YIELD AND QUALITY OF *Piper longum* L UNDER DIFFERENTIAL SPACING AND MANURIAL REGIMES IN COCONUT GARDENS

By

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THESIS

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DECLARATION

I here by declare that the thesis entitled "**Yield and quality of *Piper longum* L. under differential spacing and manurial regimes in coconut gardens**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship, associateship or other similar title, of any other university or society.

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Certified that the thesis entitled "**Yield and quality of *Piper longum* L. under differential spacing and manurial regimes in coconut gardens**" is a record of the research work done independently by **Miss.T.P.Ayisha**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

Introduction

INTRODUCTION

The genus Piper consists of about 2000 species of which 87 have been reported from India. The genus includes two important cultivated cash crops, *Piper nigrum* (black pepper) and *Piper betle* (betel vine). There are also a number of wild species in the genus *Piper* possessing medicinal properties of which most important one is *Piper longum* (long pepper or *thippali*).

The Greek name *pepari* the latin *piper* and the English *pepper* came from the Sanskrit name *peppali* which stands for long pepper. *Piper longum* is a native of Indo-Malaya region. It is growing wild in the tropical rain forests of India, Nepal, Indonesia, Malaysia, Sri Lanka, Rhio, Timor, and the Phillippines. In India, it is found mainly in Assam, Meghalaya, West Bengal, Orissa, Eastern Uttar Pradesh, Madhya Pradesh, Maharashtra and ever green forests of Western Ghats in Kerala, Karnataka and Tamil Nadu.

Long pepper is a slender aromatic climber with perennial woody roots. It is propagated mainly by cutting or layering of mature branches or by suckers planted at the beginning of rainy season. Reports are also available on propagation through tissue culture (Bhat *et al.*, 1992 and Bhat *et al.*, 1995).

The dried fruits as well as roots of *Piper longum* are attributed with numerous medicinal values and are extensively used in Ayurvedic and Unani systems of medicine. It is used for the treatment of diseases of the respiratory tract, cardiac and splenic disorders, chronic fever, loss of appetite, worm troubles, and all ailments of liver. It is a major constituent of Ayurvedic drugs recommended for increasing immunity against AIDS (Acquired Immune Deficiency Syndrome) virus and acts as an immunostimulant (Anon, 1993). The roots and the thicker parts of the stem are cut and used as *Piplamul*.

The bulk of Indian long pepper for market is derived from its wild growth in Assam, Meghalaya and West Bengal and supplemented by imports from Sri Lanka and Indonesia. Organised commercial cultivation is still not popular in this crop. Due to the peculiar ecological and agronomic requirements and lack of availability of cultivable land, this crop cannot be recommended as a sole crop in the state.

In Kerala coconut cultivation extends up to about 8.6 lakh hectares. The productivity is declining due to various factors. The only way to enhance net returns from coconut holding is by intercropping with perennials. The importance of intercropping medicinal plants in coconut gardens is of great relevance taking into account the escalating price of medicines and shortage of indigenous materials for drugs.

Many workers have reported that *thippali* could be a remunerative intercrop in irrigated coconut gardens giving economic yield up to three years. Among the varieties, *Cheemathippali* was found to give the best yield in coconut gardens. A preliminary study was conducted by Sheela (1996) for one and a half years to assess the growth and yield of long pepper as affected by spacing, organic manure and fertilizer application. It was necessary to continue the trial till the yield started declining to assess the productivity, quality and economics of *thippali* cultivation under shaded conditions of coconut gardens. Hence the present investigation was carried out with the following objectives.

1. To find out the optimum plant density for *Piper longum* grown as an intercrop in coconut gardens.

2. To find out the optimum quantity of organic manure and fertilizer for growth, yield and quality of *Piper longum*.

3. To find out the economics of *thippali* cultivation.

Review of Literature

2. REVIEW OF LITERATURE

Although recorded evidences are available about cultivation of *thippali* from the early thirties of 19th century (Roxburgh, 1832) there is limited literature available on its agronomic aspects especially on the requirement of spacing, manurial and fertilizer application, scope as an intercrop, yielding pattern over years and quality aspects. All the available literature about origin and distribution, morphology, agronomic practices, chemical composition, medicinal properties and pests and diseases are reviewed and presented in this chapter. Research on other crops belonging to the genus *Piper* are also reviewed in order to have an overall dimension of the problem.

2.1 Origin and distribution

De Candolle (1967) reported that *Piper longum* L. was cultivated for more than two thousand years and was originated in India. According to Dey and Bahadur (1973) and Nandkarni (1986) long pepper (*Piper longum*) was an indigenous plant in Eastern and Southern India. It was also reported as a native of the ever green forests of India occurring in South West Coast and Eastern Himalayan range (Chopra *et al.*, 1956; Aiyer and Kolammal, 1966; Ilyas, 1976 and Sivarajan and Balachandran, 1994). Stuart (1985) reported many countries of Southern Asia from Iran eastward as the place of origin of *Piper longum*. According to Viswanathan (1995) *Piper longum* is a native of Indo Malaya region growing wild in the tropical rain forests of India, Nepal, Indonesia, Malaysia, Sri Lanka and Phillippines.

Long pepper was found wild on the border of streams and similar places growing amongst other bushes in many parts of Southern and Eastern India especially in the erstwhile Malabar and Coromandel Coasts, Sri Lanka, Malaysia and Philippine islands (Roxburgh, 1832; Bentley and Trimen, 1880; Hooker, 1890; Dustur, 1962; Kirtikar and Basu, 1975; Khory and Katrak, 1981 and Husain *et al.*, 1992).

Dymock *et al.* (1890) reported that long pepper was the kind of pepper first known to the ancient inhabitants of Western Asia and Europe. *Piper longum* was reported as a slender aromatic climber with perennial woody roots occurring from Central Himalayan to Assam, Khasi and Mikir Hills, Lower Hills of Bengal and evergreen forests of Western Ghats from Konkan to Travancore, Nicobar Islands and cultivated at lower elevations in Anamalai Hills in Tamil Nadu and parts of Assam particularly in the Chirrapunji area (Gamble, 1967 and CSIR, 1969). According to Chopra *et al.* (1958); Ilyas (1976); Dutt (1979) and Davies (1992) *Piper longum* grows wild in Assam, Bengal, Uttar Pradesh, Kerala, Andhra Pradesh, Nepal and is cultivated on a small scale in Tamil Nadu, Assam and Bengal.

Grieve (1992) reported habitat of long pepper as Java, India, Phillippines and Singapore. Distribution of long pepper throughout India in ever green forests especially in South India was reported by Govil *et al.* (1993), Molur *et al.* (1995) and Varier (1995).

2.2 Morphology

Roxburgh (1832) reported *Piper longum* as a dioecious undershrub. It's woody perennial roots were described by Bently and Trimen (1880), Kirtikar and Basu (1975), Agarwal and Ghosh (1985) and Davies (1992).

Dey (1980) reported that the roots of *thippali* are fleshy crooked and knotted about the size of a goose quill with many smaller rootlets branching from it.

According to Viswanathan (1993a) about 95 per cent of roots of *Piper longum* are found within 20 cm depth and up to 10 cm laterally from the plant. Viswanathan (1993b) reported that the root system of one year old plant showed seven primary and six secondary roots with length 12 and 7 cm respectively.

Stems of long pepper were reported to be ascending or prostrate, much branched, stout, cylindrical, thickened above nodes and with sticking roots and branches at every node (Drury, 1873; Dustur, 1962; Aiyer and Kolammal, 1966; Kirtikar and Basu, 1975; Rahiman *et al.*, 1979; Khory and Katrak, 1981; Viswanathan, 1993a and 1995).

Roxburgh (1832) and Hooker (1890) reported that branchlets of long pepper bearing the fruits are erect with the leaves sessile. According to Bentley and Trimen (1880), Samuel *et al.* (1980), Uniyal (1980) and Varier (1995) leaves of *Piper longum* are simple, alternate, stipulate and petiolate or nearly sessile.

Long pepper flowers and bear fruits during the wet and cold season (Roxburgh, 1832). Rahiman *et al.* (1979) reported that all the wild species of pepper flower profusely in May-July. However Kapur *et al.* (1993) reported flowering and fruiting of long pepper in November to January.

Dutt (1979), Khory and Katrak (1981), Stuart (1985) and Varier (1995) reported spikes of long pepper as solitary, stalked, round and narrowed towards the upper end. According to Deymock *et al.* (1890), Dey (1980) and Kybal and Kaplicka (1990) long pepper consists of a multitude of minute fruits closely packed around a common axis, the whole forming a spike.

Female spikes vary from 15 to 25 mm in length and 7 mm in thickness and the male spikes are longer with 2.5 to 7.5 cm length and slender (Dustur, 1962; Aiyer and Kolammal, 1966; Kirtikar and Basu, 1975; Rahiman *et al.*, 1979; Rahiman and Bhagavan, 1985 and Viswanathan, 1995).

Fruits are described as small, ovoid, about 2 mm diameter, greyish green or nearly blackish when ripe and are partially sunken in the fleshy axis of the spike (Bentley and Trimen, 1880; Dymock *et al.*, 1890; Dustur, 1962; Aiyer and Kolammal, 1966; Gamble, 1967; Kirtikar and Basu, 1975; Das and Agarwal, 1991 and Viswanathan, 1995).

2.3 Factors affecting growth and yield

2.3.1 Plant density

Viswanathan (1993b and 1995) reported that for growing long pepper in coconut gardens ideal spacing was 60 x 60 cm. After analysing the growth and yield performance of *Piper longum* during the initial one and a half years grown in coconut gardens, Sheela (1996) reported that spacing of 50 x 50 cm was better.

Ramos *et al.* (1986), Reddy *et al.* (1991), Reddy *et al.* (1992) and Kurien *et al.* (1994) found that mean yield was highest with closer spacing and individual plant yield was not influenced by spacing in black pepper.

2.3.2 Organic manure

Deymock *et al.* (1890) reported that *Piper longum* required plenty of manure. Nair *et al.* (1986) stressed the importance of application of dried cowdung to long pepper twice a year.

Viswanathan (1993b and 1995) suggested the need for application of 15-25 tonnes of farm yard manure for growing long pepper. After analysing growth and yield performance of *Piper longum* during initial 1½ years grown in coconut gardens Sheela (1996) reported that 20 t ha^{-1} of organic manure is optimum.

Purseglove *et al.* (1981) reported that organic manures like guano, prawn and fish waste, soyabean cake, sterameal and bone meal were extensively used in saravak for growing pepper.

High rates of organic manures up to 15 t ha^{-1} was found to enhance the productivity of black pepper vines (Adiyoga, 1987 and Mathew *et al.*, 1995). Black pepper vines should be manured with cattle manure/compost/green leaves @ 10 kg/plant/annum just at the onset of South West monsoon (KAU, 1993).

2.3.3 Fertilizer

Misra (1992) conducted a study on the macro and micro nutrient requirement of medicinal plants and found that fertilizer application should be a routine part of the cultivation. Increased yield of *Piper longum* through supplementation by urea was reported by Pande *et al.* (1995). Growth and yield of *Piper longum* during the first year of growth when grew as an intercrop in coconut gardens was found to be higher with the application of fertilizers @ 30:30:60 NPK kg ha^{-1} (Sheela, 1996).

According to Barbieri (1949) *Piper nigrum* is capable of utilizing large quantity of fertilizer material and found that quality would not be affected by the amounts given. Inorganic fertilizers were as efficient as organic manure and were more profitable due to low cost/unit of nutrient contained (Raj, 1972).

Raj (1973) reported that higher levels of nutrients did not register a corresponding increase in the yield of black pepper vines. Pillai *et al.* (1979) also reported the response of black pepper to nitrogen application and found that higher levels of nitrogen adversely affected the yield. Similar reports were made by Reglose *et al.* (1989) and Kiteva *et al.* (1990). However Geetha and Aravindakshan (1992) reported that growth and dry matter yield of bush and vine pepper increased with increasing levels of nitrogen, phosphorus and potassium.

According to Pillai and Sasikumaran (1976) one hectare of black pepper vines with an average yield of one kilogram dry pepper per vine removed 34 kg N, 3.5 kg P_2O_5 and 32 kg K_2O for the production of berries.

Pal (1987) reported that *Piper betle* responded to nitrogen but not to phosphorus fertilization. Higher rate of nitrogen adversely affected the betel vine health (Balasubrahmanyan *et al.*, 1992a). According to Balasubrahmanyan *et al.* (1992b) the leaf nutrient concentrations associated with maximum yield in betel vine were 4.01 per cent N, 0.27 per cent P, 2.88 per cent K, 0.78 per cent Ca, 0.64 per cent Mg and 49 ppm Zn, 32 ppm, Mn and 643 ppm Fe.

2.3.4 Shade

Davies (1992) reported that *Piper longum* is a remunerative intercrop in coconut. According to Viswanathan (1993b and 1995) 20-50 per cent shade is required for growing long pepper and it could be grown as an intercrop in coconut plantations of 30 to 40 years age group. He also reported that at Rajpippala town in Gujarat, few cultivators are growing *Piper longum* as an intercrop in subabul and Eucalyptus plantations under partially shaded conditions.

Successful intercropping of long pepper and other medicinal plants was reported by Lahiri (1972), Singh *et al.* (1985) and Singh *et al.* (1990). According to Jha and Gupta (1991) *Piper longum* was most suitable as an intercrop with poplar (*Populus deltoides*).

The chlorophyll content of black pepper leaves grown under shade was higher than the leaves of crops grown in full light (Vijayakumar *et al.*, 1985; Balasimha, 1989 and Adams and Adams, 1992).

According to Wahid (1987) live support affected amount of light filtering to the pepper canopy and influenced the yield.

Mathal and Sastry (1988) reported that higher light availability during pre flowering growth of black pepper produced greater leaf area and more compact canopy structure with shorter lateral roots. This allowed the vine to accumulate higher levels of metabolites which led to greater number and higher dry weight of berries per vine.

2.3.5 Irrigation

According to Roxburgh (1832) long pepper was never to be watered. But at the commencement of the hot season the roots were to be carefully covered with straw to guard against the sun.

Long pepper was cultivated in Chirrapunji region which received very heavy rains from the end of March to middle of September which indicated its response to high moisture status in the soil (CSIR, 1969 and Ridley, 1983).

Rahiman *et al*. (1979) reported that wild species of *Piper* are mostly seen in localities where adequate moisture is available through out the year.

According to Viswanathan (1993b and 1995) *Piper longum* could be irrigated once or twice a week during hotter part of the year in Kerala, starting from January. If the main crop is irrigated, no additional irrigation is necessary. Mulching should be done in unirrigated crops.

2.3.6 Stage of growth

Roxburgh (1832) and Dutt (1979) reported that *Piper longum* would yield 285 kg ha^{-1} in the first year, 1140 kg ha^{-1} in the second year and 1710 kg ha^{-1} in the third year. After that the plants became less and less productive and the roots could be grubbed up dried and sold as *Piplamul*.

According to Drury (1873) long pepper usually yield for three or four years after which it should be replanted.

Ilyas (1976) reported that yield of *Piper longum* increased from 560 kg in first year to 1680 kg ha^{-1} $year^{-1}$ in the third year. After this vine should be replaced. If it is grown for its roots first harvest could be done 18 months after planting and root yield would be around 500 kg.

Piper longum showed an excellent performance in irrigated coconut gardens yielding 500 kg of dry spikes ha^{-1} during first year, 750 kg ha^{-1} in second year and 1000 kg ha^{-1} in third year (Davies, 1992).

Viswanathan (1993b) reported 200 kg dry spike yield during the first year, 500 kg during second year and 600 kg during 3rd year per ha. According to Viswanathan (1995) vines started bearing spikes six month after planting and was ready for harvest after two months. Three or four pickings were made as and when the spikes attained maturity for harvest. He also reported that yield of dry spikes during first year was around 400 kg ha^{-1} and increased up to 1000 kg ha^{-1} in the third year after which vine became less productive and had to be replanted.

2.3.7 Pest and Diseases

Russian worker Samal'Ko (1960) reported the infection of *Piper longum* with *Meloidogyne marioni*. He found that compounds like Dematon, Di-Syston, Methyl dematon and R_2 (diethyl-2 chloro vinyl phosphate) had no effect on the control.

Lordello (1974), Sarma (1988) and Ramana and Eapan (1995) found *Meloidogyne incognita* attacking roots of black pepper. Integrated control of root knot nematode (*Meloidogyne incognita*) on black pepper was reported by Ichinohe (1984).

Mammen (1974) reported *Meloidogyne incognita* infecting betel vine in Kerala. Systemic nematicide for control of *Meloidogyne incognita* in betel vine was reported by Jagdale *et al.* (1984). Jagdale *et al.* (1985a) reported the effect of different levels of potash on *Meloidogyne incognita* control in betel vine. Jagdale *et al.* (1985b) and Rana *et al.* (1993) reported the use of organic amendments like neem cake for the control of *Meloidogyne incognita* in betel vine. Effectiveness of *Tagetes erecta* on *Meloidogyne incognita* control in betel vine was reported by Darekar (1985).

Xanthomonas compestris pv.*beticola* found to cause severe leaf spot disease in *Piper longum* (Bhale *et al.*, 1984).

Piper longum was reported as a new host for *Colletotrichum gloeosporioides* causing leaf spot diseases (Sathyarajan and Naseema, 1985).

Chourasia and Roy (1989 and 1995) reported the influence of relative humidity on fungal association and aflatoxin production in *Piper longum* fruits. They found that the level of aflatoxin B_1 production was high when the relative humidity was between 75-76 per cent.

Occurrence of *Helopeltis thevora* as a pest of *Piper longum* was reported by Abraham (1991). He found that spraying 2 per cent neem kernel suspension reduced damage by 70 per cent.

2.4 Chemical composition

Long pepper was reported to have nearly the same chemical composition and properties as that of black pepper (Drury, 1873; Bentley and Trimen, 1880; Dymock *et al.*, 1890 and Dey and Bahadur, 1973).

According to Dustur (1962) and Dey and Bahadur (1973) and Stuart (1985) dried roots of *Piper longum* possessed the same medicinal qualities as the spikes but at a lower rate.

Atal and Banga (1962) isolated an alkaloid piplartine (MP 124-125 °C) from the stem of long pepper and its structure was determined by Atal and Banga (1963) as piperidine amide of 3, 4, 5 trimethoxy cinnamic acid.

Chatterjee and Dutta (1963) reported that the dry roots of long pepper contained 0.2-0.25 per cent piperlongumine.

Atal *et al.* (1966) reported occurrence of sesamine in *Piper longum*. Occurrence of N isobutyledene trans-2 trans 4 dienamide in *Piper longum* was reported by Dhar and Atal (1967).

Nigam and Radhakrishnan (1968) reported an essential oil yield of 0.6 per cent from long pepper as greenish yellow mobile liquid with major constituent caryophyllene. But Ilyas (1976) reported that essential oil from long pepper had spicy odour and contained 0.7 per cent zingiberine.

Chopra *et al.* (1969) reported two alkaloid piperine, piplartine, tria-contane dihydrostigmasterol and a steroid from the stem of *Piper longum*.

