

**“Effect of media and growth regulators on
rooting of black pepper (*Piper nigrum* L.)
cuttings”**

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BAGALKOT**

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rooting of black pepper (*Piper nigrum* L.)
cuttings”**

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CROPS**

By

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**UNIVERSITY OF HORTICULTURAL SCIENCES
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NOVEMBER, 2012

Affectionately dedicated

To

My Parents and brother

(RAVINDRANATH, PUSHPA AND ADARSH)

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CERTIFICATE

This is to certify that the thesis entitled **“EFFECT OF MEDIA AND GROWTH REGULATORS ON ROOTING OF BLACK PEPPER (*Piper nigrum* L.) CUTTINGS”** submitted by **Mr. AKSHAY, K.R.** in partial fulfillment of the requirement for the degree of **Master of Science (Horticulture) in Plantation, Spices, Medicinal And Aromatic Crops** to the University of Horticultural Sciences, Bagalkot is a record of *bona-fide* research work carried out by him during the period of study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associate-ship, fellowship or any other similar titles.

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(Akshay, K, R.)

“Effect of growth regulators and media on rooting of black pepper (*Piper nigrum*) cuttings”.

AKSHAY K.R.

ABSTRACT

An investigation on Effect of media and growth regulators on rooting of black pepper (*Piper nigrum* L.) cuttings was conducted during 2011-12 at the Regional Horticultural Research and Extension centre, Mudigere, University of Horticultural Sciences, Bagalkot.

The study pointed out that, among the different growth regulator formulations tried, IBA 1000 ppm formulation helped in better induction of rooting by over 70 per cent as against 43.33 per cent in the control. The next promotive effect in this regard was by treatment of IBA 500 ppm and NAA 250 ppm which recorded 66.67 and 63.33 per cent respectively. However, use of higher concentrations of both IBA and NAA were not appreciable for black pepper cuttings. Among the different rooting media tried, black pepper cuttings which were pre-treated with IBA 1000 ppm and planted in the media containing soil + sand + FYM + vermicompost (1:1:1:1) recorded highest rooting percentage i.e. 80 per cent which is on par with soil + sand + FYM + vermicompost in 2:1:1:1 proportion (76.67 %) and soil + sand + FYM + coir dust in 1:1:1:1 proportion (76.67 %). The studies revealed that black pepper plants could be multiplied easily by pre-treatment of cuttings with IBA 1000 ppm and growing in the media comprising soil + sand + FYM + vermicompost (1:1:1:1 v/v) in polyhouse conditions. As an alternative, the medium comprising of coir dust can also be used in the places where, vermicompost is scarce and costly. By this way, higher turnover of planting material can be accompanied quite easily.

NOVEMBER 2012

NARAYANA SWAMY, M.
Major Advisor

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INTRODUCTION

I. INTRODUCTION

India is the land of spices. The flavour and fragrance of Indian spices had magic spell in human civilization and culture. Since ancient days in the middle ages, taxes and rents were frequently paid in pepper and the term pepper corn rent was very vogue in those days as indicated in literature. The lure for spices attracted Greeks, Turks, Arabs, Romans, Chinese and Europeans to India ultimately leading to colonial rule. There are 109 spices listed in ISO. India contributes about 40-50 per cent of world's production of spices (Parthasarathy and Madan, 2010).

Black pepper (*Piper nigrum* L., Family: Piperaceae) popularly known as "king of spices", is the oldest and most important spice crop grown in India. It is native to Western Ghats. Black pepper is grown in 26 countries including India, Indonesia, Srilanka, Thailand, China, Vietnam, Cambodia, Brazil, Mexico and Guatemala. Vietnam is the world's largest producer (120,000 MT) and exporter of pepper followed by India (50,000 MT), Brazil (38,000 MT), Indonesia (21,500 MT) and Malaysia (15,000 MT). The total world production of black pepper is 3, 29,700 MT. (Anon., 2010).

In India black pepper is cultivated in around 1, 83,800 ha with a production of 52,000 tonnes (Anon., 2011). In India, its cultivation mainly confined to Kerala, Karnataka and Tamil Nadu, and to certain extent in Andaman and North-Eastern states.

Black pepper is widely used spice in the world and has occupied a proud place in the cuisines of both East and West. It is an indispensable item in the preparation of processed meat, sauces, soups, curry powders and pickles. From medicinal point of view it is used as a carminative, stomachic and febrifuge. The major economic products from pepper are black pepper and white pepper. Other value added products like pepper oil and oleoresin find increasing use in food industries of developed countries. Besides some new forms of pepper like preserve green pepper in brine, vinegar, dehydrated green pepper etc. are becoming more popular. Hence the black pepper is also

called as 'Black gold' on account of its economic importance. (Devasahayam *et al.*, 2010).

Black pepper can be propagated through seeds and vegetative methods. Owing to its heterozygous nature, seedlings do not breed true to type and known to have long pre-bearing period. Hence, vegetative propagation through cuttings is commercially adopted. Besides this grafting, budding and layering are also practiced. But propagation through cuttings is easier hence it is preferred for large scale multiplication. Cuttings taken from runners shoots (Creeping shoots on the ground) and orthotropic shoots (erect growing shoots) are used commercially for vegetative propagation.

Availability of adequate quantity of quality planting material for large scale multiplication is one of the major constraints in increasing the productivity of pepper in India. The recent developments like, use of growth regulators, media, greenhouse or mist technology, rapid multiplication techniques are found helpful in solving this problem to a greater extent.

Further, availability of quality planting material of black pepper is a major production constraint in all black pepper growing countries. The conventional methods adopted for establishment of pepper have the disadvantage of false sprouting and poor root development coupled with high disease incidence which eventually leads to poor establishment. In this context plant growth regulators (PGRs) have great potential in increasing the agricultural production and help in removing the barriers imposed by genetic and environmental factors.

Plant growth regulators and media, play a vital role in improving the rooting in black pepper cuttings. The maximum rooting percentage found help to increase the establishment of cuttings in nurseries. Growth regulators such as auxins increase more percentage of success and number of roots in black pepper cuttings. This would improve the vigour of freshly transplanted plant material in the field, thus reduces the rate of mortality of plants and helps to maintain adequate crop stand in the plantations. Hence

there is an immense need to increase the area under pepper plantation to meet the domestic as well as export market is of greater importance.

Keeping all these point in view the present investigations were carried out at Regional Horticultural Research and Extension Centre, Mudigere, University of Horticultural Sciences, Bagalkot, with the following objectives.

