"Agrotechniques for inducing plagiotrops in black pepper (*Piper nigrum* L.)"

BY

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THESIS

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DECLARATION

I, Ramnarace Sukhna (2012-12-115) hereby declare that the thesis entitled **"Agrotechniques for inducing plagiotrops in black pepper (*Piper nigrum* L.)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other university or society.

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With much love I dedicate this thesis to

My

Beloved Mother

&

Loving family

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

Sl. No.	Title
I	Monthly weather data during the experimental period (2012-2013)
II	Monthly weather data during the experimental period (2013-2014)

Introduction

1. INTRODUCTION

King of spices, black pepper (*Piper nigrum* L.) is the most potent member of the family *Piperaceae* (Abbasi *et al.*, 2010). Black pepper is native to India and is mostly cultivated in tropical and sub-tropical regions (Ahmad *et al.*, 2010). *Piper. nigrum* is widely used in cooking and processing of food and perfumery. The quality of peppercorn can be judged from its pungency contributed by active component, piperine (Philip *et al.*, 1992, Bhat *et al.*, 1995). Piperine is free from microbial contamination and biodeterioration, and preferred in processing of food items (Srinivasan, 2007).

Black pepper had originated in the Western Ghats of India, which is a rich source of biodiversity. The extent of variability existing in black pepper in India is also very large which has been domesticated leading to a large number of genotypes with widely varying productivity levels. However, presence of senile unproductive gardens, homestead system of cultivation and occurrence of pests and diseases contribute to low productivity of black pepper in India (Nybe *et al.*, 2008).

One of the major constraints in production of black pepper is the tall bearing column which makes harvesting difficult. The problem is becoming more and more severe due to lack of skilled labour who can climb the support. Reducing the vertical height and enabling production of laterals from lower height is one of the key factors for high productivity in other pepper growing countries. The present study is aimed to elucidate the effect of agrotechniques such as pruning, tipping and lowering in inducing plagiotrops in black pepper (*Piper nigrum* L.). The proposed study is also aimed to highlight the effect of certain treatments such as IBA, cow dung slurry, tender coconut water, sugar and charcoal paste in enhancing root initiation, length and number of roots in two to three node semi hard wood orthotropic shoot.

Pruning is an important practice in perennial horticultural crops, to attain higher level of productivity and quality. It is particularly effective in crop plants, which bear fruits on new shoots. Since pepper bear on the current season laterals and each leaf axil is potentially productive, there is much scope for pruning to improve the productivity

of black pepper. Hence, an experiment was conducted to study the effect of pruning on growth and yield of black pepper.

The dipping of nodal cuttings in 1000 ppm IBA for 45 seconds was reported to give better rooting in polybag (Pillai *et al.*, 1982, Shridhar and Singh, 1990). Sujatha (1997) obtained 90 per cent rooting in two node cuttings dipped in 1000 ppm IBA and kept in a polytent, with regular watering. Cuttings treated with 25 per cent coconut water for 12 h increased root and shoot length, number of roots and shoot dry weight (Yufdi and Ernawati 1982).

A few reports are available on the effect of the aforementioned treatments on root development in black pepper. The present investigations were envisioned to study the effects of these treatments in inducing roots in black pepper.

Considering the above facts, the present study entitled "Agrotechniques for inducing plagiotrops in black pepper (*Piper nigrum* L.)" was undertaken with the objective to develop short statured plants in black pepper for easiness in harvesting and to improve productivity per unit area of the plant.

Review of Literature

2. REVIEW OF LITERATURE

2.1 Origin

Black pepper (*Piper nigrum* L.) originated from Western Ghats of India and spread to all the pepper growing countries in Southeast Asia, some parts of Africa, as well as to Brazil in South America (Sarma *et al.*, 2013).

By the 16th century, black pepper plants were also being grown in Madagascar, Malaysia, Indonesia and elsewhere in Southeast Asia but these areas traded mainly with China or used the pepper locally (Dalby, 2002). In the last decade of 20th century, world pepper production increased dramatically as new plantations were established in Sri Lanka, Thailand, Vietnam and China.

2.2 Propagation in black pepper

Commercially, pepper is propagated through the cuttings taken from runners, creeping shoots on ground and orthotropic shoots i.e. erect growing shoots. Cuttings taken from fruiting branches produce bushy plants. Kurup (1956) suggested that single node cuttings can be successfully used in the propagation of black pepper. Winters and Muzik (1963) opined that the rooting of lateral fruiting branch cuttings of *Piper nigrum* was markedly improved by treatment with rootone and planting in vermiculite. Shridhar and Singh (1990) opined that two node cuttings proved better for black pepper multiplication than one node cuttings. Bavappa and Gurusinghe (1978) suggested that cuttings with two or three nodes from runners or primary vines root better. Single node rooted and unrooted cuttings from bamboo splits recorded 91 and 73 per cent rooting respectively.

Black pepper vines develop five types of aerial shoots, namely (a) primary stem with long internodes and adventitious roots which cling to the standards (b) top shoots, when primary stem reach a certain height and internodes are shortened (c) runner shoots which originate from the base of the vine and have long internodes which strike roots at each node (d) fruit bearing lateral branches or plagiotrops and (e) hanging shoots which originate from the laterals and hang down.

2.2.1 Planting Materials

Pepper plants under good management, continues to yield up to 30 years and full bearing commences from 4 - 5 years after planting under the conditions existing in India. In Sarawak (Malaysia), Thailand, Brazil, etc. pepper is retained only for a period of 10 - 15 years as they are trailed on non living standard of limited height and regular replanting is practiced after this effective productive period. Development of pepper plantations involves substantial investment during pre bearing period, and much emphasis should be given for proper planting material selection (Sadanandan and Nair 1973).

In India, high yielding varieties are available for the growers to choose from, in fact it is always advisable to grow a mixture of varieties than to go for a single one as a safeguard from diseases and insect pests.

In most pepper growing countries, the orthotropic, climbing shoot is used as the planting material, except in India. They are not popular in India due to their non availability, because most plantations are on living standards and the pepper vines grow unrestricted. The orthotropic climbing shoots are the best for planting as they give vigorous plants, develop fruiting laterals from the base itself and start yielding early. Earlier, the growers used to plant either the runner shoots or the climbing orthotropic shoots with the onset of the south west monsoon. Now only pre rooted cuttings from runner shoots are used for planting by most growers in India. The hanging shoots are not good as planting material as they give weak, lanky growing plants. In many pepper growing countries, the pepper plants are pruned 5 - 6 months after planting and again after one year. These stem cuttings obtained through pruning are also used as planting material (Sadanandan and Nair 1973).

2.2.1.1 ORTHOTROPIC SHOOTS AS SOURCE OF PLANTING MATERIAL IN BLACK PEPPER

2.2.1.2 Status of runner shoots as a source of planting material

In India and Sri Lanka, pepper farmers in general use exclusively runner shoot as a source of planting material. It is because of the availability of such planting material in plenty for large scale production of rooted cuttings. This method is popular among the

farming community. In India, during the olden days, farmers were planting runner shoot directly at the base of the live standards during June - July coinciding with South West monsoon period. Now farmers switched over to rooted polybag cuttings, which give better field establishment (Sarma *et al.*, 2013).

Several methods have been adopted in India like rapid multiplication method, serpentine method, etc. for the production of rooted cuttings. Majority of the farmers collect runner shoots in the month of February - March and prepare two to three node cuttings which are planted in poly bags filled with nursery mixture for rooting. These poly bags are housed in thatched sheds that would ensure high humidity. The rooted cuttings will be ready by June - July with four to five leaves. These are planted at the base of a live support/ standard. They plant these rooted cuttings in the planting hole/ pit after carefully tearing off the polythene bags. The present note is to highlight the potential of orthotropic shoots as planting material, a practice widely adopted in majority of the pepper growing countries (Sarma *et al.*, 2013).

The vines planted with runner shoots in general start flowering from third year onwards or later. In such bushes, the fruiting laterals invariably start coming up at height of two to three feet above the base of the bush. The coverage of column of the bush of pepper vine is incomplete with several gaps. As such the empty column of the bush remains unproductive. Higher the number of fruiting laterals on the column right from the base of the bush would mean higher production. This habit is missing in vines raised from runner shoots. In many case 1/3 to 2/3 of height of the column of the bush remains without fruiting laterals and hence the low production. In general, farmers prune off the unwanted runner shoots after meeting their demands for raising rooted cuttings (Sarma *et al.*, 2013).

2.2.1.3 Orthotropic shoots as source of planting material

In Indonesia, Malaysia, Vietnam, Cambodia and Brazil farmers adopt pure crop system and invariably use orthotropic shoots, as a source of planting material (Sarma *et al.*, 2013).

The canopy of the pepper bush is typically cylindrical in shape in very rare cases some farmers use runner shoots as well as hanging shoots, but orthotropic shoots are predominantly used to raise rooted cuttings. Dead wood standards/ supports to train pepper

are used in these pure pepper plantations. This is contrast to India and Sri Lanka where farmers predominantly adopt mixed cropping in coffee, tea, coconut and arecanut plantations with live support like *Gliricidia, Erythrina,* silver oak etc. In India pure pepper plantations were there earlier and even now in certain pockets. Where dead standards are used, it is possible to accommodate more number of vines/ unit area (1600 - 2010/ hectare) and there is no competition for nutrients between pepper and live standard. In Indonesia to eliminate the nutrient competition, it is recommended to prune the branches of live support 10 - 14 days before applying the fertilizer. The pruned foliage put at the base of the vine becomes a good source of organic matter. In Cambodia and Vietnam pepper bushes of about 12 feet height, with cylindrical canopy, yield about three to five kg dry pepper/ standard/ support. This clearly indicates the potential of the technique of raising pepper on dead wood pole using orthotropic shoots (Sarma *et al.*, 2013).

2.2.1.4 What is orthotropic shoot?

The leader shoots which grow along the standard end up as top shoots. These are of unlimited growth unless they are cut or pruned. In general there will be about three to four orthotropic/ leader shoots per bush (Sarma *et al.*, 2013).

2.2.1.5 How to make orthotropic shoots a source of planting material?

As mentioned earlier orthotropic shoots are of unlimited growth in nature and grow erect along the standard/ support. Orthotropic shoots can be cut or extracted from the top up to six to seven nodes down on the support. They are also called leader shoots. Too tender or too woody shoots need to be avoided. The medium matured green shoots are selected. These shoots with five to six node bits are planted directly in the planting holes. Two or three shoots per standards are used and the number varies from place to place. Orthotropic shoot as source of planting materials are obtained from two to three year old vines (Sarma *et al.*, 2013).

2.2.2.1 Multiplication of orthotropic shoots as practiced in Indonesia

Orthotropic shoots are planted in poly bags filled with nursery mixture. These are housed in humid poly chambers to induce rooting. The rooting percentage varies from 70 per cent to 80 per cent. Once rooted, the orthotropic shoots can be further multiplied. The

rooted orthotropic shoots in poly bag are allowed to grow along the bamboo support to grow further to a height of 1 - 1.5 meters (10 - 12 nodes). It takes about five to six months to reach the decided height. These shoots are further cut in to three to four node cuttings which can be planted directly or as rooted cuttings as mentioned earlier. Thus, multiplication of orthotropic shoots is possible, and the method can be effectively made use of (Sarma *et al.*, 2013).

2.2.2.2 Multiplication of orthotropic shoots as single node cuttings.

The availability of orthotropic shoots of three to four nodes is limited. In order to optimize the production of the orthotropic shoots which are in short supply, single node cuttings can be cut into single node bits with a leaf and planted in polythene bag with nursery mixture. Such poly bags are housed in humid polythene chamber to ensure good rooting. The rate of success would be around 70 - 80 per cent. Cuttings of five to six nodes would be ready for planting in a period of three to four months (Sarma *et al.*, 2013).

2.3 Production of rooted cuttings

The annual requirements of pepper planting material are very large in India running to millions. Such heavy demands led to large scale production of pre rooted cuttings in polybags. Many studies have been carried out in various pepper growing countries for developing an efficient propagation technique for pepper.

2.3.1 Use of three - node cuttings

When the large scale production of pepper cuttings started in India (in Kerala) three node cuttings from runner shoots were used. The success rates were often very low. The runner shoots from high yielding and healthy plants are kept coiled on wooden peg fixed at the base of the vine to prevent the shoots from coming in contact with soil and striking roots. The runner shoots can be separated from the mother plant in January - February, dip in a fungicide like copper oxychloride or Bordeaux mixture for one minute, surface dry in shade and after trimming the leaves, cut into 2 - 3 nodes and plant either in nursery beds or polythene bags filled with fertile soil mixture with sand and farmyard manure. Studies by various workers indicated that application of IBA 200 ppm improved the rooting percentage of cuttings, and it was the best for defoliated single node

cuttings (Suparman and Zaubin 1988). Two node cuttings dipped in IBA at 1000 ppm for 45 seconds produced highest root numbers (Pillai *et al.*, 1982). Application of 25 per cent of cattle urine gave the same effect as 2000 ppm IBA in terms of fresh and dry weight of roots and the number of roots per cutting (Suparman *et al.*, 1990).

The growth of single node cuttings in general was significantly better in the soil at 80 per cent or 100 per cent of field capacity. Ernawati and Yufdy (1990) found that single and double node plus a part of climbing shoot were better than single and double node cuttings. Adequate shade and frequent irrigation are necessary. The cuttings strike roots and become ready for planting in June.

2.3.1.1 Traditional method

Runner shoots from high yielding and healthy vines are kept coiled on wooden pegs fixed at the base of the vine to prevent the shoots from coming in contact with soil and striking roots. The runner shoots are separated from the vine during February - March, and after trimming the leaves, cuttings of 2 - 3 nodes each are planted either in nursery beds or in polythene bags filled with fertile soil. Adequate shade has to be provided and the polythene bags are to be irrigated frequently. The cuttings become ready for planting during May - June (Sasikumar *et al.*, 2009).

2.3.1.2 Rapid multiplication technique

An efficient propagation technique (commonly called as bamboo method) has been developed in Sri Lanka and it is becoming increasingly popular in India (Bavappa and Gurusinghae 1978). In this method, a trench of 45 cm depth, 30 cm width and convenient length is made. The trench is filled with rooting medium comprising of forest soil, sand and farm yard manure in 1:1:1 ratio. Split halves of bamboo with septa or split halves of PVC pipes of 1.25 - 1.50 meter length and 8 - 10 cm diameter provided with plastic septa at 30 cm intervals are fixed at 45° angle on a strong support. Rooted cuttings are planted in the trench at the rate of one cutting for each bamboo split. The lower portions of the bamboo splits are filled with rooting medium (preferably weathered coir dust - farm yard manure mixture in 1:1 ratio) and the growing vine is tied to the bamboo split in such a way so as to keep the nodes pressed to the rooting medium. The tying can be done with dried banana leaf sheath fibers or coir rope. The cuttings are irrigated regularly. As the cuttings

grow, the bamboo splits are filled with rooting medium and each node is pressed down to the rooting medium and tied. For rapid growth, a nutrient solution of urea (1 kg), super phosphate (0.75 kg), muriate of potash (0.5 kg) and magnesium sulphate (0.25 kg) in 250 liters of water is to be applied @ 0.25 liters per vine at monthly intervals. When the vine reaches the top (3 - 4 months after planting of the cutting) the terminal bud is nipped off and the vine is crushed at about three nodes above the base, in order to activate the axillary buds. After about 10 days, the vine is cut at the crushed point and removed from the rooting medium and cut between each node. Each cutting with the bunch of roots intact is planted in polythene bags filled with fumigated potting mixture. Trichoderma @ one gram and VAM @ 100 cc/kg of soil can be added to the potting mixture. Care should be taken to keep the leaf axil above the soil. The polythene bags should be kept in a cool and humid place, or should be covered with thin polythene (200 gauge) sheet to retain humidity. The buds start developing in about 3 weeks and the polybags can then be removed and kept in shade. The advantages of this method of propagation are rapid multiplication (1:40), well developed root system, higher field establishment and vigorous growth as a result of better root system (Sasikumar *et al.*, 2009). In Malaysia, Ghawas and Miswan (1984) could get on an average 54 rooted cuttings using the above method where top soil plus coconut husk was used as the rooting medium.

2.3.1.3 Trench method

A simple, cheap and efficient technique for propagating black pepper from single nodes of runner shoots taken from field grown vines has been developed. A pit of 2.0 meter x 1.0 meter x 0.5 meter size is dug under a cool and shaded area. Single nodes of 8 -10 cm length and with their leaf intact, taken from runner shoots of field grown vines are planted in polythene bags (25 cm x 15 cm, 200 gauge) filled at the lower half with a mixture of sand, soil, coir dust and cow dung in equal proportion. The single nodes are to be planted in the bags in such a way that their leaf axil is above the potting mixture. The polythene bags with the planted single nodes are arranged in the pit. After keeping the bags in the pit, the pit should be covered with a polythene sheet. This sheet may be secured in position by placing weights on the corners. The cuttings should be watered at least five times a day with a rose can and the pit should be covered with the polythene sheet immediately after watering. It is advisable to drench the cuttings two - three times

with copper oxychloride (2g/ liter). After two-three weeks of planting, the cuttings will start producing roots which are visible through the polythene bags. After the initiation of roots the frequency of watering may be reduced to three - four times a day. After about one month, new shoots start emerging from the leaf axil. At this stage it is advisable to keep the pit open for about one hour per day so that the cuttings would harden and will not dry when they are taken out of the pit. The cuttings can be taken out of the pit after two months of planting and kept in a shaded place and watered twice a day. These cuttings will be ready for field planting after about 2 months. By this method 80 - 85 per cent success can be obtained. Foliar application of nutrient solution will also enhance the growth of the cuttings (Sasikumar *et al,* 2009).

2.3.1.4 Serpentine method

Cheaper propagation technique for production of rooted cuttings of black pepper is serpentine layering. In a nursery shed with roofing sheet or shade net, rooted black pepper cuttings are planted in polythene bags holding about 500 g potting mixture, which will serve as mother plants. As the plant grows and produces few nodes small polythene bags (20 x 10 cm) filled with potting mixture may be kept under each node. The node may be kept gently pressed in to the mixture assuring contact with the potting mixture with the help of a flexible twig such as mid rib of a coconut leaflet to enable rooting at that junction. Roots start growing from the nodes and the cuttings keep on growing further. The process of keeping potting mixture filled polythene bags at every node to induce rooting at each node is repeated. In three months the first 10 to 12 nodes (from the mother plants) would have rooted profusely and will be ready for harvest. Each node with the ploythene bag is cut just below the rooted node and the cut end is also buried into the mixture to induce more roots. Polythene bags filled with solarized potting mixture or soil, granite powder and farmyard manure in 2:1:1 proportion is recommended for producing disease free rooted cuttings. The rooted nodes will produce new sprouts in a week time and will be ready for field planting in two-three months time. Daily irrigation can be given with a rose can. On an average, 60 cuttings can be harvested per mother plant in a year by this method (Sasikumar *et al.,* 2009).

2.3.1.5 Use of growth regulators in rooting of pepper cuttings

Single node stem cuttings with the attached leaf quick dipped in IBA at a concentration of 2 mg/ml in 50 per cent alcohol gave 75 per cent rooting in 21 days in a standard cocoa propagator with coir dust as the medium (Copper 1955). Traditional Indian method of using semi hard wood cuttings with 3-4 nodes was reported to give only 15 per cent rooting after six months (Creech 1955).

The same author described a method of using bamboo poles covered with moist sphagnum moss. The pepper vines planted at the base of the bamboo, kept slantingly, were allowed to grow over the post. The vines got rooted at every node, the nodal cuttings along with leaves were planted in a green house. Such plants were ready for planting in six weeks (Creech 1955, Konstantinov and Bordreva 1962).

Cuttings from selected plants were rooted in bamboo baskets, and those selected and planted in March give 90-95 per cent rooting (Nambiar and Kurian 1963). Garayar and Corbera (1957) found that the most satisfactory shoots for rooting were those which had matured in shade and had ceased elongation, and that the cuttings were to be disinfected with 15 per cent ferbam and the base dipped in 0.2 per cent IBA and kept at 95-100 per cent RH and 20-30 lux light intensity. The rooting takes place in 20-30 days.

Leite and Infrazato (1966) subjected softwood and hardwood cuttings to 15 hours preplanting treatment by immersing their bases in distilled water or in 50 mg/liter solution of either NAA or IAA and they obtained the highest rooting of 62.5 per cent in NAA. Single node cuttings gave 90-95 per cent rooting under glass covered mist spray in a vermiculite rooting medium (Huges 1966).

Dipping of nodal cuttings in 1000 ppm IBA for 45 seconds gave better rooting in polybags (Pillay *et al.*, 1982, Shridhar and Singh 1990). IBA treated cuttings planted horizontally produced more roots than those planted vertically (Zaubin 1984). Cuttings treated with 25 per cent coconut water for 12 hrs increased root and shoot length, number of roots and shoot dry weight (Yufdi and Ernawati 1982).

In South Andaman Islands 1, 2, 3 and 4-node cuttings of the var. Panniyur 1 in sand-FYM (1:1) is recommended for rooting and for proper growth of the sprouts. (Singh

and Singh 1989).Undefoliated cuttings of cv. Belantung treated with 2 per cent sucrose and 200 ppm IBA were reported to give high rooting percentage (80 per cent and 82.4 per cent respectively) (Suparman and Zaubin 1988). Better rooting is reported under pH 7.8 to 8.1 (Sangakkara 1989). Medium composed of FYM-sand-soil (1:1:1) and soil-leaf mold (7:3) were reported to give better rooting (Yufdi and Hayani 1981). Detopping at 4 -5 weeks or ringing at 3-4 weeks before taking cuttings increased rooting ability (Yufdi 1980).

Semiherbaceous cuttings collected in June perform better (Shanthamallaiah *et al.*, 1974). Nath and Mohan (1993) showed that cuttings planted in beds give better rooting than in polybags and that plastic house provided the best environment for rooting. Rau (1990) described a rooting technique in which single node cuttings with leaves are close planted in coir pith-soil cattle manure (10:1:1) mixture in humid chambers.

The cuttings dipped in 1000 ppm IBA for 45 seconds. The cuttings after rooting were transferred to the secondary nursery in poly bags for further growth. About 80 per cent rooting was reported in 25 days.

Sasikumar and George (1992) found that single node cuttings planted in polybags and kept in pits covered with polysheet with frequent water sprays gave above 90 per cent rooting without any hormone treatment. Sujatha (1997) obtained 90 per cent rooting in two node cuttings dipped in 1000 ppm IBA and kept in a polytent, with regular watering.

2.4 Training and pruning

2.4.1 Coiling and burying the pepper stem

In Kerala (India) as well as in certain areas in Indonesia and Sri Lanka, some farmers practice another method for producing more number of climbing shoots. The growing plants, one year after planting, are kept coiled around the standard under moist soil. Usually this is done in the next rainy season. Before burying the stem under soil all leaves are removed from the portion that goes under soil. This result in all the axillary buds to develop and many shoots climb up and cover the standard quickly. But no experimental data are available on the advantages of this practice. All leaves from the main stem are also removed. This is done because if they are allowed to remain they

impede the circulation of air around the base and the centre of the vine and may lead to diseases (Lawrence 1981).