Piplamool contains piperine (0.15-0.18%), piplartine (0.13-0.2%) and traces of yellow crystalline pungent alkaloid, triacontane, dihydrostigmasterol, reducing sugars and glycosides. Fruits contain alkaloid piperine, piplartine and two new alkaloids one of which is designated as alkaloid A, sesamin dihydrostigmasterol and piplasterol. Fruits on steam distillation gave 0.7 per cent of essential oil with spicy odour resembling that of pepper and ginger oil (CSIR, 1969).

Rastogi and Mehrotra (1979)reported piperlongumine, piperlonguminine, piperine, sesamine, methyl 3,4,5 trimethoxy cinnamate from roots of long pepper.

Fatty acid components in seed oil of *Piper longum* was reported by Bedi *et al.* (1971).

Atal *et al.* (1975) and Sengupta and Ray (1987) studied chemistry of *Piper longum*. They identified many compounds and the main compounds included hydrocarbons and their derivatives, phenyl propides, ligans, isobutylamides, alkaloids and epoxides.

Dutta *et al.* (1975) reported ligans like sylvatin, sesamin and diaeudesmin from seeds of *Piper longum*.

Hentriacontane, hentriacontanone 1,6 triacontanol and ß sistosterol have been isolated and identified from the leaves of *Piper longum* by Manavalan and Singh (1979).

Immature berries and stem of *Piper longum* contained essential oil, starch, resin, gum, fatty acid and piperine (Dey, 1980; Khory and Katrak, 1981; Nambiar *et al.*, 1985; Pahlow, 1986 and Nandkarni, 1986).

Sharma *et al.* (1983) reported presence of L-tyrosine, L-cysteine hydro chloride, dl-serine and L aspartic acid as free amino acid in fruits of *Piper longum*.

Two new piperidine alkaloids pipernonaline and piperundecalidine were reported from fruits of long pepper by Tabuneng *et al.* (1983), and their structure was determined on the basis of spectral data. Dehydro piperonaline was also isolated from dried fruits of *Piper longum* by Shoji *et al.* (1986) and its structure had been established from spectroscopic data.

Biosynthesis of Piperlongumine was reported by Prabhu and Mulchandani (1985). Banerjee and Chaudhuri (1986) described the crystal and molecular structure of piperlongumine. Determination of piperine in *Piper longum* by HPLC was reported by Li *et al.* (1986).

Yasushi *et al.* (1987) reported maximum yield of alkaloid from *Piper longum* by extracting with methanol three times at room temperature.

Piper longum furnished a new long chain isobutyl amide longamide besides guineensine. All piperamides were characterised by chemical degradation (Koul *et al.*, 1988).

Nine alkaloids were isolated from the cold ethanol extract of the roots of *Piper longum* by Desai *et al.* (1988). They found that three were new and named as piperolactam A, piperolactam B and piperadione. Six known compounds were identified as cepharadione B, aristolactam A 11, cepharadione A, cepharanone B, norcepharadione B and 2 hydroxy-l methoxy 4 H dibenzo quinoline 4,5 (6H) dione.

Thakur *et al.* (1989) reported that fruits and stems of long pepper contained 1 undecyl-3,4 dimethylene dioxy benzene and sesamine N isobutyl - deca trans - 4 dicinamine. The main alkaloid has been found to be piperine with minor quantities of piplartine and essential oil of fruits contained. Piperidine, caryophyllene and a sesquiterpene alcohol.

Pungency of long pepper is due to the presence of the alkaloid piperine and the resin they contained and their aroma by a volatile oil (Kybal and Kaplicka, 1990; and John, 1990).

Restogi and Mehrotra (1990) reported that roots and stem barks of *Piper longum* contained two new monocyclic sesquiterpenes, two new alkaloids piper-longumine and piperlonguminine characterised as N (3,5,4 trimethoxy cinnamoyl) piperidine-2-one-5-ene and isobutylamide of pipericacid respectively.

Husain *et al.* (1992)and Tripathi *et al.* (1996) reported several secondary metabolites from *Piper longum*. Roots contained aristolactam A, norcepharadione B, piperolactam A, cepharadine B, cepharanone A, cepharanone B, piperadinone, piperine, sesamine, methyl 3,4,5 trimethoxy cinnamate, piperlongumine, longamide and piperlonguminine. Fruits contained piperonaline, piperundecalidine and sesamin. Seeds contained sylvatin, diaeudesmin, pluviatilol, methyl pluviatilol, sesamine, asarinine, an aromatic hydrocarbon pipataline, cinnamic acids, sistosterol, guineesine and pipercide.

2.5 Medicinal properties

Uses of *Piper longum* and its medicinal properties were reported by many workers (Roxburgh, 1832; Bentley and Trimen, 1880; Fouque, 1980; Biswas and Chopra, 1982; Warrier, 1989; Thakur *et al.*, 1989; John, 1990; Suseelappan, 1991; Suveren and Sar, 1992; Shukla, 1993; Varier, 1995 and Viswanathan, 1995).

Long pepper is used against diseases of respiratory tract, rheumatism, asthma, cough, dyspepsia, palsy, apoplexy, gout, lumbago, tetanus, weakness, body ache, fever, leprocy, gonorrhoea, piles, catarrh, night blindness, hoarseness, jaundice, anemea, paralysis, cholera, hysteria, epilepsy etc. Sun dried unripe fruits and roots of *Piper longum* is cardiac stimulant, carminative, alterative, tonic, laxative, digestive, emollient, stomachic, antiseptic, emmenagogue, diuretic rubefacient, analgesic, sedative, haematinic, cholagogue, abotificient, anthelmintic, aphrodisiac (Dymock *et al.*, 1890; Chopra *et al.*, 1956; Martin and Gregory, 1962; Dustur, 1962; CSIR, 1969; Dutt, 1979; Dey, 1980; Khory and Katrak, 1981; Nambiar *et al.*, 1985; Nandkarni, 1986; Sinha and Nathawat, 1989; Husain *et al.*, 1992; Kumar *et al.*, 1993; Mustaquem, 1994; Sivarajan and Balachandran, 1994 and Viswanathan, 1995).

According to Chopra *et al.* (1958); Dey and Bahadur (1973) and Jain (1991) long pepper is largely consumed as an article of spice.

Alcoholic extract of the dry fruits and aqueous extract of the leaves of long pepper showed activity against *Micrococcus pyogenes* var. *aureus* and *Escherichia coli*. Ether extract of fruits showed larvicidal properties (CSIR, 1969).

Chopra *et al.* (1969) reported that alkaloid piplartine, essential oil sesquiterpene and the crude extract of long pepper affect ciliary movement and suppress cough reflex.

Systematic pharmacological studies on piperine from long pepper revealed that this compound elicited diverse pharmacological activities like CNS depressent, antipyretic, analgesic and antiinflammatory activity (Singh *et al.*, 1973 and Shin *et al.*, 1984).

According to Dey and Bahadur (1973) long pepper is more powerful than black pepper medicinally.

The waxy alkaloid from petroleum ether extract of *Piper longum* fruits and roots showed antifertility activity (Chandhoke *et al.*, 1978; Garg, 1981; Prakash, 1986; Das *et al.*, 1987; Reddy *et al.*, 1989; Banerji *et al.*, 1995). D' Cruz *et al.* (1980) reported anthelmintic activity of fruits of *Piper longum*. Antiovulatory effect of long pepper was reported by Reddy *et al.* (1984).

Antiinflammatory activity of *Piper longum* was reported by Sharma and Singh (1980).

An ayurvedic preparation *trikatu* which contains ginger, black pepper and *thippali* in equal proportion on dry weight basis was found to increase the bioavailability of other drugs (Atal *et al.*, 1981; Zutshi and Kaul, 1982; Manavalan, 1990 and Johri and Zutshi, 1992).

Dahanukar *et al.* (1984) reported that *Piper longum* decreased frequency and severity of attack of bronchial asthma in children.

Hepatoprotective effect of *Piper longum* was reported by Rege *et al.* (1984), Nirmala *et al.* (1985) and Koul and Kapil (1993). The presence of dehydro-piperonaline in dried fruits of long pepper having coronary vasodilating activity was reported by Shoji *et al.* (1986).

Antiallergic activity of *Piper longum* was reported by Dahanukar and Karandikar (1984). Stuart (1985) reported that the derivative of roots of *Piper longum* has the same stimulant, tonic and peptic properties of spikes.

Piperlongumine from *Piper longum* is used in the treatment of asthma and chronic bronchitis (Banerjee and Chaudhuri, 1986).

Srivastava (1989) reported that leaves and fruits of long pepper possessed antibiotic properties.

Aruna and Sivaramakrishnan (1990) reported the anticarcinogenic activity of long pepper.

Rastogi and Mehrotra (1990) Banerji *et al.* (1995) and Tripathi *et al.* (1996) reported that oil of *Piper longum* had antibacterial activity and piperlongumine showed insecticidal activity against *Musca domestica* (house fly).

Radioprotective effect of piperine from *Piper longum* was reported by Aggarwal and Kaul (1992).

Kapur *et al.* (1993) reported that juice of *Piper longum* leaves cured toothache. Decoction from *Piper longum* used as a house hold remedy for asthma was reported by Mustaquem (1994).

Banerji *et al.* (1995) reported that long pepper roots inhibited the growth of *Bacilli*. Antiamoebic activity of *Piper longum* fruits against *Entomoeba histolytica* was reported by Ghoshal *et al.* (1996).

Materials and Methods

3. MATERIALS AND METHODS

The experiment was conducted at the College of Horticulture, Vellanikkara during 1995-1997 to study the effect of differential spacing and manurial regimes on growth, yield and quality of *Piper longum*. The details of materials used and methods followed are presented.

3.1 Details of the field experiment

3.1.1 Site

The experiment was conducted at the coconut farm coming under Plantation Crops and Spices Farm Unit III (KADP) of the College of Horticulture, Vellanikkara. The site was located at 10°31' N latitude and 76°17' E longitude. The experimental field lies at an altitude of 40 m above MSL.

3.1.2 Climate

The area enjoys a typical humid tropical climate. The meteorological data during the period of investigation are given in Fig.1 and Appendix I.

3.1.3 Soil

The soil of the experimental field was loamy sand in texture. The physical and chemical properties of the soil are presented in Table 1.

3.1.4 Variety

Piper longum variety Cheemathippali was used.

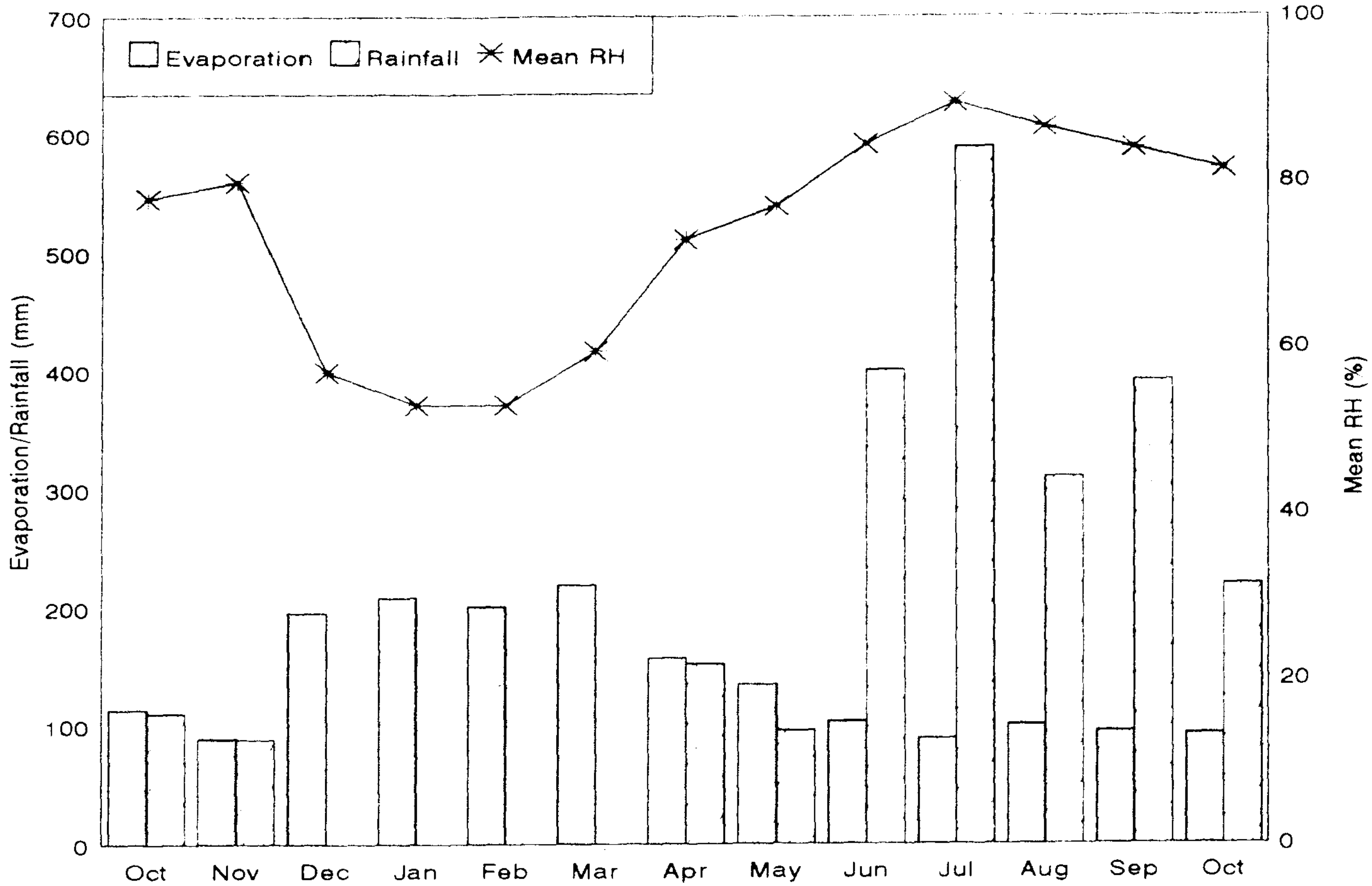

Fig.1a. Weather data of Vellanikkara from October 1995 to October 1996

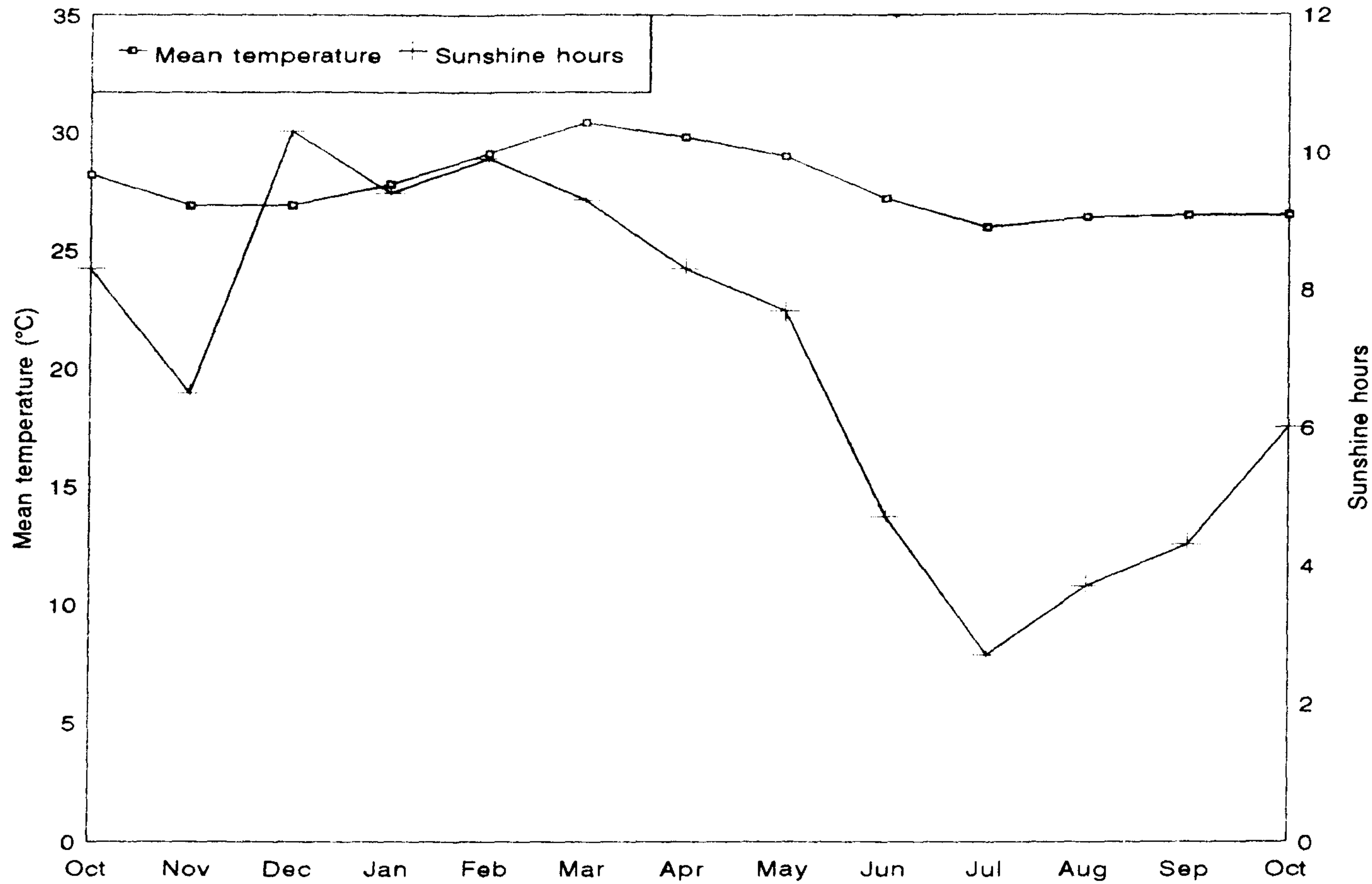

Fig.1b. Weather data of Vellanikkara from October 1995 to October 1996

Table 1. Physico-chemical characteristics of soil before the experiment

Particulars	Value	Method	Reference
A. Mechanical composition			
Sand	77.5%	Robinson's	
Silt	5.0%	International	Piper (1942)
Clay	17.5%	Pipette method	
B. Chemical composition			
pH	4.8	pH meter	Jackson (1958)
Total nitrogen	0.179%	Kjeldhal digestion and distillation method	Jackson (1958)
Available P	17.8 ppm	Bray 1 - Ascorbic acid blue colour method	Watanabe and Olsen (1965)
Available K	150 ppm	Neutral normal amonium acetate - EEL Flame photometer	Jackson (1958)

3.1.5 Design and lay out of the field

The experiment was conducted in one and a half year old *thippali* plots, laid out in randomised block design with three replications. The lay out plan is presented in Fig.2. A general and close up viewof *thippali* plots are shown in Plates 1 and 2.

3.1.6 Plot size

The gross plot size was 3.6 x 3.6 m.

3.1.7 Treatment details

The treatments consisted of three levels each of spacing, organic manure and fertilizer application. The spacingstried were 40 x 40, 50 x 50 and 60 x 60 cm giving a plant density of 62500, 40000 and 27777 ha^{-1}. The organic manure levels were 0, 10 and 20 t ha^{-1}. The fertilizer levels were 0:0:0, 30:30:60 and 60:60:120 NPK kg ha^{-1}.