- To study the effect of growth regulators on rooting of black pepper cuttings.
- To study the effect of media on rooting of black pepper cuttings under poly house conditions.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Scientific propagation is the basis for expansion of area under perennial crops. Propagation is one of the important operations in horticulture. Vegetative propagation methods like cutting, air layering, budding and grafting are widely followed to multiply plants of desired genetic constitution and maintain their purity for commercial exploitation. The art of propagation by vegetative method is gaining popularity in the field of horticulture in recent years.

Among the methods of vegetative propagation, propagation by cutting is the easiest and widely employed method which is usually followed in easy-to-root species. In cuttings, growth substances applied exogenously are found to enhance early and good root formation. Now-a-days many of the difficult-to-root plants are made to root easily by applying plant growth substances.

Various classes of growth regulators such as Auxins, Cytokinins, Gibberellin and Ethylene influence root initiation in cuttings. Of these, auxins have greater effect on root formation in cuttings. In addition to these groups, various growth retardants and promoters may have less direct part in adventitious root formation (Krul, 1968).

Black Pepper is propagated by seeds and cuttings. There are number of factors such as type of cuttings, their storage, rooting medium, and season, pre-treatment and environmental conditions that have been reported to influence the successful rooting of black pepper cuttings.

Literature on propagation of Black pepper is very meagre. Hence, available information pertaining to Black pepper as well as other related crops are mentioned under following headings.

2.1 Role of Auxins in rooting

In general, auxins are reported to favour rooting of stem cuttings of plants (Thimman and Behnke, 1950). The cuttings of Arabian jasmine (*Jasminum sambac*) soaked in aqueous solution of IAA (25 ppm) for 24 hours in the dark gave high percentage of rooting. (El-Hakim, 1954).

Cooper (1955) showed that single node cuttings of *Piper nigrum* can be used successfully by treating them with Indole butyric acid (IBA) @ two mg/ml of 50 per cent alcohol.

Singh and Bhatnagar (1955) observed that *Jasminum grandiflorum* cuttings treated with growth regulators such as IAA (1000 ppm) and NAA (500 ppm) using quick dip method gave the best rooting (90 %) compared with control (30 %).

Auxins help in the accumulation of metabolites, synthesis of new proteins, cell enlargement, cell division and increase in nitrogen content leading to callus formation which in turn grows into roots in plum (Strydem and Hartmann, 1960).

Cardoso (1961) reported that immersing the cuttings of black pepper (*Piper nigrum*) in a solution of Seradix-A at 10 drops per liter of water, increased the rooting percentage from 45 to 65 and it improved the size and vigor of the roots. The highest percentage of rooting (60 %) at 20 ppm of IAA, 70 per cent at 2000 ppm of IBA whereas 75 per cent at 1000 ppm of NAA were obtained in case of *Hibiscus rosa sinensis* L. cuttings. Both IBA and NAA 6000 ppm in quick dip method produced 100 per cent rooting (Shanmugavelu, 1961). Cent per cent rooting in mango marcots has been obtained by using NAA, IBA and NAA + IBA at 2500, 5000 and 10000 ppm both individually and in combination (Srivastava *et al.*, 1970).

Bose and Mondal (1972) tried the mist propagation of cuttings of different tropical trees, shrubs and climbers which are commercially propagated by layers and seeds. Rooting of these cuttings was promoted at

3000 ppm or 4000 ppm of IBA and there was a moderate to high percentage of rooting.

Ghosh and Basu (1974) noticed a slight fall in the concentrations of total available carbohydrates till root emergence stage, but subsequent fall in total carbohydrates was more with the onset of root emergence. This fall was greater in IBA and NAA treated cuttings than in control.

In an experiment conducted by Papaiah and Muthuswamy (1976) it was observed that highest rooting (85%) in *Jasminum sambac* with IAA at 2000 ppm. The number and length of primary roots was also maximum in cuttings treated with IAA at 2000 ppm.

Das *et al.*, (1978) reported that when the *Rosa indica* and *Rosa multiflora* cuttings treated with IAA, IBA or NAA at 1000 or 3000 ppm, it was observed that in *Rosa indica*, the best rooting (40-66 roots/cutting) was obtained in cuttings treated with IAA at 1000 ppm compared to control (7.7 roots/cutting), Whereas, in *Rosa multiflora* the best rooting (32.33 roots/cutting) was obtained with 1000 ppm of IBA when compared to control (3.29 roots/cutting).

Shin and Lee (1979) have reported that higher concentration of IBA inhibited the rooting and sprouting of chrysanthemum cuttings due to the injury caused to the callus tissue. The enhancement of rooting may not be due to actual auxin applied, but perhaps due to transformation of that auxin applied and absorbed by the cuttings. Further, synthetic auxins when applied to the cuttings usually increase the development of existing root primordium (Haissig and Davies, 1984).

The better rooting observed may be because of internal factors of cuttings such as level of auxins, rooting co-factors and carbohydrate storage which collectively influence on the root initiation of cuttings (Hartmann and Kester, 1986)

2.2 Effect of growth regulators on rooting of black pepper cuttings

2.2.1 Indole butyric acid

Somappa (1979) obtained maximum rooting, number of primary roots per cutting and length of longest root in cuttings of Indian lavender (*Bursera delpechiana*) treated with IBA at 1500 ppm.

Rooting was highest (97.36 %) in *Jasminum sambac* cuttings treated with IBA at 4000 ppm followed by IAA at 6000 ppm (67.5 %) as against control (30 %) (Singh, 1980).

Two-node cuttings of the *Piper nigrum* cv. Panniyur-I dipped in 1000 ppm of IBA for 15 to 60 second were inserted in a rooting medium in polyethylene bags. Dipping for 45 seconds gave the highest number of rooted cuttings at 20 days and 90 days (Pillay, 1982).

In black pepper, three-node cuttings rooted better than 1.0 or 2.0-node cuttings. Cuttings treated with IBA at 25 or 50 ppm concentration, rooted slightly better than those treated with combination of IBA at 25 ppm + NAA at 50 ppm or IBA at 50 ppm + NAA at 25 ppm (Hegde, G. S., 1983).

Zaubin (1984) reported that the Black pepper cuttings with nodal roots treated with IBA at 0.20 per cent produced significantly better root growth than the control and For the cuttings without nodal roots the application of IBA at 3.0 per cent produced the best root growth. IBA-treated cuttings planted horizontally produced more roots than those planted vertically.

Gupta and Kher (1986) working on chandni (*Tabernaemontana caronaria*) reported that, among the cuttings treated with IAA, IBA and NAA each at 2000, 4000 and 6000 ppm, the highest rooting percentage was observed in IBA at 2000 ppm.

