exceedingly short, stigma three or four lobed, recurved and persists on the minute berries. Fruits are small ovoid about 2.00 mm diameter, greyish green or nearly blackish (reddish, says Gamble, 1918) when ripe and are partially sunk in the fleshy axis of the spike. It is propagated by cuttings, requires optimum shade and heavy organic manuring for proper growth and productivity. Due to its peculiar climatic requirement, long pepper is not recommended as solo crop in Kerala, but as intercrop in irrigated coconut plantation (Viswanathan, 1995).

The spikes of the plant contain the alkaloids piperine (4%-5%) and piplatin and two new alkaloids one of which is designated as alkaloid A and which is closely related to pelliotorine; and three more new alkaloids - piperolactum A, piperolactum B and piporadione. The roots contain the alkaloids, piper longuminine (0.2% – 0.25%) and piper longumine (0.02%) besides piperine. Further purification of piper longumine has yielded six known alkaloids – cepharadione B, cepharadione A, cepharanone B, aristolactum A 11, norcepharadione B and 2 hydroxy 1 methoxy 4H dibenzoquinoline – 4,5 (6H) dione; lignins, viz. pluriatilol, fargosin, sesamin, asarinine, guineensine and pipercide. Besides, the dried spikes on stem distillation yield 0.7% essential oil with a spicy odour resembling that of pepper and ginger oil.

Iyer (1983) reported that long pepper is used mainly in Ayurvedic system of medicine, for about 320 classical preparations and in many herbal formulations. The medicinal uses of *Piper longum* in Ayurvedic, Unani and Sidha preparations have been described by several workers (Kirtikar and Basu, 1935; Suseelappan, 1991; Joseph and Skaria, 2001; Sasikumar, 2004). These forms are important component in Ayurvedic preparation such as 'Trikadu' (dry ginger – black pepper – long pepper) and 'Panchakolam'. It is considered as rejuvenating and revitalizing drug in Ayurveda and mature spikes of female plant, thick stems, roots and leaves are extensively used in treatment of bronchial disease, dyspepsia, worms, amoebiosis etc.

The root is pungent and has heating, stomachic, laxative, anthelmintic, carminative properties, improves the appetite, is useful in bronchitis, abdominal pains, diseases of the spleen and tumours. The unripe fruit is sweetish, cooling and useful in biliousness. The ripe fruit is sweet, pungent, a stomachic, aphrodisiac, alternative, laxative, antidiarrohoeic, antidysentric, is useful in vata and kapha, asthma, bronchitis, abdominal complaints, fevers, leucoderma, urinary discharge, tumours, piles, diseases of the spleen, pains, inflammations, leprosy, insomnia, jaundice, hiccoughs, tubercular glands and reduces biliousness (in the Ayurvedic system of medicine).

The roots and fruits are used in palsy, gout and lumbago. The root has a bitter, hot and sharp taste. It is used as a carminative, a tonic to the liver, stomachic, digestive and as a general tonic, useful in inflammation of the liver, pains in the joints, lumbago, snakebites, scorpion sting and night blindness (in the Unani system of medicine).

In the Travencore region, an infusion of the root is prescribed after parturition, to help in the expulsion of the placenta. It appears to partake, in a minor degree of the stimulant properties of the fruit.

There is a relatively high demand for this spice cum medicinal plant in domestic market in India. A survey carried out by state Government in 1987 revealed that annual requirement of pippali in Kerala is 313 ton and the demand for this crop is increasing day by day. Consequently, a large quantity of long pepper is imported to India from Malaysia and Singapore. Over the years industrial demand of long pepper is continuously increasing which is largely met by collection from its natural habitat, endangering the genetic variability and natural resource of this species. Hence it is essential to meet this demand by production through cultivation.

The yield of fresh and dried spikes and roots are the important economic character in long pepper. As the yield is a complex character and is highly influenced by the environment or is lowly heritable, the yield as such may not be best criteria for selection and it is therefore, important to study the components and estimate the degree of their association with yield. Hence the knowledge of genetic diversity in the population is highly essential for a plant breeder in the selection of desirable parents for the improvement of yield attributes and finally the yield.

The phenotypic expression of all quantitative characters is a resultant of the genetic, environment and their interaction. Hence, the progress of selection in a population is conditions by the nature and magnitude of variations. It is therefore, essential to formulate biometrical approach to partition the observed variation, heritability, genetic advance etc., as these are the most essential requisites for a sound and successful breeding programme.

As per improved aspect of long pepper is concerned, fewer information are available. The essence of any planned crop improvement programme is variability. An assembly of diverse genetic stock of any crop is the raw material from which a new variety can be molded to suit the requirement of cultivars. As such the nature and magnitude of variability among the genetic stock is the prime importance to the breeder. A wealth of genetic knowledge is of help in identifying desirable cultivars for commercial cultivation.

Improvement of spikes yield in long pepper requires knowledge of the magnitude variation in available germplasm. Interdependence quantitative characters with yield, extent of environmental influence on these factors and the heritability of genotypic material. The degree of expression of a particular character is influenced by the genetic constitutions and environment in which it is grown. Hence a study of genotypic and phenotypic correlation is useful which provides a basis for making selection based on correlated characters. Knowledge of the cause and effect and relationship between yield components and yield is an essential before initiating any improvement programme involving selection of plants for high yield. Therefore the present investigation has been envisaged to be carried out with a view –

1. To estimate the variability, heritability and genetic advance.
2. To estimate the nature and extent of variation of various yield components as well as yield and their genetic gain.

3. To determine heritability of different characters and phenotypic and genotypic correlation between pairs of characters.

4. The amount and nature of association among different characters with yield through correlation analysis.

5. The direct and indirect association between the yield and its components through path coefficient analysis.

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Chapter -2

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Long pepper (*Piper longum* L.); 2n = 24, 48, 52, 96 belongs to the family piperaceae is popularly known as Pippali, Tippali, Pipul. It is a slender, aromatic, perennial climber. It is a native of Indo-Malaya region. It was probably an earlier introduction into Europe and was highly regarded as a flavouring ingredient by the Romans. It grows wild in the Tropical rain forest of India, Nepal, Indonesia, Malaysia, Sri Lanka, Rhio, Timar and the Philippines. In India, it grows in small scattered plots mainly in Assam, Khashi hills, lower hills of West Bengal, Eastern Uttar Pradesh, Madhya Pradesh, Maharashtra and evergreen forests of Western Ghats in Kerala, Karnataka and Tamil Nadu (The Wealth of India, 1969). In Orissa, pippali or long pepper is cultivated in coastal and southern districts. The crop gives a continuous harvest of mature fruits (spikes) for 7-8 months of the year except summer months when the growth of vines and spike yield is low due to high temperature.

Owing to non-availability of standard/improved variety of long pepper, the farmers are cultivating land races which yield variable fruits. Due to lack of concentrated breeding efforts, named varieties of long pepper are very few. Keeping the above issue in view, efforts were made to assess the nature and magnitude of available variability and association of yield and its contributing traits. However, to bring out an improvement in the crop knowledge regarding association of independent attributes with other dependent traits is of great significance as selection for one trait in variability affects a number of other associated characters. Although this crop is considered as a minor crop under spice, but it plays important role to earned assured income for the farmers of different regions of Kerala, Karnataka, Orissa and parts of West Bengal. Therefore, the present investigation was carried out to study relationship of different characters with important traits which will be most useful for making further improvement in this crop.

The phenotypic expression is a resultant of the genetic, environment and their interaction. Therefore, to study the nature and extent of variability is the basic and foremost important step in all breeding programme for crop improvement. Therefore, it is essential to formulate biometrical approach to partition the observed variability into heritable and non-heritable components by calculation of genetic parameters such as genotypic coefficient of variation, heritability, genetic advance etc. as these are the most important requisite for a successful breeding programme.

2.1. Taxonomy

The earliest record of the description of *Piper* of Indian subcontinent was by Rheede (1678) in his 'Hortus Indicus Malabaricus', wherein he described five types of wild pepper including black pepper and long pepper.

Hooker (1886) divided the order Piperaceae into two tribes namely Saurureae and Piperae. Piperaceae is further divided into genus *Piper* and *Peperomia*. The genus *Piper* is again divided into six selections namely Muldera, Cubeba, Chavica, Pseudochavica, Eupiper and Heckeria. *Piper longum* comes under the selection Chavica. The selection Chavica includes fifteen species other than *Piper longum*. They are *Piper peepuloides* or *Piper officinarum*, *Piper chaba* 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 penangense.*

Purseglove *et al.* (1981) listed out the economic species of Piper other than *Piper longum*, as *Piper nigrum* which is used as a major spice, *Piper betle* L. (Betel pepper) whose leaves are chewed as masticatory, *Piper methysticum* Fors.t, whose roots provide the national beverage of Polynesians etc. Species like *Piper cubeba, Piper retrofractum* or *Piper chaba* (Java Long Pepper), *Piper clusii, Piper guineense, Piper saigonense* and *Piper longifolium* are used as spices.

2.2 Distribution

Indian Long Pepper is mostly derived from wild plants, the main source of supply being Assam, West Bengal, Nepal and Uttar Pradesh. Small quantities are also available from evergreen forests of Kerala and certain parts of Andhra Pradesh (Grieve, 1977).

A survey conducted by Rahiman *et al.* (1979) revealed the presence of *Piper longum* in the forests of Karnataka. Manilal and Sivarajan (1982) reported the distribution of *Piper longum* in Calicut. Sivarajan and Indira (1995) reported Western Ghats as the natural habitat of *Piper longum*. According to Ravindran (2000) it is common in low land forests of Khashi and Mikir hills, lower hills of West Bengal and evergreen forests of Western Ghats from Konkan to Travencore and has been recorded from Nicober islands. The cultivation of *Piper longum* in Kerala was reported by Ravindran *et al.* (2005).

2.3. Habit and external morphology

Long Pepper plant is a slender, creeping shrub, spreading on the ground and rooting at the nodes. It grows and creeps over small shrubs, rocks etc. but does not climb on trees as in the case of Black Pepper or other wild peppers. The plant produces distinct dimorphic branches. The main branches creep on the ground and have cordate leaves with long petioles (plagiotropes), while the auxiliary branches grow erect and produce leaves that are sessile or with short petiole. The former shoots are vegetative and grow by the activity of terminal bud, while the short auxiliary branches are the fruiting branches, produce fruits (spikes) opposite to leaves, and growth is sympodial. Leaves are simple, alternate and variable in size and shape. Long Pepper plant is dioceous, male and female plants are separate.

2.3.1. Stem characters

Chandy and Pilli (1979) observed that the drooping horizontal or erect nature of plagiotropes varied between plant types in black pepper and these stem characters determined the photosynthetic efficiency and yield. It was reported by Ibrahim *et al.* (1986) that internodal length in black pepper varies more than any other morphological characters.

Purseglove *et al.* (1981) reported that branches in Black Pepper are dimorphic in nature; the orthotropic vegetative climbing branches give the framework of the plant. These are stout branches with 5-12 cm long internodes; at which swollen node there is a leaf and an auxiliary bud, which can grow out to give plagiotropic fruiting branches and short adventitious roots, which adhere firmly to the climbing support. Lateral fruiting branches have no roots. Both types of stems branch, but only orthotropic branches will produce further climbing shoots and can be used for propagation.

Manuel (1994) conducted a comparative evaluation of selected types of *Piper longum* in coconut plantation and reported significant variability in stem characters like the length of longest stem, number of stems per hill, number of vegetative branches per stem and these characters influenced the dry spike yield in *Piper longum.* Internodal length of main stem, number of spike bearing branches per stem and angle of insertion of spike bearing branches significantly varied in different accessions in *Piper longum*.

Sujatha and Namboodiri (1995) reported that, in black pepper, stem characters like thickness of nodes of orthotrope, thickness of internodes of orthotrope and angle of insertion of plagiotropes influenced the yield positively.

Kumar (1998) reported that stems of long pepper are numerous, ascending, cylindrical or globose. Stems are swollen and irregularly knotty with each piece quarter inch long, irregularly thick, hard and brownish in colour. Branchlets are erect, prostrate or creeping, soft and grooved when dry. The whole stem is finely pubescent.

Ravindran and Balachandran (2005) reported that long pepper produce distinct dimorphic branches, those main branches, creeping on the ground called orthotrope and those auxiliary branches that grow erect called plagiotropes. The former shoots are vegetative in nature and grow by the activity of terminal bud, while the short auxiliary branches are fruiting branches, produce spikes opposite to the leaves and the growth is sympodial.

Jaleel (2006) studied eight accessions of the *Piper longum* viz. Assam, Kanjur, Maharashtra, NL-84-68, Viswam, Pattambi, Nilambar, Odakkali and reported that length of spike bearing branch and intermodal length of different accessions differ significantly. But at the same time angle of insertion of reproductive branches of different accessions did not differ significantly.

2.3.2. Leaf characters

According to Purseglove *et al.* (1981) *Piper nigrum* leaves on both climbing and fruiting branches are alternate and simple with petiole 2-5 cm long, which is grooved above. Lamina is ovate, entire, coriaceous, with the base oblique, obtuse or rounded and tip acuminate. Leaves are dark green and shiny above, pale and gland dotted beneath. The size varies greatly between cultivars and may be 8-20 cm or more long and 4-12 cm or more broad. There are usually 5-7 main vines.

Manuel (1994) studied four different accessions of long pepper and reported significant variability in leaf characters like leaf length, leaf width, petiole length and number of leaves per hill and found that these leaf characters did not influence the dry spike yield.

Chatterjee and Pakrashi (1997) reported that leaves of *Piper longum* types are 5-9 cm long, 3-5 cm wide, subacute, entire, glabrous, cordate with broad rounded lobes at base.

Kumar (1998) observed that leaves in long pepper are numerous, simple, stipulate and petiolate or sessile according to their position on the plant. Leaf blade varies in shape in the same plant. The upper leaves are generally sessile, damplexicaul or stem creeping, ovate or ovate oblong, acute and most often unequally sided or unequally cordate at base. It was also reported that leaves are 6.5-9.0 cm long and 3-5 cm wide. Lower leaves are broadly ovate, pale dull beneath, cordate at base. Petioles of lower leaves are 0.5-7.5 cm long and stout but that of upper ones is very short and absent. Stipules are about 1-3 cm, membranous, lanceolate, obtuse and falling soon. CSIR (1998) reported that leaves of *Piper longum* are 5-9 cm long, 3-5 cm wide, ovate, cordate with broad rounded lobes at base, subacute, entire and glabrous.

Ravindran and Balachandran (2005) found that orthotropes of *Piper longum* have cordate leaves with long petioles and plagiotropes produce leaves that are sessile or with short petiole. Leaves are simple, alternate and variable in size and shape.

Jaleel (2006) worked with eight accessions of *Piper longum* and reported that length of leaves on vegetative branch and length of leaves produced on reproductive branch differ significantly. The mean length of leaf lamina on vegetative branches was maximum for accession namely NL-84-68 (11.25 cm) and minimum for the variety Viswam (6.37 cm). On the reproductive branch, the longest leaves were observed in the male accession, Nilambur (8.97 cm) while the accession Pattambi recorded the shortest lamina length (4.49 cm) followed by Viswam (5.14 cm). It was also reported that area of leaves on vegetative branches and the leaves on reproductive branches showed significant difference between accessions. Petiole length of different accessions also showed significant variability. Shape of leaf lamina for all the eight accessions for the vegetative branch was chordate, where as it was lanceolate for the leaves of reproductive branches. The leaves of vegetative branches of all accessions except Viswam (medium green) had dark green colour and in the leaves of reproductive branches of all accessions except Odakkali (medium green) recorded dark green colour.

2.3.3. Inflorescence, flowers and spikes

Purseglove *et al.* (1981) reported in black pepper, the pendent spikes are born opposite to the leaves on plagiotropic branches and 3-5 cm long, bearing 50-150 minute flowers born in the axils of ovate fleshy bract. The flowers may be unisexual, with monoceous or dioceous or hermaphrodite but most of the cultivated types are bisexual. This may be a condition that probably originated from the wild ones as a result of continuous selection and vegetative propagation through ages. He also reported that the cultivars exhibit great variability in the percentage of bisexual or productive flowers on their spikes. Higher the percentage of bisexual flowers, greater will be the productivity and most of the high yielding and popular cultivars produce as much as 70% - 98% bisexual flowers. Purseglove *et al.* (1981) added that under intense shade conditions the bisexual types produce more female flowers and less hermaphrodite flowers.

Kumar (1998) reported that *Piper longum* produce inflorescence whose flowers are sessile, usually unbranched, elongated, simple and indeterminate. Flowers are without perianth, very densely packed and male and female parts are on separate plants. Spikes are 5 cm long, cylindrical, solitary, pedunculate and upright. Flowers are unisexual, minute and sessile. Male spikes are large, narrow and slender, bract narrow, 1-3 inch long, peltate, stamens two in number. Female spikes are 1.3-2.5 cm long and 4-5 mm in diameter, bracts circulate, flat and peltate, stigma 3-4 mm in diameter, very short and persisting. Flowering season is July-August. CSIR (1998) reported that spikes are cylindrical, pedunculate, male larger and slender, female 1.3-2.5 cm long and 4-5 mm in diameter. Cylindrical spike, male spikes are much longer than the female spikes. Female spikes are short, stout, flowers fused laterally. Female flowers consist of one ovary only that arises from axil of the bract.

Kumar (1998) reported that fruits in *Piper longum* are 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 are ovoid, crowned with a stigma and arranged with small peltate bracts beneath each. When ripe, fruits are greyish green or nearly blackish and particularly sunk in fleshy axils. Fruiting season is November to March. Seeds are globose, testa thin, within the hardened periphery.

Ravindran and Balachandran (2005) reported that fruits of *Piper longum* are small, closely packed. Fruiting is apomictic and fruits are produced without pollination. Hence male plants are not required for fruit production. He also reported that fruits of *Piper chaba* are large, more chronicle and not cylindrical as in *Piper longum*, become orange red on ripening and are more pungent with less flavour. Spikes of *Piper peepuloids* look similar to *Piper longum*. *Piper mollesua* spikes are globose with minute fruits that are not laterally fused.

2.4. Variability, Heritability and Genetic advance of quantitative traits

The effectiveness of selection depends on existence of genetic variability within or among the populations subjected to selection. Therefore, a quantitative assessment of genetic variability would be of great help in breeding for improvement of quantitative traits.

Many of the economically important characters in crop plants are quantitative in nature, greatly influenced by environment and are observable only in the phenotype and thus phenotypic variability can be easily assessed. But phenotypic variability is inadequate for the purpose of selection, since in it genetic and environmental variabilities are confounded, while it is only the genetic variability that responds to selection. However, statistical methods are now available for a partition of phenotypic variation into genetic and environmental components.

Coefficient of variation is defined as the measure of variation, independent of unit of measurement and is the standard deviation expressed as percentage of mean (Panse and Sukhatme, 1967). Genotypic coefficient of variation is the genotypic standard deviation expressed as percentage of mean and phenotypic coefficient of variation is expressed as the phenotypic standard deviation expressed as percentage of mean. A slight difference between phenotypic and genotypic standard deviation suggested negligible influence of environment on that character (Choudhury *et al.* 1973).

Heritability of a quantitative trait is one of the most important properties for selection process. It may be noted, that the heritability is a property not only of a character but also of the population and the environment conditions to which the individuals on the magnitude of all the components of variation, a change in any one of these will affect heritability. The genetic components are influenced by gene frequencies and may, therefore, differ from one population to another according to its previous history of selection. The environmental variations depend on the conditions of culture or management. More variable conditions reduce heritability, while more uniform conditions increase it. Thus, estimates of heritability obtained with different population grown under different environmental conditions are not directly comparable. Nevertheless quantitative traits do vary in their degree of heritability.

Johnson *et al.* (1955) suggested that heritability estimates along with genetic advance were more valuable than the heritability value alone in predicting the effects of selection. High heritability does not mean that the character will show high genetic effects are probably important. It is because low genetic effects are probably important. It is because low genetic advance was due to non-additive genes, whereas additives genes are responsible for high genetic advance.

Escuro *et al.* (1963) stated that genetic advance indicates the potentiality of selection at a particular level of selection intensity. The expected genetic advance from selection is the product of -

1. The selection differential measured in terms of phenotypic standard deviation.
2. Genotypic coefficient of variation.
3. The square root of heritability ratio.

Robinson (1966) reported that heritability estimates in cultivated plants can be placed into following categories:

1. Low heritability – 5 to 10 percent, e.g., yield.
2. Moderate heritability – 10 to 30 percent, e.g., components of yield.
3. Higher heritability – 30 to 60 percent, e.g., maturity characters, chemical compositions.

The above classifications represent averages of heritability estimates over various crop plants, types of procedure of determination and environments encountered in different locations and years.

From heritability value, amount of genetic progress which will result from selecting the best individual can not be assessed. But when they are used together with the selection differential, the utility is increased (Tikka *et al.* 1974).

2.5. Characters to be considered for comparative evaluation

2.5.1. Vegetative characters

According to George and Mercy (1978), a pepper vine starts yielding around fifth year of planting and yield increases and stabilizes as the vine matures. Chandy and Pilli (1979) reported that the thickness of orthotrope increases as the vine matures.

Ibrahim *et al.* (1985) reported that in black pepper internodal length varied with the varieties more than any other morphological character. The internodal length in pepper is of economic importance, as shorter internodes tend to increase total number of spikes. The variety Panniyur-1 showed most variability for internodal length.

Manuel (1994) conducted a variability study in five accessions of *Piper longum* and reported the significant variability in vegetative characters like length of longest stem, number of vegetative branches per stem, internodal length of longest stem, length of leaf, width of leaf, length of petiole, number of leaves per hill, spread of plant, number of spike bearing branches per stem and angle of insertion of spike bearing branches. Manuel (1994) conducted that selection for improvement of dry spike yield in *Piper longum* will be efficient, if it is based on vegetative characters like angle of insertion of spike bearing branch, number of stems per hill, number of spikes per spike bearing branches and number of spike bearing branches per stem.

Sujatha and Namboodiri (1995) while studying the influence of vegetative characters on yield of black pepper (*Piper nigrum* L.) observed that characters like thickness of node of orthotrope, thickness of internode of orthotrope and angle of insertion of plagiotrope influenced the yield positively.

2.5.2. Yield contributing characters

Ibrahim *et al.* (1985) reported that positive and significant relationship between yield and spike number, spike length and number of under developed berries per spike.

Manuel (1994) conducted a comparative evaluation of selected types of *Piper longum* in coconut plantations and reported that the five types of *Piper longum* did not differ significantly for the productive characters namely length of spike, diameter of spike, length of peduncle, days from planting to emergence of spike, days from emergence to maturity of spike, and ratio of weight of green spike to weight of dry spike. At the same time the *Piper longum* types differ significantly for the productive characters namely number of spikes per spike bearing branch, yield of green spike in kg/ha and yield of dry spike in kg/ha.

Manuel (1994) evaluated *Piper longum* type's *viz.* Cheematippali, Panniyur, Mala, Pattambi, Kaanjur and reported that the length of spike did not differ significantly for the five types of *Piper longum* at the first and second harvest. The length of spike varied from 4.00 cm (Pattambi) to 4.33 cm (Cheematippali). Diameter of the spike also did not vary significantly for the five types and it ranges between 2.22 cm (Pattambi) and 2.54 cm (Mala). Number of spike bearing branches differed significantly between the different accessions and was recorded in the range of 1.33 cm for Mala, which was minimum value and 3.93 cm was maximum value for Cheematippali. All the five types of *Piper longum* took almost same time from planting to emergence of spike and it varied like 163.7 days for Mala, was the minimum and 180.56 days, which was the maximum duration. Manuel (1994) also reported that all the *Piper longum* types took almost same period for the maturity of spike. The five types differed significantly in the yield of green spikes and recorded as 2621.94 kg/ha (Cheematippali), 2499.44 kg/ha (Kaanjur), 2233.06 kg/ha (Pattambi), 1813.33 kg/ha (Panniyur) and 1530.55 kg/ha (Mala). In case of dry spike yield it was reported that the maximum yield for Cheematippali (580.83 kg/ha) and minimum yield for Mala (201.95 kg/ha).