All the three levels of organic manure were tried only at a single level of plant density i.e. 60 x 60 cm spacing to know the effect of organic manure. The highest level of organic manure i.e. 20 t ha^{-1} was tried at varying levels of spacing to know the effect of spacing. All the three levels of fertilizer were tried at the same level of spacing with varying levels of organic manure application and under various spacings along with same level of organic manure application to know the interaction effects.

Fig.2 PLAN OF LAYOUT

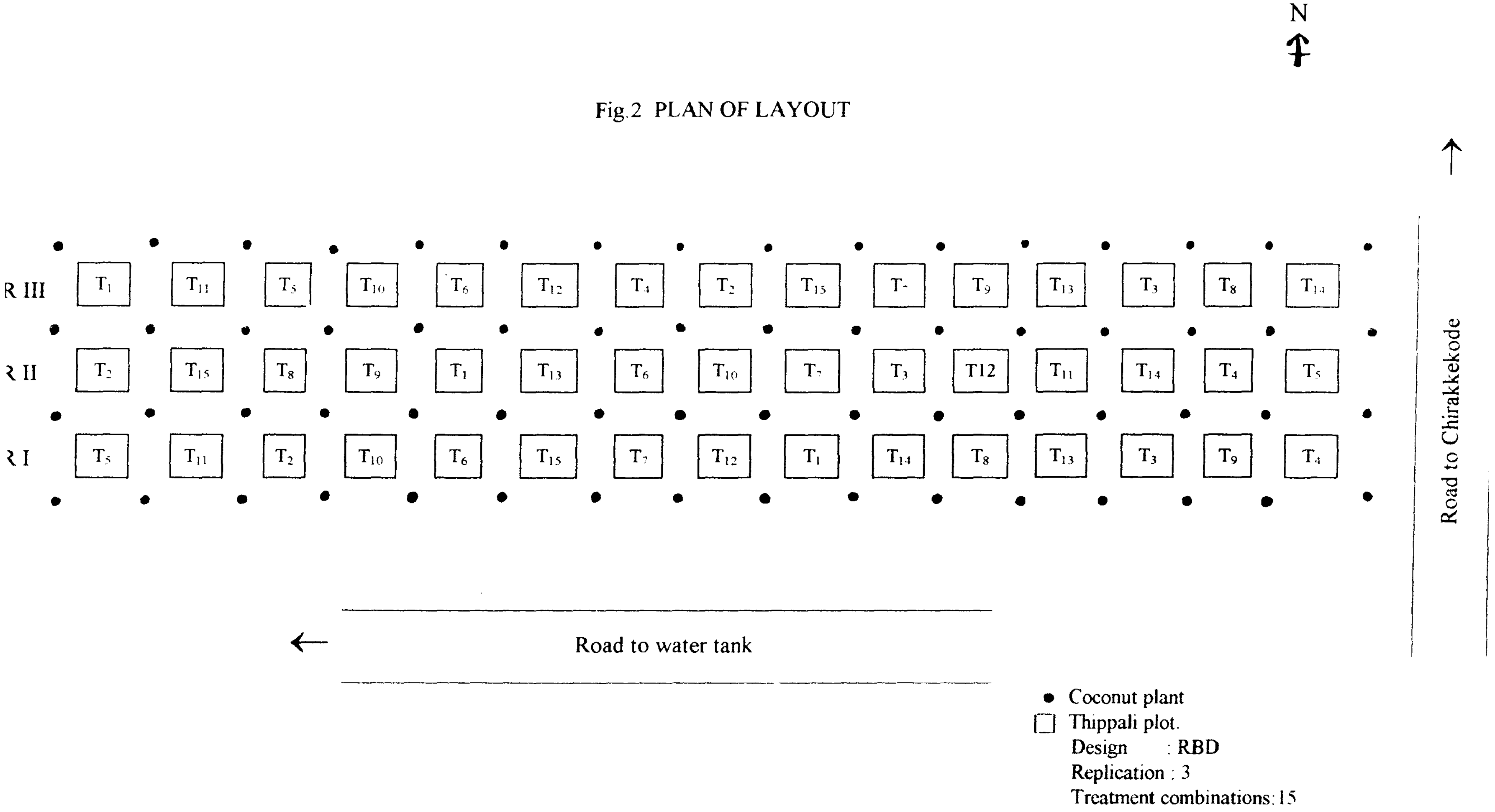

Plate 1. A general view of the experimental plot

Plate 2. A close up view of *thippali* plot

Table 2. Treatment combinations

Treatments	Spacing (cm)	Organic manure t ha^{-1}	Inorganic fertilizers NPK kg ha^{-1}
T_1	60 x 60	0	0:0:0
T_2	60 x 60	0	30:30:60
T_3	60 x 60	0	60:60:120
T_4	60 x 60	10	0:0:0
T_5	60 x 60	10	30:30:60
T_6	60 x 60	10	60:60:120
T_7	60 x 60	20	0:0:0
T_8	60 x 60	20	30:30:60
T_9	60 x 60	20	60:60:120
T_{10}	50 x 50	20	0:0:0
T_{11}	50 x 50	20	30:30:60
T_{12}	50 x 50	20	60:60:120
T_{13}	40 x 40	20	0:0:0
T_{14}	40 x 40	20	30:30:30
T_{15}	40 x 40	20	60:60:120

3.1.8 Establishment of treatments

Plots were taken in the interspaces of 20 year old coconut palms planted at 7.5 x 7.5 m spacing. *Thippali* cuttings were planted according to the treatments during the last week of April 1994 along with summer showers.

The *thippali* plants started production five months after planting. Six harvests were taken at bimonthly intervals till 15 months after planting and the data were reported by Sheela (1996). In this experiment, the growth and yield parameters were recorded from 17 to 29 months after planting.

Manuring was done in each year. During first year the organic manure (dry cowdung) with an analysis of 0.31% nitrogen, 0.28% phosphorus and 0.16% potassium was uniformly broadcasted and incorporated as per the treatments before planting. In the subsequent years manuring was done by spreading it in beds and covering with soil at the onset of South west monsoon.

Nitrogen, phosphorus and potassium were given through Factamphos (20% N and 20% P_2O_5) and muriate of potash (60% K_2O). Half the dose of nitrogen, phosphorus and potassium was given at the onset of South west monsoon. Remaining half dose was given five months after the first application in each year.

3.1.9 Irrigation and interculture

Irrigation was given once in a week during the summer months. Weeding was done before manuring. Manure was spread in beds and earthing up was done from sides. Mulching with coconut leaves was done during summer months.

3.1.10 Pests and diseases

Mealy bug attack was noticed during summer season. The pest mainly infested *thippali* shoots and spikes which were controlled by spraying starch solution.

Root knot nematode *Meloidogyne incognita* was found attacking *thippali* roots. Furadan application @ 10 kg ha^{-1} was done as a control measure (Nigam and Kumar, 1990).

In order to find out the effect of various treatments on nematode infestation, root and soil samples were collected from each plot. Nematode counts in soil and roots were also made.

3.1.1.1 Harvesting

Dark green spikes were harvested at bimonthly intervals from seventeenth month onwards. The spike yield was recorded in terms of dry weight in kg ha^{-1}.

3.2 Details of data collection

3.2.1 Collection of data on crop growth

Observation on plant growth characters were taken at bimonthly intervals from seventeen to twenty nine months after planting.

3.2.1.1 Plant height

Plant height was measured from the base of the plant to the tip of the erect branches from three plants randomly selected and the mean plant height was worked out and expressed in centimeters.

3.2.1.2 Number of branches $hill^{-1}$

The number of branches from randomly selected three hills were taken at bimonthly intervals and the average was expressed as the number of branches $hill^{-1}$.

3.2.1.3 Number of leaves $hill^{-1}$

Number of leaves was counted at bimonthly intervals from three randomly selected plants and the average was expressed as number of leaves $hill^{-1}$.

3.2.1.4 Dry matter production

Destructive sampling of one hill randomly selected from the third row in each plot was done to estimate the dry matter production at six months interval and it was expressed on per hectare basis.

3.2.2 Collection of data on yield attributing characters

3.2.2.1 Number of spikes and spike characters

Total number of spikes was taken from the selected three hills and the spikes per plant was averaged out.

Length and diameter of spikes were measured using a twine at 29 MAP from randomly selected ten spikes from each plot and the average was worked out and expressed in centimeters as length and diameter of spikes.

3.2.2.2 Fresh weight of spikes

The fresh weight of spikes was taken immediately after harvest and expressed on per hectare basis as fresh weight of spikes.

3.2.2.3 Dry weight of spikes

The spikes were air dried for four to five days and dry weight was taken and expressed on per hectare basis.

3.2.3 Soil sampling

Soil samples were collected from all the treatments before and after the experiment from four locations at 0-20 cm depth and mixed to make one composite sample and a representative subsample was drawn for each plot.

3.3 Laboratory studies

3.3.1 Plant analysis

Plant samples were dried in hot air oven at 70°C and the dry weight recorded. The samples were powdered and composite samples were stored for analysis.

Total nitrogen content of the samples was determined by Kjeldhal digestion and distillation method (Jackson, 1958). For the estimation of total phosphorus and potassium, the plant samples were digested using diacid mixture (HNO_3 and $HClO_4$ in the ratio of 2:1) and the contents were made up to 50 ml. This diacid extract was used for P and K determination. Phosphorus was determined by Vanado molybdo phosphoric yellow colour method (Jackson, 1958) in Spectronic 20 spectrophotometer. Potassium was determined using EEL flame photometer (Jackson, 1958).

Analysis of spikes was done in the same way as that of plant samples.

Nitrogen, phosphorus and potassium uptake by the crop at different intervals was computed from their respective chemical concentration and dry matter production.

3.3.2 Soil analysis

The soil samples were air dried, powdered and passed through a two mm sieve. Organic carbon in soil was determined by Walkley and Black method (Jackson, 1958).

Available nitrogen in soil was determined by alkaline permanganate method suggested by Subbiah and Asija (1956).

Available phosphorus in the soil was extracted by Bray No.I extractant and the phosphorus content was determined by ascorbic acid blue colour method (Watanabe and Olsen, 1965) in Spectronic 20 Spectrophotometer.

Available potassium in the soil was extracted by neutral normal ammonium acetate and was estimated using EEL flame photometer (Jackson, 1958).

3.3.3 Quality analysis of spikes and roots

The total alkaloids in the dried spikes and roots of *Piper longum* were determined using the Soxhlet extraction method (Harborne, 1973).

Five grams of finely powdered and dried samples of *Piper longum* was accurately weighed into the filter paper to hold the sample and the weight of the sample with filter paper was recorded. The sample packet was then dropped into the extraction tube of Soxhlet apparatus. The bottom of the extraction tube was attached to the previously weighed Soxhlet flask. Hundred ml of methanol was used as the solvent which was poured through the sample in to the flask. The top of the extraction tube was attached to the condensor. Extraction of the sample was carried out in a water bath maintained at 80°C till the solvents in the extraction tube turned colourless. The temperature of the water bath was regulated so that the solvent which volatalized condensed and dropped continuously upon the sample without any appreciable loss. At the end of the extraction period, i.e., when the previously colourless solvent in the flask turned dark coloured and solvent in the extraction tube turned colourless, the sample packet was removed from the extractor and most of the solvent was distilled off by allowing it to collect in the Soxhlet tube. The Soxhlet flask was dismantled and allowed to cool and solvent was evaporated on a water bath. The Soxhlet flask along with the residue was weighed. The residue left in the Soxhlet flask after complete evaporation of the solvent was weighed to get the total alkaloid extracted.

$$\text{Total alkaloid in g} = \text{Weight of Soxhlet flask along with residue (g)} - \text{weight of empty Soxhlet flask (g)}$$

$$\text{Total alkaloid content (\%)} = \frac{\text{Weight of residue in gram} \times 100}{\text{Weight of dried sample used for extraction}}$$

3.4 Statistical analysis

The data were subjected to analysis of variance (Panse and Sukhatme, 1985). Two factorial sets were considered viz., Fertilizer x manure and Fertilizer x spacing. For Fertilizer x manure factorial, spacing was fixed at 60 x 60 cm and for Fertilizer x spacing factorial, the manure was fixed at 20 t ha^{-1}. Each of these three factors had three levels. There was an overlapping of highest level of manure and also the highest level of spacing in the two factorial sets considered.

In the Tables three levels of fertilizer i.e., 0:0:0, 30:30:60 and 60:60:120 NPK kg ha^{-1} are represented as F_0, F_1 and F_2; organic manure as M_0, M_1 and M_2 for 0, 10 and 20 t ha^{-1} and spacing as S_1, S_2 and S_3 for 40 x 40, 50 x 50 and 60 x 60 cm respectively. Fm denoted mean of fertilizer averaged over manure and Fs mean of fertilizer averaged over spacing.

CD values are given for comparison of level of manure (M), spacing (S), fertilizer averaged over the levels of manure (Fm), fertilizer averaged over the levels of spacing (Fs), fertilizer x manure (F x M) and fertilizer x spacing (F x S) combinations.

Results and Discussion

4. RESULTS AND DISCUSSION

The results obtained from the study are presented and discussed in this chapter under the following heads.

4.1 Growth characteristics

4.2 Yield and yield attributing characters

4.3 Nutrient content and plant uptake

4.4 Qualitative analysis

4.5 Nutrient status of soil

4.6 Nematode infestation

4.7 Economic analysis

4.1 Growth characteristics

4.1.1 Height of the plant

Height of the plants from 17 to 29 months after planting (MAP) at bimonthly intervals are presented in Table 3. Height varied significantly with different treatments at all the stages of growth.

Application of organic manure resulted in a significant increase in height of the plant throughout the experiment. Among three levels, highest rate of 20 t ha^{-1} was found to have more effect in increasing the height of plants. Nair *et al.* (1986) also reported greater response in growth of *Piper longum* to higher quantities of organic manure.

Differential spacing significantly influenced the height of the plant under the same manurial level in all the stages of growth. During 17 and 19 MAP, spacing

Table 3. Effect of organic manure, fertilizer and spacing on the height of the plant (cm)

	17 MAP				19 MAP				21 MAP				23 MAP			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
S_3M_0	66.8	68.3	65.6	66.9	68.6	71.0	67.6	69.1	66.8	69.1	66.1	67.3	59.7	63.7	61.0	61.5
S_3M_1	68.5	71.8	69.7	70.0	72.2	74.7	74.4	73.8	67.1	72.7	69.4	69.7	64.8	66.6	61.0	64.1
S_3M_2	84.4	87.6	82.3	84.8	85.8	90.8	88.7	88.4	74.4	82.6	73.4	76.8	68.5	74.0	69.6	70.7
S_2M_2	87.1	89.2	85.7	87.3	87.4	89.3	84.7	87.1	72.1	74.3	69.6	72.0	68.5	71.7	65.3	68.5
S_1M_2	80.5	83.6	81.2	81.8	84.7	86.7	85.5	85.7	72.6	73.9	70.2	72.2	68.6	70.3	65.4	68.1
Mean																
Fm	73.2	75.9	72.6		75.6	78.8	76.9		69.4	74.8	69.6		64.3	68.1	64.0	
Fs	84.0	86.8	83.1		86.0	88.9	86.3		73.0	76.9	71.1		68.6	72.0	66.8	
	CD(0.5)				CD(0.05)				CD(0.05)				CD(0.05)			
	M 1.15	Fm 1.15	MxF NS		M 1.04	Fm 1.04	MxF 1.81		M 1.14	Fm 1.14	MxF 1.98		M 1.34	Fm 1.34	MxF 2.33	
	S 1.15	Fs 1.15	SxF NS		S 1.04	Fs 1.04	SxF 1.81		S 1.14	Fs 1.14	SxF 1.98		S 1.34	Fs 1.34	SxF 2.33	

	25 MAP				27 MAP				29 MAP			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
S_3M_0	61.0	63.4	61.5	62.0	65.3	66.3	65.7	65.8	65.2	65.6	64.6	65.2
S_3M_1	64.4	70.2	63.3	66.0	67.5	70.1	69.1	68.9	65.8	68.4	65.4	66.5
S_3M_2	70.0	76.0	80.5	75.5	72.5	74.7	72.3	73.2	73.9	78.1	74.0	75.3
S_2M_2	71.1	75.7	68.7	71.9	70.5	73.2	68.9	70.9	72.5	73.7	70.2	72.2
S_1M_2	70.3	75.3	73.3	73.0	71.3	74.6	71.2	72.4	68.2	69.7	68.7	68.9
Mean												
Fm	65.1	70.0	68.5		68.5	70.4	69.0		68.3	70.7	68.0	
Fs	70.5	75.7	74.2		71.5	74.2	70.8		71.5	73.9	71.0	
	CD(0.05)				CD(0.05)				CD(0.05)			
	M 1.20	Fm 1.20	MxF 2.07		M 0.92	FM 0.92	MxF NS		M 1.14	Fm 1.14	MxF NS	
	S 1.20	Fs 1.20	SxF 2.07		S 0.92	Fs 0.92	SxF NS		S 1.14	Fs 1.14	SxF 1.98	

of 50 x 50 cm was found better than the other two spacings. But 21 MAP onwards, a wider spacing of 60 x 60 cm was found superior to the other two. During earlier growth period the crop was having a low spread. Hence the competition for different growth factors was minimum and a medium plant density was found better. But as plants grew, spreading increased and wider spacing was needed for proper growth and establishment.

Significant response in plant height was noticed only for the lower level of 30:30:60 NPK kg ha^{-1}. Higher and zero levels behaved almost similarly. The response was similar at different levels of organic manure and spacing with the intermediate levels being the best.

Interaction of manure and spacing with fertilizer was found significant at all stages except 17 and 27 months. Among different treatment combinations $S_3M_2F_1$ was found superior almost throughout the growth period. The effect of manure was more pronounced, compared to different levels of spacing and fertilizer.

With respect to plant height at different stages of observations, it was found that during dry months (21 and 23 MAP) there was a reduction in the rate of growth. It was also observed that there was a general decline in height of plants from 17 to 29 MAP, probably due to the shedding of terminal portion or due to stricking of roots at the base of the branches and consequent spreading of the plants as observed by Sheela (1996) in the initial stages of the same experiment. The decline in plant height might also be due to ageing or nematode infestation later identified as serious.

4.1.2 Number of branches $hill^{-1}$

Data on the number of branches $hill^{-1}$ from 17 to 29 MAP at bimonthly intervals are presented in Table 4.

Application of organic manure significantly influenced the number of branches $hill^{-1}$, similar to height of the plant. Higher rate of organic manure (20 t ha^{-1}) was found to produce more number of branches $hill^{-1}$ than zero and 10 t ha^{-1}.

Effect of spacing on number of branches $hill^{-1}$ was found significant at all stages except in summer months (21 and 23 MAP). The two higher levels of spacing were on par and were superior to the lowest spacing adopted i.e. 40 x 40 cm. A reduction in number of branches due to high plant density was reported by Sheela (1996).

Fertilizer was found to influence the number of branches irrespective of spacing and manurial application in all the stages of growth. The fertilizer level of 30:30:60 NPK kg ha^{-1} along with a manurial application of 20 t ha^{-1} produced more branches $hill^{-1}$. Similar results of increased branching at higher levels of FYM and fertilizer in bell pepper was reported by Nagarajaswamy and Nalawadi (1982).