The better rooting observed may be because of internal factors of cuttings such as level of auxins, rooting co-factors and carbohydrate storage which collectively influence the root initiation of cuttings (Hartmann and Kester, 1986)

Thimmappa and Bhattacharjee (1990) studied the effects of IAA, IBA and NAA at 1000, 2000, 3000 ppm on adventitious root formation in stem cuttings of scented geranium (*Pelargonium graveolens*). They reported that, among the growth regulators, IBA at 2000 ppm was better for rooting than other chemicals.

Hardwood cuttings of oleander (*Nerium oleander*) treated with 2000 ppm IBA gave 100 per cent rooting, more number of roots and longest root (Patil and Shirol, 1991).

Zubenko *et al.*, (1991) reported that, cuttings of *Stevia rebaudiana* Bert. treated with exogenous phytohormones like Ivin, nicotinic acid, IAA and IBA accelerated rooting and plant growth.

Bhattacharjee and Balakrishna (1993) confirmed the cent per cent rooting in stem cuttings of *Ixora singaporensis* with IBA and NAA at 4000 ppm each and IAA and IBA at 6000 ppm each.

Rema and Krishnamoorthy (1993) reported that IBA and IAA at 2000 ppm proved to be best with rooting percentage of 73.2 and 65.1 respectively followed by IBA at 3000 ppm (60.5) in terminal cuttings of *Cinnamomum verum*.

Farooqi *et al.*, (1994) found that an increasing trend of rooting percentage, number of roots per cutting, length, thickness, fresh and dry weight of roots with the increase in concentration of IBA from 100 ppm to 300 ppm in *Rosa damascena*.

Carvalho *et al.* (1995) opined that treating stem cuttings of stevia with IAA and IBA promote rooting and increase the root number. Similarly, IBA at 4000 ppm proved significantly superior with regard to rooting percentage

(91.0%), root length (10.63 cm) and number of roots per cutting (26.30) in *Buddleia asiatica* (Gupta, 1995).

Misra (1995) studied the effect of NAA at varying concentration of 10 ppm, 40 ppm and 100 ppm with radial cutting, basal cutting and top cutting of *Gladiolus*. He found the cent per cent sprouting in radial and top cutting and 50 per cent in basal cutting in NAA 10 ppm treated cutting. Lowest sprouting percentage was obtained in radial cutting (36.1 %).

Application of Indole butyric acid (IBA) to the cuttings of lavender (*Lavendula angustifolia*) showed that, basal stem cuttings treated with 2000 ppm of IBA gave the highest percentage of rooting (72 %) and more number of roots (Kumar and Sreeja, 1996).

Bhagat *et al.*, (1998) reported that IBA at 4500 ppm exhibited best performance with respect to rooting success (90.83 %) and survival of hardwood cuttings of guava.

In stevia, shoot formation of explants appeared to be best accomplished by employing the concentration of 0.05 and 2.0 mg/ l of NAA and 6-BAP respectively and the most effective explants for large scale production of plants appeared to be micro cuttings with apical or axil buds. (Bondarev *et al.*, 2001)

The cuttings of stevia treated with IBA 500 ppm were found to be superior with respect to sprouting percentage, shoot length, number of branches, number of leaves and root length and survival percentage. The study also revealed that better rooting and sprouting of stevia cuttings could be obtained through prolonged dipping of stevia cuttings in 500 ppm IBA solution (Chalapathi *et al.*, 2001)

Chandramouli (2001) obtained the highest rooting percentage (84.66 %), maximum number of roots per cutting (27.83) and length of longest root (10.70 cm) in hard wood cuttings of Indian lavender treated with 250 ppm IBA for 18 hours followed by 250 ppm NAA.

Singh (2001) reported that IBA at 2000 ppm recorded maximum rooting percentage (77.66 %), length of roots (25.69 cm) and number of roots per rooted cutting (29.24) in the hardwood cuttings of *Jasminum sambac*.

Long pepper cuttings were treated with IBA at 100 ppm recorded the highest rooting percentage (88.33 %), number of roots (13.60), root length (15.05 cm) and vine length (24.38 cm) (Bhuse *et al.*, 2002).

In avocado micro cuttings, IBA increased endogenous IAA and indole-3-acetyl-aspartic acid (IAA sp.) concentrations before root differentiation and as the root formation proceeded (Hartmann *et al.*, 2002).

Swetha (2005) was of the opinion that, planting material of Indian lavender could be raised with high success by pre treating the cuttings with IBA 2000 ppm. Kempegowda *et al.*, (2006) recorded the maximum rooting (69.33 %) and early sprouting (15.18 days) in long pepper (*Piper longum*) cuttings treated with IBA at 1000 ppm.

Bagoury *et al.*, (2006) studied the effect of IBA on survival percentage of stem cutting of stevia. Increase in IBA concentration from 0 ppm to 500 ppm and further to 1000 ppm increased the survival percentage from 74.44 to 82.44 per cent and to 86.89 per cent, respectively. Maximum value of survival percentage (95.33 %) was obtained from basal cuttings treated with IBA at 1000 ppm while, the lowest value was associated with control (70.00 %).

Number of roots was found to be higher in stevia cuttings, which were dipped in IAA at 500 ppm, followed by coumarin at 300 ppm. Stem cuttings dipped in IAA at 500 ppm produced longer root length (0.64 cm) followed by coumarin at 300 ppm (0.58 cm) after 15 days of treatment (Koppad *et al.*, 2006).

Chandregowda and Shivaprasad (2008) revealed that, soaking the thyme cuttings overnight in IBA at 150 ppm solution was superior to either quick dip or powder formulations, for early and better rooting.

Debnath (2008) studied the effect of IBA on root proliferation of stevia with varying concentrations of IBA (0.5 mg/l, 1 mg/l, 1.5 mg/l, 2 mg/l, 2.5 mg/l and 3 mg/l) and found that increase in the concentration of IBA increased the sprouting percentage, length of roots and number of roots and callus intensity and IBA at 2 mg/l was found to be optimum for maximum root proliferation.

Florence Akwatulira *et al.*, (2011) reported that among the different growth regulator treatments, IBA at 0.8 per cent gave the highest percentages of stem cuttings that callused (57 %), rooted (41 %) and shooted (59 %), respectively in *Warburgia ugandensis* stem cuttings.

2.2.2 Naphthalene acetic acid

Jasminum grandifolium cuttings treated with 1000 ppm of IAA and 500 ppm of NAA gave the best rooting (90 %) percentage compared to control (Singh and Bhatnagar, 1955).