Sujatha and Namboodiri (1995) conducted a study on heterosis in black pepper (*Piper nigrum* L.) and 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.

Jaleel (2006) reported significant variability of spike length while evaluating the eight accessions of *Piper longum viz.* Assam, Kanjur, Maharashtra, NL-84-68, Viswam, Pattambi and two male accessions Nilambur and Odakkali and recorded that male accessions *viz.* Nilambur and Odakkali produce longest spikes with mean length of 7.55 cm and 7.31 cm respectively. At the same time for female accessions the longest spike length was recorded for NL-84-68 (4.23 cm) and the shortest spike length was for the KAU variety Viswam (2.40 cm). Spike diameter also varied between the different accessions and NL-84-68 recorded the maximum diameter 3.59 cm and the male accessions Nilambur and Odakkali produced minimum spike diameter 1.31 cm and 1.40 cm respectively. The female accession Viswam showed a spike diameter of 1.53 cm which was very near to the male accessions. The accession NL-84-68 had the boldest spike 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 and male accession Odakkali 93.6 spikes. NL-84-68 recorded the minimum number of spikes per spike bearing branch (2.60). For the spike initiation, the male accessions Nilambur took the minimum days (132 days) and the female accession NL-84-68 took the maximum number of days (178 days). The later recorded the maximum number of days for the maturity of spikes (69.60). The male accessions recorded the minimum of 56 days for maturity. Jaleel (2006) recorded variation in fresh weight of spikes for all the eight accessions NL-84-68 recorded the maximum mean spike weight (1.639 gm) followed by Maharashtra (1.58 gm). The minimum fresh weight was for Viswam, 0.36 gm per spike.

2.6. Correlation studies

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

Manuel (1994) noted that the length of longest stem, number of stems per hill, the number of vegetative branches per stem exhibited significant positive correlation with dry spike yield in *Piper longum*. The number of spike bearing branches and angle of insertion of spike bearing branches in long pepper significantly influenced the dry spike yield during 7 and 8 months after planting. Vegetative characters like length of petiole, area of leaf lamina, intermodal length of spike bearing branches, etc. did not influence the yield of *Piper longum*.

Manuel (1994) conducted correlation studies between the vegetative and reproductive characters and spike yield in *Piper longum*, and it was found that vegetative characters like length of longest stem and number of stems per hill was significantly correlated to dry spike yield. The number of vegetative branches per stem exhibited significant correlation with dry spike yield at 5, 6, 7 months after planting. During 7th and 8th month the correlation between numbers of spike bearing branches per stem and dry spike yield was significant. The angle of insertion of spike bearing branches was found to be significantly correlated to dry spike yield. The numbers of spikes per spike bearing branch showed significant correlation with dry spike yield at 5, 6, 7 months after planting. Manuel (1994) further reported highest positive correlation of green spike yield with dry spike yield followed by angle of insertion of spike bearing branch and number of stems per hill. The characters such as number of spikes per spike bearing branches per stem, length of longest stem, number of vegetative branches per stem and number of leaves per hill showed significant positive correlation with dry spike yield.

Sujatha and Namboodiri (1995) studied the characters of yield and their correlation in black pepper (*Piper nigrum* L.), and found that the dry berry yield per vine and the three reproductive characters *viz.* number of spikes per vine, number of developed berries per spike and length of spike were having highly significant correlation with dry berry yield per vine. Further they studied 580 genotypes of black pepper and estimated the correlation between yield and 20 quantitative characters. The results revealed that the reproductive characters *viz.* green spike yield per vine, green berry yield per vine, number of spikes per vine and number of underdeveloped berries per spike as well as vegetative characters like thickness of node and internode of orthotrope and angle of insertion of plagiotrope are positively and significantly correlated with yield. The intercorrelations among these characters were also positive and significant. They also reported that green spike yield per vine is also highly correlated with green berry yield per vine, spike length, spike number, number of developed berries per spike, thickness of node and internode of orthotrope and angle of insertion of plagiotrope. Positive and highly significant correlation was reported between pairs of characters *viz.* spike length and number of underdeveloped berries per spike. This is because as the length of spike increases the total number of berries also increases.

Sujatha and Namboodiri (1995) observed that in black pepper reproductive characters *viz*. green spike yield per vine, green berry yield per vine, number of spikes per vine and number of underdeveloped berries per spike are positively and significantly correlated with yield.

Sujatha and Namboodiri (1995) reported the positive and significant correlation with yield and vegetative characters like thickness of node of orthotropes, thickness of internode of orthotrope and angle of insertion of plagiotrope in black pepper. The intercorrelation between thickness of node and green spike yield per vine, spike number and spike length were also positive and highly significant. The thickness of internode also showed high intercorrelation with these reproductive characters.

2.7. Path coefficient analysis

The path coefficient analysis devised by Wright, (1921) provides a better knowledge as it reveals direct and indirect causes of association and permits a critical examination of the specific forces acting to produce a given correlation and measures the relative importance of each casual factors. Yield is a complex trait resulting from direct and indirect effects of several traits operating either in combination or individually. Selection for a trait in one direction may influence another trait by direct or indirect effect via a third variable.

In the correlation studies between the vegetative and reproductive characters and spike yield in *Piper longum*, Manuel (1994) observed that the characters such as number of spikes per spike bearing branches per stem, length of longest stem, number of vegetative branches per stem and number of leaves per hill showed significant positive correlation with dry spike yield. Path analysis revealed that angle of insertion of spike bearing branch, number of vegetative branches per stem, number of spikes per spike bearing branch, length of longest stem, number of leaves per hill, number of stems per hill showed positive direct effect towards yield. Out of these, maximum contribution to dry spike yield is through angle of insertion of spike bearing branch.

Sujatha and Namboodiri (1995) studied the characters of yield and their correlation in black pepper (*Piper nigrum* L.). Path analysis revealed positive direct effect on yield by the characters green berry yield, spike number, spike length and angle of insertion of plagiotrope. The highest correlation was exhibited by green berry yield per vine and spike number.

In another studies Sujatha and Namboodiri (1995) reported the positive and significant correlation with yield and vegetative characters like thickness of node of orthotropes, thickness of internode of orthotrope and angle of insertion of plagiotrope in black pepper. Path analysis revealed that the direct effect of above two characters is negative and small but the high and positive indirect effects through their influence on green berry yield per vine are the reason for high correlation with yield.

Sujatha and Namboodiri (1995) reported the intercorrelation of angle of insertion of plagiotrope with green spike yield per vine; green berry yield per vine and thickness of internode of orthotrope was significant. In path analysis the direct effect was found positive though small and it had a positive indirect effect through green berry yield per vine. Among the rest of vegetative characters studied, length of leaf, length of internode of plagiotrope and thickness of node of plagiotrope showed no significant and positive correlation with yield, while the length of petiole, breadth of leaf, area of leaf and thickness of internode of plagiotrope showed no significant and negative correlation with yield.

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Chapter -3

MATERIALS AND METHODS

MATERIALS AND METHOD

The present experiment entitled "Variability, Correlation and Path analysis studies in Long Pepper (*Piper longum* L.)" was carried out at the Horticulture Research Station, Orissa University of Agriculture and Technology, Bhubaneswar during 2010-2011. The materials and methods used in this investigation are described below.

3.1 Geographical location of the experimental site

The Horticulture Research Station which is under College of Agriculture, Orissa University of Agriculture and Technology, Bhubaneswar, Orissa is situated about 5 km away from Bhubaneswar and located at the latitude of $20^{0}15'$ N and longitude of $85^{0}52'$ E. It is about 62 km away from the Bay of Bengal at an altitude of 25.5 m above mean sea level.

3.2 Cropping history of experimental field

The experimental plot was cultivated in the year 2008-2009 with cowpea in kharif followed by French bean in rabi season. But land was kept fallow in the year 2009-2010. In the year 2010-2011 long pepper was planted in kharif for the present study.

YEAR	KHARIF	RABI	SUMMER
2008-2009	Cowpea	French Bean	Fallow
2009-2010	Fallow	Fallow	Fallow
2010-2011	Long Pepper	-	-

3.3 Soil

A composite soil sample was collected to determine the basic status of the soil and analyzed before commencement of the present experiment. The physico-chemical composition of the soil of the experimental field is given below.

Table 1. Physico-chemical composition of soil of the experimental field (soil depth 0-15 cm)

a. Mechanical composition

Sl. No.	Constituents	Percentage (air dry basis)	Method employed
1.	Sand		Bouyoucos Hydrometer (1962)
a)	Course sand	50.94	
b)	Fine sand	26.71	
2.	Silt	9.65	Bouyoucos Hydrometer (1962)
3.	Clay	12.70	Bouyoucos Hydrometer (1962)
4.	Texture class	Sandy loam	Bouyoucos Hydrometer (1962)

b. Chemical composition

Sl. No.	Constituents	Amount present (kg/ha)	Method followed
1.	Available nitrogen	193.2	Alkaline Potassium Permanganate method (Subbiah and Asija, 1956)
2.	Available phosphorus	160.35	Colorimeter using Olsen's extractant (Murphy and Riley, 1962)
3.	Available potassium	341.37	Flame-photometer using neutral normal ammonium acetate extracts (Jackson, 1962)
4.	Organic carbon	0.45%	Walkley and Black's rapid titration (Page *et al.*, 1982)
5.	Soil pH (soil : water = 1:2.5)	5.5	Blackman's pH meter (Piper, 1966)
6.	C:N ratio	11.54:1	-

The soil of the experimental field was thus, found to be sandy loam in texture, having low nitrogen content and available phosphorus but somewhat rich in potash. The soil pH was slightly acidic.

Climate

The experimental site comes under 18th agro climatic region of the country, i.e. Eastern Coastal plain and is turned as sub humid, characterized by warm and moist climate with hot and humid summer and mild winter. The mean annual precipitation is 1484 mm out of which 25% is received during October-May and the rest in between June-September. The average maximum temperature during the period of investigation, varied between 34.4^{0}C – 36.4^{0}C and the average minimum temperature during this period varied between 18.9^{0}C-19^{0}C. The meteorological data obtained for the period of experimentation, i.e. from August 2010 to May 2011 are presented below.

Table 2. Meteorological data collected during the period of experiment

Month	Temperature (^{0}C)		Relative humidity (%)		Rainfall (mm)	No. of rainy days above 25 mm	BSH (hr)
	Max.	Min.	Mn.	An.			
Aug, 10	33.3	26.4	92	75	253.5	15	4.7
Sep, 10	32.8	25.7	94	72	286.2	18	5.4
Oct, 10	31.8	24.5	92	71	188.3	13	4.8
Nov, 10	31.0	21.5	91	60	52.6	4	5.9
Dec, 10	27.0	14.9	90	51	41.5	6	6.2
Jan, 11	28.7	13.9	87	37	-	-	7.2
Feb, 11	31.9	17.5	92	43	24.6	2	6.9
Mar, 11	35.3	21.9	89	42	1.8	1	7.9
Apr, 11	36.4	23.9	87	45	28.2	7	7.1
May, 11	37.3	26.1	89	45	142.0	9	7.7

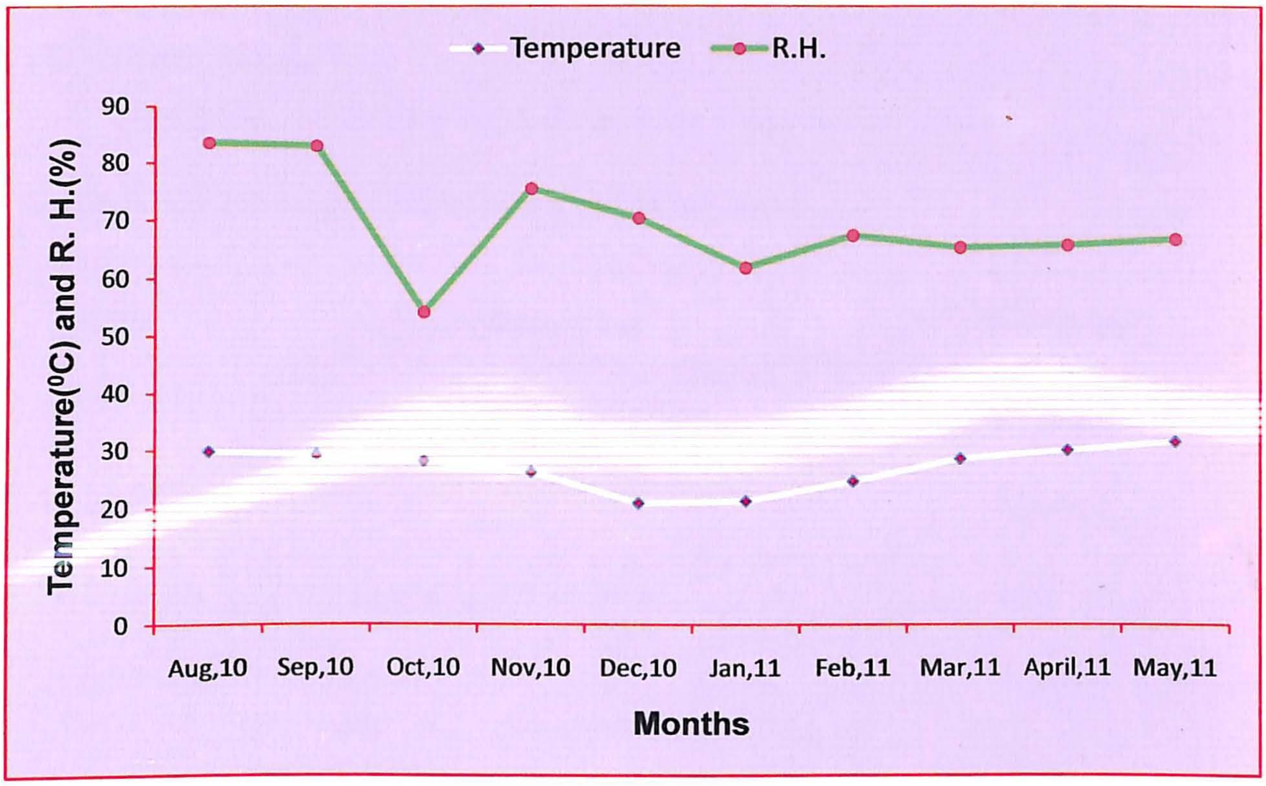

Fig 1. Meteorological data showing average temperature along with average relative humidity.

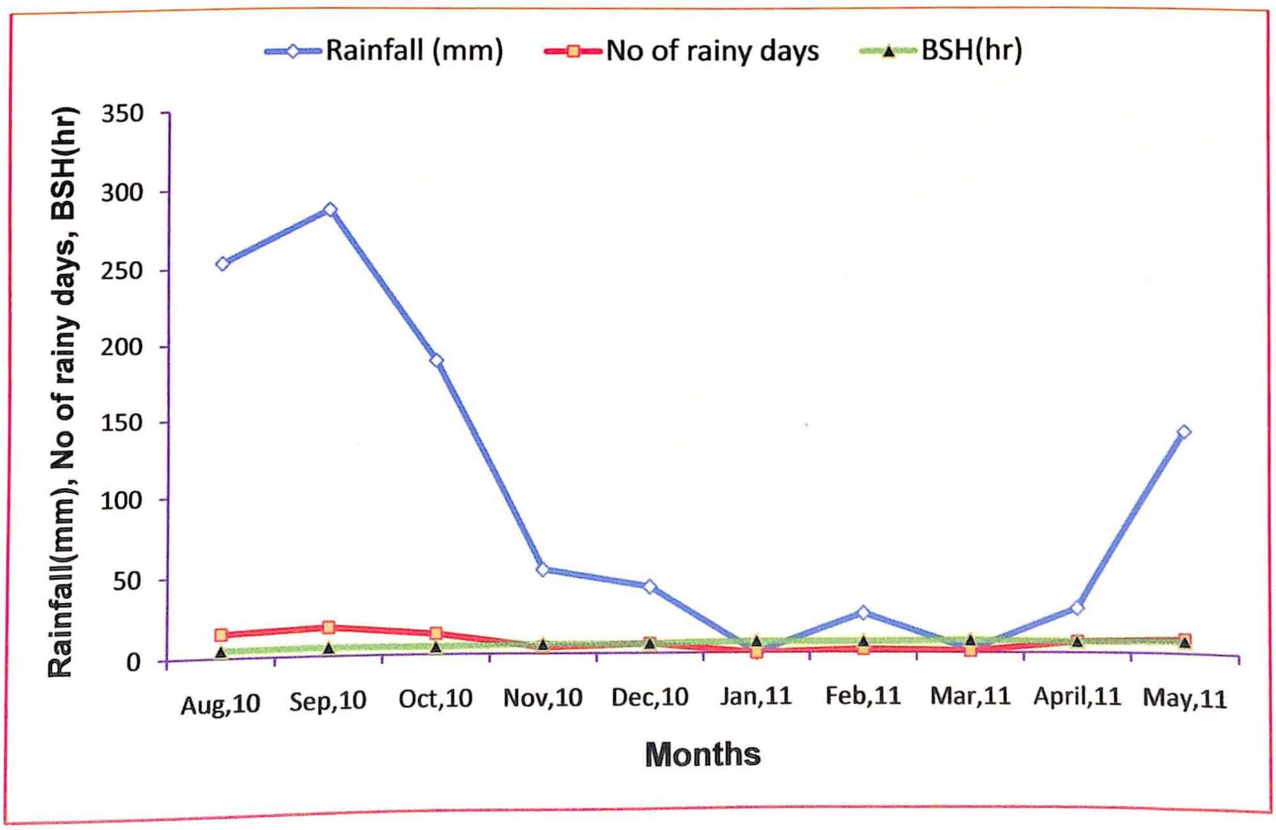

Fig 2. Meteorological data showing rainfall and no. of rainy days.

Field operation

The general operation carried out in the field were as follows –

Table 3. General operations taken out in the field

Date	Operation	Remarks
08.08.2010	Ploughing and land preparation	By tractor
13.08.2010	Weeding	Manual
18.08.2010	Weeding and layout of field	Manual
21.08.2010	Preparation of subplots, bunds and channels and manuring with FYM (8 bucket/plot)	Manual
23.08.2010	Application of basal dose of fertilizer	Manual
23.08.2010	Planting of vine cuttings	Manual

Experimental technique

The following methods have been adopted for the experiment. The experiment constituted of 16 genotypes collected from different parts of the country.

Design of the experiment

Vine cuttings of these 16 genotypes of long pepper were planted in 3 blocks taking each block as a single replication. The experiment was laid out in Randomized Complete Block Design (RCBD).

Experimental material

The material consisted of sixteen genotypes of long pepper (*Piper longum* L.) as listed in table 4. These were grown under open field conditions.

Table 4. List of cultivars/genotypes included in the experiment

Sl. No.	Symbol used	Name of the cultivars	Source of collection
1.	T_1(AC-1)	Patrapoda local	State Silviculture Nursery, BBSR
2.	T_2(AC-2)	Bhubaneswar local	State Silviculture Nursery, BBSR
3.	T_3(AC-3)	IC 85270	KAU, Thrissur
4.	T_4(AC-4)	Puri local	State Silviculture Nursery, BBSR
5.	T_5(AC-5)	Yercaud local	KAU, Thrissur
6.	T_6(AC-6)	Marotichal local - I	KAU, Thrissur
7.	T_7(AC-7)	Koraput local	State Silviculture Nursery, BBSR
8.	T_8(AC-8)	Balugaon local	State Silviculture Nursery, BBSR
9.	T_9(AC-9)	IC 85301	KAU, Thrissur
10.	T_{10}(AC-10)	Mananthody local – I	KAU, Thrissur
11.	T_{11}(AC-11)	IC 266468	KAU, Thrissur
12.	T_{12}(AC-12)	Kutanellur local	KAU, Thrissur
13.	T_{13}(AC-13)	Kottakkal local	KAU, Thrissur
14.	T_{14}(AC-14)	Thiruvananthapuram local	KAU, Thrissur
15.	T_{15}(AC-15)	Viswam	KAU, Thrissur
16.	T_{16}(AC-16)	Malapuram local	KAU, Thrissur

Plan of layout

Randomize Block Design was followed with sixteen treatments each with three replications. Altogether, there were (16 x 3) forty eight plots. The necessary paths and irrigation channels were provided as shown in Fig 3.

N

T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	R1
T_9	T_{10}	T_{11}	T_{12}	T_{13}	T_{14}	T_{15}	T_{16}	
T_9	T_5	T_7	T_2	T_8	T_{14}	T_{11}	T_3	R2
T_{15}	T_4	T_{16}	T_{12}	T_1	T_{13}	T_6	T_{10}	
T_{12}	T_{15}	T_{11}	T_7	T_{13}	T_9	T_{16}	T_6	R3
T_{14}	T_5	T_1	T_3	T_8	T_2	T_{10}	T_4	

Design - RBD, Treatment – 16, Replication – 3

T_1	Patrapoda local	T_9	IC 85301
T_2	Bhubaneswar local	T_{10}	Mananthody local – I
T_3	IC 85270	T_{11}	IC 266468
T_4	Puri local	T_{12}	Kutanellur local
T_5	Yercaud local	T_{13}	Kottakkal local
T_6	Marotichal local - I	T_{14}	Thiruvananthapuram local
T_7	Koraput local	T_{15}	Viswam
T_8	Balugaon local	T_{16}	Malapuram local

Fig 3. Layout plan of experimental field

Plate-1. Overall view of experimental plot

The details of the experiment are given below –

1.	Design	: Randomize Block Design
2.	Number of treatments	: 16
3.	Number of replications	: 3
4.	Number of plots	: 48
5.	Size of each plot	: 2.4 m. x 1.8 m.
6.	Number of rows in a plot	: 3
7.	Number of plants in each row	: 4
8.	Total numbers of plants per plot	: 12 (3 x 4)
9.	Spacing	: 60 cm. x 60 cm.
10.	Block border	: 1.0 m.
11.	Field border	: 2.0 m.
12.	Main channel	: 50 cm.
13.	Sub channel	: 35 cm.
14.	Fertilizer	: 31 kg FYM, 400 gm SSP, 100 gm MOP at basal and 77 gm urea in 3 split dose per plot
15.	Date of sowing	: 23rd August, 2010

Preparation of the experimental plot

The experimental plot was given repeated ploughing by tractor to obtain a fine tilth required for growing long pepper. It was then leveled by ladder and divided into sub plots, forty eight in number, each with a size of 2.4 m. x 1.8 m. as per design shown in fig. 3. Farm yard manure (FYM) and fertilizers were incorporated in each plot as per details given below and thoroughly and uniformly mixed with the soil. Pits were prepared by digging with a pit size of 30 cm x 30 cm x 30 cm for planting long pepper with a spacing of 60 cm x 60 cm between rows and plants with 12 numbers of plants in each plot.

Fertilizer requirement

Fertilizers at the rate of 400 gm Single super phosphate, 100 gm Murate of potash, 77 gm Zinc sulphate were incorporated with 31 kg well rotten Farm yard manure per plot as basal. 77 gm urea per plot was applied by top dressing during 45, 90, 150 days after planting of the plants.

Planting

Healthy certified planting materials were procured from different states of the country. Pits were dug at 30 cm x 30 cm x 30 cm spacing and plants were placed with 60 cm x 60 cm spacing between row to row and plant to plant in experimental plot. The vine cuttings are planted on 23rd August, 2010 in the experimental field. In each plot 12 plants were accommodated.

Aftercare of the experimental field

Staking was given with locally available materials. Regular hoeing and weeding were done to keep the plots weed free and for better aeration. Irrigations were given as and when required. During summer, irrigation was applied at an interval of 4-5 days. The growth and spike emergence of the plant, was slows down in scorching summer. So, during summer months partial shade with locally available materials had been provided to protect the plants from scorching sun. Long pepper, being a hardy plant it is less infected by diseases and pests. However, Bordeaux mixture at 1% concentration during May, and 2-3 sprays during rainy season helps to prevent the fungal diseases and application of neem kernel extract at 0.25% concentration, control the mealy bug infestation.