2.4.1.1 Pruning

Pruning is practiced to ensure leader shoot production and to induce development of lateral shoots. Three rounds of pruning are enough to obtain necessary number of climbing shoots as well as appropriate bushiness (Kurien and Nair, 1988). To maintain the crop in good and productive condition, pruning of both pepper and standard is required. Pruning of vines is needed not only for maintaining them in standard height and form, but also to stimulate production of more number of productive branches. Good pruning would enable the plants to receive maximum energy from the sunshine which is required for photosynthesis.

Regular pruning start at five months of age followed by 5 - 6 pruning once every three month had shown to increase the yield but it's still not yet been adopted by farmers. Farmers in Bangka Indonesia only prune their vine once at one year of age in order to get planting material and to encourage the formation of lateral branches, and to replace temporary standard with the permanent one. In West Kalimantan Indonesia, farmers usually give two pruning at eight and sixteen months after planting. Lampong farmers never prune their pepper vines and as compensation they do mound layering of the shoots at 12 months in order to get a good canopy and higher productivity.

According to Wahid (1984), pepper grown under dense shades will not come into good bearing, because only small proportion of the solar energy required for photosynthesis reaches the plant canopy. Therefore, standards must be pruned in such a way that enough sunshine passes through to the plants underneath. He further found that the fertilizers will not be taken up, if pepper plants are completely shaded by their live support. The rate of pruning can be as many as three times or less per year, depending on the type of live standard and climatic condition especially rainfall. However, it depends much on the financial condition of the farmers and the profits they gain from selling their produce. Pepper produces spikes on leaf axils of the current season growth of the laterals. Chandy and Pillai (1979) suggested that the production of fruiting branches can be regulated by proper pruning technique. Pruning of hanging shoots and unwanted terminal

shoots increased the extension growth of the laterals, production of bearing shoots, number of spikes and yield in the succeeding season (Kurien, 1982, Kurien and Nair, 1988). The spike characters, berry characters except berry weight and oleoresin content were unaffected by pruning.

Pruning is a regular practice in most pepper growing countries though India there is no such practice. Pruning is reported to be essential to shape the plants and to stimulate development of axillary shoots. Trials have been carried out in Sarawak, to test the efficiency of different pruning methods. Three methods of pruning are in vogue in Malaysia (Anon 1981).

1. Kuching Method
2. Sarikei method
3. Semongok method

2.4.1.2 Kuching method

When the vines are six months old (having approximately nine nodes), the shoots are pruned back to approximately 30 cm (3 - 4 nodes) from the ground. Thereafter three terminal shoots are trained up the post and these shoots are allowed to grow to ten nodes and then pruned back to three nodes from the point of the first pruning. Pruning in this manner continues until the vine reaches the top of the post.

2.4.1.3 Sarikei method

When the vines are six months old, the terminal shoots are pruned back to 3 - 4 nodes from the ground. Three terminal shoots are then trained up the post and there is no further pruning until the vines reaches the height of three quarter post. Then two or three nodes are pruned away and the vine is allowed to grow to full post.

2.4.1.4 Semongok method

When the vines are six months old, shoots are pruned back to 30 cm from the ground. Three terminal shoots are then selected and trained up the post. Hereafter the pruning is done only whenever there is a black (unproductive) node.

Trials carried out in Sarawak did not give any significant difference among the above methods as far as the yield performance is concerned, though Sarikei method was slightly better. A seven year trial gave a pooled annual mean yield of 11,124, 10,140 and 10,380 kg ha^{-1} fresh berries for Sarikei, Kuching and Semongok methods respectively (Anon. 1981). Kuching method of pruning results in column shaped plants and takes longer time to reach the top of the post as compared to the other methods. Pepper vines pruned by Sarikei or Semongok method are cone shape at the first few years and gradually become column shaped as they grow older.

Azmil and Yau (1993) concluded that three rounds of pruning is enough to obtain necessary number of climbing shoots as well as the appropriate bushiness of the pepper vines. Chong and Shahmin (1981) showed that there were no significant differences in yield between pepper vines having 3, 4 or 5 climbing shoots. In another trial Chong and Yau (1985) showed that vines with five climbing shoots produced more yield than those with 7 or 9 climbing shoots. Thus depending on the diameter of the pepper post 3-5 climbing shoots can be maintained. Lawrence (1981) has listed the following advantages for pruning:

1. To ensure that all blind nodes are removed
2. To encourage bushiness of the vine
3. To ensure that the terminal leader stems grow evenly
4. To make harvesting easier
5. To encourage the vine to produce more fruiting spikes.

Materials and methods

3. MATERIALS AND METHODS

The present investigations were conducted in the pepper research unit attached to the Department of Plantation Crops and Spices, College of Horticulture, Kerala Agricultural University Main Campus, Vellanikkara, during 2012 - 2014. The details of the materials and methods adopted and observation recorded during the course of the study are presented below.

3.1 GEOGRAPHICAL LOCATION, CLIMATE AND SOIL

Vellanikkara is located at 10^0 31'N latitude and 76^0 13'E longitudes with an altitude of 40.29 m above mean sea level. The area enjoys a typical tropical climate with an average rainfall of about 2833 mm. The meteorological data for the period of investigations recorded at meteorological observatory, Vellanikkara are presented in Appendices I and II. The soil of the experimental plot was laterite.

3.2 EXPERIMENTAL DETAILS

3.2.1 Crop and variety

Black pepper cv. Panniyur 1, a high yielding hybrid, was used for the experiment. The variety produces bold berries of medium quality and gives an average dry berry yield of 1.2 t ha^{-1}. It is not suited to heavily shaded areas. The general view of the experimental plot is shown in Plate 1.

3.2.2 Rooting medium

Potting mixture having 1:2:1 ratio of sand, soil and farmyard manure and filled in polythene bags (17.5 cm x 12. 5 cm) provided with six holes at the base, was used for planting the cuttings.

Plate 1. General view of the experimental plot

3.3 TECHNICAL PROGRAMME

3.3.1 Experiment I: Rooting of orthotropic and runner shoots

Two to three node semi hard wood orthotropic and runner shoots of mature healthy plants of Panniyur 1 were given the following treatments:

T_1 - IBA 1000 ppm

T_2 - Cow dung slurry

T_3 - Tender coconut water

T_4 - Two per cent sugar

T_5 - Charcoal paste

T_6 - Control

The treatments were carefully chosen based on earlier reports of their influence in rooting of black pepper (Suparman and Zaubin 1988, Pillai *et al.*, 1982, Suparman *et al.*, 1990, Copper, 1955, Garayar and Corbera 1957, Shridhar and Singh 1990, Yufdi and Ernawati 1982, Sujatha, 1997).

Cut ends of two to three node semi hard wood orthotropic and runner shoots were kept for 45 seconds in IBA 1000 ppm, five minutes in cow dung slurry, one minute in two per cent sugar and 12 h in 25 per cent tender coconut water before planting in polybags containing potting mixture. In the case of charcoal paste, cut ends of orthotropic and runner shoots were dipped in paste before planting.

3.3.1.1 Season of planting cuttings

Thirty cuttings were planted per treatment at monthly intervals during February, March, April, May and June of 2013.

3.3.1.2 Experimental design and layout

Completely randomized design (CRD) was adopted for laying out the experiment. There were a total of six treatments which was replicated three times with 10 plants per replication. After application of the treatments, polybags were arranged according to the layout plan and labeled. Irrigation was given twice a day.

3.3.1.3 Observations

1. Number of cuttings sprouted

The number of cuttings sprouted on a weekly basis was counted and recorded.

2. Time taken from planting to initiation of sprouting

Cuttings of each treatment were carefully observed and the number of days taken from planting to sprouting was recorded.

3. Number and length of primary roots

Representative samples of five plants from each treatment and replication were uprooted three months after planting. These were carefully and thoroughly washed in running water to remove all adhering soil particles.

After removing the roots from the stem, the number of primary roots were counted and recorded.

The length of each primary root was measured from base to the tip of the root using a measuring scale and expressed in centimeter. Subsequently the average length of primary root of each plant was worked out.

4. Number of secondary and tertiary roots three months after planting

Representative samples of five plants from each treatment and replication were uprooted three months after planting. These were carefully and thoroughly washed in running water to remove all adhering soil particles.

After removing the roots from the stem, the number of secondary and tertiary roots was counted and recorded. The average number of secondary roots per plant was worked out.

5. Weight and volume of roots three months after planting

Representative samples of five plants from each treatment and replication were uprooted three months after planting. These were carefully and thoroughly washed in running water to remove all adhering soil particles.

After removing the roots from the stem, the weight of the detached roots were taken using a balance and expressed in gram.

The volume was taken by placing the detached roots in a measuring cylinder with water. The volume was then assessed by recording the amount of water that was displaced by the detached roots. It was then expressed in ml.

3.3.2 Experiment II: Evaluation of rooted orthotrops and runners in the field

Rooted three months old cuttings from experiment 1 were transferred to field and growth observations were taken. Supports used were *Garuga pinnata.*

3.3.2.1 Treatments

T_1 - Rooted orthotropic shoots

T_2 - Rooted runner shoots

Number of cuttings/ treatment - 20

3.3.2.2 Observations

1. Monthly height increment

The height of each vine was taken at a monthly interval. Measurement was carried out from the base of the shoot to the tip of emerging leaf using a measuring scale and it was expressed in centimeter.

2. Height at production of 1st lateral

Measurement was taken from the base of each plant to the point where the first lateral shoot was initiated using a measuring scale and it was expressed in centimeter.

3. Number of laterals per plant at monthly interval

At monthly interval the number of laterals sprouted was counted and recorded.

4. Number of nodes per plant at monthly interval

At monthly interval the number of nodes was counted and recorded.

5. Internodal length at monthly interval

On a monthly basis the internodal length was measured and recorded using a measuring scale. The average internodal length was worked out.

6. Number of leaves per lateral at monthly interval

The number of leaves produced per lateral was counted and recorded. The average number of leaves per lateral was worked out.

7. Plant spread (E - W and N - S) at monthly interval

The plant spread of each vine was taken at monthly interval using a measuring scale. The measurement was done very meticulously from north to south and then east to west.

3.3.3 Experiment III: Training of vines

Cutting at 3 - 4 nodes from the ground (approximately 30cm above ground) at:

- **T_1 - Six months after planting (December)**

Ten mature healthy plants each of Panniyur 1 and Panniyur 2 were pruned 3 - 4 nodes from the ground (approximately 30 cm above ground) after six months of planting. The pruned end of each plant was covered with a piece of moist cotton wool so as to prevent desiccation.

Ten unpruned plants each of Panniyur 1 & Panniyur 2 were used as control in order to make statistical comparison.

- **T_2 - Ten months after planting (May - June)**

Ten mature healthy plants of Panniyur 1 & Panniyur 2 were pruned 3 - 4 nodes from the ground (approximately 30 cm above ground) after ten months of planting. The pruned end of the vine was covered with a piece of moist cotton wool so as to prevent desiccation and attack of fungus and other insects. Ten unpruned plants each of Panniyur 1 & Panniyur 2 were used as control in order to make statistical comparison.

- **T_3 - Tipping (removing terminal bud) three months after planting (August/ September)**

Twenty mature healthy plants of Panniyur 1 were planted on the 8th of June 2013 and the terminal buds of 10 plants were tipped/ removed on the very day. The remaining 10 untipped plants were used as control in order to make statistical comparison.

Twenty mature healthy plants of Panniyur 1 were planted on the 8th of June 2013 and the terminal buds were tipped/ removed three months after (September).

- **T_4 - Lowering the vines one year after planting (June)**

Ten mature healthy plants each of Panniyur 1 and Panniyur 2 were lowered one year after planting. The leaves were removed from the vines and then buried around the standard and covered with good top soil.

Ten mature healthy plants each of Panniyur 1 and Panniyur 2 which were not lowered were used as control in order to make statistical comparison.

3.3.3.1 Experimental design and layout

Completely randomized design (CRD) was adopted for laying out the experiment. There were a total of five treatments including control and ten replications. Each treatment was labeled accordingly and irrigation was given at three days interval.

3.3.3.2 Observations

1. **Number of orthotropic branches at monthly interval**

At monthly interval the number of orthotropic branches was counted and recorded accordingly.

2. **Height at production of 1st lateral**

Measurement was taken from the base of each plant to the point where the first lateral shoot was initiated using a measuring scale and it was expressed in centimeter.

3. Number of laterals at monthly interval

At monthly interval, the number of laterals produced was counted and recorded accordingly.

4. Number of leaves per lateral at monthly interval

The number of leaves per lateral was counted and recorded. The average number of leaves per lateral was worked out.

5. Plant spread (E - W and N - S) at monthly interval

The plant spread of each vine was taken at monthly interval using a measuring scale and expressed in centimeter. The measurement was done very meticulously from north to south and then east to west.

3.3.4 The incidence of pests and diseases

Plants were observed for incidence of various pests and diseases and appropriate control measures were adopted accordingly.

3.4 STATISTICAL ANALYSIS

Data generated on the various parameters of the experiment was analyzed statistically. ANACOVA was performed on data collected using the statistical package, 'MSTAT' (Freed, 1986). Where the f-test was significant (at 5 percent level of significance), the least significant difference (LSD) was used to compare means at P=0.05. DMRT was carried out using SPSS version 17.0.

Results

4. RESULTS

Three separate experiments were conducted in the pepper research unit attached to the Department of Plantation Crops and Spices, College of Horticulture, Kerala Agricultural University Main Campus, Vellanikkara during 2012 - 2014 to investigate on "Agrotechniques for inducing plagiotrops in black pepper (*Piper nigrum* L.)". The rooting of two to three node semi hard wood orthotropic and runner shoots, evaluation of rooted orthotrops and runners in the field and training of vines were studied during the experimental period and the data generated were subjected to statistical analysis. The results obtained are described under different headings.

4.1 EXPERIMENT 1: ROOTING OF ORTHOTROPIC AND RUNNERS SHOOTS

Two to three node semi hard wood orthotropic shoots were treated with T_1 - IBA 1000 ppm, T_2 - cow dung slurry, T_3 - tender coconut water, T_4 - two per cent sugar and T_5 - charcoal paste before planting in polybags containing potting mixture.

Thirty cuttings were planted per treatment at monthly intervals during February, March, April, May and June of 2013.

Completely randomized design (CRD) was adopted for laying out the experiment. There were a total of six treatments which was replicated three times with 10 plants per replication.

The results obtained from rooting of orthotropic shoots during the experiment are furnished below.

4.1.1 Rooting of orthotropic shoots

The data on the effect of different treatments on two to three node semi hard wood orthotropic shoots of black pepper are presented in tables 1 - 10. In tables 1 - 5 the effect of different treatments on sprouting of orthotrops in black pepper var. Panniyur 1 are presented.

In tables 6 - 10 the effect of different treatments on length of primary roots/ plant, number of secondary roots/ plant, weight of roots (g), volume of roots (ml) and number of leaves/ plant are presented.

4.1.2 Sprouting of orthotrops in black pepper var. Panniyur 1 planted in February 2013 (Table 1)

In table 1, maximum sprouting (5.00) was observed in the cuttings treated with T_3 - tender coconut water. T_1 - IBA 1000 ppm, T_4 - two per cent sugar and T_5 - charcoal paste were on par when observations were recorded 21 days after planting. However on subsequent observation 28 days after planting, maximum sprouting was observed in cuttings treated with T_2 - cow dung slurry (8.66), T_4 - two per cent sugar (8.66), T_3 - tender coconut water (7.66) and T_5 - charcoal paste (7.66).

Observations carried out 35 days after planting recorded maximum sprouting in cuttings treated with T_2 - cow dung slurry (10.00), followed by T_1 - IBA 1000 ppm (9.66), T_4 - two per cent sugar (9.66), T_3 -tender coconut water (9.00) and T_5 - charcoal paste (9.00).

From the table it is quite evident that all the treatments were effective after 28 days of planting with exception that control lagged behind.

The minimum time taken from planting of cuttings to initiation of sprouting was 17 days with maximum time telescoping up to 19 days.

4.1.3 Sprouting of orthotrops in black pepper var. Panniyur 1 planted in March 2013 (Table 2)

In table 2, cuttings planted in March showed maximum sprouting in treatments T_2 - cow dung slurry (8.66) and T_3 - tender coconut water (8.66). T_1 - IBA 1000 ppm (6.00), T_4 - two per cent sugar (7.66) and T_5 - charcoal paste (6.33) were found to be on par when observations were taken 21 days after planting.

Observations taken 28 days after planting revealed maximum sprouting in cuttings treated with cow dung slurry (9.00), tender coconut water (9.00) followed by two per cent sugar (8.33).

When observations were carried out 35 days after planting maximum sprouting was also recorded in cuttings treated with T_2 - cow dung slurry (10.00) followed by T_3 - tender coconut water (9.33) and T_4 - two per cent sugar (8.66).

The lowest sprouting was recorded in T_6 - control at 21 days after planting (4.66), 28 days after planting (5.33) and 35 days after planting (7.66). Time taken from planting to initiation of sprouting ranged from 17 - 19 days.

4.1.4 Sprouting of orthotrops in black pepper var. Panniyur 1 planted in April 2013 (Table 3)

Maximum sprouting was recorded when T_3 - tender coconut water (9.00) was applied. T_5 - charcoal paste) (7.00) and T_6 - control (7.66) were on par when observations were taken 21 days after planting.

T_1 - IBA 1000 ppm) (4.00), T_2 - cow dung slurry (6.33) and T_4 - two per cent sugar (4.66) showed much lower sprouting compared to treatments T_3 - tender coconut water, T_5 - charcoal paste and T_6 - control.

Observations taken 28 days after planting recorded maximum sprouting in cuttings treated with T_3 - tender coconut water (9.66) followed by T_5 - charcoal paste (8.66) and T_2 - cow dung slurry (8.00).

At 35 days after planting, maximum sprouting was also observed in cuttings treated with tender coconut water (9.66) followed by control (9.66), charcoal paste (9.33) and cow dung slurry (9.33).

It is quite clear that most of the treatments were effective after 28 days of planting. The time taken from planting to initiation of sprouting ranged between 17 - 19 days in different treatments.

4.1.5 Sprouting of orthotrops in black pepper var. Panniyur 1 planted in May 2013 (Table 4)

It was observed that maximum sprouting was in T_5 - charcoal paste (8.66) and T_6 - control (8.66). T_1 - IBA 1000 ppm (8.00) and T_3 - tender coconut water (7.33) were on par with T_4- two per cent sugar (8.33) 21 days after planting.

In subsequent observation on 28 days after planting T_5 - charcoal paste (9.33) and T_6 - control (9.33) recorded maximum sprouting. Observation at 35 days after planting once again showed that T_5 - charcoal paste (10.0 0) followed by T_6 - control (9.33) recorded maximum sprouting.

The minimum time taken from planting of cuttings to initiation of sprouting was 17 days whereas maximum time reaching up to 19 days in different treatments.

4.1.6 Sprouting of orthotrops in black pepper var. Panniyur 1 planted in June 2013 (Table 5)

In table 5, maximum sprouting was observed in cuttings treated with T_4 - two per cent sugar (8.66) followed by T_5 - charcoal paste (7.66). T_2 - cow dung slurry (7.00) and

T_6 - control (6.33) were on par with each other when observation was taken 21 days after planting.

Observations made 28 days after planting also showed maximum sprouting in T_4 - two per cent sugar (9.33). T_2 - cow dung slurry (7.00) and T_3 - tender coconut water (7.00) were on par with T_6 - control) (7.66).

Observations taken 35 days after planting showed that T_4 - two per cent sugar (9.33) and T_6 - control (9.33) recorded maximum sprouting. However T_1 - IBA 1000 ppm (7.00), T_2 - cow dung slurry (7.00), T_3 - tender coconut water (7.66) and T_5 - charcoal paste (8.66) were statistically on par with T_4 - two per cent sugar and T_6 - control.

The minimum time recorded from planting to initiation of sprouting was 17 - 19 days in different treatments.

4.1.7 Root characters of orthotrops in black pepper var. Panniyur 1 planted in February 2013 (Table 6)

In table 6 - 10 the number of primary roots varied from 1 - 15. All other parameters were calculated on a unit basis with respect to the corresponding primaries. Hence the number of primary roots was taken as the covariate and ANACOVA was carried out for the different parameters.

The differential effects of the treatments were noticed with regard to number of leaves/ plant for the cuttings planted in February 2013. The maximum number of leaves/ plant was recorded in T_2 - cow dung slurry (3.34) and all other treatments except control were on par with T_2 - cow dung slurry.

4.1.8 Root characters of orthotrops in black pepper var. Panniyur 1 planted in March 2013 (Table 7)

The highest number of secondary roots/ plant was recorded in cuttings treated with T_1 - IBA 1000 ppm (14.06) and was significantly superior to all other treatments. In the case of all other parameters evaluated there were no significant differences among treatments applied.

4.1.9 Root characters of orthotrops in black pepper var. Panniyur 1 planted in April 2013 (Table 8)

In the month of April there was significant difference among the various treatments applied with regards to the number of leaves/ plant.

T_1 - IBA 1000 ppm (7.19) recorded the maximum number of leaves/ plant. The lowest number of leaves/ plant was recorded in T_6 - control (5.33). There was no significant difference for all other parameters observed.