Misra (1995) studied the effect of NAA at varying concentrations (10 ppm, 40 ppm and 100 ppm) with radial cutting, basal cutting and top cutting of *Gladiolus*. He noticed that, cent per cent sprouting in radial and top cutting and 50 per cent in basal cuttings treated with NAA at 10 ppm. The lowest sprouting percentage was obtained in radial cutting (36.1).

In stevia, shoot formation in explants appeared to be best accomplished by employing 0.05 and 2.0 mg/ l of NAA and 6-BAP, respectively and the most effective explants for large scale production of plants appeared to be micro cuttings with apical or axil buds (Bondarev *et al.*, 1997).

The cuttings of stevia treated with NAA recorded higher number of roots, maximum root and shoot lengths, number of branches, number of leaves, sprouting percentage and shoot vigour index. They also found that, prolonged dipping of the cuttings in NAA at 50 ppm solution resulted in better rooting (Chalapathi *et al.*, 2001).

Euphorbia pulcherrima cuttings treated with NAA at 2000 ppm and IAA at 2000 ppm recorded the maximum rooting percentage followed by IAA at 1000 ppm (Tripathy *et al.*, 2003)

Tewary *et al.* (2004) noticed that the cuttings of *Vitex negundo* treated with stick a commercial formulation (NAA with sodium as active ingredient) and observed the maximum effect of IAA at 500-1500 ppm on rooting (100 %) followed by IAA at 1500 ppm (80 %).

2.2.3 Combination of IBA and NAA

Shanmugavelu (1961) reported that, the highest rooting percentage of 60, 70 and 75 was obtained in case of *Hibiscus rosa sinensis* L. cuttings treated with IAA, IBA and NAA at 2000 ppm, respectively. Cuttings treated with IBA and NAA at 6000 ppm by quick dip method produced 100 per cent rooting.

Madalageri *et al.* (1977) obtained enhanced bud callusing and rooting in *Ixora* cuttings treated with combination of IBA + IAA each at 5000 ppm. Bhattacharjee and Balakrishna (1993) confirmed that, cent per cent rooting was possible in stem cuttings of *Ixora singaporensis* with IBA and NAA at 4000 ppm each and IAA and IBA at 6000 ppm each.

Ghatnatti (1997) recorded the highest rooting in *Duranta plumeri* var. *Goldiana* with IBA 3000 ppm + NAA 3000ppm where starch and total carbohydrates concentrations declined during initiation and growth of the roots, indicating breakdown of carbohydrates during root development under Dharwad conditions.

Chalapathi *et al.* (1999) conducted an experiment on rooting of stevia cuttings using various growth regulators viz., IBA 1000 ppm, NAA 1000 ppm and IBA 1000 ppm + NAA 1000 ppm and found that sprouting percentage, vigour index, shoot length, number of branches and number of leaves per cutting were more in control followed by IBA 1000 ppm, NAA 1000 ppm and IBA 1000 ppm + NAA 1000 ppm. He also revealed that the performance of

cuttings was not better by directly planting them under field conditions, since no treatment has recorded at least 40 per cent sprouting.

Singh *et al.*, (2003) obtained the highest survival percentage (61.44 %), number of leaves (45.11), shoot length (28.24 cm), number of sprouts (7.11), shoot fresh (24.33 g) and dry weight (6.87 g), number of primary roots (12.77), number of secondary roots (29.55), longest root (38.93), root zone (11.21 cm²), root fresh (7.95 g) and dry weights per cutting (4.66 g) with IBA at 500 ppm in *Piper longum* cuttings. Whereas, IBA + NAA (1000+500 ppm) gave the highest main branch diameter (2.87 mm).

Rajashekhara (2004) reported that, 10 cm long stevia cuttings treated with a combination of NAA 500 ppm + IBA 500 ppm during autumn season resulted in maximum root length and highest root number.

Alamgir and Momtaz (2005) reported 50, 63, 83 and 100 per cent rooting in stem cuttings of sarpagandha treated with IBA + NAA 10 ppm each, 10 ppm NAA, 50 ppm IBA and 5 ppm 2,4-D, respectively.

2.3 Effect of different environments on rooting of cuttings

Season plays an important role in the success of different methods of vegetative propagation. Hence, in plant propagation, different environments, *viz.*, natural shade especially of singapore cherry (*Muntingia calabura*), shade net, polyhouse and polyhouse with mist have been widely used. Temperature, light intensity and humidity during different times of the day have great influence on the success of rooting, sprouting and growth of propagules. Rainy season favoured by high relative humidity coupled with fairly high temperature is congenial for rapid callus production and early rooting. Provision of ideal conditions for propagation through cuttings throughout the year is not always possible under natural conditions.

However, manipulation of environmental factor is possible under polyhouse conditions. It is worthwhile to note the efficacy of various vegetative methods inside the polyhouse, where, ideal temperature and humidity could be easily maintained or manipulated for convenience. Several

workers have reported favourable results in cuttings propagated under mist. Fischer (1941) and Garner (1944) reported excellent rooting of cuttings by a water spray applied on foliage of several horticultural crops.

A fine water spray at frequent intervals reduces the transpiration rate and brings down the leaf temperature to a lower level, thereby creating a favorable condition for rooting of leafy cuttings (Good and Turkey, 1966).

The experimental evidences showed that rooting of cuttings was higher under intermittent mist than continuous mist (Fiorino and Zucconi, 1968). Creating humid atmosphere by means of an artificial mist and planting the cuttings either in concealed pot culture house or in open conditions has proved to enhance the process of rooting (Lynn and Hartmann, 1957 and Vijayakumar, 1973).

Vijayakumar (1973) obtained successful rooting of guava cuttings under intermittent mist with IBA at 5000 ppm. It has been further established that, when the mist propagation was coupled with certain hormonal treatments, the cuttings gave better rooting than with mist alone. Rooting was highest (17.46 %) in stem cutting of plum (*Prunus domestica*) under intermittent mist as compared to only 9.8 per cent without mist (Chauhan and Reddy, 1974).

Korematsu and Shinno (1975) stated that mist propagation increased the per cent rooting and reduced the time to root in many garden trees and shrubs. Beneficial effects of intermittent mist over continuous mist have been recorded in the propagation of many tropical fruit trees (Garner and Chaudhary, 1976).

Prolings and Therios, (1976) opined that, continuous mist spray causes water logging in the bed unless adequate provision is made for drainage. Whereas, under intermittent mist, water logging is avoided, transpiration loss is reduced and temperature of the rooting medium is lowered, thus creating an environment more favorable for rooting.