Harvesting

Harvesting started from 50-55 days after planting. Harvesting of fruits was determined by change of colour from light green or pale yellow to dark green. The spikes were harvested carefully so that no injury was caused to the vines.

Plate 2. Experimental crop in the field

Selection of plants

In conducting the field experiment, the detail study of the entire population becomes impossible. In the present investigation, 5 plants of each cultivar in a replication were randomly selected for studying the various biometric characters. The selected plants were tagged for taking observations. The border rows of each plot were kept aside while selecting the sample plants.

Record of observations

1. **Vine length (cm)**

The vine length was measured from the base of the plant to the tip of the vine at the end of cropping season.

2. **Number of branches per vine**

The number of main branches produced in each representative plant till the end of observation was counted and recorded.

3. **Number of leaves per plant**

In the cropping season total number of leaves per plant was counted recorded in each month.

4. **Leaf area (cm^2)**

In the cropping year 5 leaves from each plant were collected and their area was measured.

5. **Petiole length (cm)**

Petiole length was recorded from the base of the leaf to the base of the stem and it is expressed in centimeter.

6. **Stem girth (cm)**

Stem girth of the primary branches was measured by meter scale and expressed in centimeter.

7. Number of spikes per plant

The crop was not harvested at one time but numbers of picking were made as and when the spikes were ready for harvesting. The numbers of spikes in each harvest was counted for the observational plants. They were summed up till final harvest and average number of spikes per plant was noted.

8. Spike length (cm)

From the first week of December 10 spikes from each plant without any abnormalities were collected and the length was measured precisely.

9. Spike girth (cm)

Spike girth of 10 spikes from each plant was taken immediately after harvest.

10. Spike weight (gm)

Spike weight of ten spikes from each plant was taken as fresh weight basis as well as dry weight basis.

11. Spike yield per plant

The spike yield per plant was recorded in each harvest during observation and was summed up till final harvesting.

12. Days of spike emergence

Days on which the first spike appeared was recorded.

13. Days of spike maturity

Days on which the spike was matured was recorded and maturity period was calculated from date of spike emergence to spike maturity.

14. Number of spike bearing branch

Number of spike bearing branches was recorded during cropping season.

15. Intermodal length of spike bearing branch (cm)

Intermodal length of the spike bearing branches was measured by meter scale and expressed in centimeters.

Statistical analysis

The data recorded for 15 characters as indicated above were subjected to the following statistical analysis.

Analysis of variance and test of significance

Analysis of variance (ANOVA) permits partitioning of total variance in a set of data into components due to different sources such as variance due to replication, due to genotype and due to error which were calculated for each character from mean values. The significance of differences between the replications and among the genotypes for each character was tested by F-test and difference between means of any two genotypes was tested by t-test using critical difference (C.D.) which was calculated as follows:

$$C.D. = \sqrt{\frac{2Me}{r}} \times t$$

Where,

Me = Error mean square.

r = Number of replications.

t = Table value of 't' at chosen level of significance (5% or 1%) at error degree of freedom

The mean of a particular variety for a character ($\overline{X}_i$) was compared with the grand mean ($\overline{X}$) of the treatments by help of standard error (S.E.) using following formula.

$$S.E. = \sqrt{\frac{n-1}{n} \times \frac{Me}{r}}$$

Where,

n = Number of treatments

and $\overline{X} = (\overline{X}_1 + \overline{X}_2 + \overline{X}_3 + \text{------} + \overline{X}n)/n$

Table 5. ANOVA for R.B.D. with expectation of mean square [E(MS)] under model II

Source	d.f.*	M.S.	E(MS)
Replication	(r – 1)	Mr	$\sigma_e^2+g\sigma_r^2$
Genotype	(g – 1)	Mg	$\sigma_e^2+r\sigma_g^2$
Error	(r – 1) (g – 1)	Me	σ_e^2

* **r** and **g** refer to the number of replications and genotypes respectively.

The test of significance of differences among the effects of the different components was tested by computing appropriate variance ratio. These are:

$$\text{Replication} : \frac{\text{Mr}}{\text{Me}}$$

$$\text{Genotype} : \frac{\text{Mg}}{\text{Me}}$$

Estimation of parameters of variability

Variance components

The phenotypic, genotypic and environmental variance components for different characters were estimated from mean square in "ANOVA" as given by Burton and De Vane (1953) as follows:

$$\text{Genotypic variance} = \sigma_g^2 = \frac{\text{Mg-Me}}{r}$$

$$\text{Phenotypic variance} = \sigma_p^2 = \sigma_g^2 + \frac{1}{r}\, r_e^2$$

Where,

Mg = Mean square for genotype/variety.

Me = Mean square for error.

r = Number of replication.

Coefficient of variation

Phenotypic and genotypic coefficient of variation for various characters was estimated as suggested by Burton (1952) as follows:

$$\text{Phenotypic coefficient of variation (PCV)} = \frac{\sigma_p}{\overline{X}} \times 100$$

$$\text{Genotypic coefficient of variation (GCV)} = \frac{\sigma_g}{\overline{X}} \times 100$$

Where,

σ_p = Phenotypic standard deviation.

σ_g = Genotypic standard deviation.

$\overline{X}$ = General mean of the trait.

Heritability

The components of variance previously defined in the foregoing section, were used in the estimation of heritability (broad-sense) for various traits as suggested by Hanson *et al.* (1956) in the following manner:

$$\text{Heritability} = h^2 = \frac{\sigma_g^2}{\sigma_p^2} \times 100$$

Where,

σ_g^2 = Genotypic variance.

σ_p^2 = Phenotypic variance.

Genetic advance (G.A.)

The expected genetic advance or gain from selection among genotypes for different characters was calculated using the formula suggested by Johnson et al. (1955) as follows:

$$G.A. = k.h^2.\sigma_p = k.h.\sigma_g$$

Where,

k = Standardized selection differential which takes the value of 2.06 at 5% selection intensity.

h^2 = Heritability in broad sense i.e. $\frac{\sigma_g^2}{\sigma_p^2}$

h = Heritability coefficient i.e. $\frac{\sigma_g}{\sigma_p}$

σ_g = Genotypic standard deviation for the trait.

σ_p = Phenotypic standard deviation for the trait.

G.A. (expressed in percentage of mean) = $\frac{G.A.}{\overline{X}} \times 100$

Analysis of covariance (ANCOVA)

The analysis of covariance (ANCOVA) between all possible pairs of 8 characters was computed by using plot mean values following the procedures of randomized block design analysis (Panse and Sukhatme, 1967). The symbol and content in respect of the components of covariance in the mean square of products are analogous to the mean sum of squares and the components of variance. The mean sum of products from the ANCOVA was used in the estimation of the components of variance. The form of analysis is shown in table. 6.

Table 6. **ANCOVA with expectations of mean sum of product [E(M.P.)] under model II**

Source	d.f.*	M.P.	E(M.P.)
Replication	(r – 1)	$MP_{r(x,y)}$	$\sigma_{e(xy)} + g\sigma_{r(x,y)}$
Genotype	(g – 1)	$MP_{g(x,y)}$	$\sigma_{g(xy)} + g\sigma_{g(x,y)}$
Error	(r – 1) (g – 1)	$MP_{e(x,y)}$	$\sigma_{e(xy)}$

Covariance components

The components of covariance between two characters x and y were computed from the ANCOVA using the expectations of mean sum of products in the same way as the variance components as follows:

$$\text{Error covariance} = \sigma_{e(x,y)} = Mp_{e(x,y)}$$

$$\text{Genotypic covariance between x and y} = \sigma_{g(x,y)} = \frac{Mp_{g(x,y)} = Mp_{e(x,y)}}{r}$$

$$\text{Phenotypic covariance} = \sigma_{p(x,y)} = \sigma_{g(x,y)} + \frac{1}{r}\,\sigma_{e(x,y)}$$

Where,

Mp_g = Mean sum of products of genotype.

Mp_e = Mean sum of products of error.

r = Number of replications.

Estimation of correlation coefficient

Both phenotypic and genotypic correlation coefficients between characters pairs were worked out by using appropriate variance and covariance components according to Al – Jibouri *et al.* (1958) as follows:

$$\text{Genotypic correlation} = r_g = \frac{\sigma_{g(x,y)}}{\sigma_{g(x)} \cdot \sigma_{g(y)}}$$

$$\text{Phenotypic correlation} = r_p = \frac{\sigma_{p(x,y)}}{\sigma_{p(x)} \cdot \sigma_{p(y)}}$$

Where,

$\sigma_{g(x,y)}$ = genotypic covariance between two traits x and y.

$\sigma_{g(x)}$ = genotypic standard deviation of x.

$\sigma_{g(y)}$ = genotypic standard deviation of y.

$\sigma_{p(x,y)}$ = phenotypic covariance between two traits x and y.

$\sigma_{p(x)}$ = phenotypic standard deviation of x.

$\sigma_{p(y)}$ = phenotypic standard deviation of y.

Standard error (S.E.) of the correlation coefficient was calculated by using the formula –

$$\text{S.E.}\left(r_p\right) = \sqrt{\frac{1-r_p^2}{g-2}}$$

$$\text{S.E.}\left(r_g\right) = \sqrt{\frac{1-r_g^2}{g-2}}$$

Where "g" is the number of pairs of observations utilized for covariance analysis.

Significance of estimated correlation coefficients was tested by 't' test as follows:

$$t=\sqrt{\frac{r^2}{1-r^2}} \times g-2$$

The 't' test was done at (g - 2) degrees of freedom for r_p and r_g at both 5% and 1% levels of probability, where, 'g' is the number of genotypes and 'r' is the correlation coefficient.

Path coefficient analysis

The method of analysis of path coefficients identifies a cause and effect relationship and the correlation of the casual factor with the dependent variable (effect) are partitioned into components of direct and indirect effects. Path coefficient is free from any unit like correlation coefficient (r), but in directional like regression coefficient (b). So, path coefficients are standardized partial regression coefficients which individually provides a measure of the direct effect of the casual factors on the effect of variable.

In the present study, spike yield was taken was 'effect' with other characters related to yield as casual factors. The path coefficients were obtained by solving the following equations as suggested by Dewey and Lu (1959) which provide basic relationship between correlations and path coefficients in a system of correlated causes. The equations are as follows:

$$r_{1.8} = r_{1.8} + r_{1.2}\, p_{2.8} + r_{1.3}\, p_{3.8} + \text{-----------} + r_{1.7}\, p_{7.8}$$

$$r_{2.8} = r_{2.1}\, p_{1.8} + p_{2.8} + r_{2.3}\, p_{3.8} + \text{-----------} + r_{2.7}\, p_{7.8}$$

$$r_{3.8} = r_{3.1}\, p_{1.8} + r_{3.2}\, p_{2.8} + r_{2\,8} + \text{-----------} + r_{3.7}\, p_{7.8}$$

$$r_{7.8} = r_{7\,1}\, p_{1.8} + r_{7.2}\, p_{2.8} + r_{7\,3}\, p_{3.8} + \text{-----------} + p_{7.8}$$

Where,

r_{ij} is the coefficient of correlation between i^{th} and j^{th} characters.

p_{yi} is the direct effect of i^{th} character on yield, r_y.R and p_y.R are the correlation coefficient between yield and unidentified causes on yield respectively.

The above equations were solved in the matrix method, where the direct effect of the matrix was obtained by multiplying the inverse correlation matrix for casual component traits with the correlation matrix of these traits with the effect trait and then indirect effect were calculated. Path coefficient analysis was done from both phenotypic and genotypic correlations among the characters under investigation.

The coefficient of determination (R^2) and residual effect (p_{11}.R) were calculated as follows –

$$1 = p_{11}^2 . R_{11} + \Sigma p_{iy} . r_{iy}$$

$$R^2 = \Sigma p_{iy} . r_{iy}$$

$$PR_{11} = \sqrt{1 - \Sigma p_{iy} . r_{iy}}$$

$$= \sqrt{1 - (p_{1.8} r_{1.8} + p_{2.8} r_{2.8} + p_{3.8} r_{3.8} + \text{----} + p_{7.8} r_{7.8})}$$

Hence, $PR_{11} = \sqrt{(1 - R^2)}$

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Chapter -4

EXPERIMENTAL FINDINGS

EXPERIMENTAL FINDINGS

The present investigation was undertaken to obtain information regarding the range of existing genetic variability and the relationship of various economically important characters in the promising genetic stocks of long pepper. Sixteen genotypes of long pepper were evaluated in a randomized block design with three replications during kharif, rabi and zaid season (2010-2011). Observations were recorded on randomly selected plants of each genotype in each replication for fifteen quantitative characters. The mean values of various traits were subjected to statistical analysis to study about the genetic variability, the association of yield with its components and the extent of direct and indirect effects of yield components on yield of long pepper. The result obtained are tabulated and summarized in subsequent pages.

4.1 VARIATION OF QUANTITATIVE TRAITS IN LONG PEPPER

Among sixteen genotypes of long pepper, thirteen genotypes gave their spike yield. That's why analysis of variance was done among these thirteen genotypes. The analysis of variance revealed significant differences among the genotypes in respect of all the characters studied (Table 8). Estimates of means of all the fifteen quantitative traits for different cultivars of long pepper have been presented in Table 7.

Vine length: Data pertaining to vine length recorded that AC-1 was the highest (102.33 cm), closely followed by AC-5 (101.97 cm), and AC-7 (78.44 cm), where as AC-3 (40.89 cm) was of the lowest stature with an average length.

Number of primary branches/vine: The range of variation in the number of branches/vine among long pepper genotypes was 3.07 to 7.10. AC-8 (7.10), recorded maximum number of branches/vine followed by AC-2 (7.07), AC-15 (6.07), while the minimum was in AC-11 (3.07) followed by AC-5 (3.23) and AC-6 (3.37).

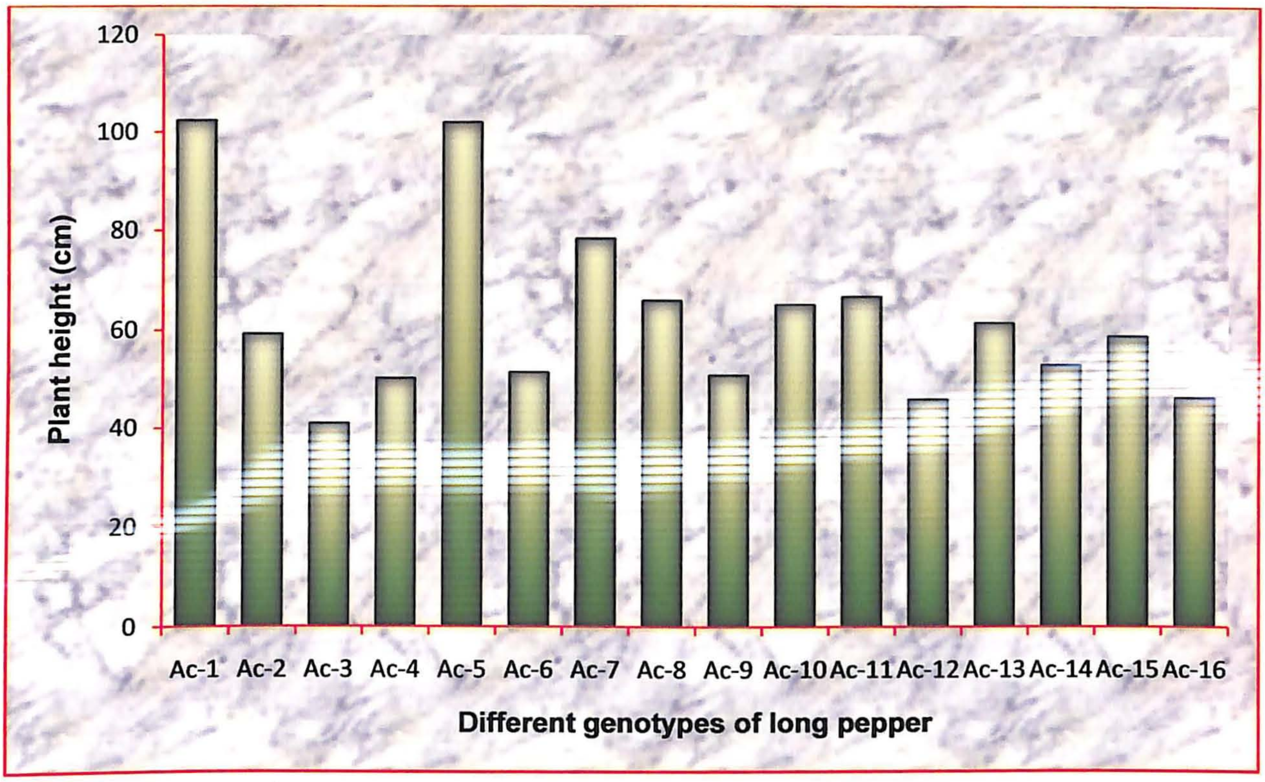

Fig 4. Variability in plant height of different long pepper genotypes

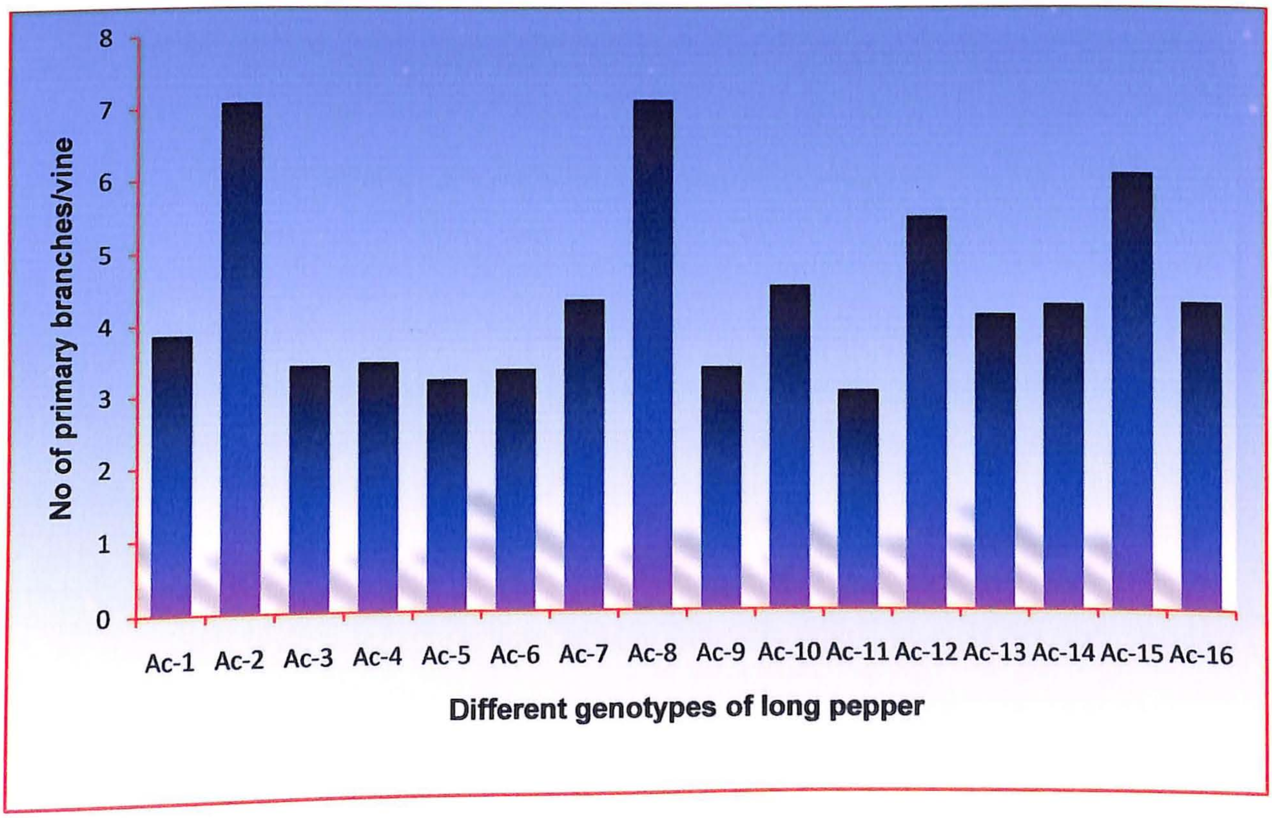

Fig 5. Variability in primary branches/vine of different long pepper genotypes

Total leaves/plant: The maximum leaves in a plant was recorded in AC-15 (130.67) followed by AC-10 (117.67), AC-16 (98), AC-2 (91) and minimum number of leaves was recorded in AC-5 (33.33) followed by AC-4 (49) and AC-1 (49.67).

Leaf area: The area of leaf was maximum in AC-7 (100.66cm^2) followed by AC-8 (98.27 cm^2) and AC-2 (91.81 cm^2). AC-3 (31.56 cm^2) and AC-9 (45.45 cm^2) had the minimum leaf area among the cultivars studied.

Petiole length: Petiole length was maximum in AC-7 (6.38 cm) followed by AC-8 (5.57 cm) and AC-1 (5.54 cm) while the minimum petiole length was observed in AC-3 (2.38 cm) followed by AC-12 (3.63 cm) and AC-9 (3.88 cm).

Stem girth: The highest stem girth was noted in AC-15 (29.84 cm) followed by AC-14 (29.20 cm), AC-1 (27.88 cm) and AC-12 (27.55 cm). However, the lowest girth was found in AC-3 (14.11 cm) followed by AC-4 (16.88 cm), AC-5 (18.71 cm) and AC-6 (19.45 cm).

Number of days for spike emergence: The maximum number of days (178) for spike emergence was recorded with AC-13 followed by AC-9 (156) and the minimum (49) with the AC-16 which was followed by AC-3 (55) within the range of 49-178.

Number of days to maturity from emergence of spike: AC-12 was recorded as the highest number of days to maturity from emergence of spike (65) followed by AC-9 (56) while the minimum number of days for maturity of spike was recorded in AC-7 (18) followed by AC-2 (21) and AC-8 (23).

Number of spike bearing branches: Number of spike bearing branch was recorded maximum in AC-3 (12.00) followed by AC-7 (11.00) and AC-10 (11.00) and minimum in AC-2 (3.67) followed by AC-5 (3.67), AC-1 (4.33) and AC-12 (4.33).