Table 1. Effect of different treatments on sprouting of orthotrops in black pepper var. Panniyur 1 planted in February 2013

Treatment	Number of cuttings sprouted 21 days after planting	Number of cuttings sprouted 28 days after planting	Number of cuttings sprouted 35 days after planting	Days taken from planting to initiation of sprouting
T_1	3.66^{abc} (2.03)	7.33^{a} (2.79)	9.66^{a} (3.18)	17
T_2	2.66^{c} (1.77)	8.66^{a} (3.02)	10.00^{a} (3.24)	18
T_3	5.00^{a} (2.33)	7.66^{a} (2.85)	9.00^{ab} (3.07)	17
T_4	4.33^{ab} (2.18)	8.66^{a} (3.02)	9.66^{a} (3.18)	18
T_5	3.00^{bc} (1.85)	7.66^{a} (2.85)	9.00^{ab} (3.07)	19
T_6	1.00^{d} (1.22)	5.33^{b} (2.40)	7.66^{b} (2.85)	19

The figures in the parenthesis are SQRT transformed values

Table 2. Effect of different treatments on sprouting of orthotrops in black pepper var. Panniyur 1 planted in March 2013

Treatment	Number of cuttings sprouted 21 days after planting	Number of cuttings sprouted 28 days after planting	Number of cuttings sprouted 35 days after planting	Days taken from planting to initiation of sprouting
T_1	6.00^{ab} (2.46)	7.00^{ab} (2.70)	7.66^{bc} (2.84)	18
T_2	8.66^{a} (3.02)	9.00^{a} (3.08)	10.00^{a} (3.24)	18
T_3	8.66^{a} (3.02)	9.00^{a} (3.08)	9.33^{ab} (3.13)	17
T_4	7.66^{ab} (2.85)	8.33^{a} (2.96)	8.66^{ab} (3.02)	18
T_5	6.33^{ab} (2.61)	6.66^{ab} (2.67)	7.00^{c} (2.73)	19
T_6	4.66^{b} (2.27)	5.33^{b} (2.40)	7.66^{bc} (2.85)	19

The figures in the parenthesis are SQRT transformed values

Table 3. Effect of different treatments on sprouting of orthotrops in black pepper var. Panniyur 1 planted in April 2013

Treatment	Number of cuttings sprouted 21 days after planting	Number of cuttings sprouted 28 days after planting	Number of cuttings sprouted 35 days after planting	Days taken from planting to initiation of sprouting
T_1	4.00^{d} (2.11)	6.66^{b} (2.65)	8.33^{ab} (2.96)	17
T_2	6.33^{bc} (2.60)	8.00^{ab} (2.91)	9.33^{ab} (3.13)	18
T_3	9.00^{a} (3.08)	9.66^{a} (3.18)	9.66^{a} (3.18)	17
T_4	4.66^{cd} (2.26)	6.33^{b} (2.59)	7.33^{b} (2.78)	18
T_5	7.00^{ab} (2.72)	8.66^{ab} (3.02)	9.33^{ab} (3.13)	19
T_6	7.66^{ab} (2.84)	8.66^{ab} (3.02)	9.66^{a} (3.18)	19

The figures in the parenthesis are SQRT transformed values

Table 4. Effect of different treatments on sprouting of orthotrops in black pepper var. Panniyur 1 planted in May 2013

Treatment	Number of cuttings sprouted 21 days after planting	Number of cuttings sprouted 28 days after planting	Number of cuttings sprouted 35 days after planting	Time taken from planting to initiation of sprouting
T_1	8.00^{ab} (2.91)	8.66^{ab} (3.02)	9.00^{ab} (3.07)	17
T_2	6.66^{b} (2.67)	7.66^{b} (2.85)	8.00^{b} (2.91)	18
T_3	7.33^{ab} (2.79)	7.66^{b} (2.85)	7.66^{b} (2.85)	17
T_4	8.33^{ab} (2.96)	8.66^{ab} (3.02)	8.66^{ab} (3.02)	18
T_5	8.66^{a} (3.02)	9.33^{a} (3.13)	10.00^{a} (3.24)	18
T_6	8.66^{a} (3.02)	9.33^{a} (3.13)	9.33^{ab} (3.13)	19

The figures in the parenthesis are SQRT transformed values

Table 5. Effect of different treatments on sprouting of orthotrops in black pepper var. Panniyur 1 planted in June 2013

Treatment	Number of cuttings sprouted 21 days after planting	Number of cuttings sprouted 28 days after planting	Number of cuttings sprouted 35 days after planting	Days taken from planting to initiation of sprouting
T_1	4.66^{b} (2.24)	6.00^{b} (2.53)	7.00^{a} (2.72)	17
T_2	7.00^{ab} (2.73)	7.00^{ab} (2.73)	7.00^{a} (2.73)	17
T_3	4.33^{b} (2.19)	7.00^{ab} (2.72)	7.66^{a} (2.85)	17
T_4	8.66^{a} (3.01)	9.33^{a} (3.13)	9.33^{a} (3.13)	17
T_5	7.66^{a} (2.84)	8.66^{ab} (3.02)	8.66^{a} (3.02)	18
T_6	6.33^{ab} (2.60)	7.66^{ab} (2.84)	9.33^{a} (3.13)	19

The figures in the parenthesis are SQRT transformed values

T_1 - IBA 1000 ppm for 45 seconds
T_2 - Cow dung slurry
T_3 - Tender coconut water
T_4- Two per cent sugar
T_5 - Charcoal paste
T_6 - Control

4.1.10 Root characters of orthotrops in black pepper var. Panniyur 1 planted in May 2013 (Table 9)

In the month of May no significant difference among the treatments were observed for all the parameters taken into consideration.

Mean length of primary roots ranged from (12.03 cm - 17.18 cm), mean number of secondary roots/ plant (14.35 - 22.45), weight of roots (0.54 - 1.03 g), volume of roots (1.15 - 1.75 ml) and number of leaves/ plant (2.24 - 3.54) respectively.

4.1.11 Root characters of orthotrops in black pepper var. Panniyur 1 planted in June 2013 (Table 10)

In table 10, no significant difference was noticed among treatments for all parameters evaluated.

T_1 - IBA 1000 ppm has proven to be the best treatment for mean length of primary roots (20.34 cm), mean number of secondary roots/ plant (24.83), weight of roots (0.80 g), and volume of roots (1.55 ml).

In the case of number of leaves/ plant, T_5 - charcoal paste recorded the maximum number of leaves/ plant (6.5) and T_1 - IBA 1000 ppm recorded the lowest number of leaves/ plant.

4.1.12 ROOTING OF RUNNER SHOOTS

Data on the effect of different treatments on two to three node semi hard wood runner shoots of black pepper are presented in tables 11 - 20. In tables 11 - 15 the effect of different treatments on sprouting of runners in black pepper var. Panniyur 1 are presented. In tables 16 - 20 the effect of different treatments on length of primary roots/ plant, number of secondary roots/ plant, weight of roots (g), volume of roots (ml) and number of leaves/ plant are presented.

Table 6. Effect of different treatments on root characters of orthotrops in black pepper var. Panniyur 1 planted in February 2013

Treatment	Length of primary roots/ plant (cm)	Number of secondary roots/ plant	Weight of roots/ plant (g)	Volume of roots/ plant (ml)	Number of leaves/ plant
1	6.94	11.72	0.44	0.88	3.36
2	8.15	11.34	0.59	1.47	3.34
3	7.10	14.16	0.43	0.79	3.21
4	6.40	15.49	0.63	1.10	2.82
5	5.61	11.98	0.47	0.91	2.78
6	6.47	8.28	0.35	0.48	0.87
CD (5 %)	NS	NS	NS	NS	1.45

Table 7. Effect of different treatments on root characters of orthotrops in black pepper var. Panniyur 1 planted in March 2013

Treatment	Length of primary roots/ plant (cm)	Number of secondary roots/ plant	Weight of roots/ plant (g)	Volume of roots/ plant (ml)	Number of leaves/ plant
1	6.24	14.06	0.76	1.42	6.97
2	4.01	4.28	0.57	1.12	5.79
3	1.70	2.77	0.44	0.91	6.79
4	2.11	5.31	0.58	1.11	6.40
5	4.49	5.38	0.51	1.09	6.65
6	5.17	7.53	0.18	0.18	5.39
CD (5 %)	NS	5.86	NS	NS	NS

Table 8. Effect of different treatments on root characters of orthotrops in black pepper var. Panniyur 1 planted in April 2013

Treatment	Length of primary roots/ plant (cm)	Number of secondary roots/ plant	Weight of roots/ plant (g)	Volume of roots/ plant (ml)	Number of leaves/ plant
1	9.51	16.76	0.68	1.28	7.19
2	16.90	21.49	0.61	1.20	6.96
3	14.07	17.66	0.45	0.96	6.61
4	13.43	16.59	0.58	1.16	6.21
5	21.78	26.32	0.50	1.00	5.68
6	13.93	18.16	0.20	0.22	5.33
CD (5 %)	NS	NS	NS	NS	2.19

Table 9. Effect of different treatments on root characters of orthotrops in black pepper var. Panniyur 1 planted in May 2013

Treatment	Length of primary roots/ plant (cm)	Number of secondary roots/ plant	Weight of roots/ plant (g)	Volume of roots/ plant (ml)	Number of leaves/ plant
1	12.03	14.35	0.77	1.60	3.14
2	14.75	20.51	0.54	1.15	2.99
3	14.14	15.98	0.87	1.75	2.24
4	16.01	22.45	1.03	1.84	2.96
5	13.65	16.19	0.73	1.41	2.71
6	17.18	18.91	0.79	1.54	3.54
CD (5 %)	NS	NS	NS	NS	NS

Table 10. Effect of different treatments on root characters of orthotrops in black pepper var. Panniyur 1 planted in June 2013

Treatment	Length of primary roots/ plant (cm)	Number of secondary roots/ plant	Weight of roots/ plant (g)	Volume of roots/ plant (ml)	Number of leaves/ plant
1	20.34	24.83	0.80	1.55	4.99
2	13.23	19.14	0.62	1.55	5.20
3	13.9	19.54	0.52	1.14	5.79
4	13.71	20.87	0.72	1.43	6.60
5	18.27	24.18	0.71	1.42	6.59
6	13.75	23.21	0.34	0.70	6.40
CD (5 %)	NS	NS	NS	NS	NS

T_1 - IBA 1000 ppm for 45 seconds
T_2 - Cow dung slurry
T_3 - Tender coconut water
T_4 - Two per cent sugar
T_5 - Charcoal paste
T_6 - Control

4.1.13 Sprouting of runners in black pepper var. Panniyur 1 planted in February 2013 (Table 11)

It could be observed from table 11 that the number of cuttings sprouted varied sparingly among the treatments with an average sprouting of three cuttings at 21 days after planting and extending up to six cuttings as the days proceeded up to 35 days.

As in the case of orthotrops sprouting was noticeable on 17 days after planting.

4.1.14 Sprouting of runners in black pepper var. Panniyur 1 planted in March 2013 (Table 12)

In the month of March the number of cuttings sprouted did not show much variation among treatments 21 days after planting. 35 days after planting 100 per cent sprouting was observed.

The minimum time taken from planting to initiation of sprouting was 17 days whereas the maximum time reaching up to 19 days.

4.1.15 Sprouting of runners in black pepper var. Panniyur 1 planted in April 2013 (Table 13)

It is quite evident that in the month of April there was no significant variation with respect to the number of cuttings sprouted in treatments T_1 - IBA 1000 ppm (5), T_2 - cow dung slurry (6), T_3 - tender coconut water (6) and T_4 - two per cent sugar (5) but there was a slight variation observed in T_5 - charcoal paste (4) and T_6 - control (3) 21 and 28 days after planting.

Unlike the two previous months February and March best result was recorded 35 days after planting. The time taken from planting to initiation of sprouting ranged from 17 to 19 days.

4.1.16 Sprouting of runners in black pepper var. Panniyur 1 planted in May 2013 (Table 14)

In table 14, the effectiveness of all treatments was quite visible 21 days after planting. In T_1 - IBA 1000 ppm (4), T_2 - cow dung slurry (6), T_3 - tender coconut water (6), T_4 - two per cent sugar (5), T_5 - charcoal paste (6) and T_6 - control (6) cuttings sprouted. 35 days after planting 100 per cent sprouting was observed in all the treatments.

The time recorded from planting to initiation of sprouting ranged from 17 to 18 days.

4.1.17 Sprouting of runners in black pepper var. Panniyur 1 planted in June 2013 (Table 15)

At 21 days after planting there was uniformity in sprouting of cuttings treated with T_1 - IBA 1000 ppm, T_2 - cow dung slurry, T_3 - tender coconut water, T_4 - two per cent sugar, T_5 - charcoal paste and T_6 - control. At 28 days after planting 100 per cent sprouting was achieved.

The time taken from planting to initiation of sprouting was seen 17 and 18 days after planting.

4.1.18 Rooting of runners in black pepper var. Panniyur 1 planted in February, March April, May and June 2013 (Tables 16 - 20)

In the months of February, March, April, May and June when runners were observed for different parameters such as length of primary roots/ plant, number of secondary roots/ plant, weight of roots (g), volume of roots (ml) and number of leaves/ plant no significant differences were seen except for number of leaves/ plant and secondary roots/ plant in the months of April and June.

In the month of April, T_3 - tender coconut water (3.11) was superior to all other treatments with respect to the number of leaves/ plant.

In June T_3 - tender coconut water (15.64) once again showed superiority to all other treatments with regard to the number of secondary roots/ plant.

Table 11. Effect of different treatments on sprouting of runners in black pepper var. Panniyur 1 planted in February 2013

Treatment	Number of cuttings sprouted			Days taken from planting to initiation of sprouting
	21 days after planting	28 days after planting	35 days after planting	
T_1	3	4	6	17
T_2	3	6	6	18
T_3	4	6	6	17
T_4	3	6	6	18
T_5	3	6	6	18
T_6	3	5	6	18

Table 12. Effect of different treatments on sprouting of runners in black pepper var. Panniyur 1 planted in March 2013

Treatment	Number of cuttings sprouted			Days taken from planting to initiation of sprouting
	21 days after planting	28 days after planting	35 days after planting	
T_1	4	6	6	18
T_2	6	6	6	18
T_3	6	6	6	17
T_4	5	6	6	18
T_5	6	6	6	18
T_6	5	6	6	19

Table 13. Effect of different treatments on sprouting of runners in black pepper var. Panniyur 1 planted in April 2013

Treatment	Number of cuttings sprouted			Days taken from planting to initiation of sprouting
	21 days after planting	28 days after planting	35 days after planting	
T_1	5	5	6	17
T_2	6	6	6	18
T_3	6	6	6	17
T_4	5	5	6	19
T_5	4	4	6	18
T_6	3	3	6	19

Table 14. Effect of different treatments on sprouting of runners in black pepper var. Panniyur 1 planted in May 2013

Treatment	Number of cuttings sprouted			Days taken from planting to initiation of sprouting
	21 days after planting	28 days after planting	35 days after planting	
T_1	4	4	6	17
T_2	6	6	6	18
T_3	6	6	6	17
T_4	5	5	6	18
T_5	6	6	6	18
T_6	6	6	6	18

Table 15. Effect of different treatments on sprouting of runners in black pepper var. Panniyur 1 planted in June 2013

Treatment	Number of cuttings sprouted			Days taken from planting to initiation of sprouting
	21 days after planting	28 days after planting	35 days after planting	
T_1	6	6	6	17
T_2	5	6	6	18
T_3	5	6	6	17
T_4	5	6	6	18
T_5	5	6	6	18
T_6	5	6	6	18

T_1 - IBA 1000 ppm for 45 seconds
T_2 - Cow dung slurry
T_3 - Tender coconut water
T_4- Two per cent sugar
T_5 - Charcoal paste
T_6 - Control

Table 16. Effect of different treatments on rooting of runners in black pepper var. Panniyur 1 planted in February 2013

Treatment	Length of primary roots/ plant (cm)	Number of secondary roots/ plant	Weight of roots/ plant (g)	Volume of roots/ plant (ml)	Number of leaves/ plant
1	1.73	4.79	0.08	0.16	1.07
2	1.83	5.30	0.12	0.14	1.55
3	2.06	0.04	0.51	1.11	3.69
4	2.51	7.08	0.09	0.18	1.83
5	3.61	7.75	0.14	0.24	1.29
6	3.99	10.03	0.21	0.42	1.73
CD (5 %)	NS	NS	NS	NS	NS

Table 17. Effect of different treatments on rooting of runners in black pepper var. Panniyur 1 planted in March 2013

Treatment	Length of primary roots/ plant (cm)	Number of secondary roots/ plant	Weight of roots/ plant (g)	Volume of roots/ plant (ml)	Number of leaves/ plant
1	1.62	3.06	0.21	0.27	1.23
2	1.82	2.01	0.18	0.28	1.24
3	1.52	1.08	0.26	0.47	1.36
4	2.17	3.38	0.44	0.85	1.75
5	3.17	7.38	0.55	0.91	1.75
6	1.22	0.71	0.33	0.62	1.04
CD (5 %)	NS	NS	NS	NS	NS

Table 18. Effect of different treatments on rooting of runners in black pepper var. Panniyur 1 planted in April 2013

Treatment	Length of primary roots/ plant (cm)	Number of secondary roots/ plant	Weight of roots/ plant (g)	Volume of roots/ plant (ml)	Number of leaves/ plant
1	4.60	5.80	0.19	0.31	2.22
2	4.65	2.47	0.14	0.24	1.69
3	8.62	8.50	0.21	0.36	3.11
4	5.30	5.90	0.31	0.66	2.20
5	2.23	3.59	0.43	0.81	1.13
6	5.88	4.25	0.32	0.65	1.42
CD (5 %)	NS	NS	NS	NS	1.16

Table 19. Effect of different treatments on rooting of runners in black pepper var. Panniyur 1 planted in May 2013

Treatment	Length of primary roots/ plant (cm)	Number of secondary roots/ plant	Weight of roots/ plant (g)	Volume of roots/ plant (ml)	Number of leaves/ plant
1	9.56	14.69	0.79	1.49	3.06
2	11.81	18.26	0.74	1.54	2.80
3	9.90	10.01	0.62	1.10	3.93
4	9.98	16.84	0.78	1.48	2.96
5	10.30	14.25	0.78	1.49	3.48
6	13.57	14.41	0.72	1.49	3.74
CD (5 %)	NS	NS	NS	NS	NS

4.1.19 Comparative evaluation of root characters of orthotrops and runners in black pepper var. Panniyur 1 planted in February (Table 21)

In the month of February, significant differences could be observed between orthotrops and runners with regard to the length of primary roots in T_1 - IBA 1000 ppm, T_2 - cow dung slurry and T_4 - two per cent sugar.

In orthotrops, maximum length of primary roots (8.32 cm) was observed in cuttings treated with cow dung slurry whereas the maximum length of primary roots (6.60 cm) in runners was observed in cuttings treated with tender coconut water. In all the treatments the length of primary roots is more in orthotrops than runners.

Orthotrops recorded the maximum number of secondary roots (16.81) in T_4 - two per cent sugar whereas runners recorded the most number of secondary roots (12.21) in T_3 - tender coconut water.

The maximum weight (0.73 g) and volume (1.40 ml) of roots in orthotrops was observed in T_1 - IBA 1000 ppm. Runners recorded the highest weight (0.75 g) and volume (1.60 ml) of roots in cuttings treated with T_3 - tender coconut water.

The highest number of leaves/ plant (3.40) in orthotrops was recorded in T_2 - cow dung slurry whereas runners recorded the highest number of leaves/ plant (3.20) in T_3 - tender coconut water.

4.1.20 Comparative evaluation of root characters of orthotrops and runners in black pepper var. Panniyur 1 planted in March (Table 22)

As can be seen from table 22 there was significant difference between orthotrops and runners in T_1 - IBA 1000 ppm with regards to length of primary roots. The length of primary roots recorded in orthotrops was 6.31 cm and in runners 1.62 cm.

In T_6 - control also significant difference existed. The length of primary roots recorded in orthotrops was 5.20 cm and 0.90 cm in runners.

Maximum number of secondary roots in orthotrops (14.29) was observed in cuttings treated with T_1 - IBA 1000 ppm. Runners (8.00 cm) recorded maximum number of secondary roots in cuttings treated with T_5 - charcoal paste.

The maximum weight (0.76 g) and volume (1.42 ml) of roots in orthotrops was observed in cuttings treated with T_1 - IBA 1000 ppm. Runners recorded the highest weight (0.55 g) and volume (0.92 ml) of roots in cuttings treated with T_5 - charcoal paste.

The highest number of leaves/ plant in orthotrops was recorded in cuttings treated with T_1 - IBA 1000 ppm (7.00) and T_5 - charcoal paste (7.00). Runners recorded the highest number of leaves/ plant (1.81) in cuttings treated with T_4 - two per cent sugar.

4.1.21 Comparative evaluation of root characters of orthotrops and runners in black pepper var. Panniyur 1 planted in April (Table 23)

In April there was significant difference between orthotrops and runners in T_1 - IBA 1000 ppm for 45 seconds, T_2 - cow dung slurry, T_5 - charcoal paste and T_6 - control. Maximum length of primary roots (21.11 cm) in orthotrops was observed in cuttings treated with T_5 - charcoal paste. In runners, the maximum length of primary roots (8.81 cm) was recorded in cuttings treated with T_3 - tender coconut water.

The highest number of secondary roots (26.08) in orthotrops was observed in T_5 - charcoal paste. Runners recorded maximum number of secondary roots (8.80) in cuttings treated with T_3 - tender coconut water

The maximum weight (0.76 g) and volume (1.42 ml) of roots in orthotrops was observed in T_1 - IBA 1000 ppm. Runners recorded the maximum weight (0.52 g) and volume (0.98 ml) of roots in cuttings treated with T_5 - charcoal paste.

The highest number of leaves/ plant in orthotrops was recorded in T_1 - IBA 1000 ppm (7.00) and T_5 - charcoal paste (7.00). Runners recorded the most number of leaves/ plant (3.20) in T_3 - tender coconut water.

4.1.22 Comparative evaluation of root characters of orthotrops and runners in black pepper var. Panniyur 1 planted in May (Table 24)

In May no significant difference was noticed between orthotrops and runners with regard to length of primary roots in T_1 - IBA 1000 ppm, T_2 - cow dung slurry, T_3 - tender coconut water, T_4 - two per cent sugar and T_6 - control. Significant difference was observed in cuttings treated with T_5 - charcoal paste where the length of primary roots in orthotrops was 14.62 cm and in runners 10.63 cm.

The maximum number of secondary roots (22.77) in orthotrops was observed in cuttings treated with T_4 - two per cent sugar and the least number of secondary roots (13.56) was recorded in cuttings treated with T_3 - tender coconut water. Runners recorded the maximum number of secondary roots (18.26) in cuttings treated with T_2 - cow dung slurry.

The maximum weight (1.07 g) and volume (1.90 ml) of roots in orthotrops was observed in cuttings treated with T_4 - two per cent sugar. Runners recorded the maximum weight (0.91 g) and volume (1.66 ml) of roots in T_6 - control. The highest number of leaves/ plant in orthotrops (3.60) and runners (4.00) was recorded in T_6 - control.

4.1.23 Comparative evaluation of root characters of orthotrops and runners in black pepper var. Panniyur 1 planted in June (Table 25)

The maximum length of primary roots in orthotrops (22.77 cm) was observed in cuttings treated with T_1 - IBA 1000 ppm. Runners recorded the maximum length of primary roots in cuttings treated with T_3 - tender coconut water. The maximum number of secondary roots/ plant in orthotrops (27.69) and runners (14.45) was observed in treatments T_1 - IBA 1000 ppm and T_3 - tender coconut water respectively.

The highest weight (0.86 g) and volume (1.77 ml) of roots in orthotrops was observed in cuttings treated with T_1 - IBA 1000 ppm. Runners recorded the highest weight (0.22 g) and volume (0.44 ml) of roots in treatments T_6 - control and T_5 - charcoal paste respectively.

The highest number of leaves/ plant in orthotrops (6.60) and runners (3.20) was recorded in treatments T_4 - two per cent sugar and T_2 - cow dung slurry respectively.