Singh (1979) reported that, the rooting response of cuttings of *Jasminum sambac* was found to be good under intermittent mist. Selvarajan and Madhava Rao (1982) opined that, the mist chamber provides most favorable environment for better rooting of patchouli cuttings.

Senanayake and Kirthisinghe (1983) observed that, in black pepper, use of 50 per cent shade combined with irrigation at every three days was the best, which recorded longest shoot, highest number of roots, maximum leaf area and dry weight of shoots, roots and leaves at 95 days after planting. The next best treatment was 35 per cent shade with daily irrigation.

Loach (1997) studied the leaf water potential and the rooting of cuttings of rhododendron under mist and polythene. He stated that propagation under polythene gave better results than mist in the lower radiation conditions. He also found that, water potential of cuttings in mist depends on three variables namely current days radiation, number of days from planting of cuttings and the previous days leaf water potential which was, relatively unimportant because cuttings were able to take up water over night from condensation on the under surface of the polythene.

Vasundhara and Farooqi (1997) opined that, use of low cost polyhouse and growth regulators as better to propagate medicinal and aromatic plants, which are propagated through cuttings, as compared to shade net conditions.

Farooqi *et al.*, (1998) found that, the medium cost green house was good for propagation through cuttings due to relatively high temperature and high humidity that prevailed during the course of propagation. Extent of rooting of medicinal and aromatic plants on an average under medium cost greenhouse was 76.30 per cent when compared to shade net conditions (25.00 %).

Murthy *et al.*, (2010) found that, among different propagating structures (greenhouse, greenhouse with mist, shade net and natural shade of Singapore cherry) used for propagating vanilla (*Vanilla planifolia*) stem

cuttings, greenhouse was more suitable for producing a longer sprout (42.4 cm) with maximum number of leaves (9.4), early rooting (17.3 days) and maximum rooting percentage (87.6 %).

2.4 Interaction effect of environment and growth regulators

Mist chamber is an important structure and the technology is a major breakthrough in propagation of plants. Rooting percentages were 11, 55 and 72 when IBA was applied to carnation at 0, 2000 and 3000 ppm, respectively. Further, the corresponding percentages using mist propagation were 27, 93 and 97, respectively (Ertan, 1969).

Bose and Mondal (1972) tried mist propagation of different tropical trees, shrubs and climbers through cuttings which are commercially propagated by layers and seeds. Rooting of those cuttings was moderate to high at 3000 and 4000 ppm of IBA.

Milind Ingle (2008) reported that, among the different environmental conditions, rooting of stevia cutting was found to be the best in the mist environment (90.00%) which was followed by shaded polytunnel condition (88.78%), shade condition (81.11 %) and open condition (72.56 %). The interaction effect of IBA (500 ppm) and mist environment was found to be significant as evident by maximum percentage of rooting (94.67 %).

Smitha (2010) reported that, long pepper (*Piper longum*) cuttings treated with different growth regulators and grown in green house condition showed considerably good response with respect to number of sprouts, length and thickness of longest sprout, rooting percentage, number of roots, length and thickness of longest root and fresh and dry weight of roots as compared to those cuttings pre treated with same growth regulators and grown under natural shade.

2.5 Biochemical factors influencing rooting in cuttings

The rooting success in cuttings irrespective of pre-treatment is very much influenced by the biochemical status of planting material used. The changes in biochemical constituents brought about by the auxin treatment in cuttings determine the ease with which rooting is accomplished.

2.5.1 Nutritional status

Several workers conducted a substantial work in order to assess the nutritional status of cuttings (Turkey and Green, 1934; Pearse, 1943; Haun and Cornell, 1951) and they opined that cuttings with higher carbohydrate and low nitrogen content produced higher percentage of rooting while converse was substantiated by Reid (1924) and Schrader (1925).

Ali and Westwood (1968) found higher amount of total carbohydrates in mature cuttings of pear (*Pyrus* sp.) than juvenile in all the three species studied and they found no relationship between rooting behavior and carbohydrate fraction.

Nanda and Anand (1970) reported that starch content and ability to root are inversely related. The low rooting corresponded with high starch and vice versa (Nanda *et al.*, 1971).

Reuveni and Adato (1974) found that easy to root offshoots of Date palm (*Phoenix dactylifera* L.) rooted well compared to difficult to root and the latter contained more reducing sugars.

Mokashi (1977) working under Dharwad conditions, obtained good rooting in easy-to-root grape cv. 'Gulabi' than in difficult-to-root cv. 'Thompson seedless' and this was attributed to the lower contents of sugars, phenolic compounds and C/N ratio but higher nitrogen and starch contents.

Singh (1980) noticed that a high sucrose to auxin ratio led to phloem production and low sucrose to auxin ratio led to xylem which is necessary for vascularization of root primordial in *Ixora*.

Champagnol (1981) showed that initial starch contents of grape vine cuttings influenced root and shoot growth. It was highest when the starch content was between 4.5 - 7.5 per cent. Similarly Rajanna (1981) found that easy-to-root kabul red pomegranate cuttings rooted better than difficult-to-root basin seedless because of higher percentage of total sugars and total phenols.

Rao and Satyanarayana(1989) found lower levels of reducing and non-reducing sugars in four year old cashew cuttings from old trees and they attributed this to early utilization in the production of root initials. High starch corresponded to poor rooting and vice versa exhibiting its hydrolysis, mobilization and utilization under auxin in rooting of oleander cuttings (Patil and Shirol, 1991).

Zhang and Masaki (1994) reported that in case of cuttings of *Prunus mume*, rooting rate was negatively correlated with total sugars and reducing sugar contents whereas negatively correlated with starch content. Higher contents of nitrogen and various sugars were associated with better rooting in case of peach (Gill, 1995).

Bondarev *et al.*, (2003) studied the effect of reducing sugar (fructose or glucose) in stevia and found that extension of the shoots and development of their root system were better in media with reducing sugar than in the medium supplemented with non-reducing sugar. Under this condition, the accumulation of dry matter in leaves and the content of the steviol glycosides in the leaves declined.

Elevated non reducing sugars (sucrose) concentrations (from 1-5%) in stevia cuttings enhanced development of root system and an increase in plant dry mass and number of leaf pairs was observed. At the same time,

3.0 per cent sucrose gave optimal steviol glycosides accumulation (Bondarev *et al.*, 2003).