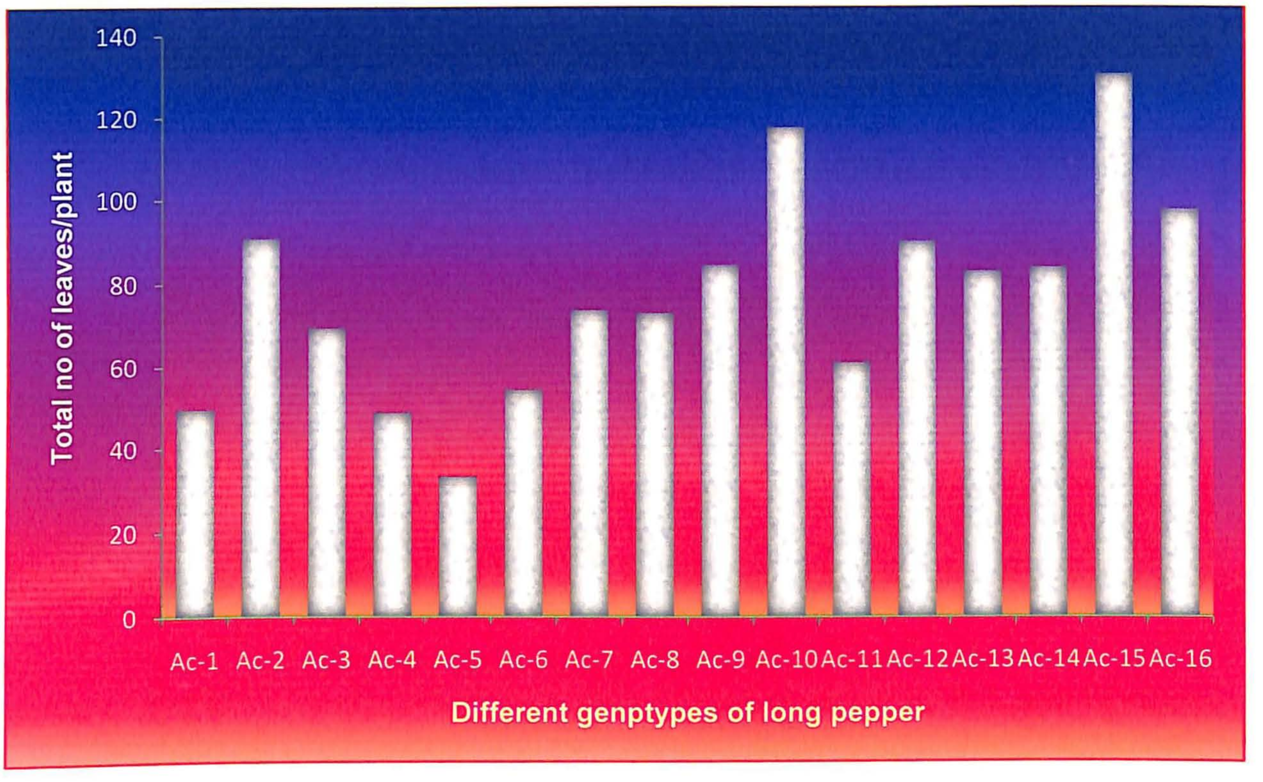

Fig 6. Variability in total no of leaf/plant of different long pepper genotypes

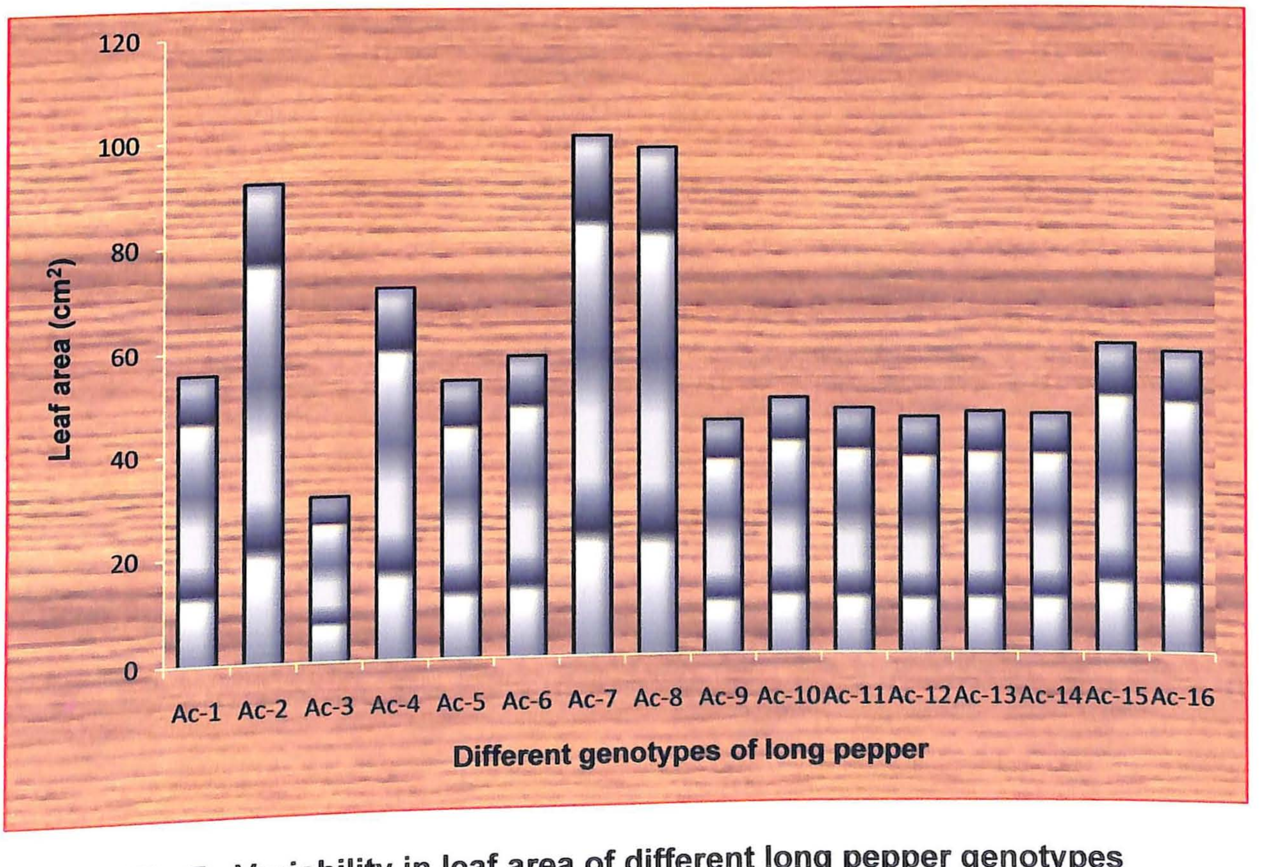

Fig 7. Variability in leaf area of different long pepper genotypes

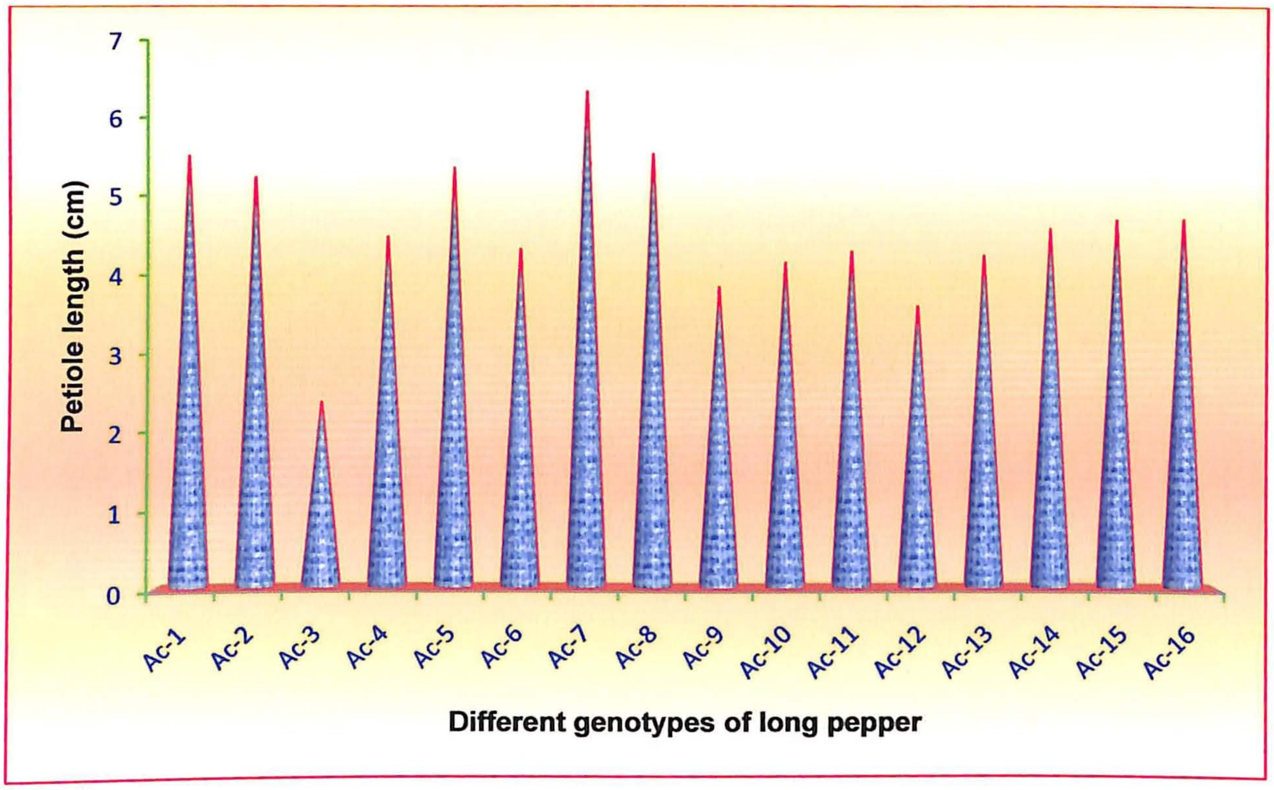

Fig 8. Variability in petiole length of different long pepper genotypes

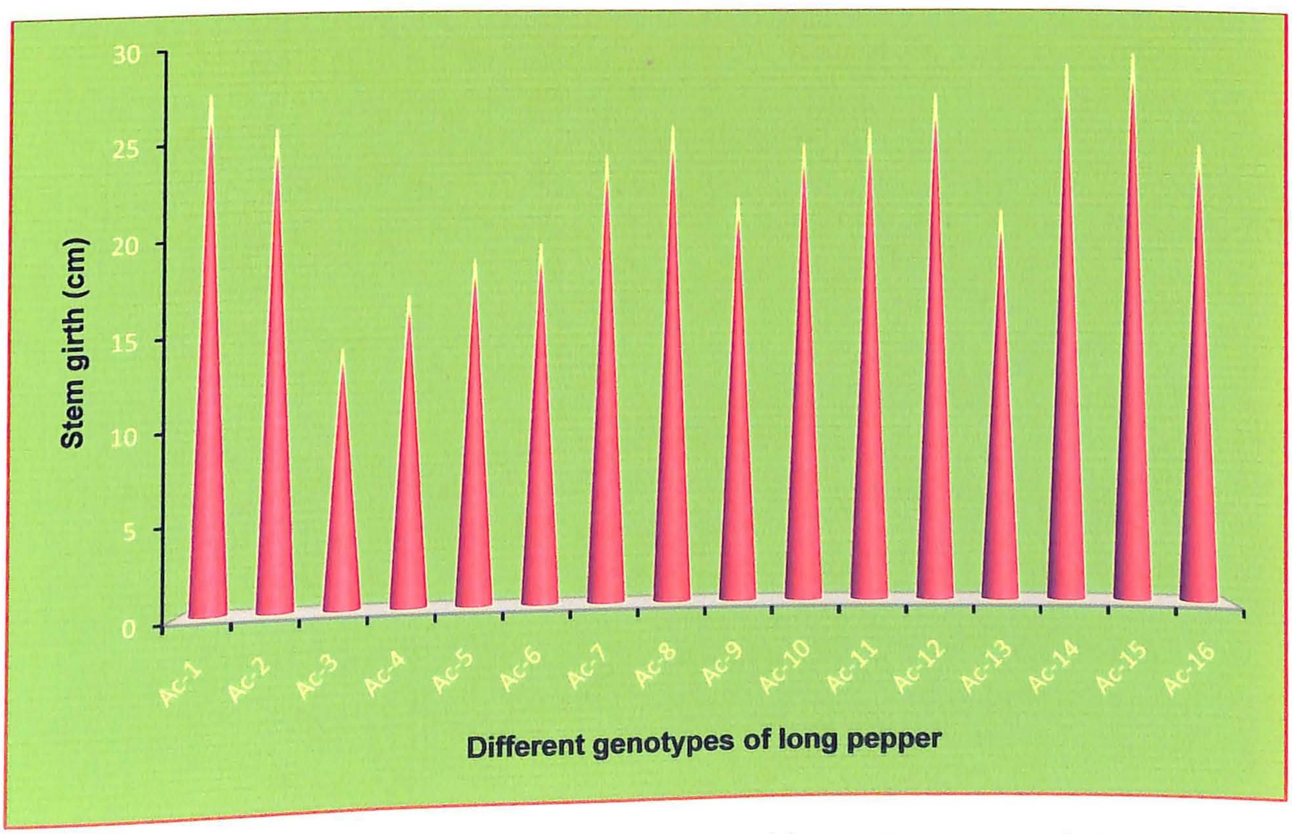

Fig 9. Variability in stem girth of different long pepper genotypes

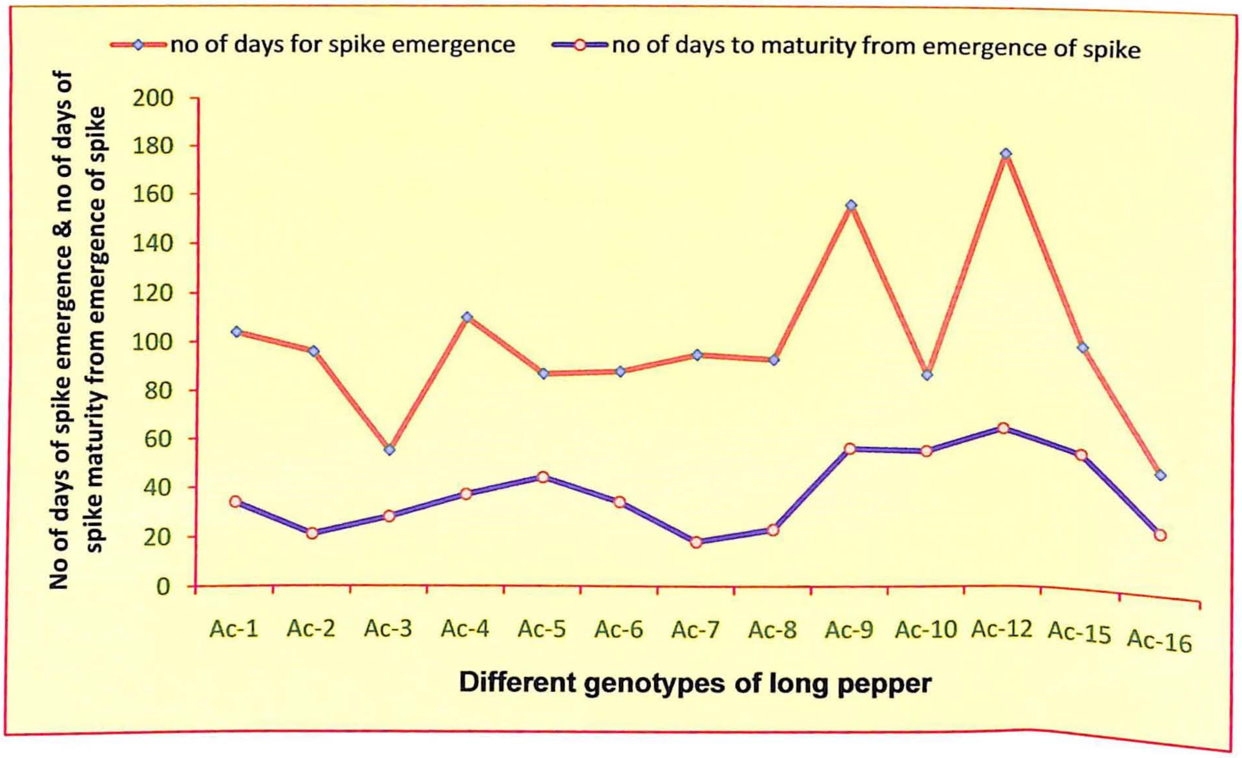

Fig 10. Variability in no of days of spike emergence and no of days of maturity of spike from emergence of spike of different long pepper genotypes

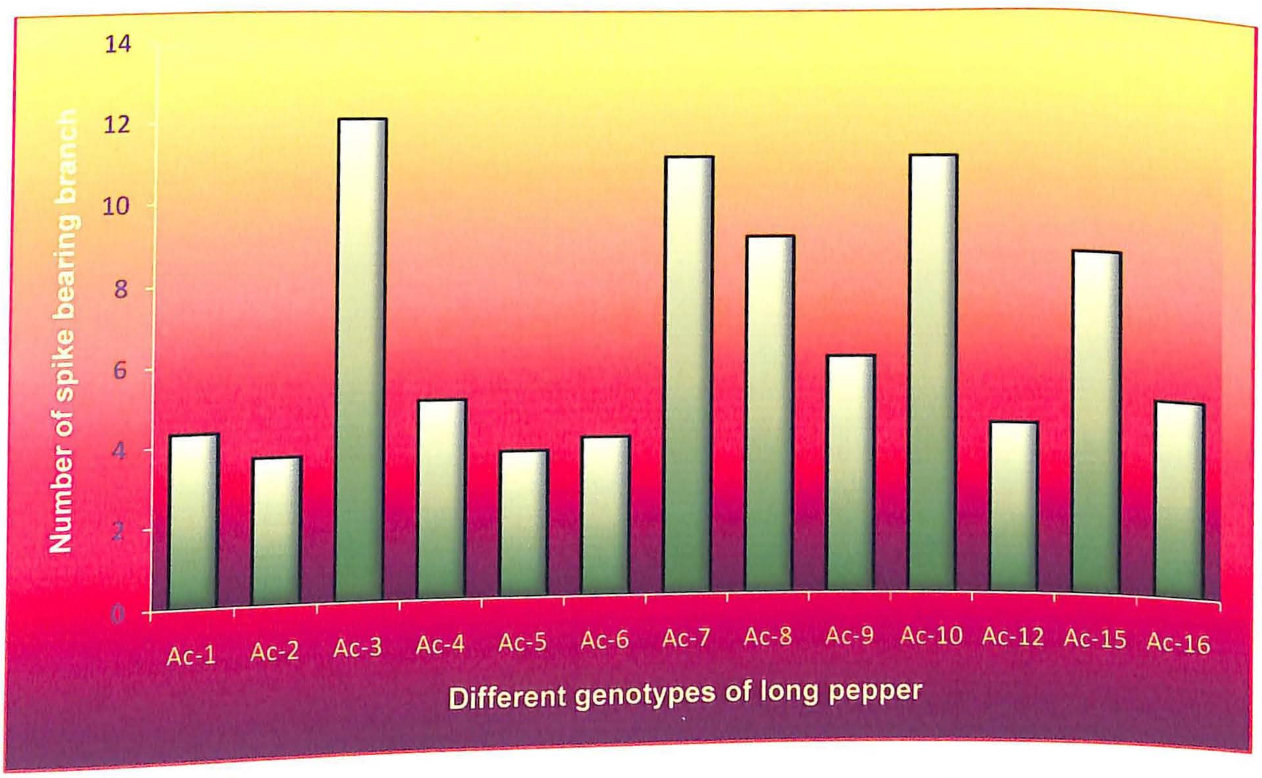

Fig 11. Variability in no. of spike bearing branch of different long pepper genotypes

Total number of spikes/plant: AC-3 produced the highest number of spikes/plant (45.67) followed by AC-10 (36.00) and AC-7 (27.67) while AC-2 had the lowest number of spikes (11.00) followed by AC-1 (14.00), AC-12 (14.33), AC-4 (16.00) and AC-8 (16.00).

Spike length: The maximum spike length was recorded in AC-10 (2.06 cm) followed by AC-6 (1.83 cm) and AC-15 (1.78 cm) and the minimum was with AC-2 (0.94 cm).

Spike girth: The highest spike girth was noted in AC-10 (0.87 cm) followed by AC-16 (0.71 cm). However, the lowest girth was found in AC-5 (0.37 cm) followed by AC-2 (0.41 cm).

Spike weight: With regards to fresh weight of single spike AC-10 showed the maximum weight (0.81 gm) followed by AC-6 (0.73 gm) and AC-12 (0.55 gm), where as AC-2 showed the minimum weight (0.32 gm) followed by AC-8 (0.38 gm).

Internodal length of spike bearing branch: The maximum internodal length was recorded in AC-1 (8.27 cm) followed by AC-7 (4.76 cm) and AC-2 (4.43 cm) and the minimum was with AC-16 (1.60 cm) followed by AC-6 (2.14 cm) and AC-5 (2.70 cm).

Spike yield/plant: With regards to fresh weight AC-10 gave maximum yield (29.16 gm) followed by AC-3 (20.24 gm), AC-6 (14.60 gm) and AC-7 (11.76), where as AC-2 gave lowest yield (3.52 gm) followed by AC-8 (5.60 gm) and AC-4 (6.72 gm).