Table 21. Comparative evaluation of the effect of different treatments on root characters of orthotrops and runners in black pepper var. Panniyur 1 planted in February 2013

Treatments	Length of primary roots/ plant (cm)			Number of secondary roots/ plant			Weight of roots/ plant (g)			Volume of roots/ plant (ml)			Number of leaves/ plant		
	Orthotrops	Runners	t value	Orthotrops	Runners	t value	Orthotrops	Runners	t value	Orthotrops	Runners	t value	Orthotrops	Runners	t value
T_1	5.06 (1.02)	0.60 (1.34)	5.91 *	7.45 (2.75)	1.73 (3.87)	2.69 *	0.73 (0.39)	0.02 (0.05)	4.00 *	1.40 (0.70)	0.04 (0.89)	4.26 *	2.80 (0.83	1.20 (0.44)	3.77 *
T_2	8.32 (4.24)	1.46 (2.15)	3.22 *	11.73 (3.30)	4.28 (5.86)	2.47 *	0.56 (0.42)	0.10 (0.13)	2.30 NS	1.10 (0.82)	0.10 (0.14)	2.66 *	3.40 (0.89)	1.60 (0.89)	3.18 *
T_3	7.06 (2.56)	6.60 (1.51)	0.35 NS	14.09 (6.78)	12.21 (3.03)	0.56 NS	0.44 (0.10)	0.75 (0.16)	3.62 *	0.80 (0.21)	1.60 (0.33)	4.47 *	3.20 (1.64	3.20 (1.48)	0.00 NS
T_4	6.98 (2.73	1.00 (2.23)	3.78 *	16.81 (3.17)	3.00 (6.70	4.16 *	0.54 (0.20)	0.01 (0.03	5.75 *	0.94 (0.32)	0.02 (0.04)	6.34 *	3.00 (1.00)	2.00 (1.73)	1.11 NS
T_5	5.67 (1.23)	2.66 (3.65)	1.74 NS	12.14 (2.44)	5.20 (7.12)	2.06 NS	0.46 (0.27)	0.09 (0.13)	2.72 *	0.90 (0.56)	0.14 (0.26)	2.74 *	2.80 (0.83)	1.40 (0.54)	3.13 *
T_6	7.56 (2.48)	3.43 (3.87)	2.00 NS	10.76 (7.29)	8.50 (11.22)	0.37 NS	0.18 (0.08)	0.18 (0.24)	0.03 NS	0.18 (0.04)	0.36 (0.46)	0.86 NS	1.20 (0.44)	1.80 (0.83	1.41 NS

The figures in parenthesis are standard deviation values

Table 22. Comparative evaluation of the effect of different treatments on root characters of orthotrops and runners in black pepper var. Panniyur 1 planted in March

Treatments	Length of primary roots/ plant (cm)			Number of secondary roots/ plant			Weight of roots/ plant (g)			Volume of roots/ plant (ml)			Number of leaves/ plant		
	Orthotrops	Runners	t value	Orthotrops	Runners	t value	Orthotrops	Runners	t value	Orthotrops	Runners	t value	Orthotrops	Runners	t value
T_1	6.31 (2.10)	1.62 (0.00)	6.71 *	14.29 (1.27)	3.06 (0.00)	25.10 *	0.76 (0.38)	0.20 (0.07)	3.11 *	1.42 (0.67)	0.26 (0.15)	3.74 *	7.00 (0.70)	1.00 (0.70)	13.41*
T_2	4.04 (3.08)	1.50 (3.35)	1.24 NS	4.38 (4.34)	1.40 (3.13)	1.24 NS	0.56 (0.42)	0.18 (0.17)	1.85 NS	1.12 (0.82)	0.28 (0.22)	2.19 NS	5.80 (0.83)	1.20 (0.44)	10.84 *
T_3	1.20 (1.64)	3.15 (4.35)	0.93 NS	1.08 (2.41)	4.15 (8.20)	0.80 NS	0.46 (0.10)	0.27 (0.20)	1.82 NS	0.98 (0.35)	0.48 (0.40)	2.06 NS	6.60 (0.54)	1.60 (1.34)	7.71 *
T_4	1.57 (3.51)	2.50 (4.12)	0.38 NS	3.48 (7.79)	4.00 (8.94)	0.09 NS	0.59 (0.21)	0.44 (0.34)	0.83 NS	1.18 (0.52)	0.86 (0.79)	0.75 NS	6.20 (0.83)	1.81 (1.78)	4.98 *
T_5	5.42 (1.66)	3.50 (5.47)	0.75 NS	8.49 (1.18)	8.00 (13.85)	0.08 NS	0.49 (0.27)	0.55 (0.26)	0.36 NS	0.98 (0.64)	0.92 (0.63)	0.14 NS	7.00 (0.70)	1.80 (1.30)	7.83 *
T_6	5.20 (1.59)	0.90 (2.10)	3.75 *	7.62 (3.98)	0.10 (0.22)	4.21 *	0.18 (0.09)	0.33 (0.18)	1.69 NS	0.18 (0.04)	0.62 (0.46)	2.10 NS	5.40 (0.54)	1.00 (0.00)	17.96 *

The figures in parenthesis are standard deviation values

Table 23. Comparative evaluation of the effect of different treatments on root characters of orthotrops and runners in black pepper var. Panniyur 1 planted in April

Treatments	Length of primary roots/ plant (cm)			Number of secondary roots/ plant			Weight of roots/ plant (g)			Volume of roots/ plant (ml)			Number of leaves/ plant		
	Orthotrops	Runners	t value	Orthotrops	Runners	t value	Orthotrops	Runners	t value	Orthotrops	Runners	t value	Orthotrops	Runners	t value
T_1	12.73 (2.23)	3.65 (4.81)	3.82 *	17.95 (4.34)	4.31 (5.85)	4.18 *	0.76 (0.38)	0.12 (0.12)	3.49 *	1.42 (0.67)	0.16 (0.15)	4.06 *	7.00 (0.70)	1.80 (1.64)	6.50 *
T_2	14.93 (6.05)	3.98 (3.17)	3.57 *	20.77 (6.70)	1.43 (1.48)	6.30 *	0.56 (0.42)	0.08 (0.11)	2.42 *	1.12 (0.82)	0.14 (0.15)	2.61 *	5.80 (0.83)	1.40 (1.14)	6.95 *
T_3	14.37 (6.68)	8.81 (5.88)	1.39 NS	17.77 (7.14)	8.80 (8.55)	1.80 NS	0.46 (0.10)	0.23 (0.24)	1.90 NS	0.98 (0.35)	0.40 (0.46)	2.21 NS	6.60 (0.54)	3.20 (1.64)	4.38 *
T_4	13.73 (7.43)	6.64 (0.86)	2.11 NS	16.70 (7.31)	7.99 (3.62)	2.38 *	0.59 (0.21)	0.42 (0.34)	0.96 NS	1.18 (0.52)	0.88 (0.72)	0.75 NS	6.20 (0.83)	2.80 (1.30)	4.90 *
T_5	21.11 (5.82)	3.28 (0.70)	6.79 *	26.08 (7.79)	5.23 (1.77)	5.83 *	0.49 (0.27)	0.52 (0.28)	0.17 NS	0.98 (0.64)	0.98 (0.61)	0.00 NS	7.00 (0.70)	1.60 (0.54)	13.50 *
T_6	12.76 (6.39)	4.93 (3.04)	2.47 *	19.07 (5.15)	2.76 (1.58)	6.79 *	0.18 (0.09)	0.24 (0.21)	0.61 NS	0.18 (0.04)	0.50 (0.63)	1.12 NS	5.40 (0.54)	1.00 (0.70)	11.00 *

The figures in parenthesis are standard deviation values

Table 24. Comparative evaluation of the effect of different treatments on root characters of orthotrops and runners in black pepper var. Panniyur 1 planted in May

Treatments	Length of primary roots/ plant (cm)			Number of secondary roots/ plant			Weight of roots/ plant (g)			Volume of roots/ plant (ml)			Number of leaves/ plant		
	Orthotrops	Runners	t value	Orthotrops	Runners	t value	Orthotrops	Runners	t value	Orthotrops	Runners	t value	Orthotrops	Runners	t value
T_1	12.70 (2.49)	9.98 (1.80)	1.97 NS	14.94 (3.13)	15.87 (3.02)	0.47 NS	0.84 (0.27)	0.90 (0.26)	0.33 NS	1.72 (0.31)	1.68 (0.25)	0.22 NS	3.20 (0.44)	3.20 (0.44)	0.00 NS
T_2	14.80 (2.85	11.81 (6.56	0.93 NS	20.56 (1.53)	18.26 (7.48)	0.67 NS	0.55 (0.38)	0.74 (0.20)	1.00 NS	1.16 (0.84)	1.54 (0.43)	0.89 NS	3.00 (0.00)	2.80 (1.09)	0.40 NS
T_3	11.43 (7.59)	9.49 (3.85)	0.50 NS	13.56 (7.89)	8.83 (8.37)	0.91 NS	0.55 (0.34)	0.52 (0.55)	0.11 NS	1.30 (0.75)	0.92 (0.98)	0.68 NS	2.00 (1.22)	3.80 (1.30)	2.25 NS
T_4	16.37 (7.04)	8.91 (5.58)	1.85 NS	22.77 (3.82)	13.78 (8.17)	2.22 NS	1.07 (0.31)	0.50 (0.40)	2.48 *	1.90 (0.18)	1.00 (0.83)	2.34 *	3.00 (0.00)	2.60 (1.51)	0.59 NS
T_5	14.62 (0.91)	10.63 (1.65)	4.71 *	17.05 (2.23)	15.20 (3.19)	1.06 NS	0.85 (0.35)	0.87 (0.31)	0.09 NS	1.58 (0.46)	1.64 (0.38)	0.22 NS	2.80 (0.44)	3.60 (0.54)	2.53 *
T_6	17.84 (4.28)	14.31 (4.02)	1.33 NS	19.51 (1.31)	16.53 (2.29)	2.51 *	0.87 (0.27)	0.91 (0.19)	0.32 NS	1.66 (0.25)	1.83 (0.17)	1.25 NS	3.60 (0.89)	4.00 (0.70)	0.78 NS

The figures in parenthesis are standard deviation values

Table 25. Comparative evaluation of the effect of different treatments on root characters of orthotrops and runners in black pepper var. Panniyur 1 planted in June

Treatments	Length of primary roots/ plant (cm)			Number of secondary roots/ plant			Weight of roots/ plant (g)			Volume of roots/ plant (ml)			Number of leaves/ plant		
	Orthotrops	Runners	t value	Orthotrops	Runners	t value	Orthotrops	Runners	t value	Orthotrops	Runners	t value	Orthotrops	Runners	t value
T_1	22.77 (3.47)	11.67 (7.28)	3.07 *	27.69 (1.86)	11.67 (7.28)	4.76 *	0.86 (0.17)	0.16 (0.11)	7.36 *	1.77 (0.33)	0.18 (0.13)	9.89 *	5.00 (1.22)	2.40 (1.51)	2.98 *
T_2	11.79 (4.39)	11.93 (2.39)	0.06 NS	17.45 (6.15)	11.93 (2.39)	1.86 NS	0.59 (0.06)	0.17 (0.07)	9.42 *	1.43 (0.22)	0.22 (0.08)	11.13 *	5.20 (0.83)	3.20 (0.44)	4.71 *
T_3	14.50 (1.41)	14.45 (4.10)	0.03 NS	20.26 (4.53)	14.45 (4.10	2.12 NS	0.53 (0.18)	0.20 (0.09)	3.65 *	1.20 (0.65)	0.38 (0.20)	2.66 *	5.80 (0.83)	3.00 (0.70)	5.71 *
T_4	13.64 (4.29)	13.09 (3.81)	0.21 NS	20.79 (3.83)	12.42 (3.45)	3.62 *	0.71 (0.22)	0.21 (0.11)	4.45 *	1.43 (0.51)	0.34 (0.19)	4.45 *	6.60 (0.54)	2.80 (0.44)	12.01 *
T_5	18.88 (1.78	9.80 (1.36)	9.04 *	24.89 (0.94)	9.80 (1.36)	20.37 *	0.73 (0.19)	0.21 (0.07)	5.52 *	1.48 (0.51)	0.44 (0.27)	3.95 *	6.60 (0.54)	2.80 (0.44)	12.01 *
T_6	12.87 (3.78)	8.39 (2.90)	2.09 NS	20.72 (3.03)	8.39 (2.90)	6.56 *	0.28 (0.25)	0.22 (0.07)	0.51 NS	0.52 (0.55)	0.32 (0.55)	0.77 NS	6.40 (0.54)	3.19 (0.44)	10.11 *

The figures in parenthesis are standard deviation values

Plate 2. Twenty one days old orthotrops

Plate 3. Forty five days old orthotrops

Plate 4. Twenty one days old runners

Plate 5. Forty five days old runners

4.1.24 Number of primary roots in orthotrops in black pepper var. Panniyur 1 (Table 26)

In table 26 it is quite obvious that in the month of February more number of primary roots were recorded in cuttings treated with IBA 1000 ppm for 45 seconds. T_1 - IBA 1000 ppm produced an average of 8.4 primary roots/ plant. T_6 - control recorded the lowest average number of primary roots/ plant (2.6).

In the month of March cuttings treated with charcoal paste produced the highest average number of primary roots/ plant (8.6). The lowest average number of primary roots/ plant was recorded in cuttings treated with T_4 - two per cent sugar (1.4).

Cuttings treated with T_1 - IBA 1000 ppm for 45 seconds in the month of April recorded the highest average number of primary roots/ plant (11.0). T_6 - control recorded the lowest average number of primary roots/ plant (5.6).

In May most of the treatments did not show significant difference with respect to the number of primary roots produced per plant. Only cuttings treated with T_3 - tender coconut water showed significantly lower number of primary roots.

In June, cuttings treated with T_1 - IBA 1000 ppm for 45 seconds once again recorded more number of primary roots/ plant (8.6). T_6 - control like in previous months recorded the lowest number of primary roots/ plant (4.6).

4.1.25 Number of primary roots in runners in black pepper var. Panniyur 1 (Table 27)

In the month of May, cuttings treated with tender coconut water recorded the highest average number of primary roots/ plant (6.6). T_1 - IBA 1000 ppm (0.6), T_2 - cow dung slurry (1.4), T_4 - two per cent sugar (0.2), T_5 - charcoal paste (0.8) and T_6 - control (1.2) were on par with each other.

In the month of June all the treatments were on par with each other with T_3 - tender coconut water recorded the highest number of primary roots/ plant.

Once again in the months of July, August and September all the treatments were on par with each other.

In April, T_4 - two per cent sugar recorded the maximum number of primary roots/ plant.

In May T_6 - control recorded the highest number of primary roots/ plant (7.2) followed by T_1 - IBA 1000 ppm (6.4) and T_5 - charcoal paste (6.2).

In June, the highest number of primary roots/ plant was recorded in cuttings treated with T_5 - charcoal paste (3.4).

4.1.26 Comparative evaluation of the number of primary roots in orthotrops and runners in black pepper var. Panniyur 1 (Table 28)

In table 28, it is clear that when comparative evaluation was carried between orthotrops and runners, significant differences were observed among treatments with respect to the number of primary roots/ plant in black pepper var. Panniyur 1.

In May, significant differences were observed between orthotrops and runners in T_1 - IBA 1000 ppm, T_4 - two per cent sugar and T_5 - charcoal paste. In T_1 - IBA 1000 ppm orthotrops recorded an average of 8.4 primary roots/ plant whereas runners recorded 0.6 primary roots/ plant.

In T_4 - two per cent sugar and T_5 - charcoal paste orthotrops and runners recorded 3.60 & 0.20 and 4.60 & 0.80 primary roots/ plant respectively.

In June significant differences were observed in almost all treatments with the exception of T_3 - tender coconut water and T_4 - two per cent sugar.

In T_1 - IBA 1000 ppm (4.40), T_2 - cow dung slurry (4.20), T_5 - charcoal paste (8.60) and T_6 - control (4.20) orthotrops produced more number of primary roots/ plant when compared to runners T_1 - IBA 1000 ppm (0.00), T_2 - cow dung slurry (0.40), T_5 - charcoal paste (0.60) and T_6 - control (0.40).

In April, significant differences were observed among all treatments when orthotrops and runners were compared. It is obvious that orthotrops recorded more number of primary roots/ plant than runners in all treatments.

Orthotrops and runners recorded in treatments, T_1 - IBA 1000 ppm (11.0 & 2.20), T_2 - cow dung slurry (4.60 & 2.40), T_3 - tender coconut water (7.40 & 3.00), T_4 - two per cent sugar (7.40 & 3.80), T_5 - charcoal paste (6.20 & 3.60) and T_6 - control (5.60 & 2.20) primary roots/ plant respectively.

In May, no significant difference was observed between orthotrops and runners whereas in June there were significant differences among all treatments applied.

Orthotrops (8.60) recorded the highest number of primary roots/ plant in cuttings treated with T_1 - IBA 1000 ppm whereas runners (3.60) recorded the highest number of primary roots/ plant in cuttings treated with two per cent sugar.

4.2 EXPERIMENT II: EVALUATION OF ROOTED ORTHOTROPS AND RUNNERS IN THE FIELD

Three months old rooted cuttings from experiment 1 were transferred to the field on the 8th of June 2013.

Observations such as monthly height increment, height at production of first lateral, number of laterals per plant, number of nodes per plant, internodal length, number of leaves per lateral, plant spread (E - W and N - S) were taken at a monthly interval from July 2013 to March 2014.

The results obtained on the rooted orthotrops and runners during the experiment are furnished below in Tables 29 - 37.

Table 26. Effect of different treatments on the number of primary roots in orthotrops in black pepper var. Panniyur 1

Treatment	February	March	April	May	June
T_1	8.40^{a} (2.95)	4.40^{ab} (2.16)	11.00^{a} (3.33)	5.20^{a} (2.37)	8.60^{a} (3.01)
T_2	4.40^{b} (2.07)	4.20^{ab} (2.05)	4.60^{b} (2.25)	4.80^{a} (2.30)	5.20^{bc} (2.38)
T_3	4.80^{ab} (2.25)	1.60^{bc} (1.26)	7.40^{ab} (2.77)	3.00^{b} (1.78)	7.00^{ab} (2.70)
T_4	3.60^{b} (1.99)	1.40^{c} (1.11)	7.40^{ab} (2.77)	5.00^{a} (2.32)	6.40^{bc} (2.61)
T_5	4.60^{ab} (2.18)	8.60^{a} (2.97)	6.20^{b} (2.57)	5.40^{a} (2.42)	7.00^{ab} (2.73)
T_6	2.60^{b} (1.73)	4.20^{ab} (2.16)	5.60^{b} (2.46)	5.20^{a} (2.38)	4.60^{c} (2.25)

The figures in parenthesis are SQRT transformed values

Table 27. Effect of different treatments on the number of primary roots in runners in black pepper var. Panniyur 1

Treatment	February	March	April	May	June
T_1	0.60^{b} (0.93)	0.00^{a} (0.70)	2.20^{a} (1.50)	6.40^{a} (2.60)	3.00^{a} (1.78)
T_2	1.40^{b} (1.20)	0.40^{a} (0.88)	2.40^{a} (1.63)	$5.40a^{b}$ (2.41)	2.80^{a} (1.80)
T_3	6.60^{a} (2.63)	1.00^{a} (1.09)	3.00^{a} (1.84)	4.40^{ab} (2.07)	2.60^{a} (1.74)
T_4	0.20^{b} (0.81)	0.60^{a} (0.98)	3.80^{a} (2.04)	2.80^{b} (1.69)	3.60^{a} (2.01)
T_5	0.80^{b} (1.04)	0.60^{a} (0.98)	3.60^{a} (2.02)	6.20^{a} (2.55)	3.40^{a} (1.96)
T_6	1.20^{b} (1.21)	0.40^{a} (0.88)	2.20^{a} (1.58)	7.20^{a} (2.75)	3.20^{a} (1.92)

The figures in parenthesis are SQRT transformed values

Table 28. Comparative evaluation of the effect of different treatments on the number of primary roots in orthotrops and runners in black pepper var. Panniyur 1

Treatments	February			March			April			May			June		
	Orthotrops	Runners	t	Orthotrops	Runners	t	Orthotrops	Runners	t	Orthotrops	Runners	t	Orthotrops	Runners	t
T_1	8.40 (3.20)	0.60 (1.34)	5.01 *	4.40 (2.40)	0.00 (0.00)	4.05 *	11.0 (5.24)	2.20 (2.04)	3.49 *	5.20 (1.09)	6.40 (2.07)	1.14 NS	8.60 (1.34)	3.00 (1.87)	5.43 *
T_2	4.40 (3.91)	1.40 (2.19)	1.49 NS	4.20 (2.48)	0.40 (0.89)	3.21 *	4.60 (0.54)	2.40 (1.51)	3.05 *	4.80 (0.44)	5.40 (1.51)	0.84 NS	5.20 (0.83)	2.80 (0.83)	4.53 *
T_3	4.80 (2.28)	6.60 (2.30)	1.24 NS	1.60 (2.30)	1.00 (1.73)	0.46 NS	7.40 (2.88)	3.00 (1.22)	3.14 *	3.00 (1.73)	4.40 (3.9)	0.73 NS	7.00 (2.44)	2.60 (0.89)	3.77 *
T_4	3.60 (1.51)	0.20 (0.44)	4.80 *	1.40 (3.13)	0.60 (0.89)	0.54 NS	7.40 (2.88)	3.80 (1.64)	2.42 *	5.00 (1.58)	2.80 (2.38)	1.71 NS	6.40 (1.67)	3.60 (0.89)	3.30 *
T_5	4.60 (2.50)	0.80 (1.30)	3.00 *	8.60 (3.57)	0.60 (0.89)	4.85 *	6.20 (1.48)	3.60 (0.54)	3.67 *	5.40 (1.14)	6.20 (2.38)	0.67 NS	7.00 (0.70)	3.40 (0.89)	7.06 *
T_6	2.60 (1.14)	1.20 (1.30)	1.80 NS	4.20 (0.83)	0.40 (0.89)	6.93 *	5.60 (0.89)	2.20 (1.30)	4.80 *	5.20 (0.83)	7.20 (1.92)	2.13 NS	4.60 (0.54)	3.20 (0.44)	4.42 *

The figures in parenthesis are standard deviation values

4.2.1 July observations on three months old rooted orthotrops and runners in field var. Panniyur 1 (Table 29)

In table 29, no significant differences were noticed between orthotrops and runners when all the parameters namely monthly height increment, number of nodes/ plant and internodal length were evaluated.

4.2.2 August observations on three months old rooted orthotrops and runners in field var. Panniyur 1 (Table 30)

There was no significant difference between orthotrops and runners when monthly height increment and number of nodes/ plant were observed but in the case of internodal length there were significant differences between both orthotrops (1.84 cm) and runners (1.64 cm).

4.2.3 September observations on three months old rooted orthotrops and runners in field var. Panniyur 1 (Table 31)

Once again in the month of September no significant differences were seen between orthotrops and runners with regards to monthly height increment and the number of nodes per plant.

There were significant differences between orthotrops and runners with respect to internodal length with orthotrops recording 2.93 cm and runners 2.45 cm respectively.

4.2.4 October, November and December observations on three months old rooted orthotrops and runners in field var. Panniyur 1(Table 32 - 34)

Similar trend seen in August and September was noticed in October (Table 32), November (Table 33) and December (Table 34) 2013 with no significant differences between orthotrops and runners for monthly height increment and number of nodes/ plant but significant difference was quite evident when internodal length was statistically analyzed.

In the month of October orthotrops recorded an internodal length of 3.95 cm whereas runners 3.40 cm.

In the month of November orthotrops recorded an internodal length of 5.98 cm whereas runners 5.26 cm.

In the month of December orthotrops recorded an internodal length of 4.90 cm whereas runners 4.47 cm.

4.2.5 January observation on three months old rooted orthotrops and runners in field var. Panniyur 1 (Table 35)

From the table 35, significant differences could be noticed between orthotrops and runners with regards to plant spread and internodal length.

Runners recorded a plant spread of 23.88 cm in contrast to a spread of 16.07 cm for orthotrops. A reversal of the situation with a significantly higher internodal length of 7.01 cm was noticed for orthotrops with only an internodal length of 6.34 cm for runners.

4.2.6 February observation on three months old rooted orthotrops and runners in field var. Panniyur 1 (Table 36)

In February 2014, significant difference were noticed between orthotrops and runners with respect to height of production of first lateral, plant spread (E - W), internodal length and number of leaves/ lateral.

Runners produced laterals at a height of 59.48 cm whereas orthotrops produced laterals at a much lower height (35.73 cm).

In the case of plant spread (E - W) runners were far more superior to orthotrops with 31.60 cm and 25.83 cm respectively. The observations were recorded in plants less than one year old hence the spread could be recorded only in one direction due to lack of sufficient growth.

It was observed that orthotrops (8.03 cm) exhibit longer internodal length when compared to runners (7.50 cm). Statistical analysis also proved that the mean number of leaves/ plant is higher in orthotrops (6.59) than runners (4.72).