Tripathy *et al.*, (2003) observed that *Euphorbia pulcherima* cuttings treated with NAA, 2000 ppm and IAA, 2000 ppm showed the maximum rooting percentage (97.78 %) followed by IAA, 1000ppm (95.56 %).

Tewary *et al.*, (2004) noticed that the cuttings treated with stick (NAA with sodium as active ingredient) showed maximum effect on rooting (100 %) at 500-1500 ppm followed by IAA at 1500ppm (80 %) in *Vitex negundo*.

2.6 Effect of rooting media on rooting of cuttings

Various media have been used successfully for growing potted plants and also for the rooting of cuttings. These media are naturally occurring organic materials such as coir dust, sawdust, sphagnum moss, peat etc. or other materials such as vermiculite, perlite etc. These media enhance rooting in cuttings mainly by possessing better water holding capacity, increased porosity and better nutritional levels over conventional sand which is normally used for the purpose. Besides these advantages, they generally carry very little pathogen load, very light in weight and hence easy to handle in green house crop production.

Sweet (1952) reported that carnation cuttings have rooted successfully in damp sphagnum moss. Ozawa and Kikugawa (1953) observed better rooting of carnation in sand and vermiculite mixture than soil mixtures. They concluded that the best physical conditions of the media for rooting were 19-35 per cent soil moisture, 60 per cent porosity and 30-40 per cent air.

Ermakov *et al.*, (1962) revealed that cuttings of grape cultivars “Frankenthal” and “Foster” planted in sand (Particle size 0.5-1.00 mm) showed 50 and 43 per cent rooting respectively and those in clay substrates showed 81.5 and 76.3 per cent rooting respectively.

Mukherjee *et al.*, (1979) working under Calcutta conditions, recorded highest percentage of rooting and large number of roots per cutting by using rooting medium of coarse sand followed by a mixture of sand and moss in the proportion of 1:1 or 1:3 in a number of popular ornamental plants. Vermiculite was also found to improve root formation while garden soil adversely affected the regeneration of roots. Coarse sand was the most suitable medium for rooting of chrysanthemum cuttings (Kher, 1976).

According to Zaharia (1985) all the substrates namely perlite, perlite + peat and volcanic puff + peat tried had no marked effect on rooting percentage of *Chrysanthemum morifolium* cuttings.

Lal and Danu (1985) reported that maximum rooting (50.0-76.6 %) was obtained with sand alone which was attributed to its high pH (8.02) and low water holding capacity (21.0 %). On the contrary, Parker and Kamp (1989) obtained maximum rooting of coleus, carnation and chrysanthemum cuttings on gravel at pH values, 7 and 8 whereas, at pH 4, 5 and 10 however rooting was poor.

Among six substrates were tested as rooting media for *Piper nigrum* cuttings, percent mortality was highest in soil (40.63) and lowest in soil + Bio-rigi + sawdust (1:1:1) (7.81) and soil + sand (1:1) (14.06) whereas, root length was greatest in soil + Bio-rigi + sawdust (1:1:1) and soil + sand (1:1) Bogantes, (1989).

Shridhar *et al.*, 1989, reported that The highest rooting percentage (30.9 %), vine length (12.7 cm) and number of leaves/cutting (4.0) were obtained with the sand + FYM rooting medium followed by sand alone in black pepper. Singh *et al.*, 1989 reported that, planting of 2-node cuttings of pepper [*Piper nigrum*] cultivar Panniyur-I in sand + FYM (50:50) recorded maximum rooting and subsequent development than control.

Uddin and Hossain (1989) opined that soil+ FYM as a best rooting medium for *Piper nigrum* Cv. Jaintipuri. Mainland (1993) reported that hard wood cuttings of blue berry cvs. High bush, Southern high bush and

Rabbit eye recorded 95 per cent rooting in a medium of pine bark covered with single layer of sawdust followed by perlite in combination with sawdust (92 %) and poorest rooting percentage was seen in quartz sand.

Bhat (1994) revealed that FYM can serve as an efficient rooting medium and found to produce cent per cent rooting success in vanilla cutting under Dharwad conditions.

Saleh and Hossni (1995) reported that sand (1:1 or 2:1v/v) resulted the highest rooting percentage, root number per cutting with best quality as compared to other planting media.

Siddagangaiah *et al.*, (1996) evaluated various rooting media indicated that vermicompost and decomposed coir pith were ideal for rooting and multiplication of vanilla. Black pepper cuttings raised in vermicompost were significantly taller and had more number of leaves than in potting mixture (Thankamani *et al.*, 1996).

Mahale (1999) working under Bangalore conditions noticed that sand and Vermicompost gave highest rooting percentage (90.20 and 89.53 %, respectively) in carnation cuttings.

Shirol *et al.*, (2001) studied the influence of different locally available rooting media viz., red soil, sand, potting mixture, vermicompost and compost on rootability of Dwarf Poinsettia cuttings. They observed that highest percentage of rooting (67.0 %) was obtained in sand + Vermicompost (1:1) followed by Vermicompost alone (63.0 %). The compost showed poor results (27.0 %) under Dharwad conditions.

Singh *et al.*, (2002) observed that agro peat, peat moss and perlite either alone or in combination with sand proved best for root initiation and rooting percentage in carnation whereas leaf mould showed poor results.

Perlite and agro peat mixture (1:1) proved to be most suited rooting medium for the purpose of adventitious root formation in Jojoba cuttings (Singh *et al.*, 2003).

The mixture containing topsoil, sand and vermicompost in a 1:1:1 ratio was the best for rooting of black pepper, producing 23.5 vigorous rooted cuttings within three and a half months from each vine, followed by the mixture containing equal ratio of topsoil and coir pith (21.43 cuttings per vine) and top soil and FYM (20.60 cuttings per vine) by rapid multiplication technique (Sit *et al.*, 2005).

Dolor *et al.*, (2009) reported that, effect of media on rooting percentage with fine sand recording 52.70 %, coarse sand + sawdust (51.60 %), Medium sand+ sawdust (48.90 %), medium sand (46.10 %), fine sand+sawdust (43.90 %), coarse sand (42.90 %) and sawdust (41.50 %) in *Irvingia wombolu* stem cuttings.

Rubasinghe *et al.*, (2009) reported that among the different rooting media studied, sand + coir dust (1:1) media with 1000mg/l NAA gave the highest root length (9.4 cm), shoot length (8.3 cm), root vigour (62) and rooting percentage (100 %), respectively in *Chirita moonii* stem cuttings.