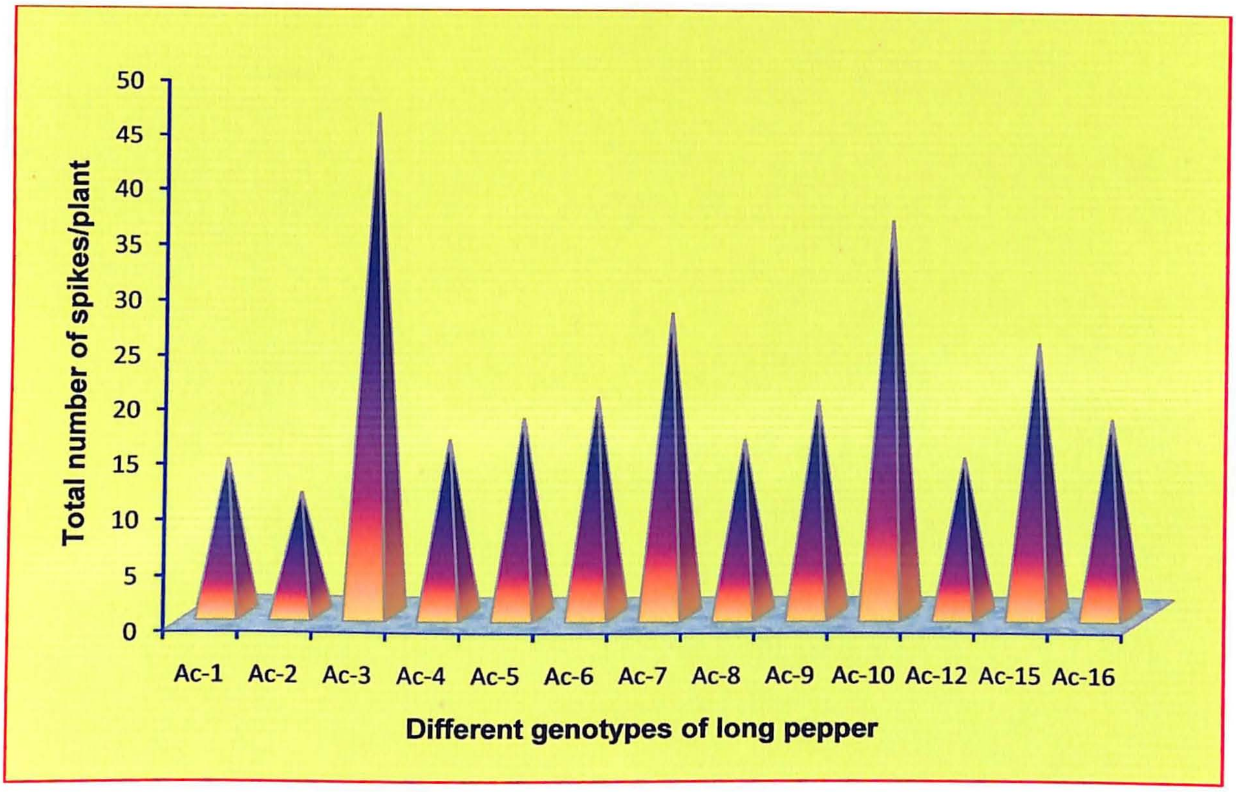

Fig 12. Variability in total spikes/plant of different long pepper genotypes

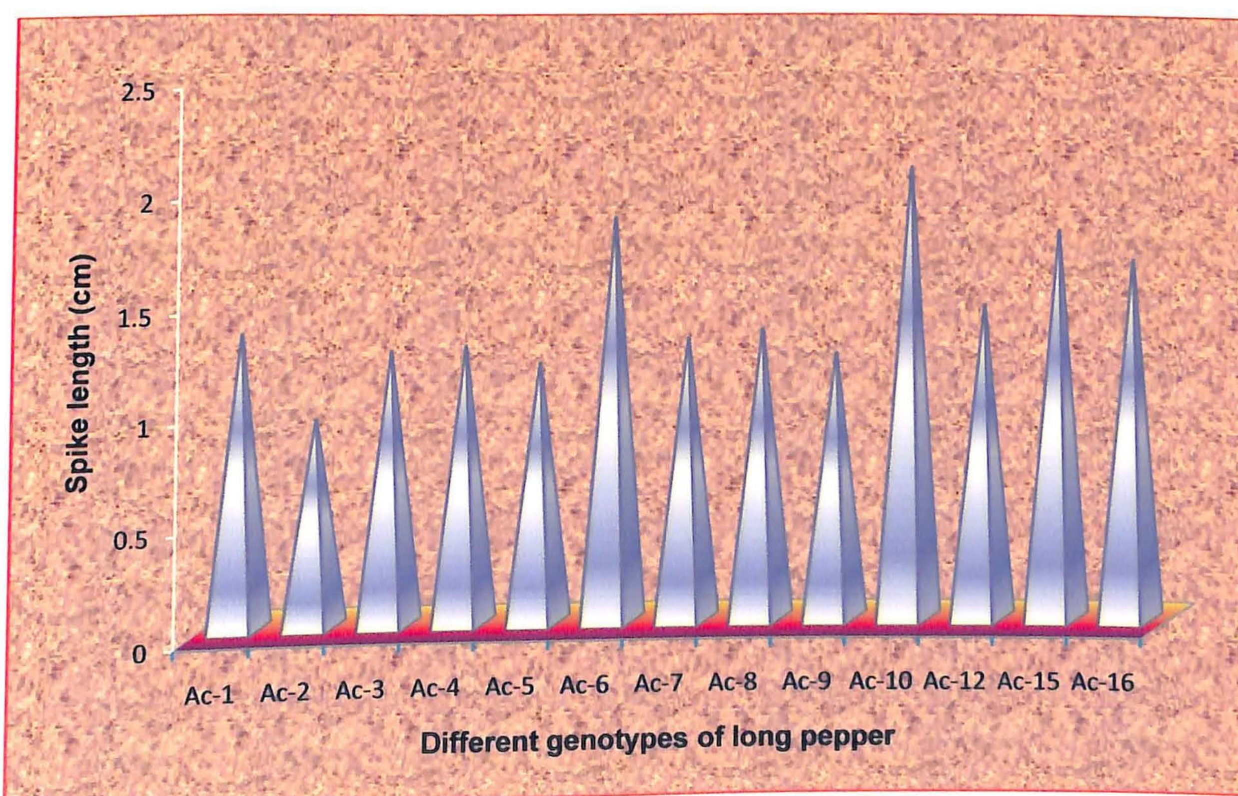

Fig 13. Variability in spike length of different long pepper genotypes

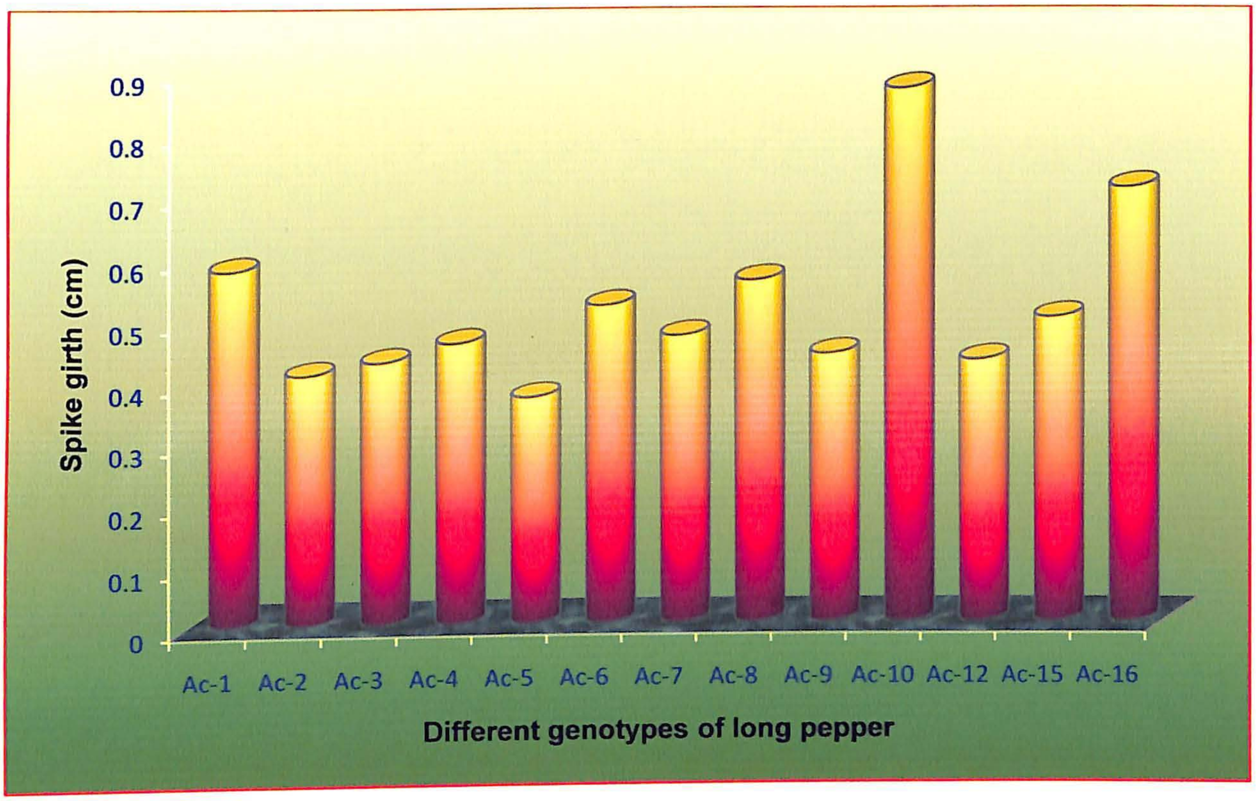

Fig 14. Variability in spike girth of different long pepper genotypes

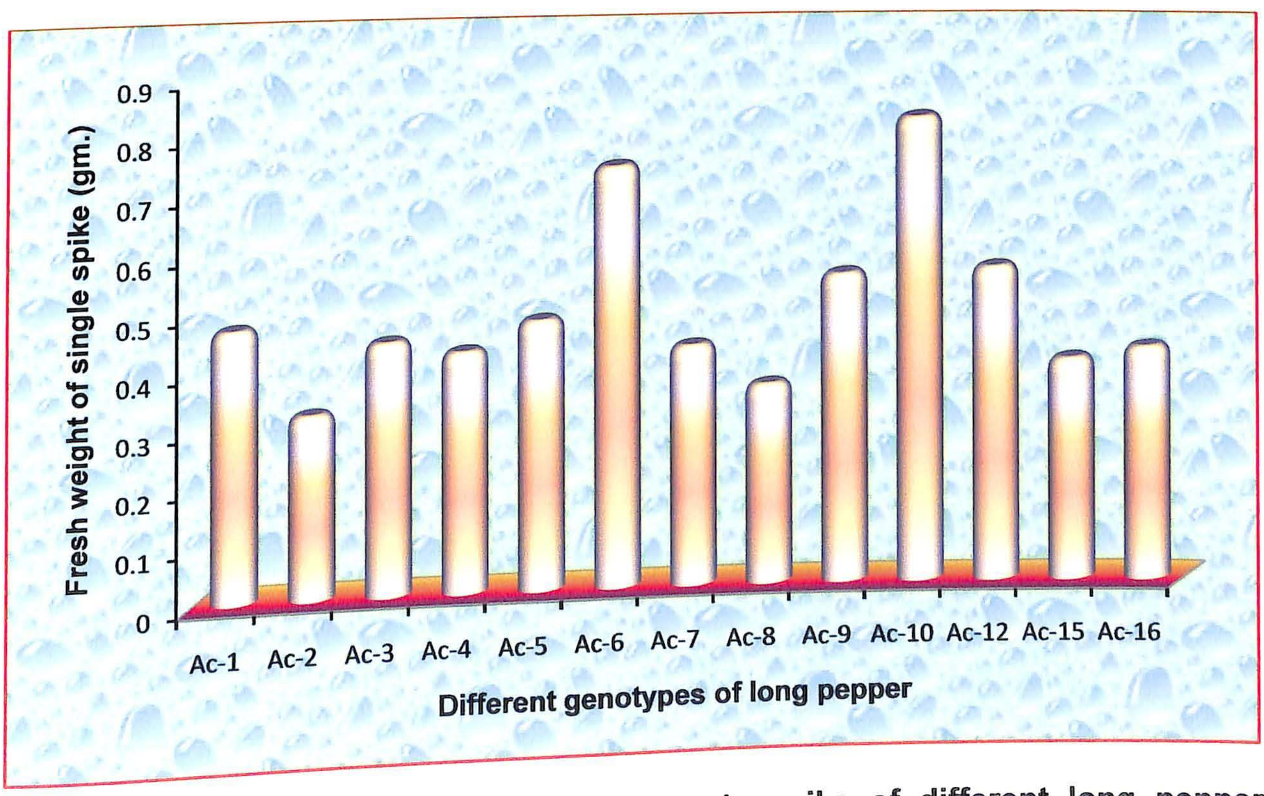

Fig 15. Variability in fresh weight of single spike of different long pepper genotypes

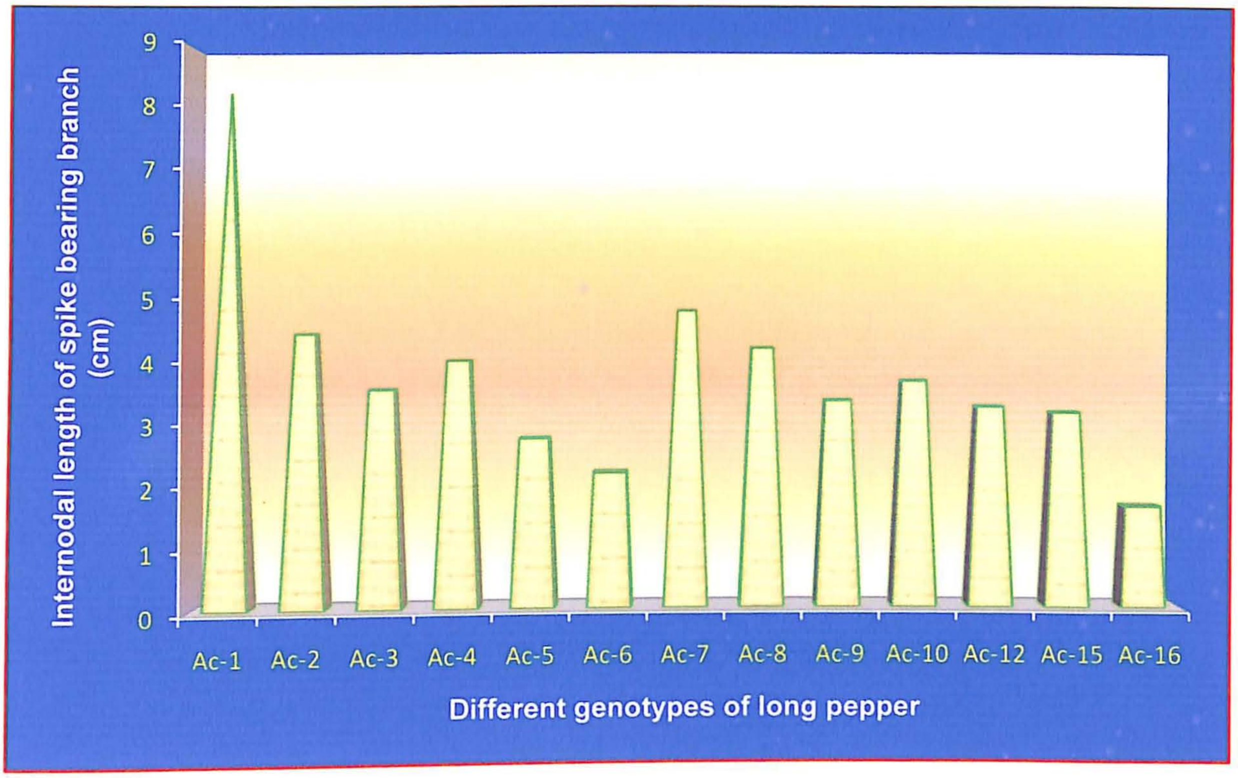

Fig 16. Variability in internodal length of spike bearing branch of different long pepper genotypes

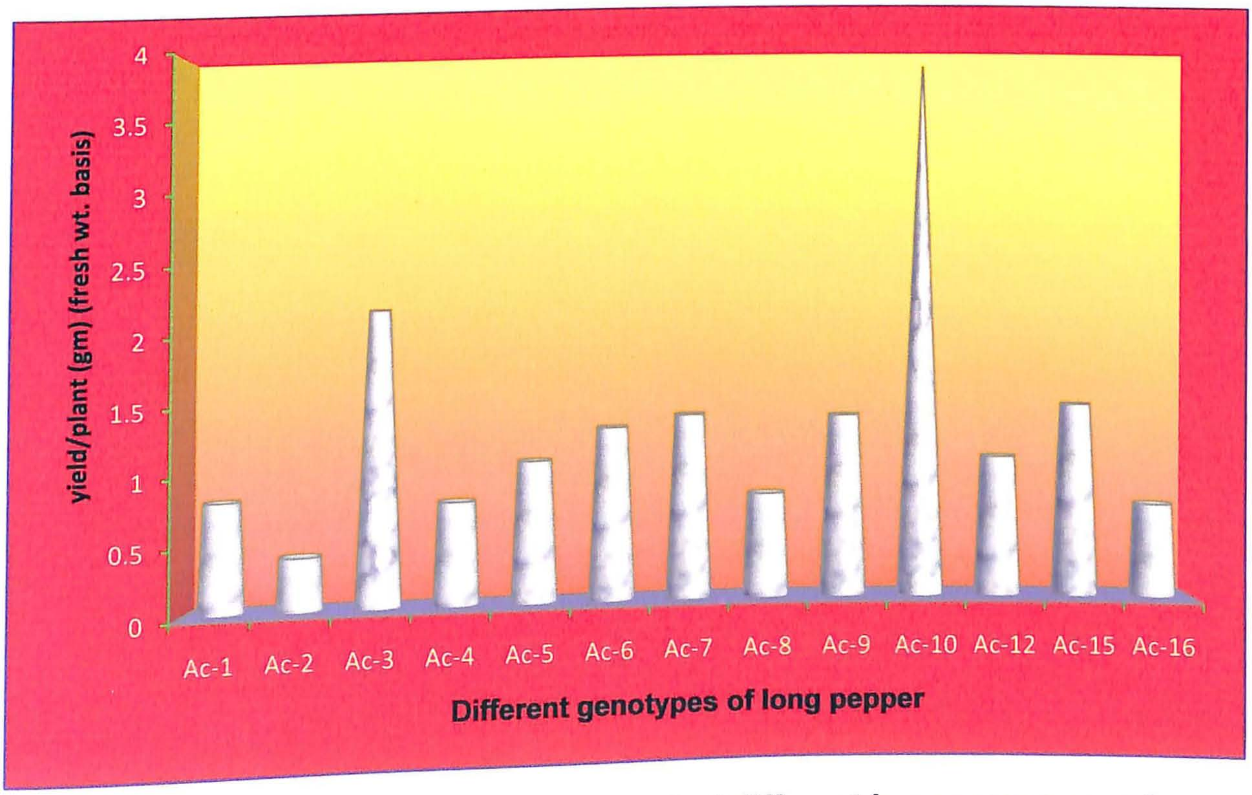

Fig 17. Variability in yield (fresh wt. basis) of different long pepper genotypes

Table 7. Mean performance of sixteen genotypes of long pepper for different quantitative characters

Genotypes	Vine length (cm)	No. of primary branch/ vine	Total leaves /plant	Leaf area (cm^2)	Petiole length (cm)	Stem girth (cm)	No. of days for spike emergence	No. of days to maturity from emergence of spike	No. of spike bearing branch	Total spikes/ plant	Spike length (cm)	Spike girth (cm)	Fresh wt. of single spike (gm)	Internodal length of spike bearing branch (cm)	Yield/plant (gm) (fresh wt basis)
AC-1	102.33	3.87	49.67	55.68	5.54	27.88	104	34	4.33	14	1.33	0.58	0.47	8.27	6.58
AC-2	59.22	7.07	91	91.81	5.26	25.89	96	21	3.67	11	0.94	0.41	0.32	4.43	3.52
AC-3	40.89	3.43	69.67	31.56	2.38	14.11	55	28	12	45.67	1.24	0.43	0.44	3.52	20.24
AC-4	50.22	3.47	49	71.69	4.51	16.88	110	37	5	16	1.26	0.46	0.42	3.98	6.72
AC-5	101.97	3.23	33.33	53.71	5.39	18.71	87	44	3.67	18	1.18	0.37	0.47	2.70	8.46
AC-6	51.52	3.37	54.67	58.26	4.36	19.45	88	34	4	20	1.83	0.52	0.73	2.14	14.60
AC-7	78.44	4.33	74	100.66	6.38	24.21	95	18	11	27.67	1.29	0.47	0.42	4.76	11.76
AC-8	66.11	7.10	73.33	98.27	5.57	25.78	93	23	9	16	1.33	0.56	0.35	4.16	5.60
AC-9	50.89	3.40	84.67	45.45	3.88	21.84	156	56	6	19.67	1.22	0.44	0.54	3.30	8.80

Contd.......

Genotypes	Vine length (cm)	No. of primary branch/ vine	Total leaves/ plant	Leaf area (cm^2)	Petiole length (cm)	Stem girth (cm)	No. of days of spike emergence	No. of days to maturity from emergence of spike	No. of spike bearing branch	Total spikes /plant	Spike length (cm)	Spike girth (cm)	Fresh wt. of spikes (gm)	Internodal length of spike bearing branch (cm)	Yield/plant (gm) (fresh wt. basis)
AC-10	65.33	4.53	117.67	49.74	4.19	24.78	87	55	11	36	2.06	0.87	0.81	3.62	29.16
AC-11	66.89	3.07	61.33	47.61	4.33	25.63	-	-	-	-	-	-	-	-	-
AC-12	45.99	5.47	90.33	45.91	3.63	27.55	178	65	4.33	14.33	1.44	0.43	0.55	3.20	7.70
AC-13	61.66	4.13	83.33	46.88	4.28	21.19	-	-	-	-	-	-	-	-	-
AC-14	53.11	4.27	84.33	46.55	4.62	29.20	-	-	-	-	-	-	-	-	-
AC-15	58.99	6.07	130.67	60.25	4.73	29.84	100	55	8.67	25	1.78	0.50	0.39	3.11	9.75
AC-16	46.44	4.30	98	58.72	4.74	24.83	49	25	5	18	1.65	0.71	0.41	1.60	7.38
SE (m) (±)	0.97	0.14	1.12	1.25	0.19	0.81	0.96	0.91	0.56	0.75	1.17	0.01	0.003	0.17	0.001
C.D. (5%)	2.81	0.39	3.22	3.61	0.54	2.32	2.79	2.64	1.64	2.18	3.41	0.03	0.01	0.51	0.002

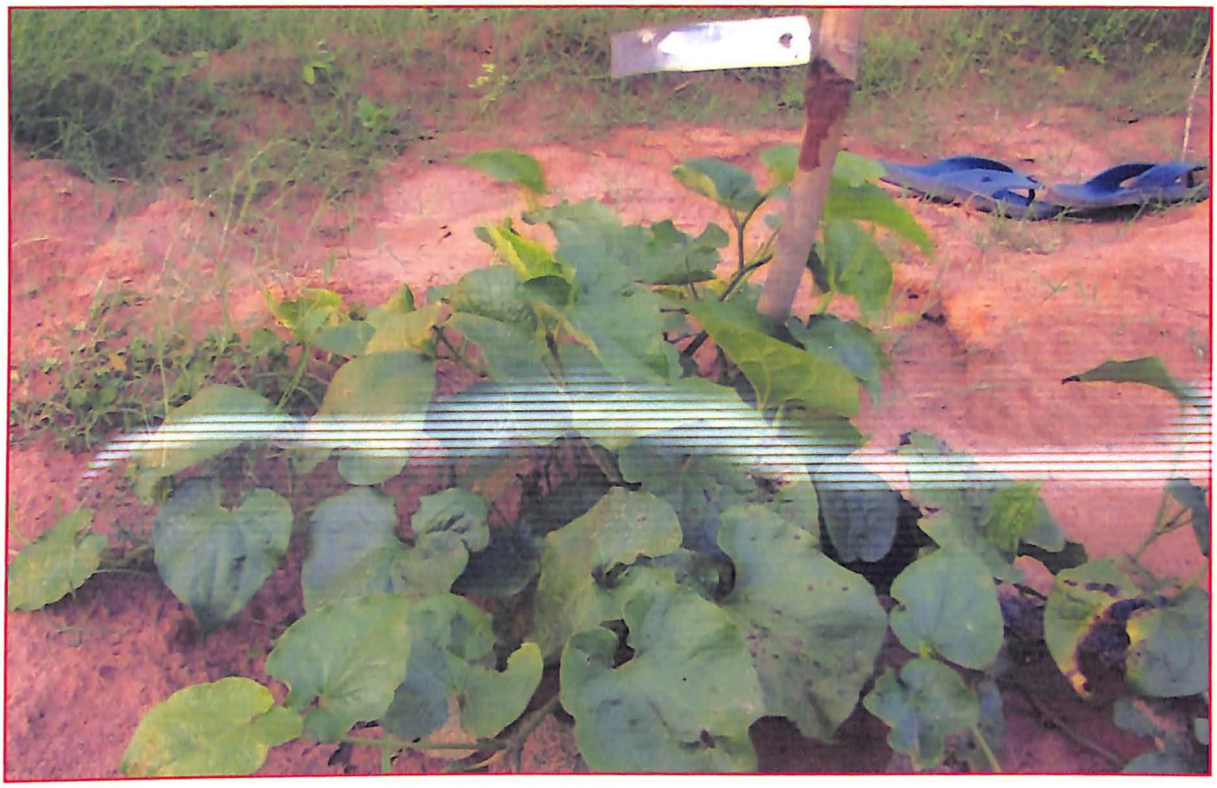

Plate 3. Response of AC-1 under field condition

Plate 4. Response of AC-2 under field condition

Plate 5. Response of AC-3 under field condition

Plate 6. Response of AC-4 under field condition

Plate 7. Response of AC-5 under field condition

Plate 8. Response of AC-6 under field condition

Plate 9. Response of AC-7 under field condition

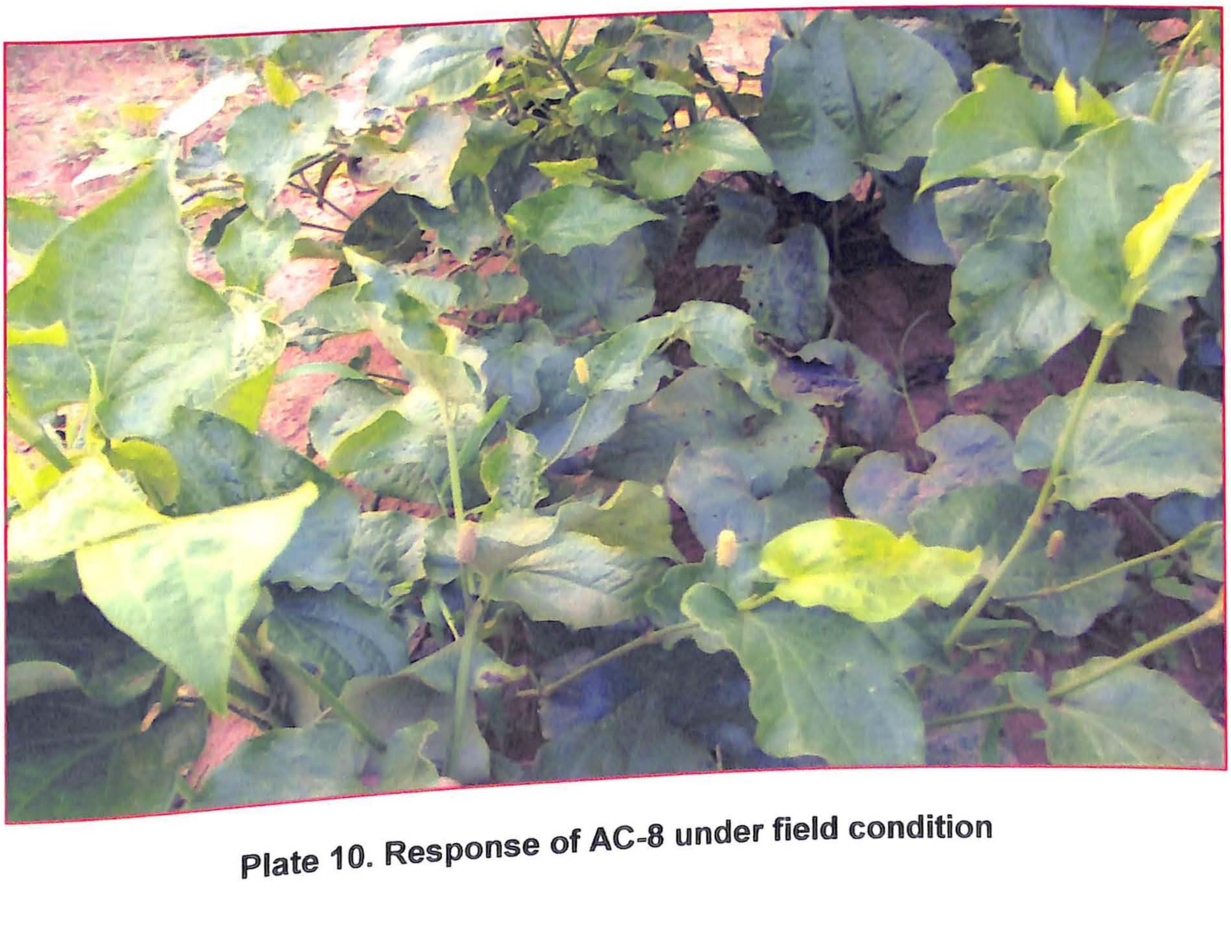

Plate 10. Response of AC-8 under field condition

Plate 11. Response of AC-9 under field condition

Plate 12. Response of AC-10 under field condition

Plate 13. Response of AC-11 under field condition

Plate 14. Response of AC-12 under field condition

Plate 15. Response of AC-13 under field condition

Plate 16. Response of AC-14 under field condition

Plate 17. Response of AC-15 under field condition

Plate 18. Response of AC-16 under field condition

Table 8. Analysis of variance for fifteen quantitative characters in long pepper genotypes

(Mean squares)

Source	d.f.	Vine length (cm)	No. of primary branch/vine	Total leaves/plant	Leaf area (cm^2)	Petiole length (cm)	Stem girth (cm)	No. of days of spike emergence	No. of days to maturity from emergence of spike
Replication	2	4.3672	0.0173	15.0781	8.6172	0.0696	0.8613	8.9844	1.6172
Genotypes	12	1210.84*	5.8531*	2350.7570*	1379.8350*	3.1673*	65.9771*	3633.4220*	720.7308*
Error	24	3.0358	0.0605	3.7435	4.8763	0.1037	2.2031	2.7513	2.4486
C.V. (%)		2.7679	5.3622	2.4756	3.4935	6.9123	6.3949	1.6613	4.1096

* Significant at 5% level

Contd......