4.2.7 March observation on three months old rooted orthotrops and runners in field var. Panniyur 1 (Table 37)

Statistical analysis of March data showed that significant differences existed between orthotrops and runners with respect to height at production of first lateral, plant spread (E - W), number of laterals/ plant and number of leaves/ lateral.

Laterals were produced from a lower height in orthotrops (39.21 cm) when compared to runners (69.28 cm). Plant spread was more in runners (43.08 cm) than orthotrops (34.80 cm).

Runners (3.20) produced more number of laterals/ plant than orthotrops (2.14). More number of leaves/ lateral was noticed in orthotrops (8.50) compared to runners (6.40).

4.3 EXPERIMENT III: TRAINING OF VINES

The results obtained on pruning, tipping and lowering of black pepper vines during the experiment are furnished below.

4.3.1 Pruning six months after planting

The data on the effect of pruning black pepper vines six months after planting are presented in tables 38 to 41. Six months pruning was done on the 4th of December 2012 and observations were recorded at two months interval.

4.3.1.1 Orthotropic shoots produced when pruning was done six months after planting var. Panniyur 1 (Table 38)

It is quite evident from table 38 that unpruned plants produced more number of orthotropic shoots when compared with pruned plants in var. Panniyur 1.

The highest number of orthotropic shoots/ plant was observed in the month of February with unpruned Panniyur 1 recording an average of 7.5 orthotropic shoots/ plant and pruned plants recorded 6.1/ plant.

Table 29 Observations of rooted orthotrops and runners one month after field planting var. Panniyur 1

Parameters	Orthotrops		Runners		t value
	Mean	SE	Mean	SE	
Plant height (cm)	14.30	1.08	14.66	1.96	1.77 NS
Number of nodes/ plant	4.139	0.28	3.75	0.39	0.803 NS
Internodal length (cm)	1.093	0.019	1.675	0.460	1.696 NS

Table 30 Observations of rooted orthotrops and runners two months after field planting var. Panniyur 1

Parameters	Orthotrops		Runners		t value
	Mean	SE	Mean	SE	
Plant height (cm)	22.13	1.25	23.58	2.95	0.523 NS
Number of nodes/ plant	4.90	0.31	4.66	0.45	0.449 NS
Internodal length (cm)	1.84	0.017	1.65	0.038	5.023 **

Table 31 Observations of rooted orthotrops and runners three months after field planting var. Panniyur 1

Parameters	Orthotrops		Runners		t value
	Mean	SE	Mean	SE	
Plant height (cm)	32.32	1.41	33.95	3.89	0.473 NS
Number of nodes/ plant	5.46	0.307	5.00	0.421	0.898 NS
Internodal length (cm)	2.93	0.025	2.45	0.064	8.087 **

Table 32 Observations of rooted orthotrops and runners four months after field planting var. Panniyur

Parameters	Orthotrops		Runners		t value
	Mean	SE	Mean	SE	
Plant height (cm)	52.30	1.65	52.04	4.47	0.065 NS
Number of nodes/ plant	6.74	0.28	6.50	0.43	0.487 NS
Internodal length (cm)	3.95	0.02	3.40	0.05	10.099 **

Table 33 Observations of rooted orthotrops and runners five months after field planting var. Panniyur 1

Parameters	Orthotrops		Runners		t value
	Mean	SE	Mean	SE	
Plant height (cm)	74.86	2.94	75.70	4.62	0.162 NS
Number of nodes/ plant	11.06	0.43	10.79	0.51	0.401 NS
Internodal length (cm)	5.98	0.02	5.26	0.05	13.334 **

Table 34 Observations of rooted orthotrops and runners six months after field planting var. Panniyur 1

Parameters	Orthotrops		Runners		t value
	Mean	SE	Mean	SE	
Plant height (cm)	63.97	2.78	64.58	4.64	0.119 NS
Number of nodes/ plant	9.25	0.40	8.62	0.47	0.976 NS
Internodal length (cm)	4.90	0.02	4.47	0.05	8.436 **

Table 35 Growth characters of rooted orthotrops and runners seven months after field planting var. Panniyur 1

Parameters	Orthotrops		Runners		t value
	Mean	SE	Mean	SE	
Plant height (cm)	82.66	2.92	83.64	4.52	0.18 NS
Height at production of first lateral (cm)	32.73	3.70	47.60	7.78	1.93 **
Plant spread (E-W) (cm)	16.07	0.60	23.88	0.44	9.06 **
Number of laterals/ plant	1.28	0.16	1.32	0.30	0.10 NS
Number of nodes/ plant	13.40	0.44	12.92	0.47	0.70 NS
Internodal length (cm)	7.01	0.26	6.34	0.46	13.47 **
Number of leaves/ lateral	4.71	0.52	3.88	0.61	1.00 NS

Table 36 Growth characters of rooted orthotrops and runners eight months after field planting var. Panniyur 1

Parameters	Orthotrops		Runners		t value
	Mean	SE	Mean	SE	
Plant height (cm)	92.64	2.97	94.16	4.57	0.29 NS
Height at production of first lateral (cm)	35.73	3.32	59.48	6.73	3.52 **
Plant spread (E-W) (cm)	25.83	0.71	31.60	0.27	6.07 **
Number of laterals/ plant	1.57	0.16	1.96	0.34	1.14 NS
Number of nodes/ plant	15.33	0.47	15.24	0.507	0.12 NS
Internodal length (cm)	8.03	0.02	7.50	0.06	9.00 **
Number of leaves/ lateral	6.59	0.57	4.72	0.51	2.21 *

Table 37 Growth characters of rooted orthotrops and runners nine months after field planting var. Panniyur 1

Parameters	Orthotrops		Runners		t value
	Mean	SE	Mean	SE	
Plant height (cm)	102.02	3.48	109.44	4.46	1.30 NS
Height at production of first lateral (cm)	39.21	2.79	69.28	5.15	5.59 **
Plant spread (E-W) (cm)	34.80	0.87	43.08	0.48	6.87 **
Number of laterals/ plant	2.14	0.17	3.20	0.33	3.11 **
Number of nodes/ plant	18.95	0.45	20.16	0.58	1.62 NS
Internodal length (cm)	9.06	0.22	9.01	0.33	1.37 NS
Number of leaves/ lateral	8.50	0.57	6.40	0.41	2.59 *

4.3.1.2 Orthotropic shoots produced when pruning was done six months after planting var. Panniyur 2 (Table 39)

Data furnished in table 39 show that unpruned plants recorded more number of orthotropic shoots than pruned plants in var. Panniyur 2.

The highest number of orthotropic shoots/ plant was observed in the month of February with unrpuned Panniyur 1 recording an average of 9.2 orthotropic shoots/ plant and pruned plants recorded 7.7/ plant.

The least number of orthotropic shoots was observed in the month of April with unpruned plants recording 2.7 and pruned plants 1.9 shoots/ plant.

4.3.1.3 Six months pruning on various morphological characters in black pepper var. Panniyur 1 & 2 (Tables 40 - 41)

In tables 40 - 41 it was observed that the height at production of first lateral in both Panniyur 1 and Panniyur 2 was much lower in pruned plants when compared to unpruned plants.

Pruned plants in var. Panniyur 1 recorded an average height of 62.6 cm whereas unpruned plants in var. Panniyur 1 recorded 72.51 cm in the month of February.

Pruned plants in var. Panniyur 2 recorded an average height of 62.6 cm whereas unpruned plants in var. Panniyur 2 recorded 75.02 cm in the month of February.

A similar trend was seen in the month of February when the number of leaves/ plant was observed in both pruned and unpruned Panniyur 1 and Panniyur 2.

Contrastingly in both Panniyur 1 and Panniyur 2, unpruned plants recorded more number of lateral/ plant and plant spread when compared to the pruned plants.

The highest number of laterals/ plant in unpruned plants var. Panniyur 1 was recorded in the month of February (15.50). In pruned plants var. Panniyur 1 the highest number of laterals/ plant was recorded in the month of August (9.00).

The highest plant spread in unpruned plants var. Panniyur 1 was recorded in the month of February (15.15 cm). In pruned plants var. Panniyur 1, the highest plant spread was recorded in the month of August (6.00 cm).

The highest number of laterals/ plant in unpruned plants var. Panniyur 2 was recorded in the month of February (12.25). In pruned plants var. Panniyur 2 the highest number of laterals/ plant was recorded in the month of December (10.65).

The highest plant spread in unpruned plants var. Panniyur 2 was recorded in the month of August (15.35 cm). In pruned plants var. Panniyur 2, the highest plant spread was recorded in the month of February (7.80 cm).

4.3.2 Pruning ten months after planting (May - June)

The data on the effect of pruning black pepper vines ten months after planting are presented in tables 42 - 45. Ten months pruning was done on the 10th of June 2013 and observations were recorded at monthly interval.

4.3.2.1 Orthotropic shoots produced when pruning was done ten months after planting var. Panniyur 1 (Table 42)

It is quite apparent that when pruning was done ten months after planting there was no significant difference between pruned and unpruned Panniyur 1 with respect to the number of orthotropic shoots produced in the month of August 2013 to February 2014.

However, in the month of March significant difference was observed between pruned and unpruned Panniyur 1. Pruned plants produced an average of 9.7 orthotropic shoots/ plant and unpruned plants produced 11.6 orthotropic shoots/ plant.

Table 38 Orthotropic shoots produced when pruning was done six months after planting var. Panniyur 1

Months	Number of orthotropic shoot produced in pruned plants	Number of orthotropic shoot produced in unpruned plants	$Z^{\dagger}$ statistic based on Mann Whitney U test
April	2.2 (7.50)	2.8 (13.50)	2.61 NS
June	3.2 (7.00)	4.2 (14.30)	2.84 *
August	4.2 (6.70)	5.4 (14.30)	3.02 *
October	4.7 (6.75)	6.1 (14.25)	2.96 *
December	4.8 (6.55)	6.1 (14.45)	3.14 *
February	6.1 (6.50)	7.5 (14.50)	3.15 *

$Z^{\dagger}$ value computed for Mann - Whitney U statistic
The figures in parenthesis are standard mean rank values

Table 39 Orthotropic shoots produced when pruning was done six months after planting in var. Panniyur 2

Months	Number of orthotropic shoot produced in pruned plants	Number of orthotropic shoot produced in unpruned plants	$Z^{\dagger}$ statistic based on Mann Whitney U test
April	1.9 (6.85)	2.7 (14.15)	3.20 *
June	2.3 (6.10)	3.6 (14.90)	3.52 *
August	3.9 (6.35)	5.5 (14.65)	3.24 *
October	4.7 (6.50)	6.3 (14.50)	3.11 *
December	6.2 (8.25)	7.3 (12.75)	1.74 NS
February	7.7 (7.60)	9.2 (13.40)	2.28 *

$Z^{\dagger}$ value computed for Mann - Whitney U statistic
The figures in parenthesis are standard mean rank values

Table 40 Effect of six months pruning on various morphological characters in black pepper var. Panniyur 1

Months	Height at production of first lateral (cm)			Number of laterals/ plant			Plant spread E-W (cm)			Number of leaves/ lateral		
	Pruned plants	Unpruned plants	z†	Pruned plants	Unpruned plants	z†	Pruned plants	Unpruned plants	z†	Pruned plants	Unpruned plants	z†
August	5.60 (62.6)	15.40 (72.51)	3.714*	9.00 (1.1)	12.00 (1.4)	1.510 NS	6.00 (12.3)	15.00 (18.2)	3.426*	15.20 (4.1)	5.80 (2.2)	3.663*
October	5.60 (62.6)	15.40 (72.51)	3.714*	7.70 (1.3)	13.30 (2)	2.339*	5.55 (14.8)	15.45 (22.5)	3.757*	14.75 (4.8)	6.25 (3.2)	3.371*
December	5.60 (62.6)	15.40 (72.51)	3.714*	7.45 (2.2)	13.55 (3.1)	2.471*	5.90 (20.3)	15.10 (24.5)	3.505*	15.20 (6.3)	5.80 (4.6)	3.688*
February	5.60 (62.6)	15.40 (72.51)	3.714*	5.50 (2.7)	15.50 (4.7)	3.963*	5.85 (21.1)	15.15 (28.3)	3.580*	15.10 (7.2)	5.90 (5.8)	3.707*

The figures in parenthesis are average values of each parameter
Mann - Whitney U statistic

Table 41 Effect of six months pruning on various morphological characters in black pepper var. Panniyur 2

Months	Height at production of first lateral (cm)			Number of laterals/ plant			Plant spread E-W (cm)			Number of leaves/ lateral		
	Pruned plants	Unpruned plants	z†	Pruned plants	Unpruned plants	z†	Pruned plants	Unpruned plants	z†	Pruned plants	Unpruned plants	z†
August	5.50 (62.6)	15.50 (75.02)	3.782*	9.00 (1.1)	12.00 (1.4)	1.510 NS	5.65 (13.9)	15.35 (20.3)	3.696*	15.40 (5)	5.60 (2.5)	3.819*
October	5.50 (62.6)	15.50 (75.02)	3.782*	9.90 (1.6)	11.10 (1.8)	0.503 NS	5.80 (19.1)	15.20 (24.6)	3.572*	15.10 (5.6)	5.90 (3.5)	3.580*
December	5.50 (62.6)	15.50 (75.02)	3.782*	10.65 (2.7)	10.35 (2.7)	0.132 NS	6.90 (25.1)	14.10 (28.3)	2.749*	15.30 (6.8)	5.70 (4.6)	3.715*
February	5.50 (62.6)	15.50 (75.02)	3.782*	8.75 (3.5)	12.25 (4)	1.440 NS	7.80 (32.9)	13.20 (35.6)	2.057*	15.20 (8.5)	5.80 (6.2)	3.642*

The figures in parenthesis are average values of each parameter
Mann - Whitney U statistic

4.3.2.2 Orthotropic shoots produced when pruning was ten months year after planting var. Panniyur 2 (Table 43)

In table 43, according to statistical analysis of data, when pruning was ten months year after planting there was no significant difference between pruned and unpruned Panniyur 2 with respect to the number of orthotropic shoots produced in the months of August, September, October, November, January, February and March.

In the month of December significant difference was noticed between pruned and unpruned Panniyur 2. Pruned plants produced an average of 5.75 orthotropic shoots/ plant and unpruned plants produced an average of 5.2 orthotropic shoots/ plant.

4.3.2.3 Ten months pruning on various morphological characters in black pepper var. Panniyur 1 (Table 44)

In the months of March, the height at production of first lateral recorded in pruned Panniyur 1 was 60.4 cm whereas unpruned Panniyur 1 recorded 69.2 cm.

Also in the month of March it was quite noticeable that when pruned and unpruned Panniyur 1 was evaluated, unpruned plants recorded more number of laterals than pruned plants. Pruned and unpruned Panniyur 1 recorded an average of 2.3 and 2.4 laterals/ plant respectively.

Unpruned plants recorded a higher plant spread of 27 cm compared to pruned plants (19.8 cm) in the month of March.

Observations carried out in March showed that pruned plants recorded the highest number of leaves/ lateral (7.3) compared to unpruned plants 6.8.

4.3.2.4 Ten months pruning on various morphological characters in black pepper var. Panniyur 2 (Table 45)

In March, the height at production of first lateral recorded in pruned Panniyur 2 was 59.9 cm and unpruned Panniyur 2 recorded 67.6 cm.

It was quite evident that unpruned plants produced more number of laterals than pruned plants in the month of March. Pruned and unpruned Panniyur 2 recorded an average of 2.6 and 2.1 laterals/ plant respectively.

Unpruned plants recorded a higher plant spread of 27.5 cm compared to pruned plants (21.5 cm) in the month of March.

Pruned plants recorded the highest average number of leaves/ lateral (7.3) compared to unpruned plants 6.8 in observations carried out in the month of March.

4.3.3 Tipping (removing terminal bud) immediately after planting

The data on the effect of tipping black pepper vines immediately after planting are presented in tables 46, 47 & 48.

4.3.3.1 Orthotropic shoots produced when tipping was done immediately after planting var. Panniyur 1 (Table 46)

In table 46 it is quite obvious that significant differences were noticed between tipped Panniyur 1 and control with respect to the number of orthotropic shoots produced when tipping was done immediately after planting.

The number of orthotropic shoots produced was significantly higher in control plants compared to plant in which tipping was done. The trend continued eight months after planting.

In March the difference between plants in which tipping was done and control became insignificant.

Panniyur 1 in which tipping was done at the time of planting and control produced the highest average number of orthotropic shoots in the month of March, with Panniyur 1 recording 11.8 and control 13 shoots respectively.

Table 42 Orthotropic shoots produced when pruning was done ten months after planting var. Panniyur 1

Months	Number of orthotropic shoot produced in pruned plant	Number of orthotropic shoot produced in unpruned plant	$Z^{\dagger}$ statistic based on Mann Whitney U test
August	1.3 (9.35)	1.5 (11.65)	1.00 NS
September	1.4 (8.95)	1.8 (12.05)	1.30 NS
October	2.5 (10.00)	2.3 (11.00)	0.39 NS
November	2.7 (9.70)	3 (11.30)	0.62 NS
December	4.6 (9.45)	5.0 (11.55)	0.81 NS
January	6.6 (8.45)	7.8 (12.55)	1.59 NS
February	8.4 (8.00)	9.9 (13.00)	1.95 NS
March	9.7 (6.95)	11.6 (14.05)	2.74 **

The figures in parenthesis are mean rank values

$Z^{\dagger}$ value computed for Mann - Whitney U statistic

Table 43 Orthotropic shoots produced when pruning was ten months after planting var. Panniyur 2

Months	Number of orthotropic shoot produced in pruned plant	Number of orthotropic shoot produced in unpruned plant	$Z^{\dagger}$ statistic based on Mann Whitney U test
August	1.5 (10.50)	1.8 (10.50)	0.00 NS
September	1.6 (10.50)	1.9 (10.50)	0.00 NS
October	2.4 (11.25)	2.6 (9.75)	0.59 NS
November	2.6 (10.35)	3.1 (10.65)	0.12 NS
December	5.75 (12.61)	5.2 (7.65)	1.97 *
January	8 (12.15)	7.9 (8.85)	1.29 NS
February	10.4 (12.70)	9.9 (8.30)	1.73 NS
March	12.1 (12.55)	11.7 (8.45)	1.65 NS

The figures in parenthesis are mean rank values

$Z^{\dagger}$ value computed for Mann - Whitney U statistic

Table 44 Effect of pruning ten months after planting on morphological characters in black pepper var. Panniyur 1

Parameters	February			March		
	Pruned plant	Unpruned plant	Z†	Pruned plant	Unpruned plant	Z†
Height at production of first lateral (cm)	60.4 (5.55)	69.2 (15.45)	3.755*	60.4 (5.55)	69.2 (15.45)	3.75*
Number of laterals/ plant	0.9 (10.00)	1 (11.00)	0.609 NS	2.3 (10.20)	2.4 (10.80)	0.25 NS
Plant spread E - W (cm)	14.4 (5.50)	21.6 (15.50)	3.800*	19.8 (5.70)	27 (15.30)	3.66*
Number of leaves/ lateral	5.9 (13.80)	4.8 (7.20)	2.619 NS	7.3 (11.90)	6.8 (9.10)	1.12 NS

The figures in parenthesis are mean rank values

Table 45 Effect of pruning ten months after planting on morphological characters in black pepper var. Panniyur 2

Parameters	February			March		
	Pruned plant	Unpruned plant	Z†	Pruned plant	Unpruned plant	Z†
Height at production of first lateral (cm)	59.9 (5.50)	67.6 (15.50)	3.795*	59.9 (5.50)	67.6 (15.50)	3.79*
Number of laterals/ plant	0.9 (11.50)	0.7 (9.50)	1.090 NS	2.6 (12.40)	2.1 (8.60)	1.58 NS
Plant spread E - W (cm)	15 (5.50)	21.6 (15.50)	3.803*	21.5 (5.55)	27.5 (15.45)	3.77*
Number of leaves/ lateral	5.5 (10.95)	5.3 (10.05)	0.388 NS	7.3 (12.30)	6.8 (8.70)	1.46 NS

The figures in parenthesis are mean rank values

Plate 8. Pruning six months after planting var. Panniyur 1

Plate 9. Pruning six months after planting var. Panniyur 2

Plate 10. Pruning ten months after planting var. Panniyur 1

Plate 11. Pruning ten months after planting var. Panniyur 2

4.3.3.2 Effect of tipping on morphological characters in black pepper var. Panniyur 1 (Table 47)

The recorded height at production of first lateral was 91 cm in Panniyur 1 and 93 cm in control.

There were significant differences in plant spread in the months of December, January, February and March.

The highest plant spread of both untipped/ control and tipped Panniyur 1 were recorded in the month of March. The untipped plants recorded a plant spread of 36 cm whereas the tipped Panniyur 1 recorded a plant spread of 30 cm.

Both untipped/ control and tipped Panniyur 1 recorded the lowest plant spread in the month of December of 21 cm and 17 cm respectively.

4.3.3.3 Effect of tipping on number of laterals and leaves per laterals in black pepper var. Panniyur 1 (Table 48)

In table 48, it is quite evident that the untipped plants produced more number of laterals and leaves per lateral than the plants in which tipping was done. Untipped and tipped plants produced the highest number of laterals/ plant in the month of March. Untipped plants recoded an average of 5.7 laterals/ plant whereas tipped plants recorded and average of 5 laterals/ plant.

Both tipped and untipped plants recorded the highest number of leaves/ lateral in the month of March. Tipped plants recorded and average of 8.2 leaves/ lateral and untipped plants recorded an average of 9.1 leaves/ lateral.

4.3.3.4 Effect of tipping the plant three months after planting in black pepper var. Panniyur 1 (Tables 49 - 50)

In table 49, when tipping was carried out three months after planting the height at production of first lateral in tipped plants were 91.3 cm whereas in untipped plants it was 98.5 cm.

From January to March, untipped plants recorded more number of laterals/ plant than plants in which tipping was done. In March tipped plants recorded an average of 3.8 laterals/ plant whereas untipped plants recorded an average of 4.1 laterals/ plant.

Once again in March untipped plants recoded higher plant spread and number of leaves/ lateral. A plant spread of 29.25 cm was recorded in tipped plants and 33.3 cm in untipped plants. Tipped plants recorded an average of 8.25 leaves/ lateral and untipped plants recorded an average 9.3 leaves/ lateral.

In table 50, from January - June untipped plants recorded more number of orthotropic shoots/ plant when tipping was done three months after planting (August/ September 2013).

From the aforementioned, when tipping was carried out three months after planting there was no significant effect on number of laterals/ plant, plant spread, number of leaves/ plant and orthotropic shoots/ plant.

4.3.4 Lowering black pepper vines one year after planting

The data on the effect of lowering black pepper vines one year after planting (June 2013) are presented in tables 51 - 53.

4.3.4.1 Orthotropic shoots produced when black pepper vines were lowered one year after planting in var. Panniyur 1 (Table 51)

In the months of October, December, January, February and March there were significant differences between lowered and control plants with respect to the number of orthotropic shoots produced when black pepper vines were lowered one year after planting.

In the month of September no significant difference was noticeable between lowered and control plants.

Plants recorded an average of 1.5 orthotropic shoots/ plant and control recorded an average of 1 orthotropic shoot/ plant.