Interaction of manure with fertilizer was found significant only at 23 and 25 MAP. Superior treatment combination was found to be $S_3M_2F_1$. The minimum number of branches was produced when it was grown under the widest plant spacing with no manure and fertilizer application.

Table 4. Effect of organic manure, fertilizer and spacing on the number of branches (hill[-1])

	17 MAP				19 MAP				21 MAP				23 MAP			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
S_3M_0	11.3	12.7	12.3	12.1	12.5	13.4	12.8	12.4	9.6	10.0	10.2	9.9	7.3	9.5	10.4	9.1
S_3M_1	14.3	15.2	13.8	14.4	14.7	16.0	14.7	15.1	11.3	12.5	11.8	11.9	11.4	12.4	11.2	11.7
S_3M_2	16.1	17.2	15.7	16.3	15.6	16.1	14.4	15.4	13.3	14.1	12.8	13.4	11.8	13.0	12.4	12.4
S_2M_2	16.0	16.0	14.7	15.6	14.9	15.2	14.3	14.8	12.6	13.4	13.1	13.0	12.2	13.7	13.1	13.0
S_1M_2	14.7	15.2	13.6	14.5	13.9	14.7	14.6	14.4	12.3	13.5	12.3	12.7	12.5	12.6	11.5	12.2
Mean																
Fm	13.9	15.0	14.0		14.3	15.1	14.0		11.4	12.2	11.6		10.2	11.6	11.3	
Fs	15.6	16.1	14.7		14.8	15.3	14.4		12.7	13.7	12.7		12.2	13.1	12.3	

17 MAP CD(0.5)						19 MAP CD(0.05)						21 MAP CD(0.05)						23 MAP CD(0.05)					
M	0.61	Fm	0.61	MxF	NS	M	0.73	Fm	0.73	MxF	NS	M	0.74	Fm	NS	MxF	NS	M	0.68	Fm	0.68	MxF	1.17
S	0.61	Fs	0.61	SxF	NS	S	0.73	Fs	NS	SxF	NS	S	NS	Fs	0.74	SxF	NS	S	NS	Fs	0.68	SxF	NS

	25 MAP				27 MAP				29 MAP			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
S_3M_0	10.1	10.7	10.6	10.5	10.6	11.5	10.2	10.8	11.1	12.2	10.6	11.3
S_3M_1	12.5	13.1	13.3	13.0	12.8	13.3	12.4	12.8	12.5	13.8	12.3	12.9
S_3M_2	14.0	15.5	13.1	14.2	15.3	16.0	14.5	15.3	14.6	14.9	14.4	14.6
S_2M_2	13.6	14.3	13.2	13.7	14.5	15.5	15.2	15.1	14.6	15.3	14.7	14.9
S_1M_2	12.3	13.3	12.0	12.5	13.1	14.0	11.6	12.9	13.6	14.2	13.2	13.7
Mean												
Fm	12.2	13.1	12.3		12.9	13.6	12.4		12.8	13.6	12.4	
Fs	13.3	14.4	12.7		14.3	15.1	13.8		14.3	14.8	14.1	

25 MAP CD(0.05)						27 MAP CD(0.05)						29 MAP CD(0.05)					
M	0.56	Fm	0.56	MxF	0.97	M	0.32	FM	0.32	MxF	NS	M	0.36	Fm	0.36	MxF	NS
S	0.56	Fs	0.56	SxF	NS	S	0.32	Fs	0.32	SxF	0.56	S	0.36	Fs	0.36	SxF	NS

4.1.3 Number of leaves hill^{-1}

The number of leaves hill^{-1} from 17 to 29 MAP at bimonthly intervals are presented in Table 5. There was a significant difference in number of leaves hill^{-1} with treatments at all the stages of growth.

Application of organic manure increased the number of leaves hill^{-1} significantly and the maximum number of leaves was produced by the highest manurial rate of 20 t ha^{-1}.

Plant population also significantly influenced the number of leaves hill^{-1}. Lower plant density resulting from the wider spacing of 60 x 60 cm, produced more leaves at 17 MAP. But this difference was levelled off in the course of next one year growth and it was found to be on par with other two spacings at 29 MAP.

Effect of fertilizer averaged over manure and spacing was significant in the number of leaves hill^{-1}. Middle dose of 30:30:60 NPK kg ha^{-1} was found significantly superior over zero and 60:60:120 NPK kg ha^{-1} up to 23 MAP. But from 25 MAP onwards 30:30:60 kg ha^{-1} was found to be on par with 60:60:120 NPK kg ha^{-1}.

Interaction of manure and spacing with fertilizer was not found significant at any stage except 19 and 29 MAP. Superior treatment combination was found to be $S_3M_2F_1$. This might be due to the higher number of branches and plant height produced by this treatment combination.

Seasonal changes were found highly influencing number of leaves hill^{-1}. During summer months leaves were found to be lowest and it increased as monsoon

Table 5 Effect of organic manure, fertilizer and spacing on the number of leaves (hill^{-1})

	17 MAP				19 MAP				21 MAP				23 MAP			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
S_3M_0	117.9	122.2	118.1	119.4	109.3	113.8	105.6	109.6	72.9	72.6	66.0	70.5	73.1	76.1	75.3	74.8
S_3M_1	127.7	132.4	129.6	129.9	115.2	122.0	116.8	118.0	88.3	91.3	82.9	87.5	87.8	96.4	89.8	91.3
S_3M_2	138.7	143.0	138.2	140.0	124.3	131.2	124.3	126.6	95.6	102.0	98.8	98.8	98.1	110.1	102.6	103.6
S_2M_2	134.9	139.8	137.3	137.3	122.4	129.5	123.2	125.0	91.4	96.0	96.1	94.5	95.4	100.3	99.6	98.4
S_1M_2	135.3	137.7	134.9	136.0	119.3	125.6	122.9	122.6	91.7	95.9	94.7	94.1	93.8	99.5	97.8	97.1
Mean																
Fm	128.1	132.5	128.6		116.3	122.3	115.6		85.6	88.6	82.6		86.3	94.2	89.3	
Fs	136.3	140.2	136.8		122.0	128.8	123.5		92.5	98.0	96.5		95.8	103.3	100.0	

17 MAP	19 MAP	21 MAP	23 MAP
CD(0.5)	CD(0.05)	CD(0.05)	CD(0.05)
M 1.58 Fm 1.58 MxF NS	M 1.12 Fm 1.12 MxF 1.93	M 3.71 Fm 3.71 MxF NS	M 3.39 Fm 3.39 MxF NS
S 1.58 Fs 1.58 SxF NS	S 1.12 Fs 1.12 SxF 1.93	S 3.71 Fs 3.71 SxF NS	S 3.39 Fs 3.39 SxF NS

	25 MAP				27 MAP				29 MAP			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
S_3M_0	95.4	100.1	99.1	98.2	101.0	105.1	105.8	104.0	103.6	104.4	105.8	104.6
S_3M_1	103.3	112.4	111.4	109.0	113.1	121.7	121.7	119.0	116.9	118.9	121.8	119.2
S_3M_2	124.7	130.8	131.4	129.0	134.6	146.3	143.0	141.3	128.9	136.3	134.8	133.3
S_2M_2	125.5	127.9	129.7	127.7	134.3	139.6	140.0	137.9	126.7	134.0	133.9	131.5
S_1M_2	120.3	126.2	122.8	123.1	134.4	141.2	137.2	137.6	133.1	133.0	134.3	133.4
Mean												
Fm	107.8	114.4	114.0		116.2	124.4	123.5		116.5	119.9	120.8	
Fs	123.5	128.3	128.0		134.4	142.4	140.0		129.6	134.4	134.3	

25 MAP	27 MAP	29 MAP
CD(0.05)	CD(0.05)	CD(0.05)
M 2.03 Fm 2.03 MxF NS	M 2.87 FM 2.87 MxF NS	M 1.64 Fm 1.64 MxF 2.84
S 2.03 Fs 2.03 SxF NS	S 2.87 Fs 2.87 SxF NS	S 1.64 Fs 1.64 SxF 2.84

started. A damp location with high organic matter content in soil was found to be congenial for the luxuriant growth of *thippali* as reported by Rahiman *et al.* (1979).

The leaf number attains more importance in the case of *Piper longum* in comparison with other plants, since the spikes are formed in the axils of newly formed sessile leaves only. As the number of leaves become more, higher will be the leaf area exposed and hence the photosynthetic activity which has a direct bearing on yield (Johnson, 1981).

4.1.4 Dry matter production by the vegetative parts

Effect of various treatments on dry matter production at six months interval from 17 to 29 MAP are presented in Table 6. Dry matter production was found to be influenced by different treatments at all the stages of growth.

Application of organic manure increased the dry matter production throughout the experiment (Fig.3a) whether fertilizer was applied or not. Among three levels, 20 t ha^{-1} was found superior over zero and 10 t ha^{-1}.

Plant population influenced the dry matter production significantly. Lowest plant density (60 x 60 cm) was found superior to others at all the stages of growth except at 29 MAP (Fig.3b). During this period the crop planted at a higher plant density (50 x 50 cm) accumulated a higher rate of dry matter because of more number of plants eventhough the growth factors like height, leaf number and number of branches were producing at a decreasing rate. The reductionin the dry matter production might be due to ageing or nematode infestation which was detected in the later stages of the experiment.

Table 6. Effect of organic manure, fertilizer and spacing on the dry matter production (kg ha^{-1})

	17 MAP				23 MAP				29 MAP			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
S_3M_0	232.4	256.4	262.0	250.8	150.9	176.8	185.1	171.0	223.3	240.7	248.1	237.4
S_3M_1	305.5	336.1	368.5	336.7	187.9	203.7	214.8	202.1	270.4	309.3	321.3	300.3
S_3M_2	351.8	432.4	467.6	417.3	249.0	256.5	272.2	259.2	330.6	337.0	300.9	322.8
S_2M_2	322.7	340.0	365.3	342.7	217.3	241.3	233.3	230.7	322.7	358.7	362.7	348.0
S_1M_2	306.3	331.3	345.8	327.8	222.9	231.3	241.7	232.0	312.5	331.3	341.7	328.5
Mean - Fm	296.6	341.6	366.0		196.0	212.3	224.0		274.7	295.7	290.1	
Fs	326.9	367.9	392.4		229.8	243.0	249.1		321.9	342.3	335.1	

	17 MAP	23 MAP	29 MAP
	CD(0.05)	CD(0.05)	CD(0.05)
	M 10.40 Fm 10.40 MxF 18.02	M 11.33 Fm 11.33 MxF NS	M 13.93 Fm 13.93 MxF 24.13
	S 10.40 Fs 10.40 SxF 18.02	S 11.33 Fs 11.33 SxF NS	S 13.93 Fs 13.93 SxF 24.13

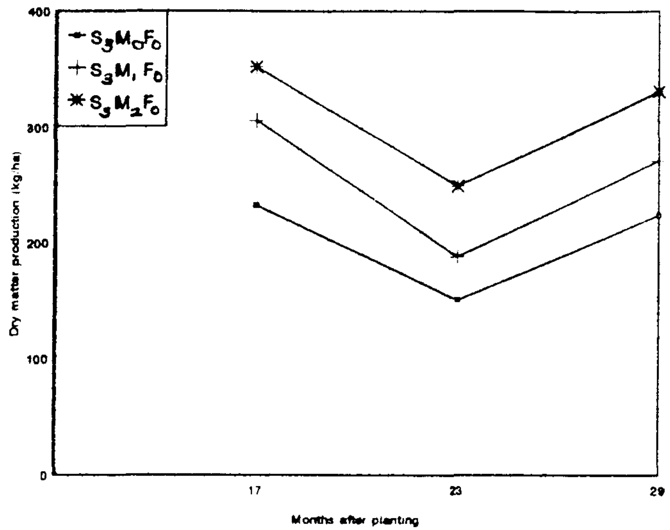

Fig.3a. Effect of organic manure on dry matter production by vegetative parts

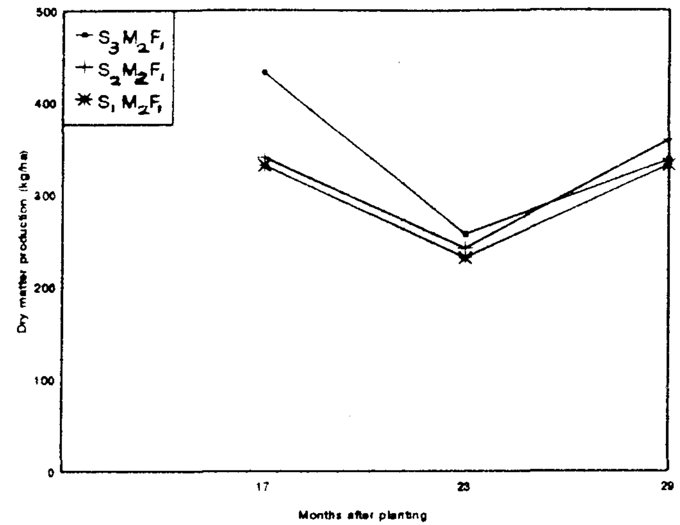

Fig.3b. Effect of spacing on dry matter production by vegetative parts

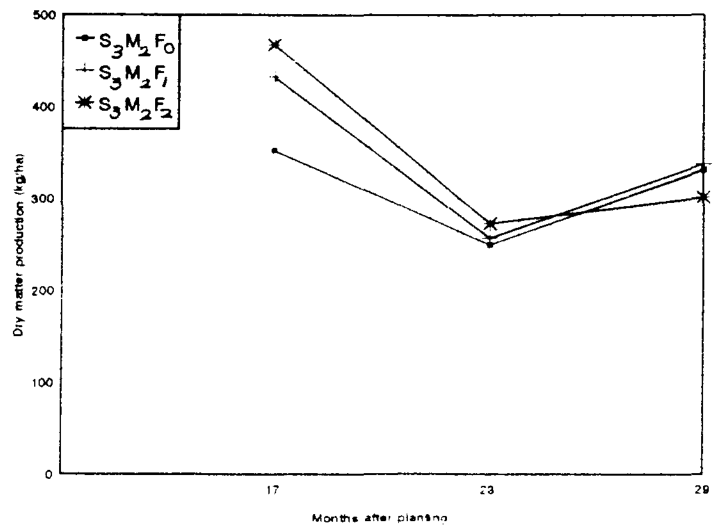

Fig.3c. Effect of fertilizer on dry matter production by vegetative parts

The dry matter production during 23 MAP, which coincided with the summer season, was less than that of 17 and 29 MAP. Hence favourable environment during rainy season was found to increase dry matter production.

Fertilizer application was found to be significantly influencing the dry matter production (Fig.3c). During 17 and 23 MAP 60:60:120 NPK kg ha^{-1} was found superior at various levels of manure and spacing. But 23 MAP the differences in dry matter production caused by fertilizer application narrowed down even though it was superior to the plots receiving no manure and fertilizer. Though the height and leaf number were relatively less in treatment receiving 60:60:120 NPK kg ha^{-1}, the dry matter production was more due to the more number of rooted spreading vines which ultimately turn unproductive.

Interaction was found significant at all stages except 23 MAP which coincided with dry periods of April. Best treatment combination was found to be $S_3M_2F_2$ at 17 MAP. But at 29 MAP it was $S_2M_2F_2$ which indicated that a higher level of manure and fertilizer coupled with a higher plant density produced higher dry matter. Lowest dry matter production was at 60 x 60 cm spacing with no manure and fertilizer application. It might be due to the less plant population and poor growth.

4.2 Yield and yield attributing characters

4.2.1 Number of spikes per hill

The number of spikes per hill from 17 to 29 MAP at bimonthly intervals are presented in Table 7.

Table 7. Effect of organic manure, fertilizer and spacing on the number of spikes (hill[-1])

	17 MAP				19 MAP				21 MAP				23 MAP			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
S_3M_0	51.0	56.3	49.2	52.1	6.5	9.5	7.1	7.7	3.3	3.7	3.9	3.6	1.1	1.4	1.0	1.2
S_3M_1	66.1	70.5	61.5	66.0	10.4	11.4	8.7	10.2	4.6	4.8	4.2	4.5	1.7	2.2	1.4	1.8
S_3M_2	84.8	94.6	91.0	90.1	11.8	12.5	13.1	12.5	5.6	6.4	6.2	6.1	3.6	4.4	3.4	3.8
S_2M_2	88.5	92.8	75.8	84.0	11.6	12.9	12.2	12.2	5.3	5.6	4.6	5.2	3.1	3.3	2.7	3.0
S_1M_2	84.0	90.5	83.3	85.9	10.5	11.7	11.9	11.3	4.5	4.8	4.1	4.5	2.8	2.9	2.7	2.8
Mean																
Fm	67.3	73.8	67.2		9.6	11.1	9.6		4.5	5.0	4.7		2.2	2.7	2.0	
Fs	84.1	92.7	83.3		11.3	12.4	12.4		5.1	5.6	5.0		3.2	3.5	3.0	

17 MAP: CD(0.5) M 3.95 Fm 3.95 MxF NS; S 3.95 Fs 3.95 SxF 6.84

19 MAP: CD(0.05) M 1.00 Fm 1.00 MxF 1.73; S NS Fs NS SxF NS

21 MAP: CD(0.05) M 0.26 Fm 0.26 MxF 0.46; S 0.26 Fs 0.26 SxF 0.46

23 MAP: CD(0.05) M 0.22 Fm 0.22 MxF 0.38; S 0.22 Fs 0.22 SxF 0.38

	25 MAP				27 MAP				29 MAP			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
S_3M_0	6.2	7.0	6.6	6.6	20.2	21.4	19.1	20.2	9.1	9.7	9.2	9.3
S_3M_1	8.8	9.7	7.9	8.8	27.5	27.9	27.3	27.6	11.5	12.3	10.9	11.5
S_3M_2	10.7	12.1	12.4	11.8	34.8	37.6	32.6	35.0	14.2	16.6	11.4	14.1
S_2M_2	10.0	11.5	9.5	10.3	29.9	31.4	27.5	29.6	13.7	13.6	13.9	13.7
S_1M_2	9.7	10.9	10.5	10.4	30.1	31.4	28.2	30.0	12.6	14.0	12.7	13.1
Mean												
Fm	8.6	9.6	9.0		27.5	29.0	26.3		11.6	12.9	10.5	
Fs	10.1	11.5	10.8		31.6	33.5	29.5		13.5	14.7	12.7	

25 MAP: CD(0.05) M 0.49 Fm 0.49 MxF 0.85; S 0.49 Fs 0.49 SxF 0.85

27 MAP: CD(0.05) M 1.68 FM 1.68 MxF NS; S 1.68 Fs 1.68 SxF NS

29 MAP: CD(0.05) M 0.82 Fm 0.82 MxF 1.42; S NS Fs 0.82 SxF 1.42

Spikes of long pepper are produced in the axil of sessile leaves. Hence more branching and leaf production increased the number of spikes. Erect branches only produced spikes and the rooted spreading branches usually turn unproductive.