Venkatesan *et al.*, (2010) revealed that, cuttings planted in the potting mixture of soil, sand and vermicompost (1:1:2 proportion) along with Azospirillum dipping significantly increased the rooting parameters like rooting percentage, number of roots per cutting and root length and shoot parameters like number of sprouts per cutting, length of sprout, number of leaves per cutting and leaf area. This treatment also significantly reduced the duration of first sprout appearance in *Gymnema sylvestre* cuttings.

Florence Akwatulira *et al.*, (2011) reported that among the different rooting media studied, Milled pine bark gave the highest percentages of stem cuttings that callused (38 %), rooted (37 %) and shooted (41 %), respectively. Milled pine bark gave the greatest number (2.87 %) and longest roots (2.93 %) and shoots (2.45 %) per stem cutting in *Warburgia ugandensis*.

MATERIAL AND METHODS

III. MATERIAL AND METHODS

The present investigations were carried out in naturally ventilated polyhouse at Regional Horticultural Research and Extension Centre, Mudigere during the period from February 2012 to June 2012, to evaluate the effect of media and growth regulators on rooting of black pepper (*Piper nigrum*) cuttings. The details of the materials used and methods adopted during the course of investigations are presented below.

3.1 Geographical location of experimental site

Mudigere is situated in hilly zone of Karnataka state at 13° - 25° N latitude and 75° - 25° E longitude at an altitude of 976 m above mean sea level.

3.2 Climate

Mudigere is considered to be mild tropical rainy region. The mean maximum temperature during the period of experimentation ranged from 27.0 to 36.6°C whereas, the mean minimum temperature ranged from 15.0 to 16.1°C. The mean relative humidity ranged from 45-92 per cent. The highest rainfall was recorded in July 2011 (294.0 mm) and lowest in April 2012 (290. 2 mm). The details of meteorological data for the period of experiment are presented in appendix-II.

3.3 Experimental details

The details of the experiment are given below.

3.3.1 Brief description of panniyur-1 variety

Panniyur-1 is an F₁ hybrid between Uthirankotta × Cheriyanakaniyakadan released from Pepper Research Station, Panniyur (Kerala Agricultural University). It is suited to all black pepper growing regions except heavily shaded areas. It contains the highest oleoresin (11.8

%), piperine (5.3 %) and essential oil (3.5 %) with an average yield of 1242 kg per hectare.

3.4 Experiment – I

Effect of growth regulators on rooting of black pepper cuttings.

3.4.1 Source of cuttings and their preparation

The healthy cuttings of Panniyur-1 variety were procured from the RHREC, Mudigere. Semi hard wood cuttings of pencil thickness (0.8-1.0 cm diameter) were selected and cuttings of 10 cm length with 2 nodes were prepared by giving a slant cut at the bottom (Plate 2).

3.4.2 Preparation of rooting media

A potting mixture consists of jungle soil, sand and FYM in the ratio of 2:1:1 was filled into 20 × 12 cm sized perforated polythene bag of 200 micron thickness. Before planting the cuttings, media was drenched with Copper oxy chloride (0.3 %) as a prophylactic measures against fungal diseases.

3.4.3 Design and layout of experiment

The experiment was laid out in the naturally ventilated polyhouse with completely randomized design. There were eleven treatments including control in which several growth regulator formulations were used at different concentrations. Each treatment was replicated thrice, with 100 cuttings per replication.

3.4.4 Details of Naturally ventilated polyhouse (NVPH)

Experiments were carried out in naturally ventilated poly house oriented in North-South direction. Its frame is made up of galvanized iron pipe and covered with 200 micron UV stabilized polyethylene film. Two sides are covered with insect proof net of 60 meshes for natural ventilation and protection against entry of insect pests. Besides this insect net, a rollable flap of polyethylene sheet has also been provided outside the insect net to



Plate 1a : General outer view of Polyhouse



Plate 1b : General inner view of Polyhouse



Plate 2 : Black pepper cuttings used for planting



Plate 3 : Close up view of sprouted cuttings

regulate the requirements of temperature and humidity depending on the season and weather conditions. The shade net with 50 per cent shade was laid out at above the headspace inside the greenhouse to manage the light intensity and temperature during summer (Plate).

3.4.5 Treatment details

Growth regulator formulation

T ₁	Control (dipped in tap water)
T ₂	IBA 500 ppm
T ₃	IBA 1000 ppm
T ₄	IBA 1500 ppm
T ₅	NAA 250 ppm
T ₆	NAA 500 ppm
T ₇	NAA 1000 ppm
T ₈	IAA 1000 ppm
T ₉	IBA + NAA 250 ppm
T ₁₀	IBA + NAA 500 ppm
T ₁₁	IBA + NAA 1000 ppm

Where, IBA = Indole Buteric Acid,

IAA= Indole Acetic Acid and

NAA=Naphthalene Acetic Acid.

3.4.6 Preparation of stock solutions

Before preparing the stock solutions, IAA, IBA and NAA were dissolved in 0.1 N NaOH solutions. The stock solutions of IBA 5000 ppm was prepared by dissolving 5000 mg IBA in one litre of distilled water. Similarly IAA 1000

ppm were prepared by dissolving 1000 mg in one litre of distilled water. For preparation of NAA 5000 ppm, 5000 mg NAA was dissolved in one litre of distilled water. The combination treatment of IBA and NAA was prepared accordingly by diluting with distilled water and made upto 250 ml.

Required concentration of IBA / NAA / IAA.	Amount of stock solution taken and volume made up to 250 ml using distilled water.
T ₁ – Control	dipped in tap water
T ₂ - IBA 500 ppm	25 ml
T ₃ - IBA 1000 ppm	50 ml
T ₄ - IBA 1500 ppm	75 ml
T ₅ - NAA 250 ppm	12.5 ml
T ₆ - NAA 500 ppm	25 ml
T ₇ - NAA 1000 ppm	75 ml
T ₈ - IAA 1000 ppm	250 ml
T ₉ - IBA 250 ppm + NAA 250 ppm	6.25 ml IBA + 6.25 ml NAA
T ₁₀ - IBA 500 ppm + NAA 500 ppm	12.5 ml IBA + 12.5 ml NAA
T ₁₁ - IBA 1000 ppm + NAA 1000 ppm	25 ml IBA + 25 ml NAA

3.4.7 Treatment of cuttings and planting

Required concentration of the growth regulator solution was taken and the cuttings were dipped upto 1.5 – 2.0 cm deep in the solution for one minute. Than they were air dried subsequently for few seconds and immediately two cuttings per polythene bag were planted and placed in naturally ventilated poly house.