Table 46 Orthotropic shoots produced when tipping was done immediately after planting in black pepper var. Panniyur 1

Months	Number of orthotropic shoot produced in tipped plant	Number of orthotropic shoot produced in untipped plant	$Z^{\dagger}$ statistic based on Mann Whitney U test
August	1.3 (10.20)	2.1 (17.20)	2.567**
September	2.1 (10.37)	3.1 (16.95)	2.325*
October	2.7 (10.23)	4.2 (17.15)	2.365*
November	3.4 (9.47)	6.5 (18.30)	2.977**
December	6.1 (9.83)	8.4 (17.75)	2.682**
January	7.8 (10.35)	9.4 (16.95)	2.248*
February	10 (10.57)	11.8 (16.65)	2.058*
March	11.8 (11.37)	13 (15.45)	1.376 NS

$Z^{\dagger}$ value computed for Mann- Whitney U statistic

Table 47 Effect of tipping the plant immediately after planting on morphological characters in black pepper var. Panniyur 1

Parameters	December			January			February			March		
	Tipped plant	Untipped Plant	t	Tipped plant	Untipped plant	t	Tipped plant	Untipped plant	t	Tipped plant	Untipped plant	t
Height at production of first lateral (cm)	91.00	93.10	1.92 NS	91.00	93.10	1.92 NS	91.00	93.10	1.92 NS	91.00	93.10	1.92 NS
Plant spread E-W (cm)	17.93	21.00	6.94 **	22.46	25.700	7.78 **	26.00	31.10	13.78 **	30.00	36.00	15.76 **

Table 48 Effect of tipping the plant immediately after planting on number of laterals and leaves/ lateral in black pepper var. Panniyur 1

Parameters	December			January			February			March		
	Tipped plant	Untipped plant	$Z^{\dagger}$	Tipped plant	Untipped plant	$Z^{\dagger}$	Tipped plant	Untipped plant	$Z^{\dagger}$	Tipped plant	Untipped plant	$Z^{\dagger}$
Number of laterals/ plant	1.4 (10.90)	2 (16.15)	1.94 *	2.5 (11.17)	3.1 (15.75)	1.65 NS	3.6 (10.53)	4.5 (16.70)	2.16 *	5 (11.13)	5.7 (15.80)	1.62 NS
Number of leaves/ lateral	6.2 (10.90)	6.9 (16.15)	1.89 *	7 (11.00)	7.6 (16.00)	1.80 NS	7.8 (10.40)	8.6 (16.90)	2.31 *	8.2 (10.43)	9.1 (16.85)	2.29 *

$Z^{\dagger}$ value computed for Mann- Whitney U statistic

The figures in the parenthesis are mean rank values

Table 49 Effect of tipping the plant three months after planting on morphological characters in black pepper var. Panniyur 1

Parameters	January			February			March		
	Tipped plant	Untipped plant	$Z^{\dagger}$	Tipped plant	Untipped plant	$Z^{\dagger}$	Tipped plant	Untipped plant	$Z^{\dagger}$
Height at production of first lateral	91.3 (11.40)	98.5 (29.60)	4.96*	91.3 (11.40)	98.5 (29.60)	4.96*	91.3 (11.40)	98.5 (29.60)	4.96*
Number of laterals/ plant	1.4 (17.27)	1.8 (23.73)	1.93 NS	2.5 (18.13)	2.9 (22.88)	1.45 NS	3.8 (17.43)	4.1 (23.58)	1.76 NS
Plant spread E -W (cm)	17.9 (10.65)	21.4 (30.35)	5.40*	22.45 (12.53)	24.6 (28.48)	4.43*	29.25 (10.85)	33.3 (30.15)	5.26*
Number of leaves per lateral	6.3 (18.00)	6.9 (23.00)	1.48 NS	7.3 (19.58)	7.7 (21.43)	0. 57 NS	8.25 (13.50)	9.3 (27.50)	4.25*

$Z^{\dagger}$ value computed for Mann- Whitney U statistic
The figures in the parenthesis are mean rank values

Table 50 Effect of tipping the plant three months after planting on the number of orthotropic shoots/ plant in black pepper var. Panniyur 1

Parameters	January			February			March			April			May			June		
	Tipped plant	Untipped plant	$Z\dagger$	Tipped plant	Untipped plant	$Z^{\dagger}$	Tipped plant	Untipped plant	$Z^{\dagger}$	Tipped plant	Untipped plant	$Z^{\dagger}$	Tipped plant	Untipped plant	$Z^{\dagger}$	Tipped plant	Untipped plant	$Z^{\dagger}$
Number of orthotropic shoots/ plant	2.4 (16.93)	3 (24.08)	2.00*	2.9 (14.50)	4.7 (26.50)	3.29*	4.95 (17.98)	5.65 (23.03)	1.39 NS	6.45 (17.80)	7.1 (23.20)	1.50 NS	8.15 (18.60)	8.6 (22.40)	1.07 NS	9.95 (17.43)	10.7 (23.58)	1.70 NS

$Z^{\dagger}$ value computed for Mann- Whitney U statistic
The figures in the parenthesis are mean rank values

4.3.4.2 Orthotropic shoots produced when black pepper vines were lowered one year after planting in var. Panniyur 2 (Table 52)

In the months of December, January, February and March there were significant differences between lowered var. Panniyur 2 and control with respect to the number of orthotropic shoots produced when black pepper vines were lowered one year after planting.

In the months of September, October and November no significant difference was noticeable between lowered var. Panniyur 2 and control.

The highest number of orthotropic shoots in lowered and control plants were observed in the month of March with 10.2 and 6.7 respectively.

The lowest number of orthotropic shoots/ plant in lowered and control plants were observed in the month of September with 1.6 and 1.2 respectively.

4.3.4.3 Plant spread eight months after lowering black pepper vines in var. Panniyur 1 & 2 (Table 53)

When plant spread was observed eight months after lowering, significant difference was evident between Panniyur 1 and control and Panniyur 2 and control.

Lowered Panniyur 1 and control plants recorded a mean plant spread of 14.70 cm and 10.10 cm respectively.

Lowered Panniyur 2 and control recorded a mean plant spread of 16.50 cm and 13.20 cm respectively.

Table 51 Orthotropic shoots produced when black pepper vines were lowered one year after planting var. Panniyur 1

Months	Number of orthotropic shoot produced in lowered plant	Number of orthotropic shoot produced in control	$Z^{\dagger}$ statistic based on Mann Whitney U test
September	1.5 (11.90)	1 (9.10)	1.12 NS
October	2.9 (13.40)	1.8 (7.60)	2.40 *
November	3.4 (13.30)	2.4 (7.70)	2.26 *
December	5.9 (15.30)	3.1 (5.70)	3.74 *
January	7.1 (15.45)	3.9 (5.55)	3.84 *
February	8.5 (15.50)	4.9 (5.50)	3.87 *
March	10.2 (15.50)	6.2 (5.50)	3.85 *

$Z^{\dagger}$ value computed for Mann - Whitney U statistic

Table 52 Orthotropic shoots produced when black pepper vines were lowered one year after planting in var. Panniyur 2

Months	Number of orthotropic shoot produced in lowered plant	Number of orthotropic shoot produced in control	$Z^{\dagger}$ statistic based on Mann Whitney U test
September	1.6 (12.10)	1.2 (8.90)	1.44 NS
October	2.1 (12.25)	1.5 (8.75)	1.43 NS
November	2.3 (11.35)	2 (9.65)	0.67 NS
December	4.8 (14.30)	3.2 (6.70)	2.96 *
January	7 (15.25)	4.2 (5.75)	3.66 *
February	9 (15.45)	5.3 (5.55)	3.80 *
March	10.2 (15.50)	6.7 (5.50)	3.83 *

$Z^{\dagger}$ value computed for Mann - Whitney U statistic

Table 53 Plant spread eight months after lowering in black pepper var. Panniyur 1 and 2

Parameters	Panniyur 1		$Z^{\dagger}$ statistic based on Mann Whitney U test	Panniyur 2		$Z^{\dagger}$ statistic based on Mann Whitney U test
	Lowered	Control		Lowered	Control	
Plant spread (E-W) (cm)	14.70 (12.45)	10.10 (8.55)	1.486 *	16.50 (14.25)	13.20 (6.75)	2.861*

$Z^{\dagger}$ value computed for Mann - Whitney U statistic
The figures in parenthesis are mean rank values

Plate 12. Four months old tipped black pepper plant var. Panniyur 1

Plate 13. Four months old untipped black pepper plant var. Panniyur 1

Plate 14. One year old lowered black pepper plant var. Panniyur 1

Plate 15. One year old lowered black pepper plant var. Panniyur 2

Discussion

5. DISCUSSION

Black pepper (*Piper nigrum* L.) is a perennial climbing vine grown for its berries which are extensively used as spice and in medicine. Even though India is a major producer of black pepper, productivity is low compared to other pepper producing countries. In order to sustain the world market and to meet the domestic demand, we have to increase our pepper production by suitable management practices. The present investigations were carried out in the pepper research unit attached to the Department of Plantation Crops and spices, College of Horticulture, Kerala Agricultural University Main Campus, Vellanikkara during 2012 - 2014.

5.1 EXPERIMENT 1: ROOTING OF ORTHOTROPIC AND RUNNER SHOOTS

The data on the effect of different treatments on two to three node semi hard wood orthotropic and runner shoots of black pepper are discussed below under various headings.

5.1.1 Effect of different treatments on sprouting of orthotrops in black pepper var. Panniyur 1

In the month of February, T_3 - tender coconut water had significant effect on the number of cuttings sprouted 21 days after planting. 28 days after planting maximum sprouting was noticed in all treatments with the exception of control (Table 1). It could be observed that T_1 - IBA 1000 ppm for 45 seconds, T_2 - cow dung slurry, T_3 - tender coconut water, T_4 - two per cent sugar and T_5 - charcoal paste exerted significant effect on sprouting of orthotropic cuttings.

In the month of March, after perusing the analyzed data, maximum sprouting was evident in treatments T_2 - cow dung slurry and T_3 - tender coconut water 21 days after planting. Also in March maximum sprouting was observed in almost all treatments 28 days after planting (Table 2).

Like in the two previous months, in April also maximum sprouting of orthotropic cuttings was noticed in T_3 - tender coconut water 21 days after planting. Compared to the two previous months orthotropic cuttings showed a slight variation in sprouting with 90 percent cuttings sprouted in almost all treatments 28 days after planting.

However, maximum sprouting was achieved 35 days after planting in all the treatments including control (Table 3).

In May, T_5 - charcoal paste had maximum effect on sprouting of orthotropic shoots 21 days after planting. What is most conspicuous is that T_6- control showed maximum sprouting of cuttings 21 days after planting.

Favorable sprouting was also noticed in T_1 - IBA 1000 ppm for 45 seconds, T_3 - tender coconut water and T_4 - two per cent sugar 21 days after planting.

Once again in the month of May, statistical analysis of data confirmed approximately 90 per cent sprouting in almost all treatments including control 28 days after planting. Maximum sprouting in all treatments was achieved 35 days after planting (Table 4).

Contrary to previous months, in June maximum sprouting was noticed in cuttings treated with T_4 - two per cent sugar and T_5 - charcoal paste 21 days after planting. Maximum sprouting was observed in almost all treatments 28 days after planting (Table 5).

In February, March, April, May and June 90 -100 per cent sprouting was obtained in cuttings treated with T_1 - IBA 1000 ppm for 45 seconds, T_2 - cow dung slurry, T_3 - tender coconut water, T_4 - two per cent sugar and T_5 - charcoal paste 35 days after planting.

It can be concluded that throughout the experimental period initiation of sprouting was observed in 17 to 19 days in all treatments.Total number of cuttings sprouted in different treatments ranged from 7.0 to 10.0. The effect of different treatments in sprouting was varying in different months.T_2 _ cow dung slurry was the best treatment during February and March planting whereas T_3- tender coconut water and control were superior in April.

In May planting T_5- charcoal paste had 100 per cent sprouting. In June T_4- two per cent sugar and control were superior. Thus it can be seen that treatment effects are varying

in different months. The experiment will have to be repeated for two or more seasons before drawing up conclusions.

5.1.1.1 Effect of different treatments on root characters of orthotrops in black pepper var. Panniyur 1

As can be seen from tables 6 - 10 the different treatments for rooting of cuttings did not have any significant effect from February to June for length of primary roots, number of secondary roots (except in March) and weight and volume of roots. The only significant influence with respect to root characters was the superiority of IBA 1000 ppm in March 2013 in the number of secondary roots. This was not repeated in the other months.

The number of primary roots was maximum in cuttings treated with IBA 1000 ppm (T_1) during February, April, May and June planting. During March cuttings treated with charcoal paste (T_5) recorded maximum number of primary roots. Number of primary roots was lower in control during February, April and June planting while it was on par with T_1 - IBA 1000 ppm during May planting.

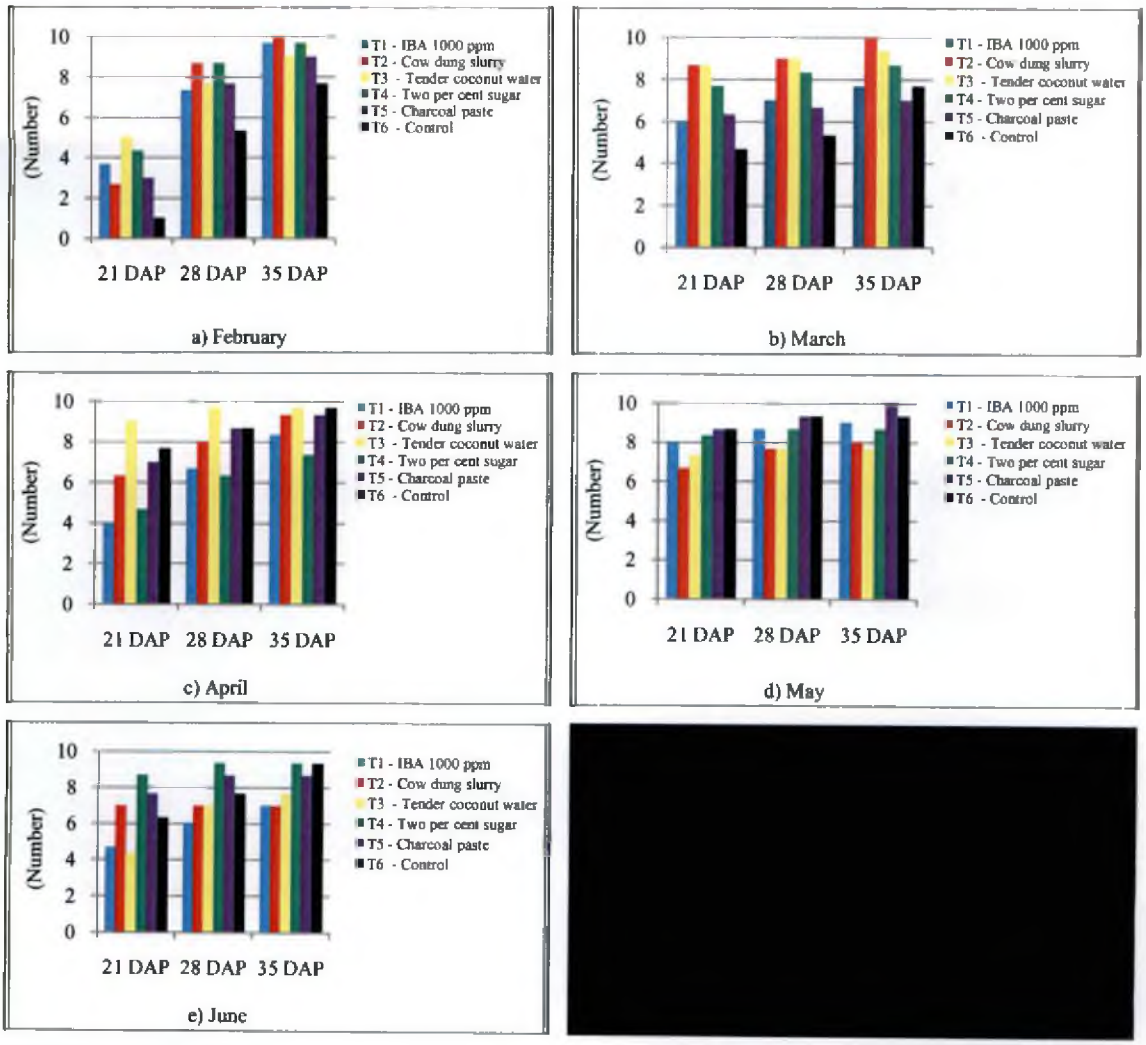
Sujatha and Nybe (2008) also reported that IBA treatment did not have significant effect on rooting of pepper cuttings of five varieties.

In the month of June, cuttings treated with charcoal paste produced the highest average number of primary roots/ plant (Table 26).

According to (Pillai *et al.*, 1982, Shridhar and Singh, 1990) dipping of nodal cuttings in 1000 ppm IBA for 45 seconds gave better rooting in polybag. Sarma *et al.*, (2013) reported that rooting percentage of orthotrops varied from 70 to 80 per cent.

Sujatha (1997) obtained 90 per cent rooting in two node cuttings dipped in 1000 ppm IBA and kept in a polytent with regular watering.

Sasikumar and George (1992) found that single node cuttings planted in polybags and kept in pits covered with polysheet with frequent water sprays gave above 90 per cent rooting without hormone treatment. Repeating trials for one or two more seasons will give a clearer picture.



*DAP: Days after planting

Fig.1. Effect of different treatments on sprouting of orthotrops in black pepper var. Panniyur 1

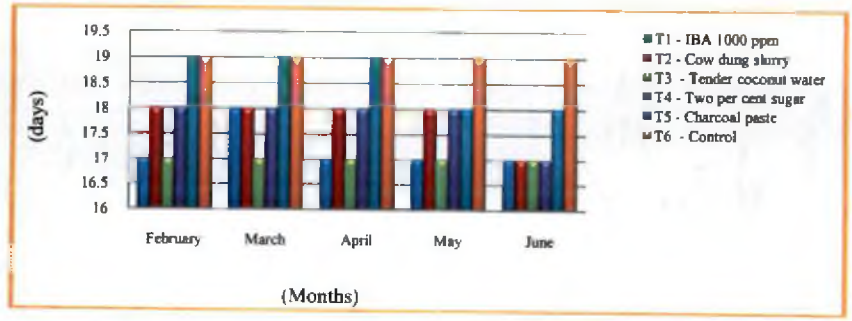
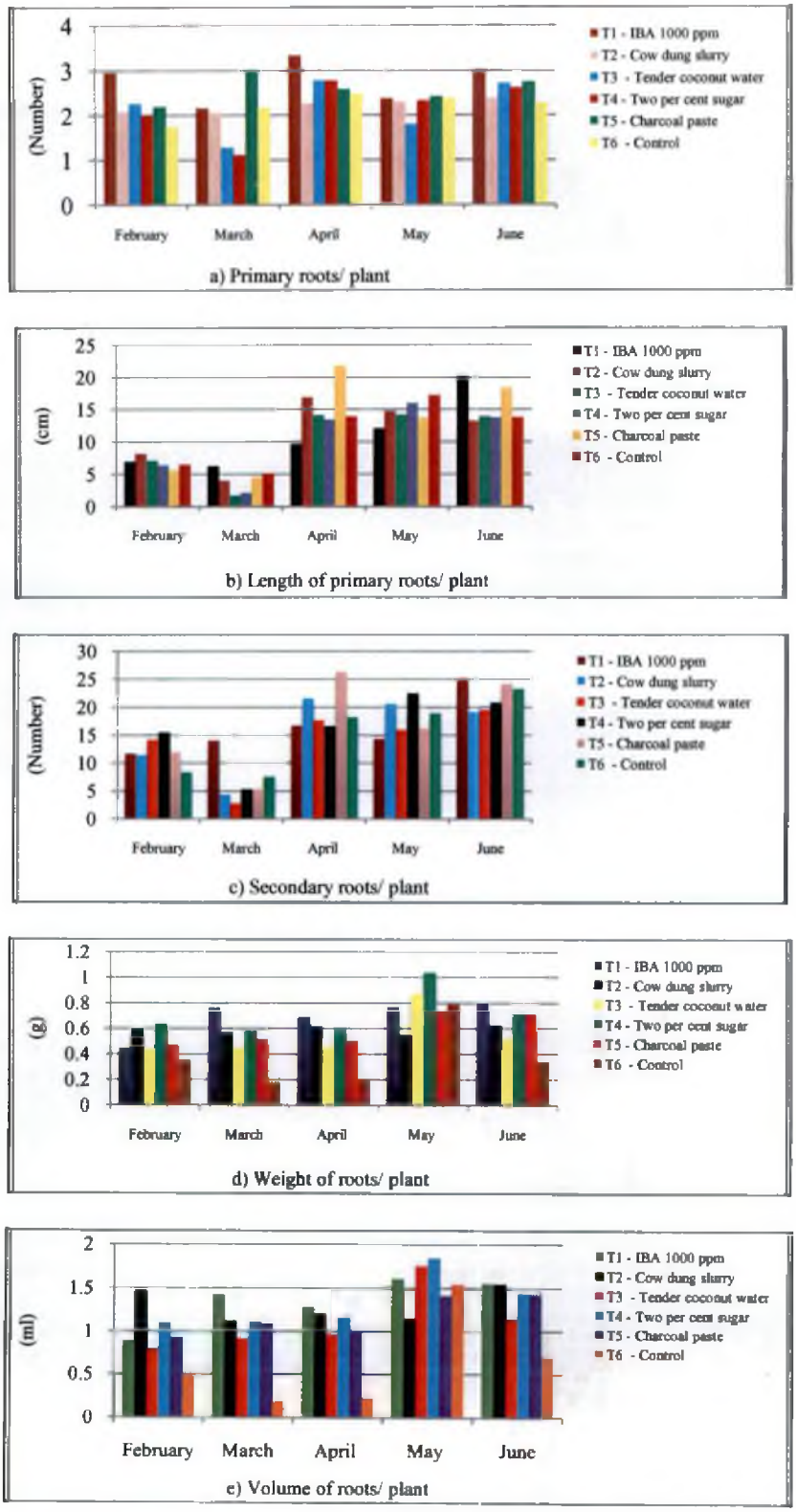


Fig.2. Days taken from planting to initiation of sprouting of orthotrops in black pepper var. Panniyur 1



g.3. Effect of different treatments on root characters of orthotrops in black pepper var. Panniyur 1

5.1.1.2 ROOTING OF RUNNER SHOOTS

In this experiment, six cuttings were planted per treatment at monthly intervals during February, March, April, May and June of 2013.

The cuttings were treated with T_1 - IBA 1000 ppm for 45 seconds, T_2 - cow dung slurry, T_3 - tender coconut water, T_4 - two per cent sugar and T_5 - charcoal paste before planting in polybags containing potting mixture.

The data on the effect of the different treatments on two to three node semi hard wood runner shoots of black pepper are discussed hereunder.

5.1.1.3 Effect of different treatments on sprouting of runners in black pepper var. Panniyur 1

After the monthly data was thoroughly scrutinized, it indicated that 90 per cent of runner shoots sprouted 21 days after planting in the months of March, April, May and June in all the treatments. February was the only month in which 50 per cent sprouting was observed 21 days after planting (Tables 11 - 15).