After a peak bearing of spikes at 17 MAP (October 1995), there was a drastic reduction in spike number which showed again an increasing trend but at a lower level from 25 (June 1996) to 27 MAP. It again fell into a declining trend during 29 MAP (October 1996). A comparison of average spike number from October 1995 to October 1996 showed that within one year there was a reduction of 84 per cent (from 76 to 12 spikes $hill^{-1}$). It was seen that the maximum bearing of spikes was during 17 MAP and after that the spike production was almost negligible throughout the non-rainy period. During rainy months the spike production resumed along with new flushing. The effect of water stress in reducing crop yield had been reported by Kramer (1983).

As observed in the case of growth characters, application of organic manure was found influencing the number of spikes per plant at all the stages of growth. Higher rate of 20 t ha^{-1} was found superior.

There was a significant effect of spacing on the number of spikes in almost all the stages of growth. Wider spacing of 60 x 60 cm was found superior to the other two spacings producing 90, 84 and 86 spikes $hill^{-1}$ respectively. High density planting resulted in less number of spikes per plant due to competition for light, nutrients and water. At wide spacing of 60 x 60 cm plants produced more branches and leaves. Since spikes were formed on newly formed sessile leaves, it was found higher with wider spacing.

Fertilizer application was found significantly influencing spike production. A moderate level (30:30:60 NPK kg ha^{-1}) was found superior. Eventhough dry matter production was found to increase with an NPK level of 60:60:120 kg ha^{-1}, the number of spikes $plant^{-1}$ was not found increased. This was due to the fact that spikes were produced on erect branches only.

Among the treatment combinations, $S_3M_2F_1$ was found superior. Low density (60 x 60 cm) with no manure showed the lowest number of spikes per plant in all the stages of growth. Only a moderate level of fertilizer application was needed whether organic manure was applied in plenty or not irrespective of the spacing.

4.2.2 Length and diameter of fresh spikes

The length and diameter of the spike determine the size of the spike which ultimately influences yield. The length and diameter observed at 29 MAP are presented in Table 8.

Length varied from 2.98 to 3.03 cm, while diameter varied from 1.00 to 1.04 cm. Different treatments did not influence the length and diameter indicating that these are varietal characters.

4.2.3 Fresh and dry weight of spikes

Fresh and dry weight of spikes at bimonthly intervals from 17 to 29 MAP are presented in Tables 9 and 10 respectively.

Table 8. Effect of organic manure, fertilizer and spacing on length and diameter of spikes

	Length (cm)				Diameter (cm)			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
S_3M_0	3.03	3.01	3.03	3.02	1.03	1.01	1.02	1.02
S_3M_1	2.98	3.02	3.00	3.00	1.02	1.04	1.03	1.03
S_3M_2	3.01	3.00	3.00	3.00	1.01	1.00	1.03	1.01
S_2M_2	2.99	3.02	3.01	3.01	1.04	1.02	1.04	1.03
S_1M_2	3.03	3.03	3.00	3.02	1.00	1.02	1.00	1.01
Mean - Fm	3.01	3.01	3.01		1.02	1.02	1.03	
Fs	3.01	3.02	3.00		1.02	1.01	1.02	

CD(0.05)						CD(0.05)					
M	NS	Fm	NS	MxF	NS	M	NS	Fm	NS	MxF	NS
S	NS	Fs	NS	SxF	NS	S	NS	Fs	NS	SxF	NS

Table 9 Effect of organic manure, fertilizer and spacing on fresh weight of spikes (kg ha^{-1})

	17 MAP				19 MAP				21 MAP				23 MAP			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
S_3M_0	385.5	418.1	395.7	399.8	44.3	67.4	57.6	56.5	36.1	41.7	39.3	39.1	13.4	15.7	10.5	13.2
S_3M_1	547.7	676.8	616.7	613.7	104.9	146.8	97.8	116.5	50.1	58.8	53.1	54.0	19.8	28.1	24.3	24.1
S_3M_2	1574.0	2399.7	1746.8	1906.9	170.3	183.7	176.2	176.7	75.8	82.3	79.5	79.2	49.5	60.4	47.5	52.5
S_2M_2	1108.8	1771.9	1367.3	1416.0	148.7	168.0	162.5	159.8	72.2	75.8	74.3	74.1	47.8	58.0	53.9	53.2
S_1M_2	891.8	1015.1	922.0	943.0	145.3	160.9	150.8	152.3	73.2	76.9	75.2	75.1	45.9	55.1	52.5	51.2
Mean																
Fm	835.7	1164.9	919.7		106.5	132.7	110.5		54.0	60.9	57.3		27.6	34.7	27.5	
Fs	1191.5	1728.9	1345.4		154.8	170.9	163.2		73.7	78.3	76.3		47.7	57.8	51.3	

	17 MAP	19 MAP	21 MAP	23 MAP
	CD(0.5)	CD(0.05)	CD(0.05)	CD(0.05)
	M 176.73 Fm 176.73 MxF 306.10	M 7.17 Fm 7.17 MxF 12.42	M 4.47 Fm 4.47 MxF NS	M 2.93 Fm 2.93 MxF 5.07
	S 176.73 Fs 176.73 SxF 306.10	S 7.17 Fs 7.17 SxF NS	S NS Fs NS SxF NS	S NS Fs 2.93 SxF 5.07

	25 MAP				27 MAP				29 MAP			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
S_3M_0	58.2	78.7	69.8	68.9	222.6	236.1	227.9	228.4	106.3	112.9	110.2	109.8
S_3M_1	93.0	98.0	93.2	94.7	356.4	376.6	365.2	366.1	141.2	149.6	140.6	143.8
S_3M_2	120.1	135.1	128.5	127.9	507.3	525.6	517.1	516.7	170.8	181.1	177.8	176.5
S_2M_2	109.7	129.1	122.8	120.5	510.3	521.9	513.9	515.4	170.5	177.2	169.1	172.3
S_1M_2	109.0	124.6	117.1	116.9	496.3	509.6	488.9	498.3	169.1	176.7	172.1	172.6
Mean												
Fm	90.4	104.0	97.2		362.1	379.5	370.1		139.4	147.9	142.9	
Fs	112.9	129.6	122.8		504.7	519.1	506.7		170.1	178.3	173.0	

	25 MAP	27 MAP	29 MAP
	CD(0.05)	CD(0.05)	CD(0.05)
	M 3.61 Fm 3.61 MxF 6.25	M 6.06 FM 6.06 MxF NS	M 2.13 Fm 2.13 MxF 3.68
	S 3.61 Fs 3.61 SxF NS	S 6.06 Fs 6.06 SxF NS	S 2.13 Fs 2.13 SxF 3.68

Table 10 Effect of organic manure, fertilizer and spacing on the dry weight of spikes (kg ha^{-1})

	17 MAP				19 MAP				21 MAP				23 MAP			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
S_3M_0	77.0	82.8	79.3	79.7	8.6	13.3	11.5	11.1	7.0	8.3	7.3	7.5	2.7	3.1	2.1	2.6
S_3M_1	108.8	135.0	122.0	121.9	20.8	29.3	18.7	22.9	9.3	11.8	10.4	10.5	3.7	5.6	4.7	4.6
S_3M_2	314.1	479.0	348.6	380.6	34.0	36.7	34.9	35.2	15.1	16.4	15.8	15.8	9.9	12.1	9.5	10.5
S_2M_2	221.9	354.8	271.9	282.9	31.5	33.1	32.5	32.4	14.9	14.9	14.6	14.8	9.5	11.3	10.8	10.5
S_1M_2	176.3	202.4	184.0	187.6	29.1	31.6	29.8	30.2	14.3	15.3	15.0	14.9	9.2	11.0	10.5	10.2
Mean																
Fm	166.7	232.2	183.3		21.1	26.4	21.7		10.5	12.2	11.2		5.4	6.9	5.4	
Fs	237.5	345.4	268.2		31.5	33.8	32.4		14.8	15.6	15.1		9.5	11.5	10.2	

17 MAP	19 MAP	21 MAP	23 MAP
CD(0.5)	CD(0.05)	CD(0.05)	CD(0.05)
M 35.39 Fm 35.39 MxF 61.29	M 1.72 Fm 1.72 MxF 2.99	M 0.98 Fm 0.98 MxF NS	M 0.54 Fm 0.54 MxF 0.94
S 35.39 Fs 35.39 SxF 61.29	S 1.72 Fs 1.72 SxF NS	S NS Fs NS SxF NS	S NS Fs 0.54 SxF 0.94

	25 MAP				27 MAP				29 MAP			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
S_3M_0	10.8	15.0	13.1	12.9	42.7	44.9	43.1	43.6	20.4	21.3	22.0	21.2
S_3M_1	16.5	19.7	17.8	18.0	66.7	70.8	71.8	69.8	26.7	27.9	26.0	26.8
S_3M_2	23.8	27.3	25.7	25.6	97.4	104.3	98.3	100.0	32.6	33.9	34.0	33.5
S_2M_2	22.0	24.2	24.5	23.6	98.0	104.0	100.9	100.9	32.2	33.0	31.6	32.3
S_1M_2	21.6	24.4	23.4	23.1	97.3	101.1	95.2	97.9	31.9	33.7	32.3	32.6
Mean												
Fm	17.0	20.7	18.9		68.9	73.3	71.1		26.6	27.7	27.3	
Fs	22.4	25.3	24.5		97.5	103.7	98.1		32.2	33.5	32.6	

25 MAP	27 MAP	29 MAP
CD(0.05)	CD(0.05)	CD(0.05)
M 1.16 Fm 1.16 MxF NS	M 2.83 FM 2.83 MxF NS	M 0.51 Fm 0.51 MxF 0.88
S 1.16 Fs 1.16 SxF NS	S NS Fs 2.83 SxF NS	S 0.51 Fs 0.51 SxF 0.88

Fresh and dry weight of spikes followed a similar trend as that of number of spikes. The total dry matter production was not an indication of total spike yield since spikes were produced only on erect branches and in the axils of sessile leaves. During 17 MAP highest yield was recorded. The maximum fresh and dry spike yields were 2400 and 479 kg ha^{-1} respectively for the treatment combination $S_3M_2F_1$. From 19 and 23 MAP i.e. from December to April fresh and dry weight of spikes were found decreasing. The fresh and dry weight decreased to 60 and 12 kg ha^{-1} respectively during April for the same treatment combination. The other treatment combinations were producing still lesser yields. Vegetative growth was also found suppressed during this period. But with the onset of monsoon from June to October yield was found to be increased due to favourable growth conditions. Similar seasonal yield variation was observed during the first year of production of *thippali* as reported by Sheela (1996).

Application of organic manure was found to have definite role on fresh and dry weight of spikes. Heigher rate of 20 t ha^{-1} was found significantly superior (Fig.4a) and its effect was very much clear during the peak harvest stage at 17 MAP.

The effect of various spacings were found significant at all stages except 21 and 23 MAP which coincided with dry periods where the crop growth was almost nil. The crop almost faded away in dry months. Lowest plant density of 27777 plants ha^{-1} resulted from 60 x 60 cm spacing produced significantly higher yield in terms of both fresh and dry weight of spikes (Fig.4b).

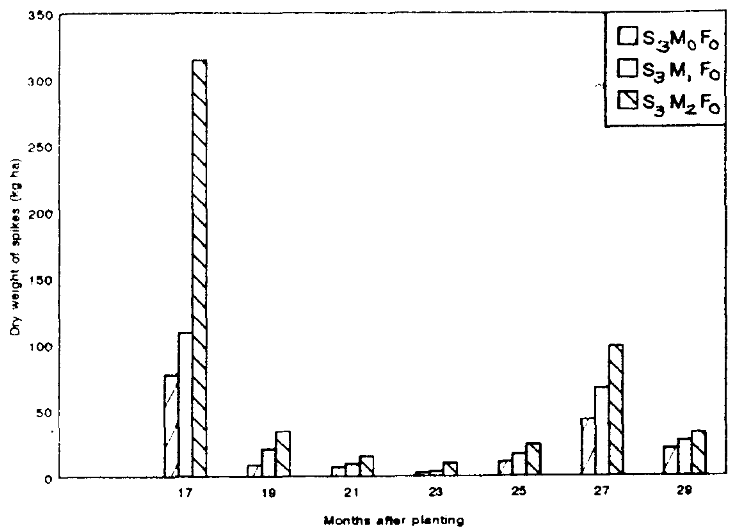

Fig.4a. Effect of organic manure on dry weight of spikes

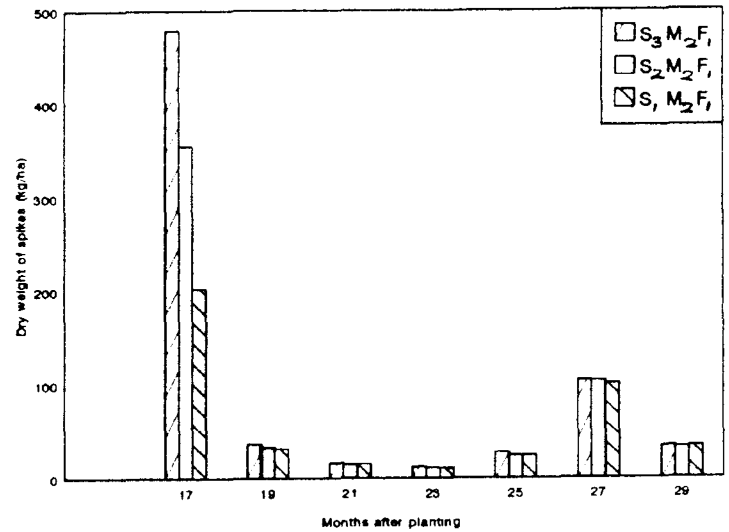

Fig.4b. Effect of spacing on dry weight of spikes

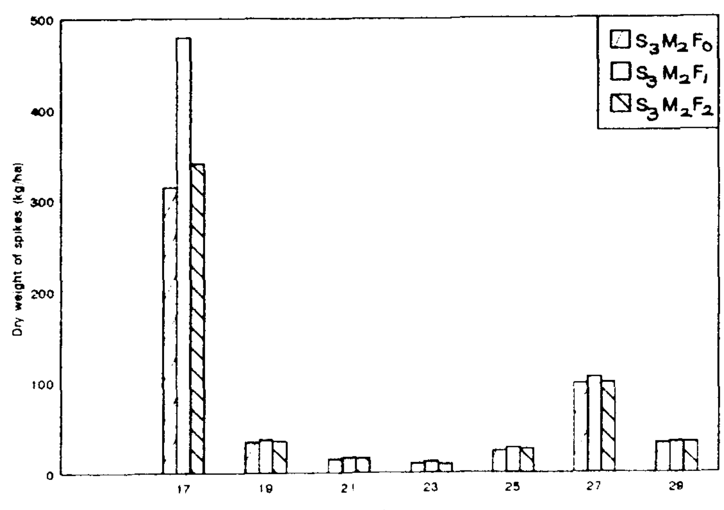

Fig 4c Effect of fertilizer on dry weight of spikes

With regard to fertilizer, lower dose of 30:30:60 NPK kg ha^{-1} was found optimum throughout the experiment (Fig.4c). Effect of fertilizer was more at higher levels of organic manure (20 t ha^{-1}).

The dry weight of the spikes followed a similar pattern throughout the experiment and recorded about one fifth of the fresh weight. This indicated that the driage is independent of the season and various management practices imposed on plants as reported by Sheela (1996). Similar studies were made by Viswanathan (1995) who recorded an average green to dry spike ratio of around 10:1.5 after comparing seven geographical races of *thippali*. Driage for *Piper nigrum* was recorded as 25-28 per cent by Purseglove *et al.* (1981) and they found that the driage was mainly governed by varietal characters rather than growing conditions.

4.2.4 Cumulative fresh and dry weight of spikes

Total fresh and dry weight of spikes obtained from seven harvests taken from one and a half years to two and a half years of growth as influenced by different treatments are presented in Table 11.

Organic manure was found significantly influencing the total yield of spikes. By applying 10 t organic manure, the mean fresh spike yield increased from 916 to 1413 kg ha^{-1} and it was further increased to 3036 kg ha^{-1} by application of 20 t ha^{-1} showing that there was more than three times yield increase over control by applying 20 t of organic manure. The same trend was followed with and without fertilizer aplication, but the yield increase was more due to organic manure application even when fertilizer was applied.

Table 11. Effect of organic manure, fertilizer and spacing on cumulative fresh and dry weight of spikes (kg ha^{-1})

	Fresh weight				Dry weight			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
S_3M_0	866	971	911	916	189	189	178	179
S_3M_1	1313	1535	1391	1413	253	300	271	275
S_3M_2	2668	3568	2873	3036	527	653	567	582
S_2M_2	2168	2843	2464	2492	430	575	487	497
S_1M_2	1931	2119	1979	2009	380	475	390	415
Mean - Fm	1616	2025	1725		316	381	338	
Fs	2256	2843	2439		446	568	481	

Fresh weight: CD(0.05)
M 184.6 Fm 184.6 MxF 319.7
S 184.6 Fs 184.6 SxF 319.7

Dry weight: CD(0.05)
M 62.6 Fm NS MxF NS
S 62.6 Fs 62.6 SxF NS

Similar results were observed in the case of dry spike yield also. The mean dry spike yield increased from 179 to 582 kg ha^{-1} by applying 20 t of organic manure per hectare. This result revealed the need for application of a high dose of organic manure when *thippali* is cultivated.

Plant density was found significantly influencing fresh and dry weight of spikes. When the plant density was more there was a significant reduction in the yield. The highest population of 62500 plants per hectare produced 2009 kg ha^{-1} fresh spike yield whereas it was increased to 2492 kg and 3036 kg when the population decreased to 40000 and 27777 plants per hectare, respectively.

In the case of dry weight of spikes also the same pattern was followed. The highest plant population gave an average yield of 415 kg ha^{-1} whereas it was increased to 497 and 582 kg ha^{-1} when the population decreased to the lower levels. It showed that 60 x 60 cm spacing leading to a population of 27777 plants per hectare was the best for *thippali*. The decrease in yield due to high density might be due to more competition. Similar results were reported by Vishwanathan (1995). However Sheela (1996) analysed the growth and yield performance of *thippali* during the initial one and a half years grown in coconut gardens and reported that spacing of 50 x 50 cm was better.

Significant increase in cumulative fresh and dry weight of spikes was shown by varying levels of fertilizer application. The fresh spike yield increased from 1616 kg to 2025 kg when 30:30:60 NPK kg ha^{-1} was applied giving an increase of 409 kg over control. But a further increase in fertilizer dose reduced the yield irrespective of the organic manure application and the plant population. The results also showed that the effect of fertilizer was more pronounced where 20 t of organic manure was applied. However the maximum production was achieved at the moderate level of 30:30:60 NPK kg ha^{-1}.

The same trend was shown in the case of dry weight of spikes also. The average yield increased from 316 to 381 kg ha^{-1} by applying 30:30:60 NPK kg ha^{-1} and it decreased to 338 kg ha^{-1} by applying the higher dose of fertilizer. A higher level of organic manure (20 t ha^{-1}) along with 30:30:60 NPK kg ha^{-1} was the most effective at a spacing of 60 x 60 cm in dry spike yield.

The maximum fresh spike yield was 3568 kg ha^{-1} and the dry weight was 653 kg ha^{-1} when the crop was grown with an organic manure application of 20 t ha^{-1} and with 30:30:60 NPK kg ha^{-1} under a spacing of 60 x 60 cm. A higher level of organic manure application was more effective than fertilizer application. Role of organic manure in sustaining and enhancing growth and spike yield of *thippali* were stressed by several workers (Nair *et al.*, 1986 and Viswanathan, 1993b).