(Mean squares)

Source	d.f.	No. of spike bearing branch	Total spikes/plant	Spike length (cm)	Spike girth (cm)	Fresh wt. of single spike (gm)	Internodal length of spike bearing branch (cm)	Yield/plant (gm) (fresh wt. basis)
Replication	2	0.3333	1.2568	0.0006	0.0001	0.0001	0.1393	0.0001
Genotypes	12	29.3419*	288.1924*	0.2956*	0.0577*	0.0613*	7.8722*	0.0321*
Error	24	0.9444	1.6731	0.0004	0.0002	0.0004	0.0911	0.0001
C.V. (%)		14.4111	5.9768	1.4159	3.0461	1.3462	8.0437	0.6021

* Significant at 5% level

4.2 VARIABILITY, HERITABILITY AND GENETIC ADVANCE

Variability

The range, mean, phenotypic and genotypic variances for the quantitative characters studies in long pepper have been presented in Table 9 and Table 10. From the Table 9, it is observed that the maximum mean range of 49 to 178 and the minimum mean range of 0.32 to 0.81 were recorded for number of days for emergence of spike and fresh weight of single spike respectively.

The maximum (1212.98) and minimum (0.02) value of phenotypic variances were also noticed for number of days for emergence of spike and spike girth respectively. The relatively higher phenotypic variances were also recorded for total number of leaves/plant (786.08), leaf area (463.19), vine length (405.63), number of days for spike maturity from emergence (241.87), total number of spike/plant (97.18), stem girth (23.46), while the lower values were recorded for fresh weight of single spike (0.03), spike length (0.09), spike yield/plant (0.58), Petiole length (1.12), number of primary branch/vine (1.99), internodal length of spike bearing branch (2.68), number of spike bearing branch (10.41). In general the estimates of phenotypic variances were higher than their genotypic variances for all the characters studied.

The genotypic variance also showed minimum (0.01) for spike girth and maximum (1210.22) for number of days for emergence of spike. Characters like total number of leaves/plant (782.34), leaf area (458.32), vine length (402.60), number of days for spike maturity from emergence (239.43), total number of spike/plant (95.51), stem girth (21.26) showed higher genotypic variance as compared to fresh weight of single spike (0.02), spike length (0.08), spike yield/plant (0.56), Petiole length (1.02), number of primary branch/vine (1.93), internodal length of spike bearing branch (2.59), number of spike bearing branch (9.47).

Table 9. Range, mean, phenotypic variance, genotypic variance for quantitative characters in genotypes of long pepper.

Sl. No.	Character	Range	Mean	Phenotypic variance	Genotypic variance
1	Vine length (cm)	40.89 - 102.33	62.95	405.63	402.60
2	Number of primary branch/vine	3.07 - 7.07	4.59	1.99	1.93
3	Total number of leaves /plant	33.33 - 130.67	78.15	786.08	782.34
4	Leaf area (cm2)	31.56 - 100.66	63.21	463.19	458.32
5	Petiole length (cm)	2.38 - 6.38	4.69	1.12	1.02
6	Stem girth (cm)	14.11 - 29.84	23.21	23.46	21.26
7	Number of days for spike emergence	49 - 178	99.85	1212.98	1210.22
8	Number of days for spike maturity from emergence	18 - 65	38.08	241.87	239.43
9	Number of spike bearing branch	3.67 - 12.00	6.74	10.41	9.47
10	Total number of spike /plant	11.00 - 45.67	21.64	97.18	95.51
11	Spike length (cm)	0.94 - 2.06	1.43	0.09	0.08
12	Spike girth (cm)	0.37 - 0.87	0.52	0.02	0.01
13	Fresh weight of single spike (gm)	0.32 - 0.81	0.49	0.03	0.02
14	Internodal length of spike bearing branch (cm)	1.60 - 8.27	3.75	2.68	2.59
15	Spike yield/plant (gm)	3.52 - 29.16	1.86	0.58	0.56

Phenotypic and genotypic coefficient of variation

The estimates of phenotypic and genotypic coefficient of variation, heritability in broad sense, genetic advance and genetic advance as the percentage of mean are presented in Table 10 (Fig.18). The phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all the traits under study. The PCV and GCV estimates of the characters ranged from 20.87 and 19.86 % for stem girth to 47.85 and 45.62 % for number of spike bearing branch respectively. The relative magnitude of PCV estimates indicated that it was low for stem girth and moderate (PCV < 33%) for vine length, number of primary branch/vine, petiole length, spike length, spike girth, fresh weight of single spike and high (PCV > 33%) for characters like total number of leaves/plant, leaf area, number of days for spike emergence, number of days for spike maturity from emergence, number of spike bearing branch, total number of spike/plant, spike yield/plant. The genotypic coefficient of variation revealed similar trend with that of PCV.

Heritability

A perusal of the data (Table 10) revealed that the most heritable character was spike yield/plant (heritability in broad sense being 99.98%). It was obvious to note that heritability of all characters was very high (more than 90%). Interestingly, twelve out of fifteen characters included for aforesaid parameters showed even more than 95% heritability *viz.*, vine length (96.25%), number of primary branch/vine (96.96%), spike length (99.59%), spike girth (98.71%), fresh weight of single spike (99.79%), total number of leaves/plant (99.52%), leaf area (98.95%), number of days for spike emergence (99.77%), number of days for spike maturity from emergence (98.99%), total number of spike/plant (98.28%), internodal length of spike bearing branch (96.61%), spike yield/plant (99.98%). The other three character *viz.*, petiole length, stem girth and number of spike bearing branch showed more than 90% heritability (90.78%, 90.61% and 90.93% respectively).

Genetic advance

So far as genetic advance is concerned it had wide range for all characters under experimentation. The genetic advance ranged from 0.28 for spike girth to 71.58 for number of days for spike emergence followed by total number of leaves/plant (57.48), leaf area (43.87), vine length (41.17), number of days for spike maturity from emergence (31.71), total number of spikes/plant (19.96), stem girth (9.04), number of spike bearing branch (6.04) while others characters like internodal length of spike bearing branch (3.26), number of primary branch/vine (2.82),petiole length (1.98), spike yield/plant (1.54), spike length (0.64), fresh weight of single spike (0.29) showed lower values. Since it is not necessary that a character exhibiting high heritability will also give high genetic advance, an estimation of genetic advance is useful in obtaining the information about the characters under study. In the present investigation genetic advance estimated was maximum for number of days for spike emergence (71.58) followed by total number of leaves/plant (57.48), the minimum value being 0.28 for spike girth (Table 10).

Expected genetic advance (GA) or genetic gain under selection (5% selection intensity) among the genotypes was estimated for each character and was expressed as percentage of mean. The estimated GA under selection for the characters varied from 38.95% for stem girth to 92.22% for total number of spikes/plant. The expected genetic advance was high (more than 45%) for all the characters except stem girth (38.95%) and petiole length (42.58%).

Data presented in Table 10 and Fig. 18 revealed that internodal length of spike bearing branch, total number of spikes/plant, spike yield/plant, number of days for spike maturity from emergence expressed high genotypic coefficient of variation, high heritability but characters like petiole length, stem girth showed low compared to others and also low genetic advance as percentage of mean. The characters like total number of leaves/plant, leaf area, vine length, number of primary branch/vine, number of days for spike emergence showed moderately high genotypic coefficient of variability but high value in the heritability and genetic advance in percentage of mean while rest of characters scored low values in all the parameters.

Table 10. PCV, GCV, heritability (h^2) and genetic advance (GA) for quantitative characters in genotypes of long pepper

Sl. No	Character	PCV (%)	GCV (%)	h^2 (%)	GA	GA* (%)
1	Vine length (cm)	31.99	31.88	96.25	41.17	65.42
2	Number of primary branch /vine	30.76	30.29	96.96	2.82	61.45
3	Total number of leaves/plant	35.87	35.79	99.52	57.48	73.55
4	Leaf area (cm2)	34.05	33.87	98.95	43.87	69.40
5	Petiole length (cm)	22.77	21.69	90.78	1.98	42.58
6	Stem girth (cm)	20.87	19.86	90.61	9.04	38.95
7	Number of days for spike emergence	34.88	34.84	99.77	71.58	71.69
8	Number of days for spike maturity from emergence	40.84	40.64	98.99	31.71	83.29
9	Number of spike bearing branch	47.85	45.62	90.93	6.04	89.62
10	Total number of spike/plant	45.55	45.16	98.28	19.96	92.22
11	Spike length (cm)	22.03	21.98	99.59	0.64	45.19
12	Spike girth (cm)	26.78	26.61	98.71	0.28	54.45
13	Fresh weight of single spike (gm)	29.44	29.41	99.79	0.29	60.52
14	Internodal length of spike bearing branch (cm)	43.66	42.91	96.61	3.26	86.88
15	Spike yield/plant (gm)	40.22	40.21	99.98	1.54	82.83

* Genetic advance (at 5% selection intensity) expressed as percentage of mean

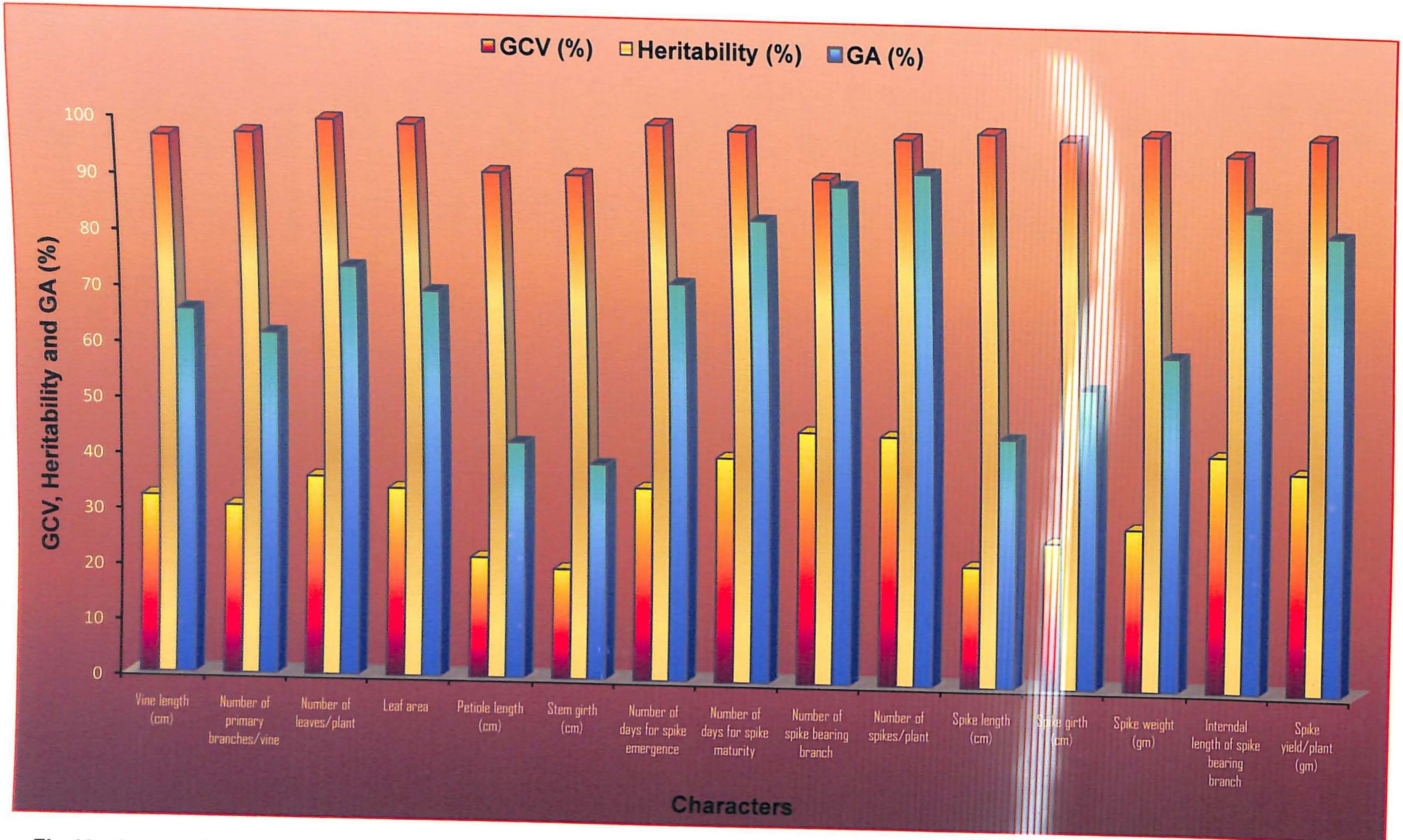

Fig 18. Genotypic coefficient of variation (GCV), Genetic advance (GA) and heritability (h^2) of quantitative characters in long pepper

4.3 CHARACTER ASSOCIATION STUDIES IN LONG PEPPER GENOTYPES

Estimates of phenotypic and genotypic correlations for the various combinations of yield and its components are presented in Table 11 and Table 12, respectively. It is observed that genotypic correlations in general were higher in magnitude than the phenotypic correlation coefficient.

Phenotypic correlation coefficient

The phenotypic correlation (r_p) estimates among fifteen characters ranged from - 0.181 between internodal length of spike bearing branch and spike yield/plant to - 0.125 between vine length and spike yield. There was a high significant positive correlation between vine length and petiole length and internodal length of spike bearing branch at phenotypic level. Other quantitative characters like leaf area, stem girth had low positive correlation with vine length, whereas low negative associations existed in number of days for spike emergence, spike girth and fresh weight of single spike. The remaining characters like total leaves/plant, number of primary branches/vine, spike length, number of spike bearing branch, number of days for spike maturity from emergence, spike yield/plant and total number of spikes/plant had high and moderately high negative correlations at phenotypic level with vine length.

Total leaves/plant, leaf area and stem girth exhibited a high significant positive association with number of primary branches/vine. Number of days for spike maturity from emergence, total number of spikes/plant, spike length, fresh weight of single spike and spike yield/plant showed negative correlation, while petiole length, number of spike bearing branch, number of days for spike emergence, internodal length of spike bearing branch, spike girth, showed low positive correlation with number of primary branches/vine.

Stem girth and spike length showed a high significant positive phenotypic correlation with total number of leaves/plant. It also had low and moderately negative correlation at phenotypic level with leaf area, petiole length and internodal length of spike bearing branch, while rest of characters like number of spike bearing branch, spike yield/plant, number of days for spike emergence, number of days for spike maturity from emergence, total number of spikes/plant, fresh weight of single spike were positively correlated.

Petiole length exhibits a high significant positive correlation with leaf area. Stem girth, number of spike bearing branch and internodal length of spike bearing branch had low and moderate positive correlation with leaf area, while other characters like number of days for spike emergence, number of days to maturity from emergence of spike, spike length, spike girth, fresh weight of single spike, spike yield/plant showed high and moderate negative correlation with leaf area.

High low negative correlation at phenotypic level was seen between number of days for spike maturity from emergence, total number of spikes/plant, fresh weight of single spike and petiole length, while rest of characters like stem girth, spike girth and internodal length of spike bearing branch, noticed high and low non significant positive correlation with petiole length, while rest of the characters like number of spike bearing branch, spike yield/plant, spike length, number of days for spike emergence were negatively correlated.

Number of spike bearing branch, total number of spikes/plant, fresh weight of single spike, spike yield/plant were high and lowly negative correlated with stem girth while others characters like number of days for spike emergence, number of days to maturity from emergence of spike, spike length, spike girth, showed moderate and low positive correlation.

Number of days for spike emergence was highly positive correlated with number of days to maturity from emergence of spike. Fresh weight of single spike and internodal length of spike bearing branch showed moderate positive correlation while total number of spikes/plant, spike girth, number of spike bearing branch, spike length, spike yield/plant showed high and moderate negative correlation with number of days for spike emergence.

Number of spike bearing branch and internodal length of spike bearing branch showed moderate negative correlation with number of days to maturity from emergence of spike. The other characters like total number of spikes/plant, spike length, spike girth, fresh weight of single spike, spike yield/plant showed moderate positive correlation.

Total spike/plant and spike yield/plant had high significant positive correlation with number of spike bearing branch while the other characters like spike length, spike girth, fresh weight of single spike, internodal length of spike bearing branch showed moderate positive correlation.

Spike yield/plant showed high significant positive correlation with total number of spikes/plant. Internodal length of spike bearing branch showed low negative correlation while spike length, spike girth, fresh weight of single spike, showed moderate correlation.

Spike girth, fresh weight of single spike, spike yield/plant had very high significant correlation with spike length. Internodal length of spike bearing branch showed moderate negative correlation.

Spike yield/plant exhibits high significant positive correlation with spike girth while fresh weight of single spike showed moderate positive correlation and internodal length of spike bearing branch had very low negative correlation with spike girth.

Spike yield/plant showed high significant positive correlation with fresh weight of single spike while internodal length of spike bearing branch showed low negative correlation.

Internodal length of spike bearing branch exhibits low negative correlation with spike yield/plant.

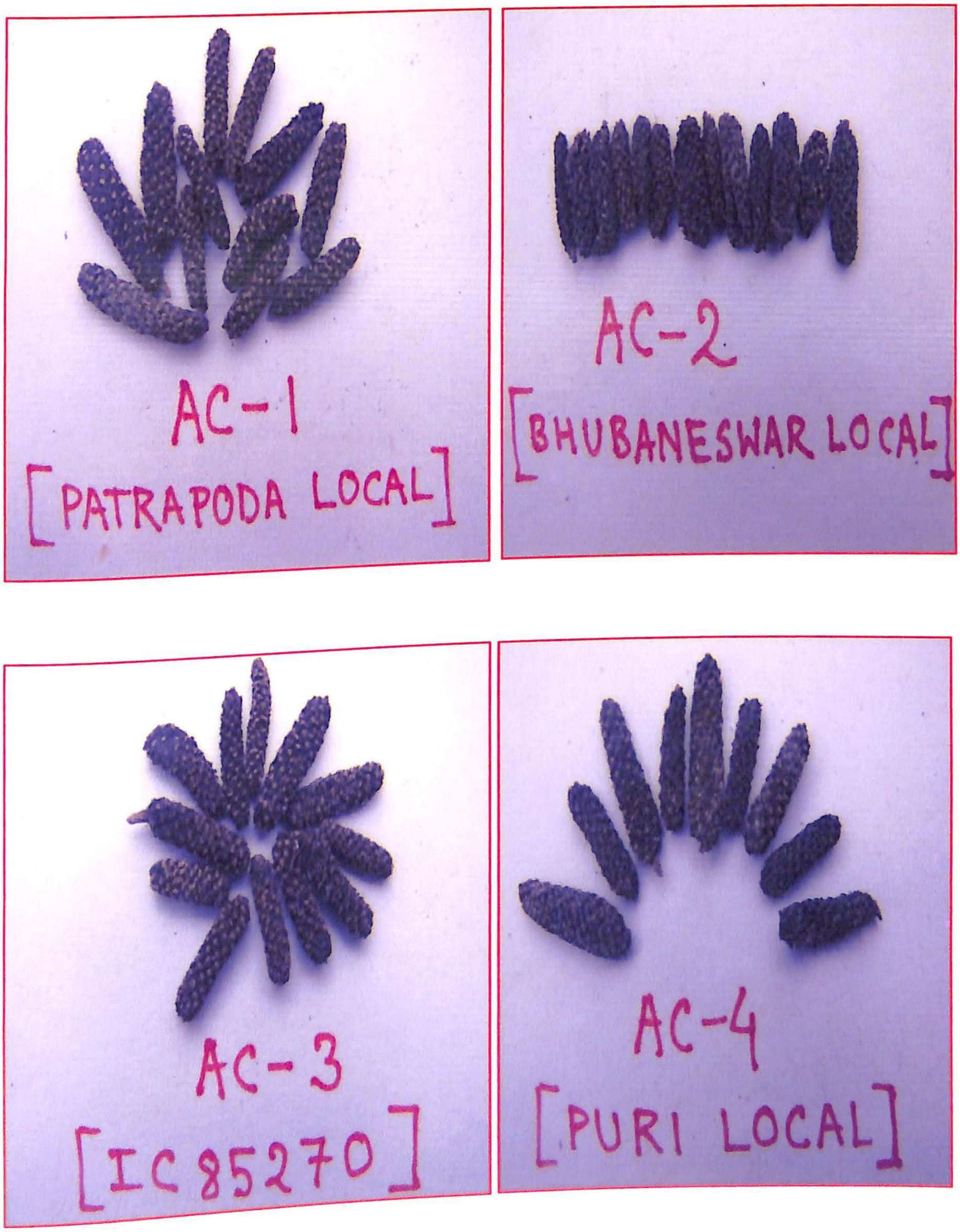

Plate 19. Dry spikes of different genotypes of long pepper

Plate 19. Dry spikes of different genotypes of long pepper

Plate 19. Dry spikes of different genotypes of long pepper

Genotypic correlation coefficient

The genotypic correlation (r_g) estimates among fifteen characters ranged from - 0.1840 between internodal length of spike bearing branch and spike yield to - 0.1253 between vine length and spike yield. Vine length showed high significant positive genotypic correlation with petiole length and internodal length of spike bearing branch. Leaf area and stem girth recorded moderate positive correlation, while rest of the characters scored non-significant negative correlation with vine length.