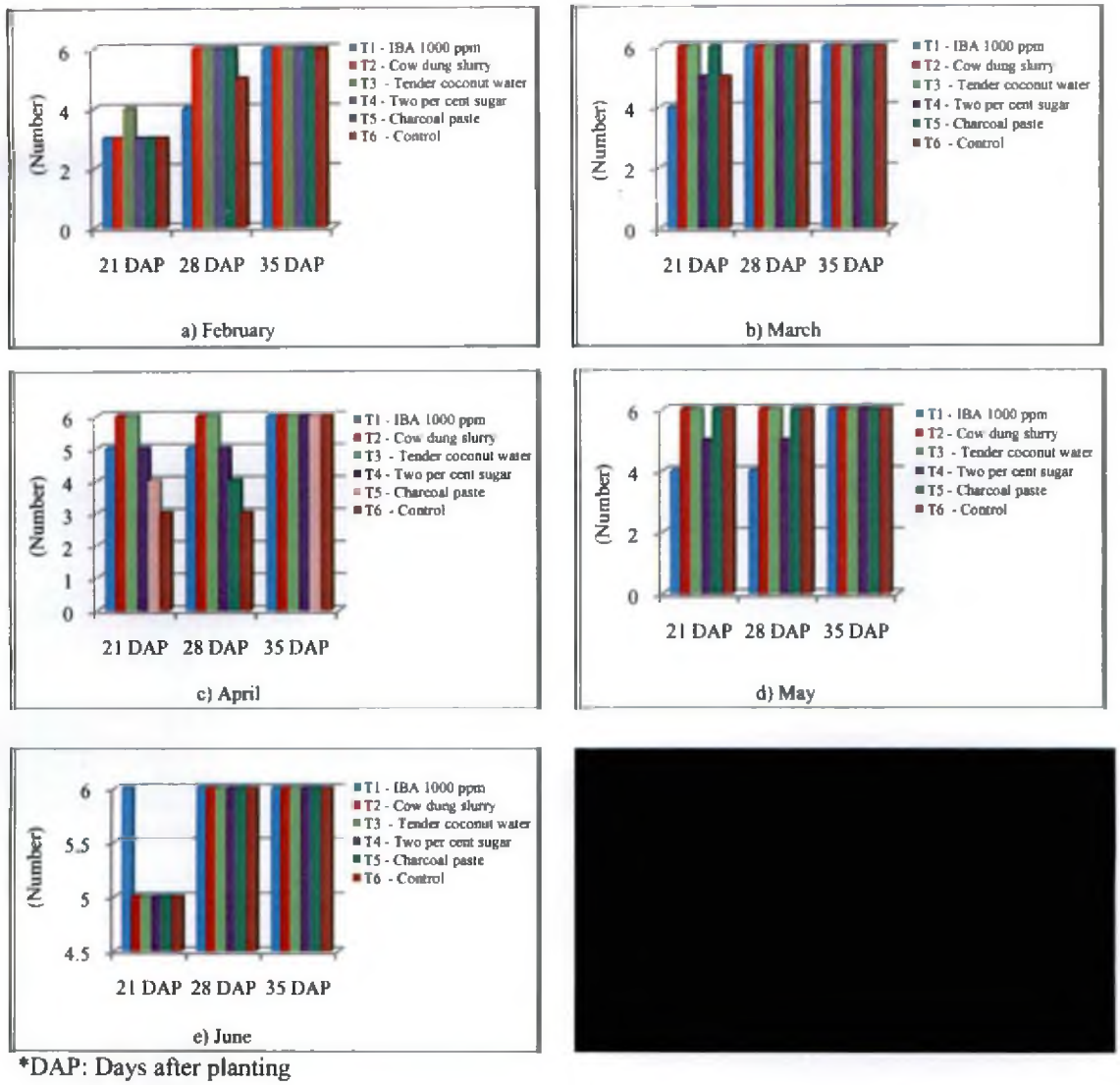
Yufdi and Hayani (1981) reported that a medium comprising of FYM - sand - soil (1:1:1) and soil - leaf mold (7:3) were reported to give better rooting.

As in the case of orthotrops, from February to June, the minimum time recorded from planting to initiation of sprouting was 17 days whereas the maximum time reaching up to 19 days.

Throughout the experiment period all the cuttings sprouted irrespective of treatments including control probably indicating that sprouting is independent of treatments imposed.

5.1.1.4 Effect of different treatments on root characters of runners in black pepper var. Panniyur 1

Like in orthotrops, observations carried out in February, March and May showed that, T_1 - IBA 1000 ppm for 45 seconds, T_2 - cow dung slurry, T_3 - tender coconut water, T_4 - two per cent sugar and T_5 - charcoal paste did not show significant effect on mean



*DAP: Days after planting

Fig.4. Effect of different treatments on sprouting of runners in black pepper var. Panniyur 1

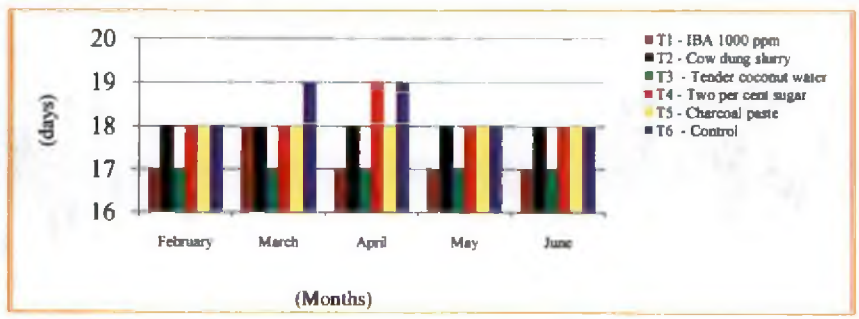


Fig.5. Days taken from planting to initiation of sprouting of runners in black pepper var. Panniyur 1

length of primary roots, mean number of secondary roots/ plant, weight of roots (g), volume of roots (ml) and number of leaves/ plant (Tables 16, 17 & 19).

Exception were seen in the months of April and June where T_3 - tender coconut water had significant effect on the mean number of secondary roots/ plant and number of leaves/ plant respectively (Tables 18 & 20).

Yufdi and Ernawati (1982) reported that cuttings treated with 25 per cent coconut water for 12 h increased root and shoot length, number of roots and shoot dry weight.

Analyzed data indicated that in the months of February and March cuttings treated with T_3 - tender coconut water recorded the highest average number of primary roots/ plant (Table 27). In February planting, control plants were statistically on par with T_1 - IBA 1000 ppm in the number of primary roots produced. In April T_4 - two per cent sugar recorded the highest number of primary roots/ plant.

In June the highest number of primary roots/ plant was recorded in cuttings treated with T_5 -charcoal paste (Table 27).

5.1.1.5 Comparative evaluation of the effect of different treatments on root character of orthotrops and runners in black pepper var. Panniyur 1

Comparative evaluation of the effect of the different treatments on root characters of orthotrops and runners in black pepper var. Panniyur 1 indicated that orthotrops were superior to runners (Tables 21 - 25).

From March - June orthotrops showed superiority in length of primary roots, number of secondary roots, weight of roots (g), volume of roots (ml), number of leaves/ plant. There was a slight variation in February where runners recorded higher weight and volume of roots than orthotrops.

Orthotrops also produced more number of primary roots/ plant in all the five months compared to runners (Table 28). Of all the treatments applied, T_1 - IBA 1000 ppm for 45 seconds proved to be the best with the highest number of primary roots/ plant.

The observations on rooting of orthotrops are contrary to the general feeling that orthotrops or top shoots are shy rooters compared to runners.

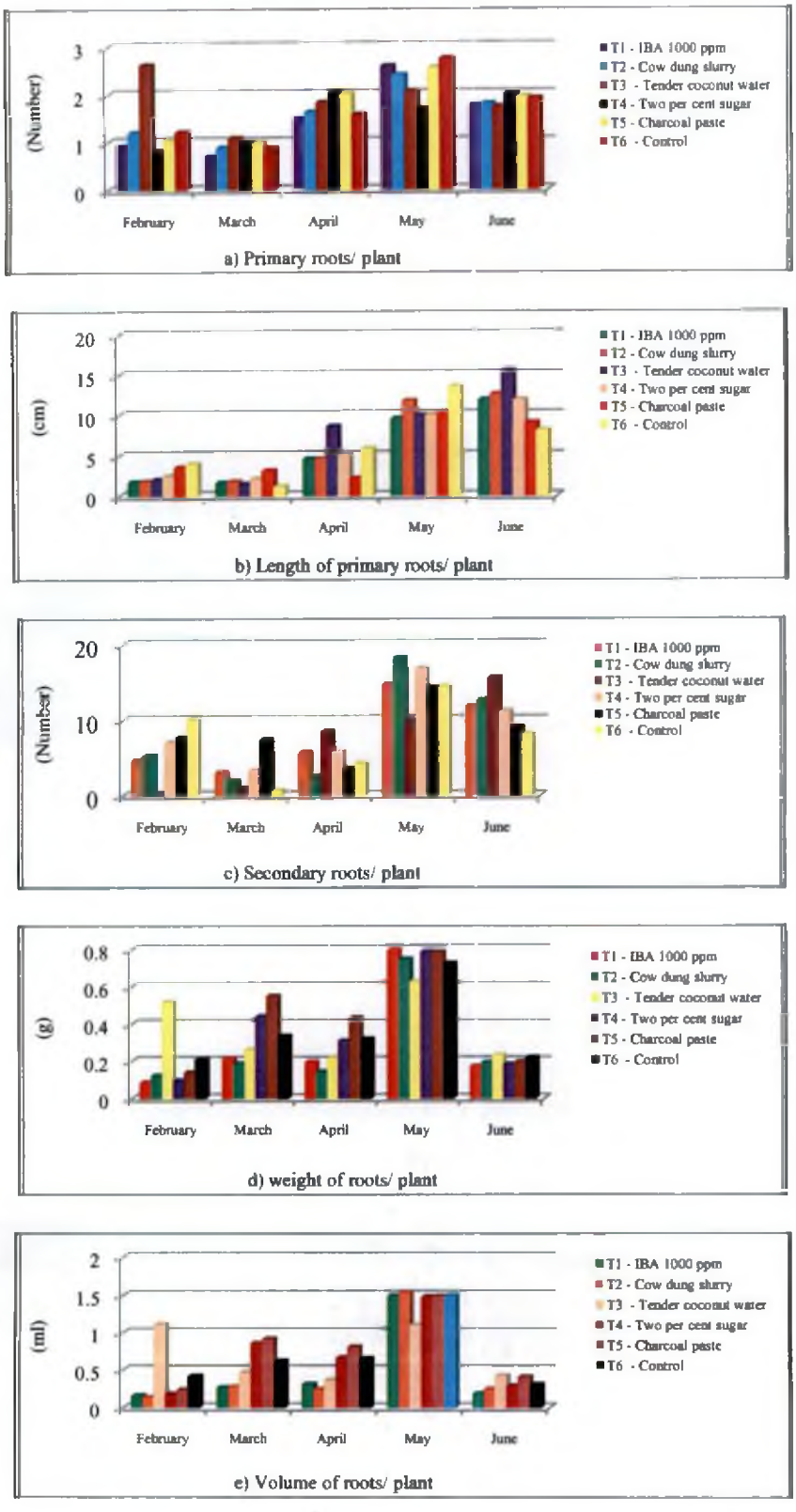


Fig.6. Effect of different treatments on root characters of runners in black pepper var. Panniyur 1

The effect of different treatments on rooting of orthotrops or runners did not give conclusive results as their influence was varying in different months. In the case of orthotrops IBA 1000 ppm (T_1) and charcoal paste (T_5) were superior whereas in runners tender coconut water (T_3), two per cent sugar (T_4) and control were superior in producing more number of primary roots.

5.2 EXPERIMENT II: EVALUATION OF ROOTED ORTHOTROPS AND RUNNERS INTHE FIELD

The results obtained from planting three months old rooted cuttings in the field are discussed hereunder.

5.2.1 Effect of rooted orthotrops and runners on morphological characters in var. Panniyur1

Observations on rooted orthotrops and runners planted in the field showed that there was no significant difference between the two planting material with respect to plant height and number of nodes per plant during different months after planting. However, the orthotrops showed longer internodes compared to runners.

Plant raised from runners showed better plant spread but those raised from orthotrops showed significant superiority in the height at production of first lateral in the 8th and 9th month after planting. This is a positive indication because laterals and inflorescence production in orthotrops could be expected from a lower height.

There was no significant difference between the two types of shoots in the number of laterals produced till eight months after planting. In the 9th month after planting the plants raised from runners showed an increase in the lateral production. However there was a difference of only one lateral.

Sarma *et al.* (2013) reported that rooted orthotrops starts flowering by 2nd year and fruiting laterals start right from the base of the bush/ vine which is cylindrical in shape. Gaps in the canopy of the bush are seldom noticed, and hence the column with productive fruiting laterals throughout the height of the bush ensures higher yields.

However it is too early to jump into conclusions in a perennial crop like black pepper based on number of laterals in the first year after planting.

5.3 EXPERIMENT III: TRAINING OF VINES

Pruning refers to the judicious removal of any plant part and is practiced to ensure leader shoot production, induce the development of lateral shoots and maintain pepper vines in standard height and form. Good pruning would enable the plants to receive maximum energy from the sunshine which is required for photosynthesis.

The black pepper vine is capable of producing spike on each leaf axil of the current season laterals. Therefore, induction of new growth as a result of pruning can be a way for higher production in pepper. The results obtained from the present investigations are discussed hereunder.

5.3.1 Effect of pruning plants six months and ten months after planting

Pruning failed to have a significant effect on the number of orthotropic shoots produced in both Panniyur 1 and Panniyur 2. This was elucidated in tables 38 & 39 with unpruned plants recording more number of orthotropic shoots/ plant.

When pruning was done six months after planting in December there was significant reduction in growth of the plants in terms of plant spread. Number of lateral produced per plant was significantly superior in unpruned Panniyur 1. Panniyur 2 did not show any significant effect for this treatment.

Pruning at six months (December) was followed by severe summer under Kerala conditions which could be the reason for lack of rejuvenation. The weather parameters especially rainfall can affect the number of flushes produced in pepper and its growth habit, ultimately affecting the yield.

However, the pruned plants produced lateral from a significantly lower height and had more number of leaves per lateral which are positive indications (Tables 40 & 41).

Since leaves are the photosynthesizing parts of the plants, its number and area will be having a decisive role in the final yield of a crop. The reserved nutrients present in the laterals can play a crucial role in the reproductive phase.

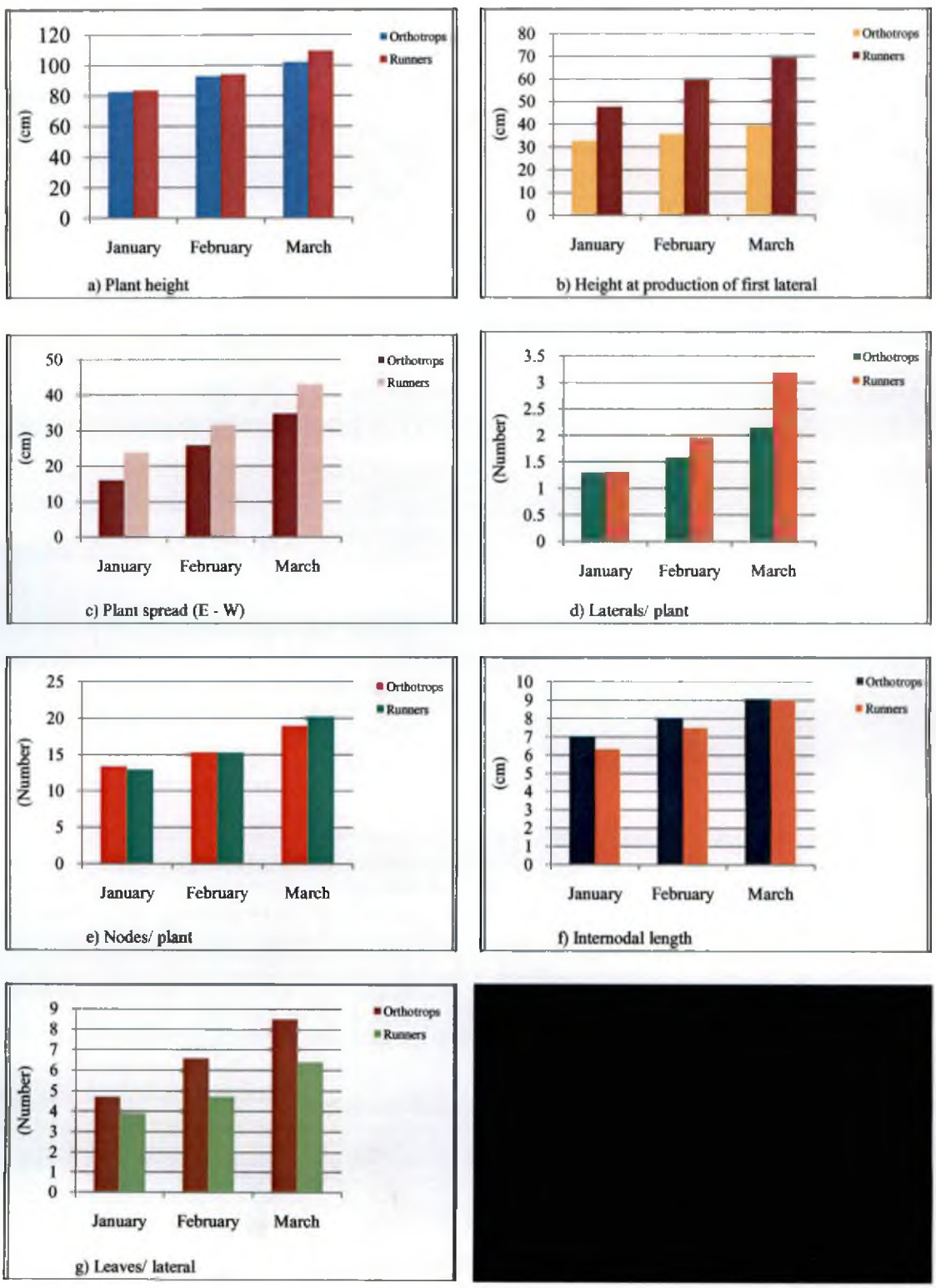


Fig. 7. Comparison between rooted orthotrops and runners planted in the field var. Panniyur 1

So the higher number of leaves/ lateral, number of laterals, plant spread, and orthotropic shoots observed when pruning was carried out six months and ten months after planting respectively may result in higher yield in pruned Panniyur 1 and Panniyur 2 compared to unpruned pepper vines.

Thanuja (2003) reported that pruning had significant effect on vegetative characters like number of leaves, leaf area per lateral and length of lateral during 2001. In the present study also there was an increase in the number of leaves per lateral which is in conformity with the earlier findings.

In the case of pruning ten months after planting, there was no significant difference between pruned and unpruned plants in both Panniyur 1 and Panniyur 2 for the number of orthotropic shoots produced.

The height at production of first lateral was significantly lowered in pruned plants compared to unpruned plants in both Panniyur 1 and Panniyur 2.

However, the plant spread was more in unpruned plants. Lowering the height at production of lateral is a positive indication for lowering the height of production and improving productivity at manageable height (Tables 44 & 45).

Kurien and Nair (1998) reported that three rounds of pruning are enough to obtain necessary number of climbing shoots as well as appropriate bushiness but in the present study pruning was carried out only once in each case (December and June) respectively hence such a pronounced effect was not observed in pepper vines.

Chong and Shahmin (1981) showed that there were no significant differences in yield between pepper vines having 3, 4 or 5 climbing shoots.

In another trial, Chong and Yau (1985) showed that vines with five climbing shoots produced more yield than those with 7 or 9 climbing shoots. In the present study, pruning ten months after planting in Panniyur 1 and Panniyur 2 produced in excess of five orthotropic shoots/ plant. This may result in higher yield in black pepper var. Panniyur 1 and Panniyur 2.

5.3.2 Effect of tipping the plant immediately and three months after planting

Tipping refers to the removal of the terminal bud and its aim is to induce the production of orthotropic shoots, increase the number of laterals and to produce laterals from a much lower height.

5.3.2.1 Morphological characters

As in other training methods tipping immediately after planting had a positive effect on lowering the height at production of first lateral and negative influence on production of orthotropic shoots (Tables 46 - 48). The untipped plants produced more number of orthotropic shoots as compared to the tipped plants. Also plant spread was more in untipped plants.

The positive influence of tipping at three months after planting was again in lowering the height of production of first lateral. Plant spread was more in untipped plants. This could be due to the shock in the first year after pruning.

This is an indication that irrespective of when tipping was done there was not much difference in plant spread, number of leaves/ laterals and number of orthotropic shoots. One has to take into consideration that these are preliminary evaluations which has to be repeated in order to confirm findings. Not much experimental data are available on the advantages of tipping the plant immediately and three months after planting.

5.3.3 Lowering black pepper vines one year after planting

Before burying the stem under soil all leaves are removed from the portion that goes under soil. This result in all the axillary buds to develop and many shoots climb up and cover the standard quickly.

5.3.3.1 Effect of lowering black pepper vines one year after planting on the number of orthotropic shoots and morphological characters var. Panniyur 1 & 2

Lowering had significant effect on the number of orthotropic shoots produced in Panniyur 1 and Panniyur 2 (Tables 51 & 52). The lowered plants in var. Panniyur 1 and Panniyur 2 produced more number of orthotropic shoots/ plant compared to control.