4.3 Nutrient content and plant uptake

4.3.1 Nitrogen content

4.3.1.1 Nitrogen content of vegetative parts

Nitrogen content of vegetative parts from 17 to 29 MAP at six months interval are presented in Table 12. Nitrogen content was found influenced by different treatments, at all stages of observation.

Nitrogen content of vegetative parts was found decreasing as the crop growth advanced. Lowest nitrogen content was recorded at 29 MAP. Sheela (1996)

Table 12. Effect of organic manure, fertilizer and spacing on nitrogen content of vegetative parts (%)

	17 MAP				23 MAP				29 MAP			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
S_3M_0	1.06	1.34	1.67	1.36	1.01	1.14	1.23	1.13	1.02	1.03	1.03	1.03
S_3M_1	1.57	1.74	1.79	1.70	1.40	1.48	1.79	1.56	1.06	1.18	1.21	1.15
S_3M_2	1.90	2.54	2.45	2.30	1.43	1.51	2.09	1.67	1.34	1.41	1.57	1.44
S_2M_2	1.23	2.48	2.18	1.96	1.16	2.22	2.28	1.89	1.05	1.34	1.36	1.25
S_1M_2	1.33	1.81	1.91	1.68	1.21	1.70	1.73	1.55	1.04	1.09	1.19	1.11
Mean - Fm	1.51	1.88	1.97		1.28	1.38	1.70		1.14	1.21	1.27	
Fs	1.49	2.28	2.18		1.27	1.81	2.03		1.14	1.28	1.38	

17 MAP CD(0.05)	23 MAP CD(0.05)	29 MAP CD(0.05)
M 0.083 Fm 0.083 MxF 0.144	M 0.060 Fm 0.060 MxF 0.105	M 0.044 Fm NS MxF NS
S 0.083 Fs 0.083 SxF 0.144	S 0.060 Fs 0.060 SxF 0.105	S 0.044 Fs 0.044 SxF 0.076

reported that nitrogen content in vegetative parts of long pepper was highest at 5 MAP with mean value of 3.5 per cent, 2.5 per cent at 9 MAP and 2.0 per cent at 13 MAP. Reduction in nitrogen content of vegetative parts with ageing might be probably due to mobilisation of nitrogen to spikes or decreased absorption due to reduced growth rate in advanced stage. Similar variation in the leaf nitrogen content of *Piper nigrum* was reported by Sushama (1982).

Addition of organic manure @ 20 t ha^{-1} was found to result in higher nitrogen content in vegetative parts.

Effect of spacing was also found significant. *Thippali* planted at wider spacing of 60 x 60 cm accumulated more N. At high plant density (40 x 40 cm and 50 x 50 cm spacing) greater competition for added nitrogen might have occurred and resulted in lower nitrogen content in vegetative parts.

With regard to fertilizers, higher level (60:60:120 NPK kg ha^{-1}) of application lead to more nitrogen content than zero and 30:30:60 NPK kg ha^{-1}. But the higher nitrogen content and dry matter production could not increase the spike yield. This might be due to the fact that spikes were produced only on erect branches and while finding out the total dry matter production the unproductive vines were also taken into account.

Among different treatment combinations $S_3M_2F_2$ was found to have more nitrogen on vegetative parts at two and a half years after planting.

4.3.1.2 Nitrogen content of spikes

Nitrogen content of spikes from 17 to 29 MAP at six months interval are presented in Table 13.

Table 13. Effect of organic manure, fertilizer and spacing on nitrogen content of spikes (%)

	17 MAP				23 MAP				29 MAP			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
S_3M_0	2.48	3.48	3.69	3.22	3.18	3.47	3.84	3.50	2.38	3.04	3.53	2.99
S_3M_1	3.31	3.42	3.30	3.34	3.72	3.85	3.74	3.77	3.24	3.14	3.66	3.35
S_3M_2	3.55	3.59	4.25	3.79	3.76	3.83	4.67	4.09	3.44	3.41	4.25	3.70
S_2M_2	3.33	3.76	3.87	3.66	3.51	3.94	3.91	3.79	3.36	3.49	3.68	3.51
S_1M_2	3.16	3.27	3.71	3.38	3.62	3.70	3.84	3.72	3.11	3.21	3.74	3.35
Mean - Fm	3.11	3.50	3.75		3.55	3.72	4.08		3.02	3.19	3.81	
Fs	3.35	3.54	3.94		3.63	3.82	4.14		3.30	3.37	3.89	

17 MAP	23 MAP	29 MAP
CD(0.05)	CD(0.05)	CD(0.05)
M 0.046 Fm 0.046 MxF 0.079	M 0.027 Fm 0.027 MxF 0.047	M 0.048 Fm 0.048 MxF 0.083
S 0.046 Fs 0.046 SxF 0.079	S 0.027 Fs 0.027 SxF 0.047	S 0.048 Fs 0.048 SxF 0.083

The nitrogen content in spikes was more than in vegetative parts. Crop stage/ageing did not influence the N content of spikes. Higher nitrogen content in spikes might be due to the presence of higher content of alkaloids and phenolics of which the main constituent is nitrogen (see 4.4.2). The vegetative parts contain relatively lesser quantities of alkaloids compared to spikes as reported by Manavalan and Singh (1979) and Husain *et al.* (1992).

Effect of different treatments was found significant on nitrogen content of spikes similar to nitrogen content of vegetative parts. Application of organic manure @ 20 t ha^{-1} along with 60:60:120 NPK kg ha^{-1} was able to produce more N content in spikes under a spacing of 60 x 60 cm in all the stages. During 17 MAP i.e., the peak bearing stage also the N content in spikes was the highest for this treatment combination (4.25%). The treatment without manure and fertilizer application recorded the lowest nitrogen content (2.48%). This showed that application of nutrients increased nitrogen content of spikes.

In general, the spikes produced and matured during the summer months contained relatively greater N as seen in the harvest made during 23 MAP, during the months of April, though the harvest was poor. The spikes produced during rainy periods contained relatively less N even though the yield were better.

4.3.1.3 Total nitrogen uptake

Response of different treatments on nitrogen uptake at six months interval from 17 to 29 MAP are presented in Table 14. Significant differences were observed with respect to different treatments.

Table 14. Effect of organic manure, fertilizer and spacing on total nitrogen uptake (kg ha^{-1})

	17 MAP				23 MAP				29 MAP			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
S_3M_0	4.38	6.32	7.33	6.01	1.60	2.14	2.36	2.03	2.76	3.13	3.33	3.08
S_3M_1	8.42	11.85	11.87	10.71	2.59	3.33	4.09	3.34	3.73	4.72	5.05	4.50
S_3M_2	17.88	28.24	26.35	24.16	3.94	4.33	6.13	4.80	5.54	5.90	6.19	5.88
S_2M_2	11.41	21.79	18.48	17.23	2.86	5.81	5.73	4.80	4.47	5.98	6.12	5.52
S_1M_2	9.65	12.52	13.46	11.88	3.02	4.34	4.58	3.98	4.24	4.69	5.29	4.74
Mean - Fm	10.23	15.47	15.18		2.71	3.27	4.19		4.01	4.58	4.86	
Fs	12.98	20.85	19.43		3.27	4.83	5.48		4.75	5.53	5.86	

	17 MAP	23 MAP	29 MAP
	CD(0.05)	CD(0.05)	CD(0.05)
	M 1.546 Fm 1.546 MxF 2.678	M 0.270 Fm 0.270 MxF 0.468	M 0.264 Fm 0.264 MxF NS
	S 1.546 Fs 1.546 SxF 2.678	S 0.270 Fs 0.270 SxF 0.468	S 0.264 Fs 0.264 SxF 0.458

Nitrogen uptake is the product of dry matter accumulation and nitrogen content. During 23 MAP, dry matter production was found reduced hence nitrogen uptake was also lower than other two period of observation. As the age of the crop advanced there was a drastic reduction in the N uptake. The N uptake was found maximum during 17 MAP because of higher dry weight accumulation at that period in terms of both vegetative matter as well as spike yield. The spikes contained a higher N concentration (three times that of vegetative parts) and the dry spike yield was also the highest at 17 MAP.

Organic manure application was found to increase N uptake significantly and the higher rate of 20 t ha^{-1} resulted in higher N uptake by plants. The dry matter production was also maximum under this level.

Plants grown under wider spacing of 60x 60 cm removed higher N. High density planting as discussed earlier led to competition for growth factors which resulted in low N uptake. But in summer the uptake was found to be very low in all the plots.

During the maximum production stage of 17 MAP, application of 30:30:60 NPK kg ha^{-1} resulted in more N uptake, which was on par with the higher dose of 60:60:120 NPK ka ha^{-1}. This showed that for the crop *thippali* a manurial level of 20 t ha^{-1} and fertilizer level of 30:30:60 NPK kg ha^{-1} and a spacing of 60 x 60 cm were the best in terms of productivity and N uptake. In the later stages since the crop growth is stunted there was only reduced N uptake. Dry matter production played an important role in nutrient uptake (Richards, 1969).

4.3.2 Phosphorus content

4.3.2.1 Phosphorus content of vegetative parts

Effect of various treatments on phosphorus content of vegetative parts at six months interval from 17 to 29 MAP are presented in Table 15.

The P content in vegetative parts ranged from 0.36 to 0.53 per cent. A higher level of spacing under higher level of manurial and fertilizer application increased P content. Higher dose of 20 t ha^{-1} increased the availability of phosphorus to plants resulting in higher content in vegetative parts. The role of organic matter in enhancing phosphorus availability from soil was reported by Tisdale *et al.* (1993) and Joseph *et al.* (1995). There was a slight increase in P content when the plant growth was reduced after the peak bearing stage.

4.3.2.2 Phosphorus content of spikes

The influence of different treatments on phosphorus content of spikes is presented in Table 16. Different treatments were found influencing the phosphorus content of spikes.

The P content in spikes ranged from 0.45 to 0.59 per cent. There was only marginal difference between vegetative parts and spikes unlike N. The N:P ratio in the spikes was much higher than that of vegetative parts. The high content of N in spikes might be due to the higher content of secondary metabolites like alkaloids and phenolics which are mainly constituted by nitrogen. Phosphorus content in spikes was comparatively less at peak bearing stage like N, probably due to the dilution effect. The P content in spikes increased due to higher rate of organic manure and fertilizer application. However, influence of plant density on phosphorus

Table 15. Effect of organic manure, fertilizer and spacing on phosphorus content of vegetative parts (%)

	17 MAP				23 MAP				29 MAP			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
S_3M_0	0.36	0.38	0.39	0.38	0.38	0.38	0.39	0.38	0.43	0.45	0.46	0.45
S_3M_1	0.36	0.38	0.39	0.38	0.40	0.41	0.44	0.41	0.48	0.50	0.51	0.49
S_3M_2	0.42	0.45	0.46	0.44	0.48	0.51	0.52	0.50	0.51	0.52	0.53	0.52
S_2M_2	0.41	0.42	0.44	0.42	0.45	0.47	0.47	0.46	0.49	0.51	0.53	0.51
S_1M_2	0.39	0.41	0.41	0.41	0.42	0.43	0.44	0.43	0.47	0.49	0.50	0.49
Mean - Fm	0.38	0.40	0.41		0.42	0.43	0.45		0.47	0.49	0.50	
Fs	0.41	0.43	0.44		0.45	0.47	0.48		0.49	0.51	0.52	

17 MAP	23 MAP	29 MAP
CD(0.05)	CD(0.05)	CD(0.05)
M 0.005 Fm 0.005 MxF NS	M 0.006 Fm 0.006 MxF 0.010	M 0.004 Fm 0.004 MxF 0.008
S 0.005 Fs 0.005 SxF 0.009	S 0.006 Fs 0.006 SxF 0.010	S 0.004 Fs 0.004 SxF 0.008

Table 16. Effect of organic manure, fertilizer and spacing on phosphorus content of spike (%)

	17 MAP				23 MAP				29 MAP			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
S_3M_0	0.45	0.46	0.47	0.46	0.52	0.53	0.53	0.53	0.51	0.53	0.54	0.53
S_3M_1	0.48	0.49	0.50	0.49	0.53	0.55	0.55	0.54	0.56	0.56	0.57	0.56
S_3M_2	0.51	0.51	0.52	0.51	0.56	0.57	0.57	0.57	0.56	0.57	0.58	0.57
S_2M_2	0.50	0.51	0.51	0.51	0.57	0.57	0.58	0.57	0.57	0.58	0.59	0.58
S_1M_2	0.50	0.51	0.51	0.51	0.55	0.57	0.57	0.56	0.57	0.57	0.57	0.57
Mean - Fm	0.48	0.49	0.50		0.54	0.55	0.55		0.54	0.55	0.57	
Fs	0.50	0.51	0.51		0.56	0.57	0.57		0.57	0.57	0.58	

	17 MAP	23 MAP	29 MAP
	CD(0.05)	CD(0.05)	CD(0.05)
	M 0.005 Fm 0.005 MxF NS	M 0.005 Fm 0.005 MxF NS	M 0.004 Fm 0.004 MxF 0.008
	S 0.005 Fs 0.005 SxF NS	S 0.005 Fs 0.005 SxF NS	S 0.004 Fs 0.004 SxF 0.008

content of spikes was found low, similar to that of early stages of the crop as reported by Sheela (1996).

4.3.2.3 Phosphorus uptake

The uptake of phosphorus at six months inteval from 17 to 29 MAP is shown in Table 17. Different treatments were influencing P uptake significantly.

Phosphorus uptake was found to be the highest during 17 MAP which was the most productive stage. Lowest P uptake was recorded at 23 MAP due to summer season, which resulted in lower dry matter production and poor yield.

Even though phosphorus content of vegetative parts and spikes increased on ageing, phosphorus uptake was found reduced at 29 MAP. Dry matter production was also reduced during this period. The result showed that P uptake was influenced by dry matter production.

Organic manure application @ 20 t ha^{-1}, wider spacing of 60 x 60 cm and a lower fertilizer dose of 30:30:60 NPK kg ha^{-1} resulted in more phosphorus uptake by the plant. Phosphorus uptake was around 1/5 to 1/6 of nitrogen uptake mainly due to the lower P content in spikes compared to N.

4.3.3 Potassium content

4.3.3.1 Potassium content of vegetative parts

Effect of different treatments on potassium content of vegetative parts at six months intervals from 17 to 29 MAP are presented in Table 18. Potassium content of vegetative parts varied from 1.22 to 2.49 per cent at different stages of growth.

Table 17. Effect of organic manure, fertilizer and spacing on total phosphorus uptake (kg ha^{-1})

	17 MAP				23 MAP				29 MAP			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
S_3M_0	1.17	1.34	1.39	1.30	0.63	0.68	0.73	0.68	1.05	1.18	1.32	1.18
S_3M_1	1.63	1.92	2.03	1.86	0.69	0.79	0.85	0.78	1.57	1.68	1.77	1.67
S_3M_2	3.07	4.40	3.94	3.80	1.09	1.26	1.29	1.21	1.86	1.93	1.79	1.86
S_2M_2	2.44	3.23	2.97	2.88	0.94	1.08	1.08	1.03	1.77	2.02	2.09	1.96
S_1M_2	2.09	2.38	2.37	2.28	0.92	1.01	1.05	0.99	1.65	1.79	1.90	1.78
Mean - Fm	1.95	2.55	2.45		0.80	0.91	0.95		1.50	1.60	1.63	
Fs	2.53	3.34	3.09		0.98	1.12	1.14		1.76	1.92	1.93	

	17 MAP	23 MAP	29 MAP
	CD(0.05)	CD(0.05)	CD(0.05)
	M 0.222 Fm 0.222 MxF 0.384	M 0.054 Fm 0.054 MxF 0.093	M 0.089 Fm 0.089 MxF 0.154
	S 0.222 Fs 0.222 SxF 0.384	S 0.054 Fs 0.054 SxF NS	S 0.089 Fs 0.089 SxF 0.154

Table 18. Effect of organic manure, fertilizer and spacing on potassium content of vegetative parts (%)

	17 MAP				23 MAP				29 MAP			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
S_3M_0	1.42	1.44	1.46	1.44	1.36	1.49	1.52	1.45	1.22	1.26	1.32	1.27
S_3M_1	1.48	1.52	1.53	1.51	1.70	1.76	1.79	1.75	1.36	1.40	1.42	1.39
S_3M_2	1.59	1.62	1.64	1.62	1.91	2.34	2.49	2.25	1.52	1.56	1.59	1.56
S_2M_2	1.52	1.55	1.56	1.54	2.08	2.12	2.21	2.14	1.48	1.51	1.51	1.50
S_1M_2	1.49	1.50	1.52	1.50	2.08	2.14	2.16	2.12	1.47	1.48	1.50	1.49
Mean - Fm	1.50	1.52	1.54		1.66	1.86	1.93		1.36	1.41	1.44	
Fs	1.53	1.55	1.57		2.02	2.20	2.29		1.49	1.52	1.54	

17 MAP	23 MAP	29 MAP
CD(0.05)	CD(0.05)	CD(0.05)
M 0.009 Fm 0.009 MxF NS	M 0.045 Fm 0.045 MxF 0.078	M 0.019 Fm 0.019 MxF NS
S 0.009 Fs 0.009 SxF NS	S 0.045 Fs 0.045 SxF 0.078	S 0.019 Fs 0.019 SxF NS

Potassium content in vegetative parts was slightly higher during 23 MAP. Spike yield during this period was lowest compared to other stages. Hence the translocation of potassium from vegetative parts to spikes must have been lower.

Addition of organic manure (20 t ha^{-1}) increased potassium content of vegetative parts at all the stages of growth. Effect of spacing was found significant and a wider spacing of 60 x 60 cm was superior over 50 x 50 and 40 x 40 cm. The decreasing trend of potassium content in pepper when plant population increased was reported by Reddy *et al.* (1992).

An increasing trend in K concentration in vegetative parts was observed with increasing fertilizer application up to 60:60:120 NPK kg ha^{-1}. Potassium is taken up fast and in large quantities compared to other primary nutrients, if it is readily available in soil. It is even consumed in excess quantities than needed. The role of K in plants is more in carbohydrate metabolism (Tisdale *et al.*, 1993). The K content in vegetative parts was comparable to that of N even though high quantity of K was applied.

4.3.3.2 Potassium content of spikes

The influence of different treatments on potassium content of spikes is given in Table 19. Potassium content of spikes was slightly higher than potassium content of vegetative parts, in general.