Number of primary branches/vine established high significant positive correlation with total number of leaves/plant, leaf area and stem girth at genotypic levels. Characters like number of days to maturity from emergence of spike, total number of spikes/plant, spike length, fresh weight of single spike and spike yield showed high and low negative correlation where as rest of the characters showed low positive correlation with number of primary branches/vine.

Stem girth and number of days of spike emergence showed high significant correlation with total number of leaves/plant. Internodal length of spike bearing branch, petiole length and leaf area showed low negative correlation while other characters had moderate high correlation with total number of leaves/plant.

Leaf area showed very high significant positive correlation with petiole length. Stem girth, number of spike bearing branch and internodal length of spike bearing branch showed moderate positive correlation while other characters showed high and low negative correlation with leaf area.

Total number of spikes/plant showed high significant negative correlation with petiole length. Stem girth, spike girth and internodal length of spike bearing branch showed moderate positive correlation where as rest of the characters showed high and low negative correlation.

Stem girth recorded low negative correlation with number of spike bearing branch, total number of spikes/plant, fresh weight of single spike and spike yield,

Genotypic correlation coefficient

The genotypic correlation (r_g) estimates among fifteen characters ranged from - 0.1840 between internodal length of spike bearing branch and spike yield to - 0.1253 between vine length and spike yield. Vine length showed high significant positive genotypic correlation with petiole length and internodal length of spike bearing branch. Leaf area and stem girth recorded moderate positive correlation, while rest of the characters scored non-significant negative correlation with vine length.

Number of primary branches/vine established high significant positive correlation with total number of leaves/plant, leaf area and stem girth at genotypic levels. Characters like number of days to maturity from emergence of spike, total number of spikes/plant, spike length, fresh weight of single spike and spike yield showed high and low negative correlation where as rest of the characters showed low positive correlation with number of primary branches/vine.

Stem girth and number of days of spike emergence showed high significant correlation with total number of leaves/plant. Internodal length of spike bearing branch, petiole length and leaf area showed low negative correlation while other characters had moderate high correlation with total number of leaves/plant.

Leaf area showed very high significant positive correlation with petiole length. Stem girth, number of spike bearing branch and internodal length of spike bearing branch showed moderate positive correlation while other characters showed high and low negative correlation with leaf area.

Total number of spikes/plant showed high significant negative correlation with petiole length. Stem girth, spike girth and internodal length of spike bearing branch showed moderate positive correlation where as rest of the characters showed high and low negative correlation.

Stem girth recorded low negative correlation with number of spike bearing branch, total number of spikes/plant, fresh weight of single spike and spike yield, while the rest characters like number of days for spike emergence, number of days to maturity from emergence of spike, spike length and internodal length of spike bearing branch showed moderate positive correlation.

Number of days to maturity from emergence of spike showed high significant positive correlation with number of days for spike emergence. Fresh weight of single spike and internodal length of spike bearing branch showed low positive correlation, while number of spike bearing branch, total number of spikes/plant, spike length, spike girth and spike yield/plant showed moderate and low negative correlation.

Fresh weight of single spike had high significant positive correlation with number of days to maturity from emergence of spike. Internodal length of spike bearing branch and number of spike bearing branch showed moderate negative correlation. The rest of the characters showed moderate positive correlation.

Total number of spikes/plant and yield/plant showed high significant positive correlation with number of spike bearing branch. Spike length, spike girth showed moderate and fresh weight of single spike, internodal length of spike bearing branch showed low positive correlation.

Yield/plant had high significant positive correlation with total number of spikes. Internodal length of spike bearing branch showed low negative correlation and rest of the characters like spike length, spike girth and fresh weight of single spike showed moderate high correlation with total number of spikes.

Fresh weight of single spike and spike girth had high significant positive correlation with spike length where as yield/plant had a high significant positive correlation with both spike length and spike girth. Internodal length of spike bearing branch had low negative correlation with both spike length and spike girth.

Internodal length of spike bearing branch and spike yield/plant showed a high significant positive correlation with fresh weight of single spike, while yield/plant was negatively correlated with internodal length of spike bearing branch.

Table 11. Phenotypic correlation coefficient (r_p) among different characters in long pepper

Sl. No.	characters	correlation	No. of primary branch/ vine	Total leaves/ plant	Leaf area (cm^2)	Petiole length (cm)	Stem girth (cm)	No. of days of spike emergence	No. of days to maturity from emergence of spike	No. of spike bearing branch	Total spikes/ plant	Spike length (cm)	Spike girth (cm)	Fresh wt. of single spike (gm)	Internodal length of spike bearing branch (cm)	Yield/plant (gm) (fresh wt. basis)
1	Vine length (cm)		-0.1015	-0.4275	0.2158	0.6635*	0.211	-0.0736	-0.1129	-0.1381	-0.224	-0.1801	-0.0222	-0.0737	0.5655*	-0.125
2	No. of primary branch/vine			0.5215*	0.5619*	0.2884	0.6269*	0.1027	-0.1247	0.0707	-0.2971	-0.0789	0.0308	-0.4202	0.078	-0.1316
3	Total leaves/ plant				-0.0388	-0.1707	0.5655*	0.0538	0.3318	0.385	0.2461	0.4943*	0.4477	0.0731	-0.2483	0.4518*
4	Leaf area (cm^2)					0.7661*	0.2904	-0.0912	-0.6167*	0.0368	-0.3972	-0.2922	-0.0774	0.4825	0.2244	-0.2724
5	Petiole length (cm)						0.4094	-0.0924	-0.4222	-0.1663	-0.4899	-0.1643	0.0279	-0.3269	0.3606	-0.2678
6	Stem girth (cm)							0.2934	0.1905	-0.083	-0.3778	0.2374	0.2868	-0.1199	0.2775	-0.0097
7	No. of days of spike emergence								0.6508*	-0.3042	-0.4196	-0.1666	-0.3363	0.1533	0.1446	-0.1521
8	No. of days to maturity from emergence of spike									-0.1117	0.0188	0.3771	0.0537	0.4996	-0.1968	0.3133
9	No. of spike bearing branch										0.8128*	0.2489	0.292	0.0461	0.0311	0.633*
10	Total spikes/ plant											0.3243	0.2453	0.2925	-0.1539	0.6944*
11	Spike length (cm)												0.7423*	0.6801*	-0.3292	0.7401*
12	Spike girth (cm)													0.4855	-0.0094	0.688*
13	Fresh wt. of single spike (gm)														0.1931	0.7393*
14	Internodal length of spike bearing branch (cm)															-0.181

Significant at 5% level

Table 12. Genotypic correlation coefficient (r_g) among different characters in long pepper

Sl. No.	characters	correlation	No. of primary branch/ vine	Total leaves/ plant	Leaf area (cm^2)	Petiole length (cm)	Stem girth (cm)	No. of days of spike emergence	No. of days to maturity from emergence of spike	No. of spike bearing branch	Total spikes/ plant	Spike length (cm)	Spike girth (cm)	Fresh wt. of single spike (gm)	Internodal length of spike bearing branch (cm)	Yield/plant (gm) (fresh wt. basis)
1	Vine length (cm)		-0.1034	-0.4303	0.2185	0.6999*	0.2131	-0.0738	-0.1142	-0.1535	-0.2299	-0.1826	-0.024	-0.0738	0.5804*	-0.1253
2	No. of primary branch/vine			0.5257*	0.5717*	0.2941	0.6893*	0.1064	-0.1231	0.0787	-0.3071	-0.0763	0.0286	-0.4282	0.0904	-0.1339
3	Total leaves/ plant				-0.0394	-0.1816	0.5973*	0.0543	0.3361	0.3925	0.2483	0.4969*	0.4516	0.073	-0.2538	0.4530
4	Leaf area (cm^2)					0.8083*	0.3096	-0.0926	-0.6196*	0.0376	-0.402	-0.2925	-0.0825	-0.4852	0.2322	-0.2742
5	Petiole length (cm)						0.4669	-0.0964	-0.4397	-0.1751	-0.5205	-0.167	0.0259	-0.3481	0.3809	-0.2812
6	Stem girth (cm)							0.3091	0.2044	-0.0867	-0.4198	0.2462	0.3057	-0.1263	0.3023	-0.0101
7	No. of days of spike emergence								0.6533*	-0.3209	-0.4245	-0.1679	-0.3399	0.1547	0.1423	-0.1525
8	No. of days to maturity from emergence of spike									-0.1146	0.0247	0.3805	0.0542	0.5039*	-0.2089	0.3154
9	No. of spike bearing branch										0.8544*	0.2569	0.3079	0.0481	0.031	0.6642*
10	Total spikes/ plant											0.3258	0.2478	0.2953	-0.1573	0.7001*
11	Spike length (cm)												0.7491*	0.6824*	-0.3343	0.7414*
12	Spike girth (cm)													0.4903	-0.0147	0.6924*
13	Fresh wt. of single spike (gm)														0.869*	0.7401*
14	Internodal length of spike bearing branch (cm)															-0.184

Significant at 5% level

4.4 PATH ANALYSIS OF YIELD COMPONENTS IN LONG PEPPER GENOTYPES

Path coefficient analysis was used to determine the direct and indirect association of quantitative traits on yield.

A perusal of the results (Table. 13 and 14) obtained in path analysis for long pepper revealed that total number of spikes/plant (0.5669, 0.4128) had highest positive direct effect on yield at both genotypic and phenotypic level respectively. followed by fresh weight of single spike (0.3019, 0.0171), spike girth (0.2658, 0.2251), leaf area (0.1751, 0.2247) and number of days for spike emergence (0.1278) at genotypic level. The direct effects of all the characters showing high and lower values were cancelled by their respective indirect effects *via.* leaf area, total spikes/plant, spike girth, fresh weight of single spike. Weight of spike showed a strong positive indirect effect *via.* total number of spikes/plant, internodal length of spike bearing branch and spike length though direct effect on yield was low (0.0171). Similarly positive indirect effect of spike length *via.* total number of spikes/plant, spike girth and fresh weight of single spike. Number of spike bearing branch showed positive indirect effect *via.* total number of spikes/plant, spike girth, number of days to maturity from emergence of spike. total number of leaves/plant though it had low and negative effect on yield (-0.0020). Similarly number of days to maturity from emergence of spike had also low and negative effect on yield (- 0.1260) but had strong positive indirect effect *via.* total number of spikes/plant, spike girth, fresh weight of single spike, spike length, internodal length of spike bearing branch and number of days for emergence of spikes. Stem girth showed positive indirect effect *via.* number of days for emergence of spikes, spike girth, petiole length, total number of leaves/plant, leaf area, vine length and number of primary branches/vine. Petiole length showed positive indirect effect *via.* leaf area, vine length and number of days to maturity from emergence of spike. total number of leaves/plant showed positive indirect effect *via.* spike girth, total number of spikes/plant and internodal length of spike bearing branch. Number of primary branches/vine showed strong

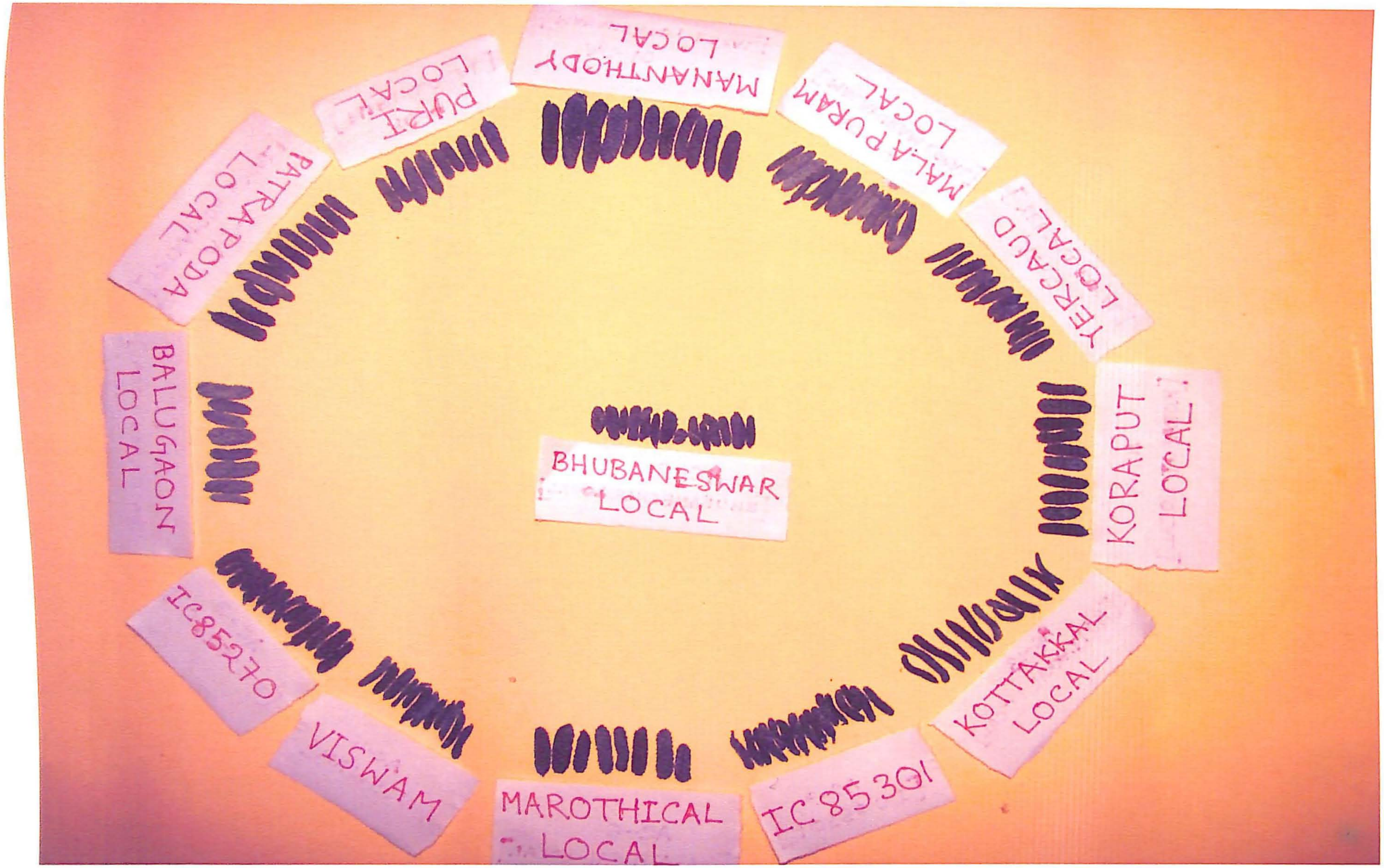

Plate 20. Variability in spikes of long pepper genotypes

Table 13. Path analysis of genotypic correlations

Sl. No.	characters	Vine length (cm)	No. of primary branch/ vine	Total leaves/ plant	Leaf area (cm^2)	Petiole length (cm)	Stem girth (cm)	No. of days of spike emergence	No. of days to maturity from emergence of spike	No. of spike bearing branch	Total spikes/ plant	Spike length (cm)	Spike girth (cm)	Fresh wt. of single spike (gm)	Internodal length of spike bearing branch (cm)	Yield/plant (gm) (fresh wt. basis)
1	Vine length (cm)	**0.0526**	-0.0053	-0.0171	0.0383	0.0189	0.0019	-0.0094	0.0144	0.0003	-0.1303	-0.0053	-0.0063	-0.0126	-0.0889	-0.1253
2	No. of primary branch/vine	-0.0054	**0.0507**	0.0209	0.1001	0.0080	0.0060	0.0136	0.0155	-0.0002	-0.1741	-0.0022	0.0075	-0.0730	-0.0138	-0.1339
3	Total leaves/ plant	-0.0226	0.0267	**0.0397**	-0.0069	-0.0049	0.0052	0.0069	-0.0424	-0.0008	0.1408	0.0145	0.1182	0.0125	0.0389	0.4530
4	Leaf area (cm^2)	0.0115	0.0290	-0.0016	**0.1751**	0.0219	0.0027	-0.0118	0.0781	-0.0001	-0.2279	-0.0085	-0.0216	-0.0828	-0.0356	-0.2742
5	Petiole length (cm)	0.0368	0.0149	-0.0072	0.1415	**0.0271**	0.0041	-0.0123	0.0554	0.0004	-0.2951	-0.0049	0.0068	-0.0594	-0.0583	-0.2812
6	Stem girth (cm)	0.0112	0.0350	0.0237	0.0542	0.0126	**0.0087**	0.0395	-0.0258	0.0002	-0.2378	0.0072	0.0800	-0.0215	-0.0463	-0.0101
7	No. of days of spike emergence	-0.0039	0.0054	0.0022	-0.0162	-0.0026	0.0026	**0.1278**	-0.0823	0.0006	-0.2406	-0.0048	-0.0889	0.0264	-0.0217	-0.1525
8	No. of days to maturity from emergence of spike	-0.0060	-0.0062	0.0133	-0.1085	-0.0119	0.0018	0.0835	**-0.1260**	0.0002	0.0140	0.0111	0.0142	0.0859	0.0319	0.3154
9	No. of spike bearing branch	-0.0081	0.0039	0.0155	0.0066	-0.0047	-0.0007	-0.0410	0.0144	**-0.0020**	0.4843	0.0074	0.0806	0.0082	-0.0048	0.6642
10	Total spikes/ plant	-0.0121	-0.0156	0.0099	-0.0704	-0.0141	-0.0037	-0.0543	-0.0031	-0.0017	**0.5669**	0.0095	0.0649	0.0504	0.0241	0.7001
11	Spike length (cm)	-0.0096	-0.0039	0.0197	-0.0512	-0.0045	0.0021	-0.0215	-0.0479	-0.0005	0.1847	**0.0292**	0.1961	0.1164	0.0512	0.7414
12	Spike girth (cm)	-0.0013	0.0015	0.0179	-0.0144	0.0007	0.0027	-0.0435	-0.0068	-0.0006	0.1405	0.0219	**0.2618**	0.0836	0.0023	0.6924
13	Fresh wt. of single spike (gm)	-0.0039	-0.0217	0.0029	-0.0849	-0.0094	-0.0011	0.0198	-0.0635	-0.0001	0.1674	0.0199	0.0128	**0.0171**	0.0297	0.7401
14	Internodal length of spike bearing branch (cm)	0.0305	0.0046	-0.0101	0.0407	0.0103	0.0026	0.0182	0.0263	-0.0001	-0.0892	-0.0098	-0.0039	-0.0331	**-0.1531**	-0.1840

Residual effect – 0.0462. Bold figures denoted the direct effect.

Table 14. Path analysis of phenotypic correlation

Sl. No.	characters	Vine length (cm)	No. of primary branch/ vine	Total leaves/ plant	Leaf area (cm^2)	Petiole length (cm)	Stem girth (cm)	No. of days of spike emergence	No. of days to maturity from emergence of spike	No. of spike bearing branch	Total spikes/ plant	Spike length (cm)	Spike girth (cm)	Fresh wt. of single spike (gm)	Internodal length of spike bearing branch (cm)	Yield/plant (gm) (fresh wt. basis)
1	Vine length (cm)	**0.0308**	-0.0028	-0 0407	0.0485	0.0074	-0.0071	0.0014	-0.0043	-0.0139	-0.0925	0.0027	-0.0050	-0 0223	-0 0458	-0 1250
2	No. of primary branch/vine	-0.0031	**0.0281**	0 0497	0.1263	0.0032	-0.0212	-0.0019	-0.0047	0.0071	-0.1226	0 0012	0.0069	-0 1269	-0 0063	-0 1316
3	Total leaves/ plant	-0 0132	0.0146	**0.0953**	-0.0087	-0.0019	-0.0191	-0.0010	0.0125	0.0386	0 1016	-0 0074	0.1008	0 0221	0 0201	0 4518
4	Leaf area (cm^2)	0.0066	0.0158	-0 0037	**0.2247**	0.0085	-0.0098	0.0017	-0 0233	0 0037	-0.1639	0 0043	-0.0174	-0 1457	-0 0182	-0.2724
5	Petiole length (cm)	0 0204	0.0081	-0 0163	0.1722	**0.0111**	-0.0139	0 0017	-0.0159	-0 0167	0.2022	0 0024	0 0063	-0 0987	-0.0292	-0 2678
6	Stem girth (cm)	0.0065	0.0176	0 0539	0.0653	0.0046	**-0.0338**	-0.0055	0 0072	-0 0083	-0.1559	-0 0035	0 0646	-0 0362	-0 0225	-0.0097
7	No. of days of spike emergence	-0 0023	0.0029	0 0051	-0.0205	-0.0010	-0.0099	**-0.0186**	0 0245	-0 0305	-0.1732	0 0025	-0.0757	0 0463	-0 0117	-0 1521
8	No. of days to maturity from emergence of spike	-0 0035	-0.0035	0 0316	-0.1386	-0.0047	-0.0064	-0.0121	**0.0377**	-0 0112	0.0078	-0 0056	0 0121	0 1509	0 0159	0 3133
9	No. of spike bearing branch	-0 0043	0.0020	0 0367	0.0083	-0.0019	0 0028	0 0057	-0 0042	**0.1004**	0.3355	-0 0037	0.0657	0 0139	-0 0025	0 6330
10	Total spikes/ plant	-0 0069	-0.0083	0 0234	-0.0893	-0.0055	0.0128	0 0078	0 0007	0 0816	**0.4128**	-0 0048	0.0552	0 0883	0 0125	0.6944
11	Spike length (cm)	-0 0055	-0.0022	0 0470	-0.0657	-0.0018	-0.0080	0.0031	0 0142	0 0249	0.1338	**-0.0148**	0.1671	0 2054	0 0267	0 7401
12	Spike girth (cm)	-0 0007	0.0009	0 0426	-0.0174	0.0003	-0.0097	0 0063	0 0020	0 0293	0.1012	-0 0110	**0.2251**	0 1466	0 0008	0 6880
13	Fresh wt. of single spike (gm)	-0 0023	-0.0118	0 0069	-0.1084	0.0036	-0.0041	-0 0029	0 0188	0 0046	0.1207	-0 0101	0 1092	**0.3019**	0 0156	0 7393
14	Internodal length of spike bearing branch (cm)	0 0174	0 0022	-0 0236	0.0504	0.0040	-0 0093	-0 0026	-0 0074	0 0031	-0 0635	0 0048	-0 0021	-0 0583	**-0.0809**	-0 1810

Residual effect – 0.0754. Bold figures denoted the direct effect.

positive indirect effect *via.* leaf area and negative indirect response to the total number of spikes/plant and fresh weight of single spike. Vine length had no positive indirect effect but showed strong negative indirect effect *via.* total number of spikes/plant and internodal length of spike bearing branch. Number of days to maturity from emergence of spike (- 0.1260), number of spike bearing branch (- 0.0020) and internodal length of spike bearing branch (- 0.1531) at genotypic level and stem girth (- 0.0338), number of days for spike emergence (- 0.0186), spike length (- 0.0148) and internodal length of spike bearing branch (- 0.0809) at phenotypic level showed low direct negative effect with spike yield.

From the path analysis, it appears that total number of spikes/plant, fresh weight of single spike, spike girth, leaf area, number of days for spike emergence showed high direct effects on spike yield. High indirect effects through these characters were also observed. This clearly shows that total number of spikes/plant, fresh weight of single spike, spike girth are three important yield contributing characters in long pepper. Further the leaf area, number of days for emergence of spike, number of spike bearing branch also influenced the yield substantially. Therefore, these important traits should be viewed for selection and hybridization programme of long pepper for further improvement of yield.