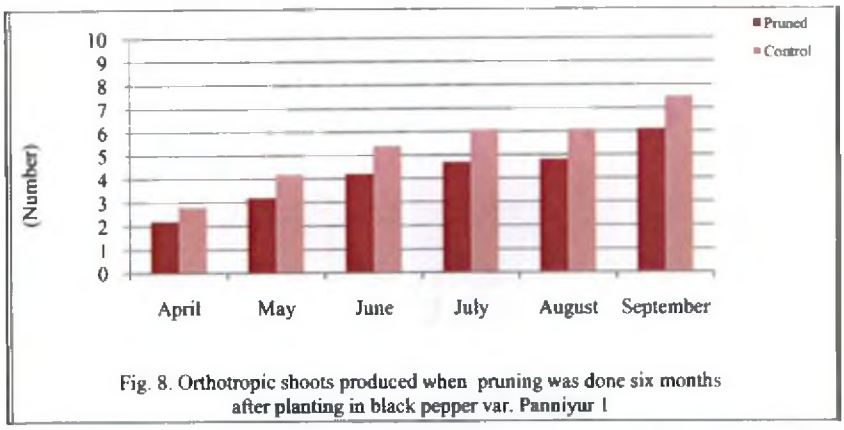


Fig. 8. Orthotropic shoots produced when pruning was done six months after planting in black pepper var. Panniyur 1

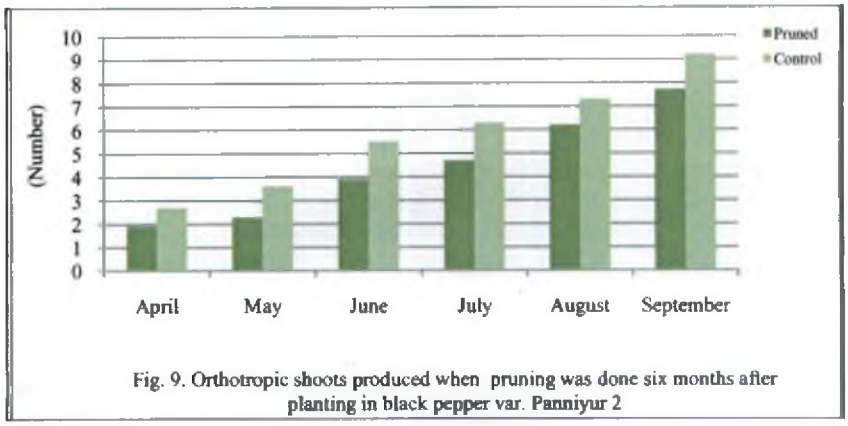


Fig. 9. Orthotropic shoots produced when pruning was done six months after planting in black pepper var. Panniyur 2

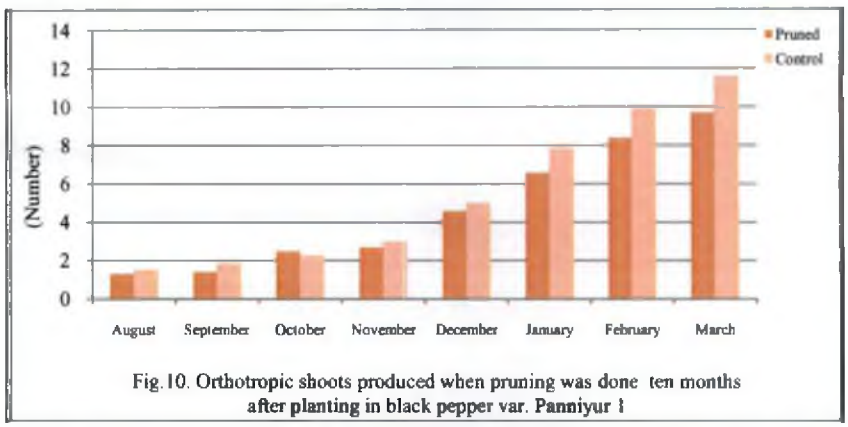


Fig.10. Orthotropic shoots produced when pruning was done ten months after planting in black pepper var. Panniyur 1

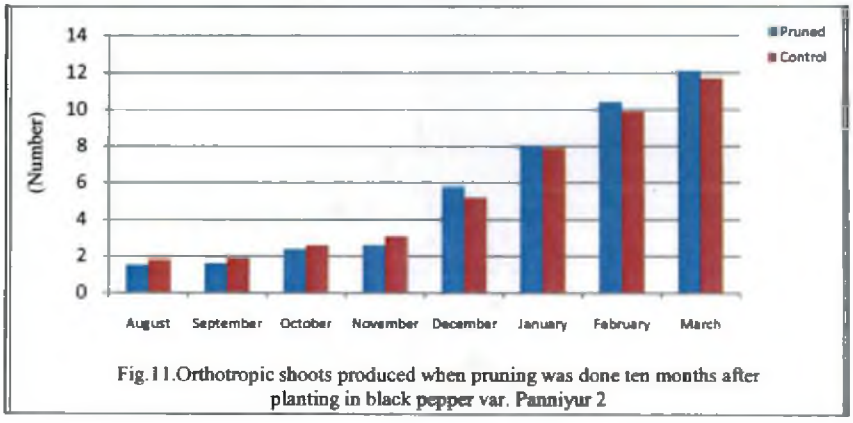


Fig.11.Orthotropic shoots produced when pruning was done ten months after planting in black pepper var. Panniyur 2

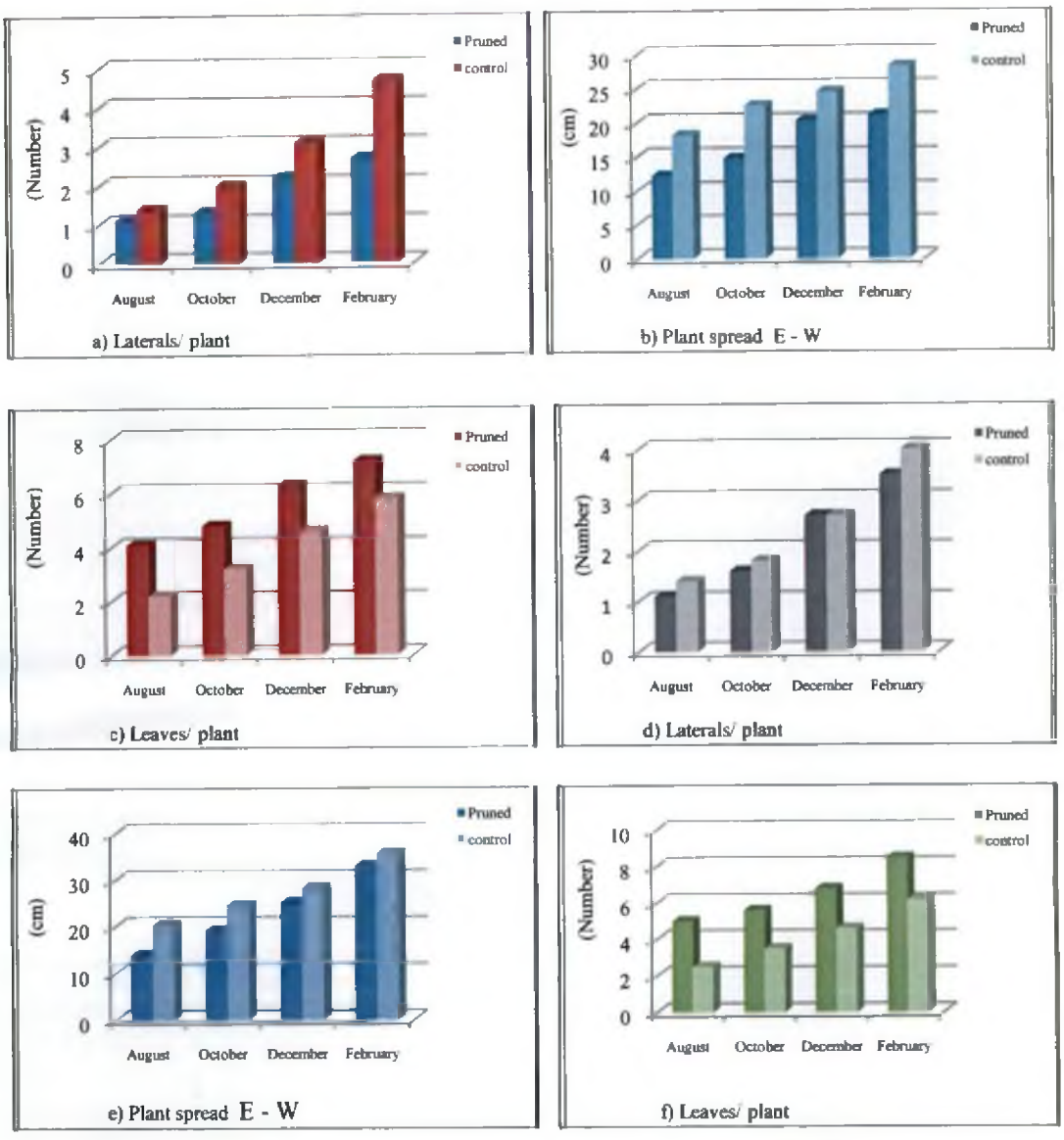


Fig.12. Effect of six months pruning on morphological characters in black pepper var. Panniyur 1 & 2

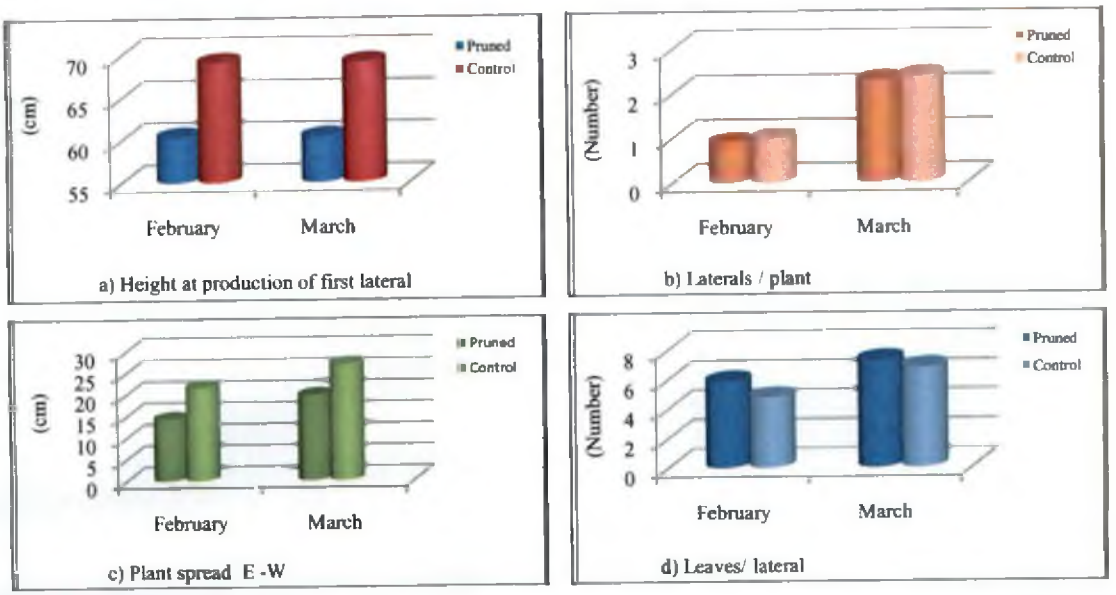


Fig.13. Effect of pruning ten months after planting on morphological characters in black pepper var. Panniyur 1

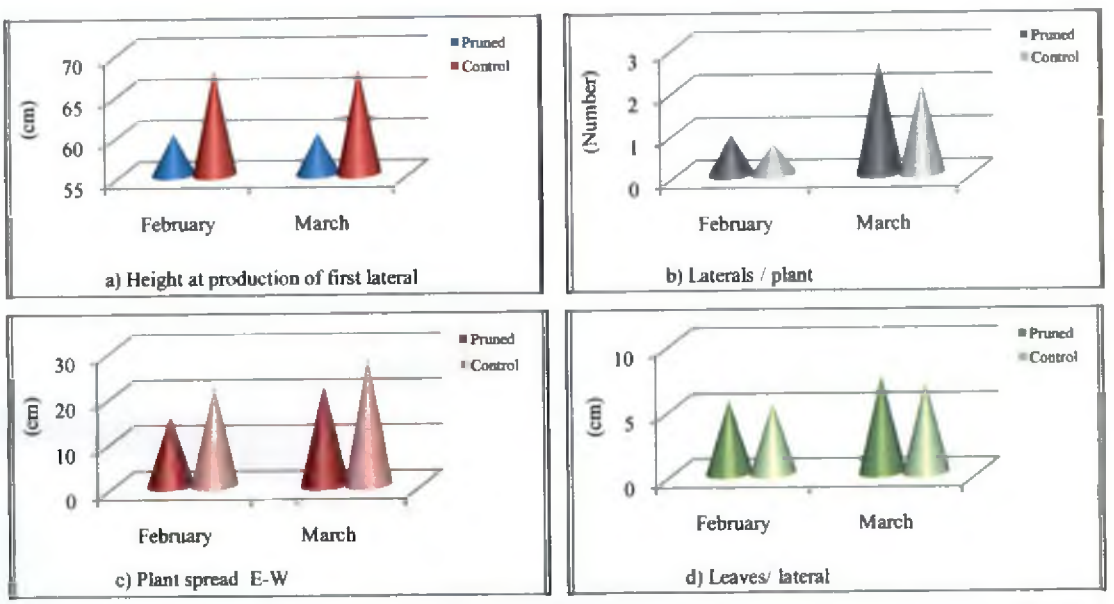


Fig.14. Effect of pruning ten months after planting on morphological characters in black pepper var. Panniyur 2

In both Panniyur 1 and Panniyur 2 lowering exert significant effect on plant spread. The lowered plants recorded a higher plant spread than control. This is clear cut evidence that lowering of black pepper vines one year after planting had significant effect on morphological characters (Table 53)

Lawrence (1981) had reported that in Kerala (India) as well as in certain areas in Indonesia and Sri Lanka, some farmers practice this method for producing more number of climbing shoots. The growing plants, one year after planting, are kept coiled around the standard under moist soil. Usually this is done in the next rainy season.

Like tipping/ removal of terminal buds in black pepper vines, there is no experimental data available on the advantages of lowering the vines one year after planting. Hence a more detailed study for a few more years is required to confirm the result.

Thus it can be concluded that in the present study there was no significant influence for any of the treatments in the rooting of either orthotrops or runners. Thus it can be concluded that pepper cuttings need not given any treatment to enhance rooting.

Orthotrops showed superiority in all root characters compared to runners showing that orthotrops are promising as planting material.

Orthotrops showed significant superiority compared to runners in lowering the height at production of lateral. The height at production of first lateral was lowered in all the pruning and training treatments also, like tipping at planting and three months after planting and pruning in June.

One of the major problems in black pepper cultivation in India is the height at which laterals start developing. Usually it is at 1.5 to 2m from ground level. Due to this $1/3^{rd}$ of the productive height of the plant is wasted.

Lowering the height at production of first lateral can definitely have a role in improving the bearing column of pepper and improving the productivity.

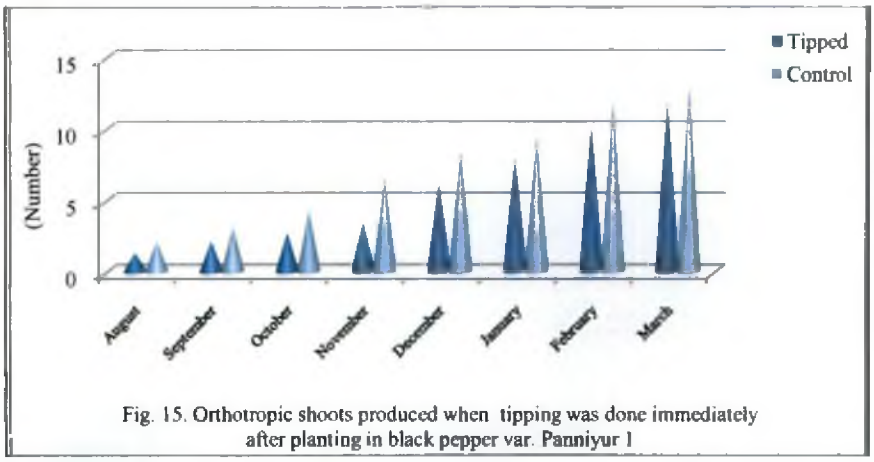


Fig. 15. Orthotropic shoots produced when tipping was done immediately after planting in black pepper var. Panniyur 1

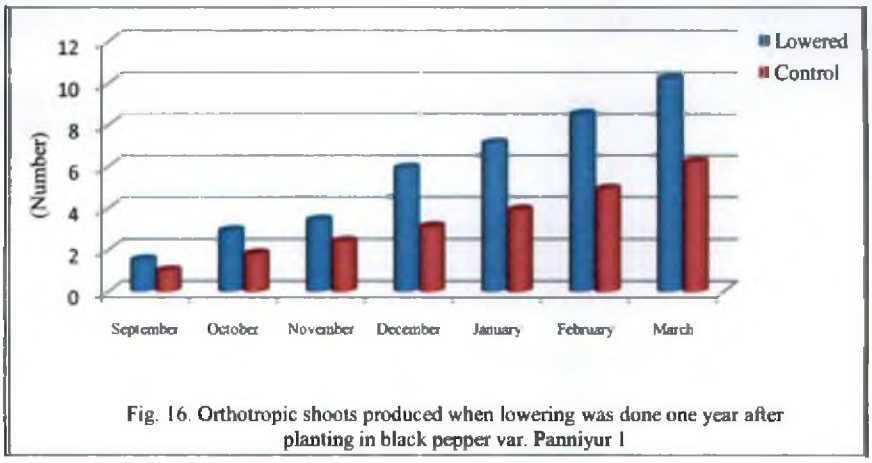


Fig. 16. Orthotropic shoots produced when lowering was done one year after planting in black pepper var. Panniyur 1

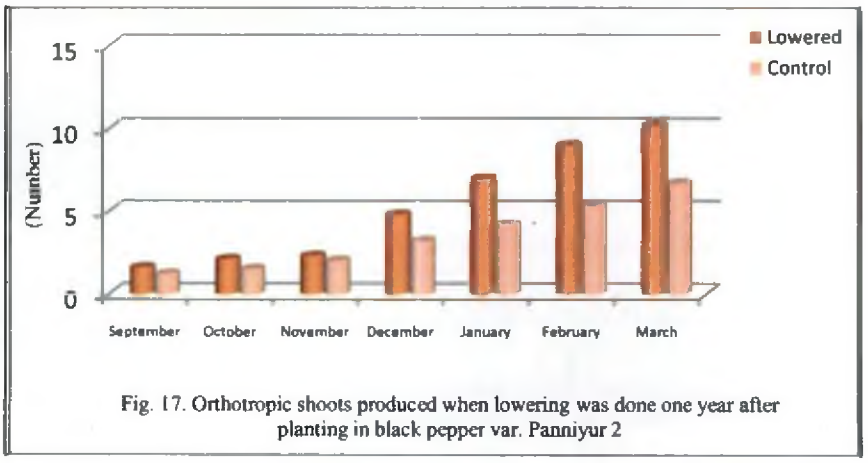


Fig. 17. Orthotropic shoots produced when lowering was done one year after planting in black pepper var. Panniyur 2

Summary

6. SUMMARY

Experiments of the research project entitled "Agrotechniques for inducing plagiotrops in black pepper (*Piper nigrum* L.)" were conducted in the pepper research unit attached to the Department of Plantation Crops and Spices, College of Horticulture, Kerala Agricultural University Main Campus, Vellanikkara, during 2012 - 2014. The salient results obtained are summarized below:

6.1 EXPERIMENT 1: ROOTING OF ORTHOTROPIC AND RUNNERS SHOOTS

In the experiment on rooting of orthotropic shoots and runners, the different treatments given were, T_1 - IBA 1000 ppm, T_2 - cow dung slurry, T_3 - tender coconut water, T_4 - two per cent sugar, T_5 - charcoal paste and T6 - control.

The initiation of sprouting was observed in 17 to 19 days in all treatments. Total number of cuttings sprouted in different treatments ranged from 7.0 to 10.0. The effect of different treatments in sprouting was varying in different months.T_2 - cow dung slurry was the best treatment during February and March planting whereas T_3 - tender coconut water and control were superior in April. In May planting T_5 - charcoal paste had 100 per cent sprouting. In June T_4 - two per cent sugar and control were superior.

The different treatments like T_1 - IBA 1000 ppm for 45 seconds, T_2 - cow dung slurry, T_3 - tender coconut water, T_4 - two per cent sugar and T_5 - charcoal paste failed to have significant effect on length of primary roots, number of secondary roots/ plant, weight of roots (g), volume of roots (ml) and number of leaves/ plant in orthotrops as well as runners.

6.2 EXPERIMENT II: EVALUATION OF ROOTED ORTHOTROPS AND RUNNERS IN THE FIELD

Three month old rooted orthotrops and runners planted in the field did not have significant difference on plant height and number of nodes/ plant.

The height at production of first lateral was significantly reduced in rooted orthotrops but plant spread and number of laterals were more in runners.

6.3 EXPERIMENT III: TRAINING OF VINES

Pruning six months after planting failed to have significant positive effect on the number of orthotropic shoots produced/ plant, number of laterals/ plant and plant spread in both Panniyur 1 and Panniyur 2 compared to control.

However pruning six months after planting had significant positive effect on the height at production of first lateral and number of leaves/ plant.

Pruning carried out ten months after planting failed to have significant effect on the number of orthotropic shoots produced in Panniyur 1and Panniyur 2.

Pruning after ten months of planting had significant positive effect on height at production of first lateral in both Panniyur 1 and Panniyur 2.

Tipping immediately after planting showed a significant negative effect on the number of orthotropic shoot and plant spread. The height at production of first lateral was lowered but the effect was not significant. Tipping had a negative effect on number of laterals/ plant but positive effect on number on leaves/ lateral.

Tipping carried out three months after planting also had a significant positive effect on height at production of first lateral but the effect was negative on plant spread.

Unlike in other pruning and training treatments, lowering had significant positive effect on the number of orthotropic shoot produced and plant spread in both Panniyur 1 and 2.

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Appendices

Appendix I

Monthly weather data during the experimental period (2012-2013)

Month	Temperature Mean Maximum (^{0}C)	Temperature Mean Minimum (^{0}C)	Relative humidity mean (%)	Mean sunshine hours	Total rainfall (mm)	Number of rainy days
December	33.0	23.2	58	8.1	19.8	0
January	34.1	22.3	52	8.7	0.0	0
February	34.7	23.3	57	8.6	84.4	2
March	35.4	24.4	64	7.7	14.6	2
April	34.9	25.1	71	6.1	0.0	0
May	33.6	25.2	77	4.0	99.1	5
June	28.5	22.7	90	1.0	1031.8	28
July	28.4	22.7	91	0.8	932.3	30
August	29.9	22.9	84	4.3	305.9	16
September	30.0	22.2	85	3.7	344.1	17
October	30.8	22.6	83	5.3	369.8	16
November	32.6	23.9	73	6.2	82.0	5
December	31.9	22.3	61	7.2	0.5	0

Appendix II

Monthly weather data during the experimental period (2013-2014)

Month	Temperature Mean Maximum (^{0}C)	Temperature Mean Minimum (^{0}C)	Relative humidity mean (%)	Mean sunshine hours	Total rainfall (mm)	Number of rainy days
January	32.9	23.0	51	9.0	0.0	0
February	34.7	22.9	56	8.6	0.0	0
March	36.7	24.2	55	8.5	0.0	0

"Agrotechniques for inducing plagiotrops in black pepper (*Piper nigrum* L.)"

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ABSTRACT OF THE THESIS
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ABSTRACT

The investigations on "Agrotechniques for inducing plagiotrops in black pepper (*Piper nigrum* L.)" were conducted under three experiments at the pepper research unit attached to the Department of Plantation Crops and Spices, College of Horticulture, Kerala Agricultural University Main Campus, Vellanikkara during 2012-2014.

The first experiment was carried out with an objective to elucidate the effects of treatments T_1 - IBA 1000 ppm, T_2 - cow dung slurry, T_3 - tender coconut water, T_4 - two per cent sugar and T_5 - charcoal paste in enhancing sprouting and root characters in two to three node semi hard wood orthotropic and runner shoots.

The effect of different treatments on sprouting was varying in different months. The minimum time recorded from planting to initiation of sprouting in orthotrops and runners was 17 days. Maximum sprouting was observed on 21 and 28 days after planting in runners and orthotrops respectively.

There was no significant difference among the treatments with respect to the length of primary roots, number of secondary roots/ plant, weight of roots (g), volume of roots (ml) and number of leaves/ plant in runners and orthotrops.

The second experiment was aimed at evaluating rooted orthotrops and runners in the field.

Three months old rooted orthotrops and runners planted in the field showed that the height at which first lateral was produced was much lowered in orthotrops than runners. However plant spread was better in runners.

The third experiment was conducted to study the influence of pruning, tipping and lowering on the growth of black pepper.

Pruning carried out six months after planting showed that unpruned plants produced more number of orthotropic shoots in both Panniyur 1 and 2. Pruining at ten months after

planting did not have significant effect on the number of orthotropic shoots produced both in Panniyur 1 and Panniyur 2.

When pruning was done six months and ten months after planting, the height at which first lateral was produced was much lower in pruned plants compared to the unpruned plants.

Tipping immediately after planting had a negative effect on the number of orthotropic shoot produced and plant spread. However, the height at which first lateral was produced was lower in tipped plants compared to the untipped plants but the difference was not significant.

When tipping was carried out three months after planting there was significant lowering of height at production of first lateral but plant spread was more in untipped plants.

Lowering had significant positive effect on number of orthotropic shoots produced and plant spread in both Panniyur 1 and Panniyur 2.