Different levels of organic manure and fertilizer were found to have their effect on potassium content of spikes at all the stages. But spacing had no effect at

Table 19. Effect of organic manure, fertilizer and spacing on potassium content of spikes (%)

	17 MAP				23 MAP				29 MAP			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
S_3M_0	1.73	1.79	1.84	1.79	1.86	1.87	1.90	1.88	1.90	1.91	1.93	1.91
S_3M_1	1.82	1.84	1.87	1.85	1.91	1.91	1.93	1.92	1.94	1.96	1.97	1.96
S_3M_2	1.87	1.88	1.88	1.88	1.97	1.98	2.00	1.98	1.99	2.01	2.02	2.01
S_2M_2	1.85	1.87	1.88	1.87	1.93	1.94	1.95	1.94	1.98	1.98	2.00	1.99
S_1M_2	1.84	1.86	1.87	1.86	1.94	1.95	1.96	1.95	1.97	1.98	1.98	1.98
Mean - Fm	1.81	1.84	1.86		1.91	1.92	1.94		1.94	1.96	1.97	
Fs	1.86	1.87	1.88		1.95	1.96	1.97		1.98	1.99	2.00	

	17 MAP	23 MAP	29 MAP
	CD(0.05)	CD(0.05)	CD(0.05)
	M 0.021 Fm 0.021 MxF 0.038	M 0.007 Fm 0.007 MxF NS	M 0.007 Fm 0.007 MxF NS
	S NS Fs NS SxF NS	S 0.007 Fs 0.007 SxF NS	S 0.007 Fs 0.007 SxF NS

the peak bearing stage even though it had its effect at later stages when the dry matter production was less.

4.3.3.3 Potassium uptake

Potassium uptake at six months interval from 17 to 29 MAP are presented in Table 20. Influence of different treatments was found significant.

Application of organic manure (20 t ha^{-1}) increased K uptake significantly, due to increased dry matter production. Wider spacing was found superior. Higher levels of fertilizer increased K uptake especially during later stages. Hence K uptake pattern followed similar trend as that of N and P. Higher N, P and K uptake was found at 17 MAP i.e., the peak bearing stage which showed that there is a direct relationship between dry matter production and nutrient uptake. But the K uptake was found to be lower than N uptake at the peak bearing stage indicating that there was no need of applying such high level of K to the crop.

4.4 Qualitative analysis of *thippali*

4.4.1 Crude alkaloid content of roots

Influence of different treatments on crude alkaloid content of roots at two and a half years after planting is presented in Table 21. The manure and fertilizer applied was found to influence crude alkaloid content of roots.

About 22 different alkaloids were reported in *Piper longum*. Along with total crude alkaloid, the content of different alkaloids probably might have changed; however independent estimations were not done.

Table 20. Effect of organic manure, fertilizer and spacing on total potassium uptake (kg ha^{-1})

	17 MAP				23 MAP				29 MAP			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
S_3M_0	4.63	5.16	5.27	5.02	2.10	2.68	2.83	2.54	3.09	3.41	3.68	3.39
S_3M_1	6.48	7.58	7.93	7.33	3.26	3.69	3.93	3.63	4.19	4.86	5.05	4.70
S_3M_2	11.49	15.99	14.19	13.89	4.97	6.25	6.97	6.06	5.65	5.93	5.87	5.81
S_2M_2	9.11	11.87	10.81	10.60	4.71	5.34	5.40	5.15	5.44	6.05	6.11	5.87
S_1M_2	7.78	8.74	8.69	8.41	4.80	5.14	5.41	5.12	5.21	5.57	5.76	5.51
Mean - Fm	7.53	9.58	9.13		3.44	4.21	4.58		4.31	4.73	4.87	
Fs	9.46	12.20	11.23		4.83	5.58	5.92		5.43	5.85	5.91	

	17 MAP	23 MAP	29 MAP
	CD(0.05)	CD(0.05)	CD(0.05)
	M 0.731 Fm 0.731 MxF 1.266	M 0.273 Fm 0.273 MxF 0.473	M 0.263 Fm 0.263 MxF NS
	S 0.731 Fs 0.731 SxF 1.266	S 0.273 Fs 0.273 SxF 0.473	S 0.263 Fs 0.263 SxF NS

Table 21. Effect of organic manure, fertilizer and spacing on crude alkaloid content of roots and spikes (%)

	Roots				Spikes			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
S_3M_0	2.89	3.07	3.06	3.01	5.91	5.90	5.84	5.88
S_3M_1	3.12	3.13	3.03	3.09	5.90	6.00	5.94	5.95
S_3M_2	3.19	3.25	3.14	3.19	6.02	6.22	5.96	6.07
S_2M_2	3.16	3.22	3.19	3.19	5.78	5.81	5.80	5.80
S_1M_2	3.14	3.21	3.20	3.18	5.78	5.86	5.82	5.82
Mean - Fm	3.07	3.15	3.08		5.94	6.04	5.91	
Fs	3.17	3.23	3.18		5.86	5.96	5.86	

Roots CD(0.05)						Spikes CD(0.05)					
M	0.022	Fm	0.022	MxF	0.038	M	0.021	Fm	0.021	MxF	0.037
S	NS	Fs	0.022	SxF	0.038	S	0.021	Fs	0.021	SxF	0.037

Crude alkaloid content of roots varied from 2.89 to 3.25 per cent. The content was found lower than in spikes. Similar findings were reported by Dustur (1962). Dey and Bahadur (1973) and Stuart (1985). They had reported that the dried roots of *Piper longum* possessed the same medicinal qualities as the spikes but in an inferior degree.

The crude alkaloid content of roots was found increased by organic manure application @ 20 t ha^{-1} from 3.01 to 3.19 per cent. Regarding the level of fertilizers, a lower dose of 30:30:60 NPK kg ha^{-1} was found superior irrespective of the spacing and manurial application. Under varying levels of manurial application the alkaloid content in roots increased from 3.07 per cent at F_0 level to 3.15 per cent at F_1 level. It was again reduced to 3.08 per cent at F_2 level. The effect of fertilizer averaged over spacings was significant and the highest crude alkaloid content (3.23%) was also for F_1 level compared to 3.17 and 3.18 for F_0 and F_2 levels respectively. There was no significant effect due to various plant densities.

4.4.2 Crude alkaloid content of spikes

Influence of different treatments on crude alkaloid content of spikes after two and a half years of planting are presented in Table 21. There was a significant difference in crude alkaloid content in spikes due to various treatments, which varied from 5.78 to 6.22 per cent.

Application of organic manure @ 20 t ha^{-1} and fertilizer 30:30:60 NPK kg ha^{-1} with a plant density of 27777 ha^{-1} was found to increase the crude alkaloid content. Reason might be due to increased availability of various nutrients to each plant which changed the nutrient content in spikes and the content of different alkaloids and phenolics. At higher level fertilizer application crude alkaloid content was found to be reduced. This showed that *thippali* need only lower dose of fertilizer in order to get higher yield and quality.

Among different treatment combinations crude alkaloid from roots and spikes was found higher with 20 t ha^{-1} organic manure, wider spacing of 60 x 60 cm and a dose of 30:30:60 NPK kg ha^{-1}.

Eventhough the alkaloid content was varying significantly, the size and weight of the spike was found to be same. It may be due to the accumulation of nutrient in different forms including as secondary metabolites like phenolics and alkaloids. There is also report that the nitrogen can be accumulated as nitrite, nitrozamine etc. which are detrimental to biological system (Maynard *et al.*, 1976).

4.4.3 Alkaloid yield from spikes

The effect of various treatments on alkaloid yield from spikes during the period under study is presented in Table 22.

Alkaloid yield is the product of cumulative dry spike yield and alkaloid content. Different treatments were found influencing the alkaloid yield from spikes significantly.

Application of organic manure increased alkaloid yield. The highest rate (20 t ha^{-1}) of organic manure application was found superior. Plant density also had its influence on alkaloid yield. Wider spacing of 60 x 60 cm was found superior.

With regard to fertilizer, lower dose of 30:30:60 NPK kg ha^{-1} produced highest spike and alkaloid yield compared to zero and 60:60:120 NPK kg ha^{-1}.

Table 22. Cumulative alkaloid yield from spikes produced from 17 to 29 MAP (kg ha^{-1})

	F_0	F_1	F_2	Mean
S_3M_0	10.00	11.12	10.42	10.51
S_3M_1	14.91	10.82	16.12	13.95
S_3M_2	31.73	40.65	33.82	35.40
S_2M_2	25.13	33.43	28.22	28.92
S_1M_2	21.93	27.86	22.74	24.18
Mean - Fm	18.88	20.86	20.12	
Fs	26.26	33.98	28.26	

CD(0.05)
M 3.851 Fm 3.851 MxF NS
S 3.951 Fs 3.851 SxF NS

Interaction effect of manure and spacing with fertilizer was not found significant with respect to alkaloid yield from spikes.

4.5 Nutrient status of soil

4.5.1 Organic carbon content of soil

Effect of various treatments on organic carbon content of soil before and after the experiment (at 17 and 29 MAP) are presented in Table 23.

Different treatments were found significantly influencing the organic carbon content of soil. Among this organic manure has a pronounced effect. After the experiment highest organic carbon (1.41%) was recorded in field with highest rate of organic manure application of 20 t ha^{-1} and a wider spacing of 60 x 60 cm with a fertilizer dose of 60:60:120 NPK kg ha^{-1}. There was a significant increase in organic carbon due to increasing doses of fertilizer. The plot receiving no manure and fertilizer resulted in very poor organic carbon content (0.44%).

The interaction effects of manure with fertilizer and spacing with fertilizer were significant. After the experiment the organic carbon was less in plots where there was more population density. The oxidation and absorption of organic carbon are more in the rhizosphere of plants and hence high density planting can reduce the organic carbon content in soil.

The organic carbon content was found decreasing after the experiment. This indicated that there was a depletion of organic carbon after continuous cropping even though organic matter was applied every year, a fact very well established by Brady (1990) and Tisdale *et al.* (1993). They reported that under continuous

Table 23. Effect of organic manure, fertilizer and spacing on organic carbon content of soil (%)

	17 MAP				29 MAP			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
S_3M_0	0.75	0.82	0.84	0.80	0.44	0.57	0.51	0.51
S_3M_1	1.01	1.08	1.14	1.08	0.87	0.91	0.94	0.91
S_3M_2	1.24	1.35	1.54	1.38	1.16	1.34	1.41	1.30
S_2M_2	1.22	1.28	1.27	1.26	1.06	1.12	1.15	1.11
S_1M_2	1.23	1.28	1.28	1.26	1.11	1.11	1.10	1.10
Mean - Fm	1.00	1.08	1.17		0.82	0.94	0.95	
Fs	1.23	1.30	1.36		1.11	1.19	1.22	

	17 MAP CD(0.05)						29 MAP CD(0.05)					
	M	0.042	Fm	0.042	MxF	0.072	M	0.038	Fm	0.038	MxF	0.065
	S	0.042	Fs	0.042	SxF	0.072	S	0.038	Fs	0.038	SxF	0.065

cultivation soil organic matter declined, depending on environment and quantity of residue returned to the soil. Towards the end of the experiment the biomass yield also decreased and there was not much addition of organic matter through leaf fall. This also might have caused reduction of organic carbon in soil. The organic matter represented total soil N since 95 per cent of total N is organic N. Cutlivation and continued cropping usually resulted in a rapid depletion of nitrogen by 40-65 per cent in a system in which non legumes were involved (Strugis, 1936 and Ghosh and Kanzaria, 1964).

4.5.2 Available nitrogen content of soil

The available nitrogen content of soil before and after the experiment are presented in Table 24.

Application of organic manure was found significantly influencing available nitrogen content of soil. The higher rate of 20 t ha^{-1} was found to maintain higher level of available nitrogen in soil. Muthuvel (1973) had reported that application of organic manure increased available nitrogen content in soil due to increased microbial activity leading to greater mineralisation.

Plant density influenced available N content in soil. In plots with low plant density (60 x 60 cm spacing) available N content was found significantly greater than those with higher plant densities. The dry matter accumulation was also more in plots having a higher content of organic carbon and available N.

Regarding the effect of fertilizers, at higher level of application (60:60:120 NPK kg ha^{-1}) available N content was found higher, compared to zero and 30:30:60 NPK kg ha^{-1} levels.

Table 24. Effect of organic manure, fertilizer and spacing on available nitrogen content of soil (%)

	17 MAP				29 MAP			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
S_3M_0	0.013	0.013	0.014	0.013	0.012	0.012	0.014	0.013
S_3M_1	0.015	0.016	0.015	0.015	0.014	0.015	0.016	0.015
S_3M_2	0.016	0.017	0.018	0.017	0.016	0.017	0.017	0.017
S_2M_2	0.015	0.016	0.017	0.016	0.015	0.015	0.016	0.015
S_1M_2	0.014	0.014	0.015	0.014	0.015	0.015	0.016	0.015
Mean - Fm	0.015	0.015	0.016		0.014	0.014	0.016	
Fs	0.015	0.015	0.017		0.015	0.016	0.016	

17 MAP CD(0.05)						29 MAP CD(0.05)					
M	0.0004	Fm	0.0004	MxF	0.0006	M	0.0005	Fm	0.0005	MxF	NS
S	0.0004	Fs	0.0004	SxF	NS	S	0.0005	Fs	0.0005	SxF	NS

Interaction was found not significant except at 17 MAP where interaction effect of manure with fertilizer was found significant. Stumpe and Kolbe (1968) reported an increase of three per cent available nitrogen through combined application of manure and fertilizer in chillies.

4.5.3 Available phosphorus content of soil

Table 25 represents the effect of various treatments on available phosphorus content of soil which was found influenced by different treatments.

Organic manure was found to have a pronounced effect and a higher available P content was found in the plots receiving 20 t ha^{-1} organic manure. Organic manure at higher dose might have enhanced mineralisation of native P (McIntosh and Varney, 1973 and Joseph *et al.*, 1995).

Regarding spacing and fertilizers, a wider spacing of 60 x 60 cm and fertilizer @ 60:60:120 NPK kg ha^{-1} resulted in higher available P content in soil.

Available P content was found decreasing after the experiment. However uptake of P by the plant was relatively less than other nutrients. Since the loss of P from applied fertilizer is less, a major portion of applied P must have been fixed and retained in the soil, in an unavailable form resulting in a reduction of available P in soil. The lowest content was noted in plots without manure and fertilizer application.

4.5.4 Available potassium content of soil

Effect of various treatments on available potassium content of soil are presented in Table 26.

Table 25. Effect of organic manure, fertilizer and spacing on available phosphorus content of soil (kg ha^{-1})

	17 MAP				29 MAP			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
S_3M_0	11.18	13.31	14.03	12.84	8.09	8.96	9.02	8.69
S_3M_1	15.36	15.59	15.79	15.58	12.65	13.56	14.05	13.42
S_3M_2	18.51	18.59	18.63	18.58	15.07	16.13	16.32	15.84
S_2M_2	17.93	18.40	18.78	18.37	13.87	15.35	15.48	14.90
S_1M_2	17.86	18.25	18.56	18.22	13.83	14.35	14.52	14.24
Mean - Fm	15.02	15.83	16.15		11.94	12.88	13.13	
Fs	18.10	18.41	18.66		14.26	15.28	15.44	

CD(0.05) 17 MAP:
M 0.452 Fm 0.452 MxF 0.782
S NS Fs NS SxF NS

CD(0.05) 29 MAP:
M 0.212 Fm 0.212 MxF NS
S 0.212 Fs 0.212 SxF 0.366

Table 26. Effect of organic manure, fertilizer and spacing on available potassium content of soil (kg ha^{-1})

	17 MAP				29 MAP			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
S_3M_0	87.43	98.23	102.00	95.89	86.27	94.83	96.63	92.58
S_3M_1	106.43	112.90	117.43	112.26	101.73	105.00	110.77	105.83
S_3M_2	118.40	128.23	135.40	127.34	115.27	118.20	121.40	118.29
S_2M_2	112.47	116.00	116.77	115.08	107.43	111.27	113.60	110.77
S_1M_2	94.17	95.73	99.33	96.41	92.90	94.83	98.00	95.24
Mean - Fm	104.09	113.12	118.28		101.09	106.01	109.60	
Fs	108.34	113.32	117.17		105.20	108.10	111.00	

17 MAP						29 MAP					
CD(0.05)						CD(0.05)					
M	1.758	Fm	1.758	MxF	NS	M	1.567	Fm	1.567	MxF	2.714
S	1.758	Fs	1.758	SxF	3.045	S	1.567	Fs	1.567	SxF	NS

The highest available K content was found in the plots receiving highest level of organic manure and fertilizer and with the minimum plant density. Potassium was supplied in double dose than N and P through application of fertilizers. Potassium is a nutrient which is easily subjected to leaching loss. Organic manure can protect it against leaching.

Lower plant density increased available K in soil. When plant density was increased there would have been more removal. Hence available K content was found to be lower.

The effect of fertilizer on available K content was found significant. After the experiment it was seen that in unmanured plots by applying 30:30:60 NPK kg ha^{-1} resulted in an increase of available K by 8 kg where as in manured plots it was 3-4 kg. However, it did not result in an enhanced retention of available K in soil, indicating greater loss of K from the soil system with higher application rates. The K uptake by plants (Table 20) also did not show much difference with moderate and higher levels of K and hence, changing the present nutrient ratio of 1:1:2 to 1:1:1 should be examined.

4.5 Nematode infestation

A general decline in plant growth was observed during the crop growth period of June to October 1996. Symptoms of nematode infestation was first identified when plant samples were drawn for observation during October. After detailed study it was confirmed that root knot nematode *Meloidogyne incognita* was attacking *thippali*. In India, so far no reports are available about nematode infestation in *thippali*. However, Russian worker Smal'ko (1960) reported *Meloidogyne marioni* forming root galls on *Piper longum*.

Root growth was found affected and it was modified in to galls. Infected plants were found to have poor and reduced growth and showed yellowing (Plate 3). It is a sedentary parasite and once they become located within tissues of the plant they do not move.

4.5.1 Nematode count

Effect of various treatments on nematode count in roots and soil are presented in Table 27.

4.5.1.1 Nematode count in roots

Effect of organic manure on reducing population of nematode was found pronounced. Higher rate of 20 t ha^{-1} was found reducing nematode population significantly compared to zero and 10 t ha^{-1}. Organic manure might be containing other predatory nematodes in large numbers which might have caused the reduction in root knot nematode count in high organic manure applied plots. Reduction in population of *Heterodera sachachtii* (beet eel worm) was reported by Duddington *et al.* (1956) as a result of microplot application of organic manure.

Wider spacing of 60 x 60 cm was found reducing nematode population since it is sedentary in habit. Fertilizer application was also found reducing nematode population but only at lower levels.

Plate 3. A healthy and nematode infested plant of *thippali* showing root galls

Plate 4. Nematode free and mildly infested plants of *thippali* after three years


A HEALTHY PLANT OF THIPPALI
NEMATODE INFESTED THIPPALI


NEMATODE FREE PLANTS YEARS
AFTER PLANT
MILDLY INFESTED PLANTS THREE YEARS
AFTER PLANTING

Table 27. Effect of organic manure, fertilizer and spacing on nematode count in roots and soil

	Count/2 g of roots				Count/200 g of soil			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
S_3M_0	610	577	605	597	269	141	154	188
S_3M_1	351	338	350	346	182	174	175	177
S_3M_2	21	10	20	17	49	18	35	34
S_2M_2	45	40	43	43	152	139	144	145
S_1M_2	78	64	70	71	158	142	146	149
Mean - Fm	327	308	325		167	111	121	
Fs	48	38	44		120	100	108	

CD(0.05) (roots)
M 15.5 Fm 15.5 MxF 26.9
S 15.5 Fs NS SxF NS

CD(0.05) (soil)
M 11.7 Fm 11.7 MxF 20.2
S 11.7 Fs 11.7 SxF NS

4.5.1.2 Nematode count in soil

Meloidogyne incognita population was found lower in soil compared to roots even though the trend was found similar to that of roots.