Chapter - 5

DISCUSSION

DISCUSSION

The present experiment was carried out to gather genetic information on yield and its attributes for launching an efficient breeding programme in Long pepper. The success of breeding programme based on hybridization followed by selection will be more effective if the genetic diversity is greater among the parents. An assessments of the nature and the extent of variability is therefore one of the basic approaches for planning effective breeding programme to bring out improvement in the crop.

The present experimentation on variability of Long pepper would help to select superior genotypes to improve productivity and adaptability under different agro-climatic conditions of Odisha. As the selection is mainly based on the phenotypic observations, their reflections on genotypic value may not hold good unless the yield of fruits of Long pepper are subjected to statistical analysis, as the complex character like yield is the resultant of complete interactions of several polygenetically controlled quantitative characters.

The experimental findings have been presented in the preceding pages and the outstanding results are discussed hereafter.

Analysis of variance of the various quantitative characters studied in Long pepper indicated presence of differences among genotypes in respect of each trait. The large amount of variation existing in the collected germplasms revealed that considerable improvement can be made through selection with regards to all the characters *viz.*, vine length, number of primary branches/vine, total number of leaves/plant, leaf area, petiole length, stem girth, total number of spike/plant, spike length, spike girth, fresh weight of spike, dry weight of spike, number of days of emergence of spike, number of days to maturity from emergence of spike, number of spike bearing branches/plant, internodal length of spike bearing branches, yield/plant (on fresh weight basis and dry weight basis. There was wide range of variation for all the traits, though not of the same magnitude, which may be attributed to the differential breeding backgrounds and geo-ecological disparities among the regions from which these cultivars have originated.

Two aspects are most important for understanding the breeding principles i.e. (1) selection can not create variability but acts only on the existing variability and (2) selection can act effectively only on heritable difference (Allard, 1960). Therefore, first and foremost requirement for selection is to ascertain whether genetic variability of these characters present in the population, is at significant level or not. From the observations, it is clear that there exists a wide range of phenotypic variation indicating large phenotypic variability for quantitative traits in long pepper.

The genotypic variances are obtained by deducting the environmental variances from their respective phenotypic variances. The larger genotypic variance of the character can be attributed to its additive components and additive x additive type interactions instead of dominance and epistatic components and usually favours an effective selection as these are easily fixable. From the analysis of phenotypic and genotypic coefficient of variation shown in Table 10 reveals that phenotypic coefficient of variation was greater than genotypic coefficient of variation for all the quantitative characters studied and this indicates that the phenotypic coefficient of variation exhibits parallelism with the genotypic coefficient of variation. Further the differences between the values of these two parameters for all the characters were found comparatively less which concludes that all the traits show high resistance to the environmental influence (Panse, 1957).

In the present experiment it is noted that number of spike bearing branch, number of days for spike maturity from emergence, total number of spike/plant, internodal length of spike bearing branch, spike yield/plant, total number of leaves/plant, Leaf area, number of days for spike emergence had high and moderately high GCV which indicated the range of the genetic variability in a character and also helps in the comparison of the genetic variability present in the various other characters. Thus if a genotypic variability is high for a character which is governed by additive gene then the character can be improved by selection. The rest of the traits offer little scope for selection due to their low genetic coefficient of variation. Manuel *et al.* (1994) also recorded high genotypic coefficient of variation for spike yield/plant in long pepper.

The study of genetic coefficient of variation along with the heritability estimate is essential to obtain best picture of heritable variation (Burton, 1952). The heritability is one of much interest to the plant breeder primarily as an important parameter of selection for a particular character and as an index of transmissibility. Characters not influenced by environment are highly heritable and that may influence the selection procedure used by plant breeder (Pohelman and Borthakur, 1972).

High heritability in broad sense was recorded for almost all the character. Vine length (96.25%), number of primary branch/vine (96.96%), spike length (99.59%), spike girth (98.71%), fresh weight of single spike (99.79%), total number of leaves/plant (99.52%), leaf area (98.95%), number of days for spike emergence (99.77%), number of days for spike maturity from emergence (98.99%), total number of spike/plant (98.28%), internodal length of spike bearing branch (96.61%), spike yield/plant (99.98%) showed relatively higher heritability estimates than the other characters. Similar findings for yield/plant, total number of spikes/plant, number of days for emergence of spike, number of days to maturity from emergence of spike by Manuel *et al.* (1994); for spike length, spike girth, spike weight total number of spikes, spike yield by Jaleel, (2006) in long pepper and number of spikes/vine, number of developed berries/spike and length of spike by Sujatha and Namboodiri (1995) in black pepper are in agreement with the present findings. High heritability values predicted as highly heritable traits and environment plays a relatively a limited role in bringing out the observed phenotypic variability. Comparing the heritability estimates with genotypic coefficient of variation, in the present study, it is observed that high values were obtained for both the parameters in case of number of days for spike maturity from emergence, total number of spike, internodal length of spike bearing branch, spike yield and other quantitative traits also showing high heritability with low genetic coefficient of variation, suggested that whatever variation is there can be inherited, nevertheless selection for such characters are of less importance. Though the study of heritability estimates is of great importance yet their scope is limited since their estimation in broad sense are prone to changes in environment and the materials. The heritability estimates in conjunction with the genetic advance, would give the best picture of genetic progress to be expected from the selection than heritability alone (Johnson *et al.*, 1955).

From the results of the present experiment it is clear that the genetic advance as percentage of mean is high for total number of spike/plant, number of spike bearing branch, number of days for spike maturity from emergence, internodal length of spike bearing branch, spike yield/plant where as other characters shows moderate values. Ibrahim *et al.*, (1985) revealed high genetic advance for yield/plant, total number of spikes/plant; high genetic advance for yield/plant, number of spike bearing branch by Sujatha and Namboodiri (1995); Jaleel, (2006) for total spikes/plant, yield/plant, number of days for spike emergence, spike girth and spike length.

From a comparative study of genotypic coefficient of variation, heritability estimates and genetic gain, it was observed that in general, characters like number of days to maturity from emergence of spike, total number of spikes/plant, internodal length of spike bearing branch, spike yield/plant recorded higher estimates for the aforesaid parameters which may be ascribed to additive gene effects (Johnson *et al.*, 1955 and Panse *et al.*, 1957) and selection for these characters will be proved to be useful. The genotypic coefficient of variation and genetic advance for total number of spikes/plant, internodal length of spike bearing branch, spike yield/plant were high. Heritability was low for number of spike bearing branch, petiole length, stem girth but high in case of spike length, spike girth, fresh weight of single spike, total number of leaves/plant relatively which may be due to non additive gene effects indicating that little improvement will be possible, if selection for this trait is practiced. Other characters showed moderate low GCV and GA indicating that selection for these characters would not be effective and ascribed to dominance or epistatic gene action. High heritability value accompanied with low genetic advance for characters was probably due to non-additive gene effect involving dominance deviation and epistatic influence. (Bharathi *et al.*, 2006).

Yield of spikes in long pepper being the complex character, is ultimate effect of interaction of several yield components which are highly influenced by the environment. Of these various components, a few of which directly and positively associated with yield, often prove to be useful indicators in selection. Therefore the knowledge of association between yield and its attributes is of great significance. Griffing (1952) suggested that correlation responses are chiefly due to pleiotropic manifestation of one gene complex, whose primary function is to control the balance between the competitive abilities of two opposite tendencies in growth. After estimating variability, heritability and genetic advance in the present material, it is worthwhile to study the inter-relationship of these quantitative traits and their correlation coefficient at phenotypic and genotypic levels. Robinson (1966) suggested that correlation studies are helpful in choosing superior genotypes from their phenotypic expression.

Data relevant to the phenotypic and genotypic correlation coefficients have been presented in Table 11 and 12. From the data, it is clear that the genotypic correlation coefficients had higher values for most of the characters than those phenotypic correlation coefficients indicating a strong inherent association between the various characters studied. The phenotypic expression of correlation for different quantitative traits under study was lessened by the influence of environment. Spike yield showed a positive significant correlation with total number of spikes/plant at phenotypic and genotypic level. It had also a low to high positive correlation with number of days to maturity from emergence of spike, spike length, spike girth, number of spike bearing branch, fresh weight of single spike at both levels. The low correlation may be due to the low size of sample. Spike yield in long pepper positively correlated with mentioned characters have been reported by Manuel, (1994), Jaleel (2006) and in black pepper by Sujatha and Namboodiri (1995).

Fruit yield exhibited non significant negative association at both levels for the characters like vine length, number of primary branches/vine, leaf area, stem girth, petiole length, number of days for emergence of spike and internodal length of spike bearing branch. Significant genotypic correlations among the yield components indicated that they were closely inter-related. The association of spike yield with number of spikes/plant had higher values at genotypic level than that of phenotypic which suggests that correlation of these two traits is highly affected by the conditions external to them and genetic association might be swamped under different set of environmental conditions. Some contradictions of results with present findings obtained by some workers might be due to the difference in the sets of genotypes and environmental conditions.

There was strong significant positive correlation of vine length with petiole length and internodal length of spike bearing branch at both phenotypic and genotypic levels. Its correlation with number of primary branches/vine, total number of leaves/plant, number of days for spike emergence, number of days for spike maturity, number of spike bearing branch, total number of spikes/plant, spike length, spike girth, fresh weight of single spike and spike yield showed negative correlation at both levels.

There was a strong positive association between number of primary branches/vine and total number of leaves, leaf area, stem girth at both phenotypic and genotypic levels. Most of the characters like petiole length, number of days for spike emergence, number of spike bearing branch, spike girth, internodal length of spike bearing branch showed positive correlation with number of primary branches/vine which indicated its more importance for selection. Similar findings were also noted by Manuel (1994). He noted the length of longest stem, the number of vegetative branches/stem exhibited significant positive correlation with spike yield.

Similarly there was a strong positive association between total number of leaves with stem girth and spike length at both phenotypic and genotypic levels. Here also most of the characters like number of days for spike emergence, number of spike bearing branch, number of days for spike maturity, spike girth, internodal length of spike bearing branch, total number of spikes, spike weight showed positive correlation with number of primary branches/vine which indicated its more importance for selection.

Between leaf area and petiole length there was a strong positive association at phenotypic as well as at genotypic levels. But here most of the quantitative characters showed negative correlation with leaf area. This indicated that leaf area had low correlation with yield.

Petiole length showed significant negative correlation with total number of spikes at both phenotypic and genotypic levels. Also most of the quantitative characters showed negative correlation and its positive correlation exhibited only for stem girth, spike girth and internodal length of spike bearing branch. Chandy and Pilli (1979) also reported that petiole length, leaf area, and thickness of internode of plagiotrope showed negative non significant correlation with yield.

Stem girth recorded moderate non significant positive correlation with number of days for spike emergence, number of days for spike maturity, internodal length of spike bearing branch, spike length, spike girth. But stem girth showed low non significant correlation with spike yield.

There was strong significant positive correlation of days of spike emergence and days for spike maturity. But its correlation with total number of spikes/plant was negatively significant correlated with phenotypic and genotypic levels, where as other characters showed negative association except internodal length of spike bearing branch and fresh weight of spike. This observation indicated that early flowering helps in early maturity which helps in early harvesting.

Fresh weight of single spike recorded strong positive correlation with number of days for spike maturity. Number of spike bearing branch and internodal length of spike bearing branch showed negative correlation and other characters showed moderate positive correlation with days for spike maturity.

There was strong positive significant correlation of number of spike bearing branch with total number of spikes and spike yield. It indicates that more number of spike bearing branch produce more number of spikes which helps to increase the spike yield. Similar findings were found by Manuel (1994), George and Mercy (1978).

There was strong significant positive correlation of total number of spikes/plant with yield at phenotypic and genotypic levels. Thus plant having more number of spikes will result more number of yield/plant. Similar results were also recorded by Sujatha and Namboodiri (1995), Jaleel (2006).

Length of spikes recorded strong significant positive correlation with spike girth, fresh weight of spike and spike yield. This indicating that spike having more length will result more spike girth, more spike weight and more yield/plant.

There was strong significant positive correlation between spike girth and yield. That means the spikes which have more girth help to increase spike yield.

Weight of spike recorded strong significant positive correlation with yield at both phenotypic and genotypic levels. This indicated that fruit with more weight will get more yields. Similar finding was also observed by Ibrahim *et al.*, (1985) Manuel (1994), Sujatha and Namboodiri (1995).

From the above discussion, it can be concluded that simultaneous improvement of fruit yield and number of spikes/plant, weight of spike and yield, spike girth and yield/plant, length of spikes and spike girth, number of spike bearing branch and total number of spikes, fresh weight of single spike and number of days for spike maturity, days of spike emergence and days for spike maturity, leaf area and petiole length, total number of leaves with stem girth can be made if selection is to be made for any one of the correlated characters.

Results of correlation study indicated that total number of spikes/plant, fresh weight of spike, spike length, spike girth, number of spike bearing branch, number of days for spike maturity, days of spike emergence, leaf area, petiole length were important components of spike yield in long pepper.

Correlation coefficients which measure the association between any two traits may not give true and comprehensive picture of a rather complex situation. The association between any two characters which are measured, do not exist by themselves alone but are parts of complicated pathways in which other traits are also interwoven. The indirect association becomes complex and important due to more number of variables in the correlation study. In such a situation the path coefficient analysis devised by Wright (1921) provides better knowledge as it reveals direct and indirect causes of association and permits a critical examination of the specific forces acting to produce a given correlation and measures the relative importance of each casual factor.

The casual relationship with values of correlation and path coefficient for the components of yield and the direct and indirect effects is shown in Table. 13 and Table. 14. Path coefficient analysis revealed that total number of spikes/plant had highest positive direct effect at both phenotypic and genotypic levels followed by spike girth, number of days for emergence of spike, leaf area. Spike length, petiole length, total number of leaves/plant, vine length, number of primary branches/vine, spike weight showing the moderately high positive direct effect on yield. Manuel (1994) observed that the characters such as number of spikes per spike bearing branches per stem, length of longest stem, number of vegetative branches per stem and number of leaves per hill showed significant positive correlation with dry spike yield.

Spike girth showed second highest value of positive direct effect on yield, it had strong significant positive correlation with total number of spikes/plant and along with positive indirect effects through spike length, fresh weight of spikes, total leaves/plant, number of primary branches/vine, petiole length, internodal length of spike bearing branch. The positive effect of spike girth with yield was also reported by Sujatha and Namboodiri (1995).

Leaf area showed next high positive direct effect on yield and it is negatively correlated with yield. This negative correlation is due to the high negative indirect effect of total number of spikes/plant, spike girth, spike weight, internodal length of spike bearing branch.

Weight of spike showed moderately high direct effect on yield but through it was positively correlated with yield. The positive correlation is due to its positive indirect effect via spike girth, total number of spikes/plant, internodal length of spike bearing branch and number of days for spike maturity. The positive direct effect for spike weight was also reported by Manuel (1994), Jaleel (2006).

Internodal length of spike bearing branch recorded negative direct effect on yield and it was negatively correlated with yield at both phenotypic and genotypic level. The negative indirect effect is due to its negative correlation with spike girth, spike weight, total number of spikes, total number of leaves and stem girth. Similarly number of days for spike maturity and number of spike bearing branch showed negative direct effect on yield at genotypic level but it was positively correlated with yield where as spike length recorded negative direct effect on yield at phenotypic level it had also positively correlated with yield.

Since two major yield contributing characters like total number of spikes/plant and spike girth affected yield directly and positively via each other. It may concluded that more attention should be paid towards the number of spikes/plant followed by spike girth, spike weight, petiole length, leaf area in formulating a sound breeding programme. These characters there could be used as useful criteria in developing high yielding varieties in long pepper.

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Chapter -6

SUMMERY & CONCLUSION

SUMMERY AND CONCLUSION

Sixteen diverse genotypes of long pepper were evaluated in a randomized block design with three replications to understand the amount of genetic variability present in the base population, which is an essential requirement for achieving success in a breeding programme. Further, the knowledge of genetic correlation among yield components themselves and their relationship with yield, heritability and expected genetic gain are of great importance for selecting superior genotypes. When correlation studies involve many traits then it becomes difficult to determine the importance of each of the casual factor. The path coefficient analysis provides an effective means of understanding direct as well as indirect causes of association. The results of this investigation are summarized below:

Analysis of variance showed that there are significant differences among the genotypes of long pepper for all the fifteen quantitative characters *viz.* vine length, number of primary branches/vine, total number of leaves/vine, leaf area, petiole length, stem girth, number of days for spike maturity, number of days for spike emergence, total number of spikes/plant, number of spike bearing branch, spike length, spike girth, fresh weight of single spike, internodal length of spike bearing branch, spike yield.

A wide range of variation was observed in almost all the quantitative traits studied in long pepper. High phenotypic and genotypic variance were observed in vine length, total number of leaves/vine, leaf area, number of days for spike maturity, number of days for spike emergence. Total number of spikes/plant, stem girth, number of spike bearing branch showed moderately high values, while the remaining characters had low variance.

A wide range of genetic diversity was also recorded in the characters *viz.* number of days for spike maturity, number of days for spike emergence, total number of leaves/vine, number of spike bearing branch, total number of spikes/plant, internodal length of spike bearing branch. Spike length, spike girth, petiole length showed moderately high genotypic coefficient of variation, while stem girth showed moderately low value for this parameters.

High heritability (> 95%) was marked for vine length, number of primary branches/vine, total number of leaves/vine, leaf area, number of days for spike maturity, number of days for spike emergence, total number of spikes/plant, spike length, spike girth, fresh weight of single spike, internodal length of spike bearing branch. Other characters showed lower values for this parameter.

Genetic advance as percentage of mean was recorded high for total number of spikes/plant. Moderately high to moderately low values of genetic advance were noticed for vine length, number of primary branches/vine, total number of leaves/vine, leaf area, number of days for spike maturity, number of days for spike emergence, fresh weight of single spike, internodal length of spike bearing branch. Other characters showed low values and genetic advance is lower for the stem girth.

Considering the three genetic parameters namely, genotypic coefficient of variation, heritability and genetic advance as percentage of mean it was evident that phenotypic selection will be effective for the total number of leaves/vine, number of spike bearing branch, total number of spikes/plant, internodal length of spike bearing branch. Total number of spikes/plant, number of spike bearing branch recorded high GCV and genetic advance. Moderately low heritability compared to other characters, which indicated that this trait is highly influenced by environment. The rest of other characters *viz.* spike length, spike girth, fresh weight of single spike, stem girth, petiole length showed low GCV and GA, which are ascribed to epistatic gene effect.

Phenotypic and genotypic correlation coefficients among the various quantitative characters indicated that vine length, petiole length, total number of leaves, number of primary branches, leaf area, stem girth, number of days for spike emergence, number of days for spike maturity, number of spike veering branch, total number of spikes, spike length spike girth, fresh weight of spikes were positively and significantly correlated with each other and simultaneous improvement can be made if selection is performed for any one of the correlated characters. Some other combinations of variables showing negatively significant association were number of days for spike maturity, fresh weight of spikes, leaf area, total number of spikes, petiole length. Low positive correlations between different variables though not significant were observed because the size of the sample was small.

Path coefficient analysis indicated that total number of spikes/plant had maximum positive direct effects on yield. Spike girth, number of days for emergence of spike, leaf area, vine length, number of primary branches had moderately high positive effect on yield but it cannot be ignored because it had high values of heritability, GCV and GA. Similarly, the indirect effects of different components on yield/plant showed that number of spike bearing branch via total number of spikes/plant increased the yield of long pepper.

CONCLUSION

From the results of present investigation it is concluded that besides direct selection for yield, indirect selection through the number of spikes/plant, leaf area, spike length, spike girth, spike weight, number of spike bearing branch should be considered for further improvement of spike yield in long pepper.

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Chapter -7

BIBLIOGRAPHY

BIBLIOGRAPHY

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*Originals not seen.

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APPENDICES

APPENDICES

Appendix – I (Vine length)

S.V.	d.f.	S.S.	M.S.	F
Block	2	8.734375	8.367188	1.438559
Genotypes	12	14530.08	1210.84	398.8527
Error	24	72.85938	3.035807	
Total	38	14611.67		

Appendix – II (Number of primary branches/vine)

S.V.	d.f.	S.S.	M.S.	F
Block	2	0.0345459	0.017273	0.2854861
Genotypes	12	70.23706	5.853089	96.73944
Error	24	1.452087	0.060504	
Total	38	71.7237		

Appendix – III (Total number of leaves/plant)

S.V.	d.f.	S.S.	M.S.	F
Block	2	30.15625	15.07813	4.027826
Genotypes	12	28209.08	2350.757	627.9586
Error	24	89.84375	3.74349	
Total	38	28329.08		

Appendix – IV (Leaf area)

S.V.	d.f.	S.S.	M.S.	F
Block	2	17.23438	8.617188	1.767156
Genotypes	12	16558.02	1379.835	282.9674
Error	24	117.0313	4.876302	
Total	38	16692.28		

Appendix – V (Petiole length)

S.V.	d.f.	S.S.	M.S.	F
Block	2	0.1392822	0.0696411	0.6717198
Genotypes	12	38.00824	3.167354	30.55055
Error	24	2.48822	0.1036758	
Total	38	40.63574		

Appendix – VI (Stem girth)

S.V.	d.f.	S.S.	M.S.	F
Block	2	1.722656	0.8613281	0.3909719
Genotypes	12	791.7246	65.97705	29.94814
Error	24	52.87305	2.203044	
Total	38	846.3203		

Appendix – VII (Number of days for spike emergence)

S.V.	d.f.	S.S.	M.S.	F
Block	2	17.96875	8.984375	3.265499
Genotypes	12	43601.07	3633.422	1320.619
Error	24	66.03125	2.751302	
Total	38	43685.07		

Appendix – VIII (Number of days for spike maturity)

S.V.	d.f.	S.S.	M.S.	F
Block	2	3.234375	1.617188	0.6604627
Genotypes	12	8648.769	720.7308	294.3479
Error	24	58.76563	2.448568	
Total	38	8710.769		

Appendix – IX (Number of spike bearing branch)

S.V.	d.f.	S.S.	M.S.	F
Block	2	0.666626	0.333313	0.3529203
Genotypes	12	352.1027	29.34189	31.06794
Error	24	22.66663	0.9444428	
Total	38	375.4359		

Appendix – X (Total number of spikes/plant)

S.V.	d.f.	S.S.	M.S.	F
Block	2	2.513672	1.256836	0.7512405
Genotypes	12	3458.309	288.1924	172.2594
Error	24	40.15235	1.673014	
Total	38	3500.975		

Appendix – XI (Spike length)

S.V.	d.f.	S.S.	M.S.	F
Block	2	0.001137	0.0005684	1.392523
Genotypes	12	3.546883	0.2955736	724.1387
Error	24	0.0097961	0.00040817	
Total	38	3.557816		

Appendix – XII (Spike girth)

S.V.	d.f.	S.S.	M.S.	F
Block	2	0.000246	0.000123	0.4903389
Genotypes	12	0.692133	0.0576778	229.8876
Error	24	0.006021	0.0002509	
Total	38	0.698401		

Appendix – XIII (Spike weight)

S.V.	d.f.	S.S.	M.S.	F
Block	2	0.0002498	0.0001249	2.921933
Genotypes	12	0.7352219	0.0612684	1432.967
Error	24	0.0010261	0.0000428	
Total	38	0.7364979		

Appendix – XIV (Internodal length of spike bearing branch)

S.V.	d.f.	S.S.	M.S.	F
Block	2	0.2786865	0.1393433	1.528965
Genotypes	12	94.46619	7.872183	86.37873
Error	24	2.187256	0.0911356	
Total	38	96.93213		

Appendix – XV (spike yield)

S.V.	d.f.	S.S.	M.S.	F
Block	2	0.2786865	0.1393433	1.528965
Genotypes	12	94.46619	7.872183	86.37873
Error	24	2.187256	0.0911356	
Total	38	96.93213		