After three years about 95 per cent of plants were found to be destroyed by root knot nematode. A few survived plants were found free from nematode and produced fruits. But mildly nematode infested plants were stunted in growth and produced lesser number of spikes (Plate 4).

4.6 Economic analysis of *thippali* cultivation

Since *thippali* is a perennial plant, economic yield and net returns can not be expected during the first year. Even though several researchers reported an economic fruiting period upto three years with increased production year after year (CSIR, 1969, Davies, 1992, Viswanathan, 1993b and 1995), in the present study growth and yield was found to be declining one and a half year after planting.

Sheela (1996) had analysed the economics of *thippali* cultivation for the first 17 months which is given in Appendix-2. During that period a net loss due to high initial establishment cost and low yield was observed for all the treatments. The same field was maintained for the present study.

Economics of *thippali* cultivation from 17 to 29 MAP are shown in Table 28. During this period highest total expenditure was for the treatments involving high dose of organic manure (20 t ha^{-1}) and fertilizer (60:60:120 NPK kg ha^{-1}). But total and net returns were found to be the highest in the treatment

Table 28. Economics of thippali cultivation per ha from 17 to 29 MAP

Treatments	Weeding	Irrigation	Manure	Fertilizer	Application cost		Charge for picking spikes	Total expenditure	Total returns	Net returns
					Manure	Fertilizer				
$S_3M_0F_0$	1125	800	-	-	-	-	3750	5675	16913	11238
$S_3M_0F_1$	1125	800	-	1363	-	1125	3750	8163	18867	10704
$S_3M_0F_2$	1125	800	-	2726	-	1125	3750	8401	47833	9432
$S_3M_1F_0$	1125	800	3000	-	1125	-	3750	8675	25250	16575
$S_3M_1F_1$	1125	800	3000	1363	1125	1125	3750	12288	29997	17709
$S_3M_1F_2$	1125	800	3000	2726	1125	1125	3750	13651	27140	13489
$S_3M_2F_0$	1125	800	6000	-	1500	-	3750	13175	52680	39505
$S_3M_2F_1$	1125	800	6000	1363	1500	1125	3750	15663	65343	49680
$S_3M_2F_2$	1125	800	6000	2726	1500	1125	3750	17026	56677	39651
$S_2M_2F_0$	1125	800	6000	-	1500	-	3750	13175	43003	29828
$S_2M_2F_1$	1125	800	6000	1363	1500	1125	3750	15663	57533	41870
$S_2M_2F_2$	1125	800	6000	2726	1500	1125	3750	17026	48670	31644
$S_1M_2F_0$	1125	800	6000	-	1500	-	3750	13175	37960	24785
$S_1M_2F_1$	1125	800	6000	1363	1500	1125	3750	15663	47537	31874
$S_1M_2F_2$	1125	800	6000	2726	1500	1125	3750	17026	39023	21997

Wages (men) @ Rs.80/-
Wages (women) @ Rs.75/-
Price of organic manure Rs.300 t^{-1}
Fertilizer - Factomphos Rs.6410 t^{-1}
Muriate of potash Rs.4016 t^{-1}

combination $S_3M_2F_1$ followed by $S_2M_2F_1$. Lowest net returns was observed for the plot receiving no manure and high dose of fertilizer.

During the second year all the treatment combination gave a net profit unlike that of first year where a net loss was observed.

The economics of *thippali* cultivation from planting up to 29 MAP is given in Table 29. Net returns as high as Rs.37468 was obtained for the treatment combination with the highest rate of organic manure (20 t ha^{-1}) and a moderate level of fertilizer (30:30:60 NPK kg ha^{-1}) under wider spacing (60 x 60 cm). A net loss was observed for the treatments with no organic manure application because of very low yield (Fig. 5). Similarly close spacing of 40 x 40 cm with a plant population of 62500 plants ha^{-1} also showed a net loss as high as Rs.31323 ha^{-1}, because of high cost of planting material and reduced yield due to competition, when plant growth advanced.

Higher returns per rupee invested (1.61) was observed for $S_3M_2F_1$, closely followed by $S_3M_2F_0$ (1.55) indicating that a spacing of 60 x 60 cm and an organic manure application of 20 t ha^{-1} with no or low level of fertilizer application are capable of producing economic yield in *thippali*. The study also showed that there was reduced yield and net returns when no manure was applied and also under very high plant densities. Heavy dose of fertilizer application also reduced the yield and net returns.

Future line of work

From the experiment it was found that during the peak bearing stage the highest N uptake was 28.2 kg ha^{-1}. Whereas it was 4.4 kg ha^{-1} and 16.0 kg ha^{-1}

Table 29. Economics of thippali cultivation (per ha) from planting upto 29 MAP

Treatments	Total expenditure the end of 29 MAP	Total returns at the end of 29 MAP	Net returns at the end of 29 MAP	Returns per rupee invested
$S_3M_0F_0$	41127	41413	-714	0.98
$S_3M_0F_1$	46825	46817	-8	1.00
$S_3M_0F_2$	48148	43433	-4715	0.90
$S_3M_1F_0$	49252	53900	4648	1.09
$S_3M_1F_1$	55075	64747	9672	1.18
$S_3M_1F_2$	57523	56690	-833	0.99
$S_3M_2F_0$	57127	88430	31303	1.55
$S_3M_2F_1$	61825	99293	37468	1.61
$S_3M_2F_2$	65273	94627	29354	1.45
$S_2M_2F_0$	70100	82053	11953	1.17
$S_2M_2F_1$	74798	102383	27585	1.37
$S_2M_2F_2$	77246	92270	15024	1.19
$S_1M_2F_0$	94850	69710	-25140	0.73
$S_1M_2F_1$	99548	82187	-17361	0.83
$S_1M_2F_2$	101996	70673	-31323	0.69

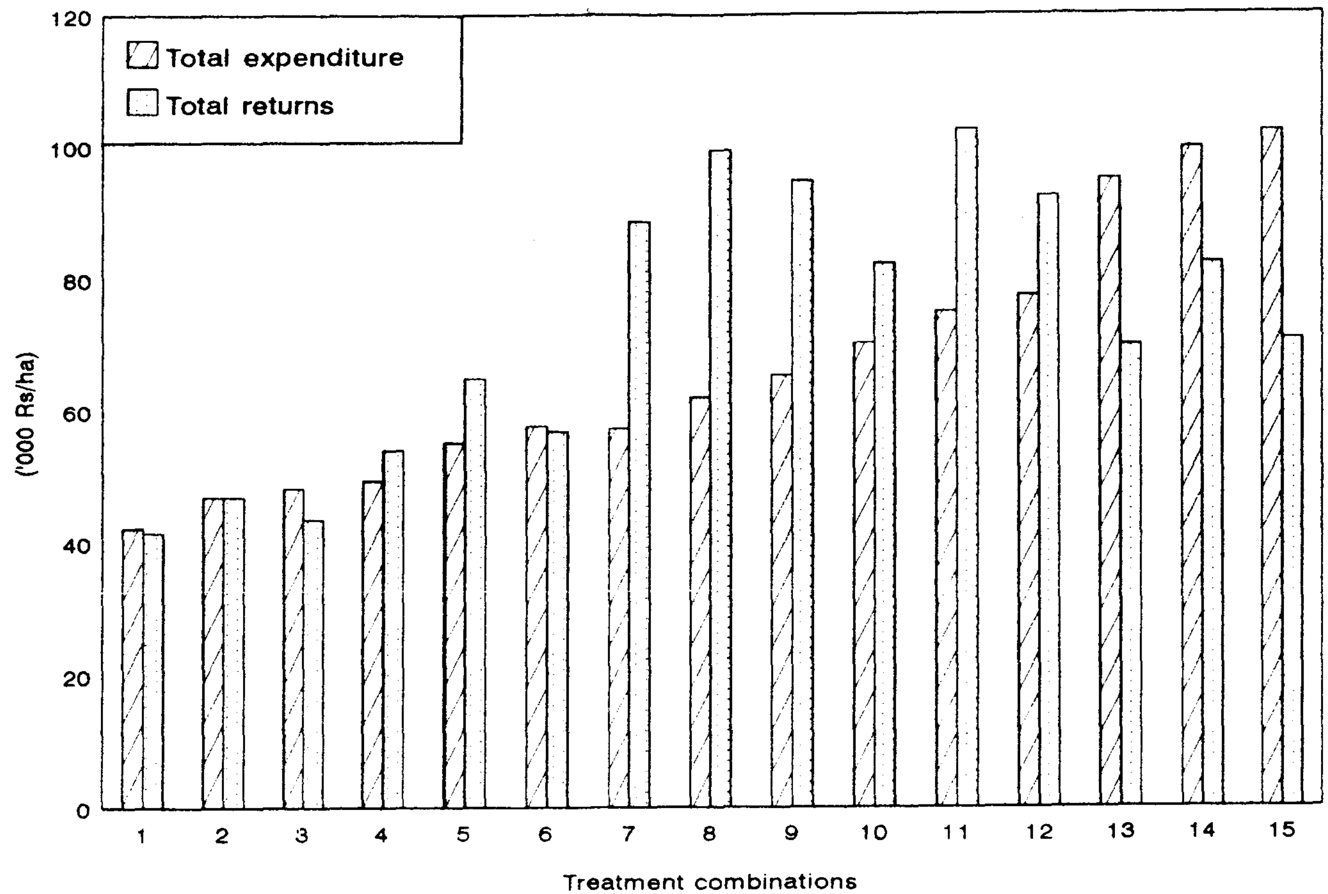

Fig.5. Total expenditure and total returns per hectare from planting upto 29 months after planting

respectively for P and K, indicating that relatively less quantities of P and K are taken up by the crop *thippali*. So further trials can be conducted using different nutrient ratios to find out a more reasonable fertilizer recommendation for the crop.

Since root knot nematode *Meloidogyne incognita* was found attacking *thippali*, proper management practices have to be identified for its control without affecting quality.

Different treatments were found influencing crude alkaloid content from spikes and roots which are contributed by more than 22 different alkaloids. The content of individual alkaloids has to be find out from spikes, vegetative parts as well as roots.

Summary

SUMMARY

A field experiment was conducted at KADP (Kerala Agricultural Development Project) Farm, College of Horticulture during 1995-96 to evaluate yield and quality of *Piper longum* to differential spacing and manurial regimes in coconut gardens. The experiment was laid out in randomised block design with three replications. The treatments included three levels of spacing (60 x 60 cm, 50 x 50 cm and 40 x 40 cm), organic manure (0, 10, 20 t ha^{-1}) and inorganic fertilizers (0:0:0, 30:30:60, 60:60:120 NPK kg ha^{-1}). The plant populations per hectare were 27777, 40000 and 62500 for 60 x 60, 50 x 50 and 40 x 40 cm spacing respectively. The growth and yield characters for the first year of bearing were studied by Sheela (1996). Further studies on growth, yield and quality were conducted upto two and a half years in this experiment.

The growth characters like plant height, number of branches, number of leaves and dry matter production were significantly higher when a spacing of 60 x 60 cm was given with the application of 20 t ha^{-1} organic manure and 30:30:60 NPK kg ha^{-1}. Yield attributing characters like number of spikes per plant, fresh and dry weight of spikes and cumulative yield were also significantly higher for the same treatment combination. Peak bearing stage was at 17 MAP after which there was a drastic reduction in yield. The length and diameter of spikes did not vary with different treatments indicating them as varietal characters. The dry weight of spikes was one fifth of fresh weight and was not influenced by different treatment. There was a general decline in growth and yield of the plant by 17 months growth.

The nitrogen content of vegetative parts decreased whereas phosphorus content increased with ageing. K content in vegetative parts remained relatively stable during the entire growth period. The nitrogen content in spikes was much higher than vegetative parts. But P and K content in vegetative parts and spikes were almost same. The NPK uptake was higher in plots receiving 20 t ha^{-1} organic manure under 60 x 60 cm spacing with a moderate level of fertilizer (30:30:60 NPK kg ha^{-1}) application. This combination also produced the highest crude alkaloid yield.

After the experiment, organic carbon, available nitrogen, phosphorus and potassium in soil were found to be more in the plots receiving organic manure @ 20 t ha^{-1} and fertilizer 60:60:120 NPK kg ha^{-1} with a spacing of 60 x 60 cm. However, it was observed that irrespective of the treatments there was a general decline in the nutrient status of the soil due to continuous cropping.

Economic analysis of *thippali* cultivation revealed that during second year all the treatment combinations gave a net profit. From planting upto 29 MAP net returns as high as Rs.37468 was observed for the treatment combination with a high rate of organic manure (20 t ha^{-1}) with medium dose of fertilizer (30:30:60 NPK kg ha^{-1}) and under wider spacing (60 x 60 cm).

Growth and yield was found to be declining after two years of growth. The root knot nematode (*Meloidogyne incognita*) infestation also might have accentuated the decline. It was also observed that nematode infestation was lower in the plots with a lower plant density receiving a high rate of organic manure.

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* Originals not seen

Appendices

APPENDIX-I

Weather data of Vellanikkara from January 1995 to December 1996

	1995											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Mean temperature °C	27.7	29.4	30.7	30.8	28.7	27.4	26.6	27.2	26.8	28.2	26.9	26.9
Rainfall (mm)	0.0	0.5	2.8	118.7	370.5	500.4	884.7	448.7	282.5	110.4	88.4	0.0
Mean Relative Humitity (%)	58.5	60.0	60.0	71.0	78.0	85.5	88.5	86.0	82.0	78.0	80.0	5.7
Sunshine hours	9.6	10.0	9.3	9.1	6.5	3.7	2.1	3.7	6.2	8.3	6.5	10.3
Average wind speed (km/hr)	9.1	6.4	4.4	4.0	3.8	10.1	1.7	2.0	2.0	1.8	1.1	6.7
Evaporation (mm)	178.5	172.2	190.2	164.3	129.3	103.7	88.5	96.4	97.7	113.8	89.1	195.9

	1996											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Mean temperature °C	27.8	29.1	30.4	29.8	29.0	27.2	26.0	26.5	26.5	26.5	27.6	26.2
Rainfall (mm)	0.0	0.0	0.0	152.0	95.4	400.3	588.7	310.0	391.6	219.3	22.1	60.4
Mean Relative Humitity (%)	53.0	53.0	59.5	73.0	77.0	84.5	89.5	86.5	84.0	81.5	71.5	67.5
Sunshine hours	9.4	9.9	9.3	8.3	7.7	4.7	2.7	3.7	4.3	6.0	7.1	6.8
Average wind speed (km/hr)	7.1	7.1	3.6	3.0	2.5	3.0	2.7	3.0	2.7	2.0	3.7	6.4
Evaporation (mm)	208.6	200.9	219.2	157.1	135.0	103.4	88.9	100.4	94.9	92.8	119.0	138.4

APPENDIX-2

Economics of thippali cultivation (ha^{-1}) upto 17 MAP*

Treatment	Cost of planting materials	Cost for planting	Irrigation	Weeding	Manure cost	Fertilizer cost	Manure applicat-ion cost	Fertilizer applicat-ion cost	Picking of spikes	Total cost of cultivat-ion	Yield kg ha-1	Returns	Net returns upto 17 MAP	Returns rupee invested
$S_3M_0F_0$	27777	3000	800	1125	-	-	-	-	3750	36452	245.0	24500	-11952	0.672
$S_3M_0F_1$	27777	3000	800	1125	-	1085	-	1125	3750	38662	279.5	27950	-13337	0.672
$S_3M_0F_2$	27777	3000	800	1125	-	2170	-	1125	3750	39747	256.0	25600	-14147	0.644
$S_3M_1F_0$	27777	3000	800	1125	3000	-	1125	-	3750	40577	286.5	28650	-11927	0.700
$S_3M_1F_1$	27777	3000	800	1125	3000	1085	1125	1125	3750	42787	347.5	34750	-8037	0.812
$S_3M_1F_2$	27777	3000	800	1125	3000	2170	1125	1125	3750	43872	295.5	29550	-14322	0.673
$S_3M_2F_0$	27777	3000	800	1125	6000	-	1500	-	3750	43952	237.5	35750	-8202	0.813
$S_3M_2F_1$	27777	3000	800	1125	6000	1085	1500	1125	3750	46162	339.5	33950	-12212	0.735
$S_3M_2F_2$	27777	3000	800	1125	6000	2170	1500	1125	3750	48247	379.5	37950	-9297	0.803
$S_2M_2F_0$	40000	3000	800	1125	6000	-	1500	-	3750	56925	390.5	39050	-17875	0.685
$S_2M_2F_1$	40000	3000	800	1125	6000	1085	1500	1125	3750	59135	448.5	44850	-14285	0.758
$S_2M_2F_2$	40000	3000	800	1125	6000	2170	1500	1125	3750	60220	436.0	43600	-16620	0.724
$S_2M_2F_0$	62500	3000	800	1125	6000	-	1500	-	3750	81675	317.5	31750	-49907	0.388
$S_2M_2F_1$	62500	3000	800	1125	6000	1085	1500	1125	3750	83885	346.5	34650	-49235	0.413
$S_2M_2F_2$	62500	3000	800	1125	6000	2170	1500	1125	3750	84970	316.5	31650	-53320	0.372

Cost of planting material - Rs.0.50 $plant^{-1}$
Wages (Men) @ Rs.80/-
Wages (Women) @ Rs.75/-
Price of organic manure Rs.300/- t^{-1}
Fertilizer
Urea @ Rs.3.50 kg^{-1}
Mussoriphos @ Rs.3.00 kg^{-1}
Muriate of potash @ Rs.4.50 kg^{-1}
Price of dried spikes - Rs.100/- kg^{-1}

* Adapted from Sheela (1996)

YIELD AND QUALITY OF *Piper longum* L UNDER DIFFERENTIAL SPACING AND MANURIAL REGIMES IN COCONUT GARDENS

By

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ABSTRACT OF A THESIS

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ABSTRACT

An experiment was conducted during 1995-1996 in the KADP Farm of the College of Horticulture, Vellanikkara, to evaluate the yield and quality of *Piper longum* to differential spacing and manurial regimes in coconut gardens. The experiment was laid out in randomised block design with three replications. The growth and yield during 17-29 months after planting were studied.

The study revealed that growth and yield characteristics increased with an application of 20 t ha^{-1} organic manure and 30:30:60 NPK kg ha^{-1}. The optimum spacing was found to be 60 x 60 cm.

The growth and yield of the crop was poor in dry months and the peak yield was obtained at 17 MAP. After that there was a general decline. The two peak bearing stages were identified during July-August and October-November months.

The nitrogen content of vegetative parts decreased with ageing, but phosphorus content increased and potassium content remained more or less same. The N content in spikes was much higher than vegetative parts unlike that of P and K. The NPK uptake was higher in plots receiving 20 t ha^{-1} organic manure and 30:30:60 NPK kg ha^{-1} under a spacing of 60 x 60 cm.

Nutrient status of the soil was found decreasing after the experiment even though organic manure and fertilizers were applied every year.

Economic analysis of *thippali* cultivation revealed that it could be a profitable intercrop in coconut gardens if planted under a spacing of 60 x 60 cm with an application of organic manure @ 20 t ha^{-1} and fertilizer @ 30:30:60 NPK kg ha^{-1}.