3.4.8 After care

Immediately after planting, the poly bags were lightly watered and later on watering was done on every day depending upon the moisture content. Weeds were removed in the poly bags as and when noticed. Polythene bags were drenched with COC (0.3 %) to check the incidence of the fungal diseases including rot.

3.4.9 Observations recorded

The planted cuttings were allowed to rooting for 75 days. Five cuttings per treatment per replication were carefully removed from the polyhouse and dipped in water to remove the sand particles adhering to roots to record the observations pertaining to roots *viz.*, days taken for root initiation, percentage of rooted cuttings and number of roots per cutting.

3.4.10 Root parameters

3.4.10.1 Days taken for root initiation

The observations were recorded at two days interval by taking five cuttings per replication from 30th day to 46th day after planting and results were expressed in days.

3.4.10.2 Percentage of cuttings rooted

This parameter was calculated at 75 days after planting by taking the ratio of number of rooted cuttings to total number of cuttings planted and was multiplied by 100. This parameter was computed using the following formula

$$\text{Percentage of cuttings rooted} = \frac{\text{Number of cuttings rooted}}{\text{Number of cuttings planted}} \times 100$$

3.4.10.3 Number of roots per rooted cutting

The number of adventitious roots per cutting was counted under each treatment and the mean was expressed as the number of roots per cutting. This excludes lateral roots present on the adventitious roots.

3.4.10.4 Length of the longest root

The length of the longest root per cutting in each treatment was measured from point of initiation of the root to the growing tip and their mean was used to express the length of the longest root in centimeters.

3.4.10.5 Fresh weight of roots per rooted cutting

The roots were separated from the sampled cuttings and the fresh weight of roots was recorded using an electronic balance and the mean was calculated and expressed in grams.

3.4.10.6 Dry weight of roots per rooted cutting

After recording the fresh weight, the same roots were dried in hot air oven at 65° C till constant weight was noted. The mean dry weight was expressed in grams.

3.4.11 Shoot parameters

3.4.11.1 Number of days taken for sprouting

The planted cuttings were observed daily under each treatment and the number of days required for sprouting was recorded and their mean was used to calculate the days taken for first sprout to appear.

3.4.11. 2 Per cent sprouting

The per cent sprouting was counted at 30, 60 and 75 days after planting by taking the ratio of number of cuttings sprouted to the number of cuttings planted and multiplied by 100.

$$\text{Percentage of cuttings sprouted} = \frac{\text{Number of cuttings sprouted}}{\text{Number of cuttings planted}} \times 100$$

3.4.11.3 Length of new shoot per cutting

The length of new shoot per cutting was measured after 30, 60 and 75 days after planting and its means were expressed in centimeters. Five cuttings in each replication were used for recording the length of the longest sprout per cutting.

3.4.11.4 Number of leaves on sprout per cutting

The number of leaves at 30, 60 and 75 days after planting was counted and their mean was used to record this parameter.

3.4.11.5 Fresh weight of shoot per rooted cutting

The roots were separated from the sampled cuttings and the fresh weight of roots was recorded using an electronic balance and the mean were expressed in grams.

3.4.11.6 Dry weight of shoot per rooted cutting

After recording the fresh weight, the same roots were dried in hot air oven at 65° C till constant weight was noted. The mean dry weight was noted.

3.4.12 Biochemical analysis

Biochemical analysis was done for total sugars, reducing sugars and non-reducing sugars. At the time of preparation of cuttings for planting, a sample of 100 g each of the plant material from basal 1.0 - 1.5 cm portion of semi-hard wood cuttings was collected and oven dried then ground to fine powder for the purpose of all biochemical estimations. Similarly another lot of 100 g each of plant sample at the time of taking rooting observations was also collected for the biochemical analysis. The methods used for the estimation of different biochemical constituents are given below.

3.4.12.1 Total sugars

For estimation of total sugars 500 mg of oven dried finely ground sample was extracted successively thrice using 80 per cent ethanol. A known volume (1 ml) of this extract was taken in a test tube and alcohol was evaporated on a boiling water bath. Distilled water was added and volume made upto 10 ml. The total sugar content in the alcohol free extract with 1N HCl on a hot water bath for 20 minutes at 50°C and after neutralizing it with 1N NaOH, the total sugars were estimated by Di nitro salicylic acid (DNSA) method (Miller, 1972)., The results were expressed in percentage on dry weight basis.

3.4.12.2 Reducing sugar

Reducing sugars in the extract was determined by using Di nitro-salicylic acid (DNSA) method (Miller, 1972). The results were expressed in percentage on dry weight basis.

3.4.12.3 Non-reducing sugars

Non-reducing sugars were computed by deducting the value of reducing sugars from the amount of total sugars. The results were expressed in percentage on dry weight basis.

3.4.12.4 Chlorophyll content of leaf

Chlorophyll content of leaf was analyzed by collecting the healthy, fully matured leaves from fifth node from the tip of stem at peak growth stage.

Chlorophyll-a, chlorophyll-b and total chlorophyll content of leaf tissue were determined by using Di methyl Sulfoxide (DMSO) as suggested by Shaof and Lium (1976).

Fresh and fully matured leaves from the plant were brought in polyethylene bags from the field and were cut into small pieces. A known weight of sample (100 mg) was incubated in 7.0 ml of DMSO at 65°C for 120 minutes. After the incubation, supernatant was collected by decanting and

leaf tissue was discarded. Then the volume of the supernatant was made up to 10 ml using DMSO.

The absorbance of the extract was measured at 645 nm and 663 nm using DMSO as blank in spectrophotometer (Elico India).

The chlorophyll-a, chlorophyll-b and total chlorophyll contents were calculated by using the formulae given below.

$$\text{Chlorophyll - a} = [12.7(A_{663}) - 2.69(A_{645})] \times \frac{V}{1000 \times W \times a}$$

$$\text{Chlorophyll - b} = [22.9(A_{645}) - 4.68(A_{663})] \times \frac{V}{1000 \times W \times a}$$

$$\text{Total chlorophyll} = [20.2(A_{645}) + 8.02(A_{663})] \times \frac{V}{1000 \times W \times a}$$

Where,

A= Absorbance at specific wave lengths (645 nm and 663 nm)

V= Volume of the extract (10 ml)

W= Fresh weight of the sample (100 mg)

a = Path length of light in cuvette (1 cm)

3.5 Experiment - II

Effect of media on rooting of black pepper cuttings under poly house conditions.

3.5.1 Source of cuttings and their preparation

Similar type of cuttings are taken as in experiment-I.

3.5.2 Preparation of rooting media

Different proportions of rooting media consisting of sand, soil, FYM and saw dust or coir dust or coffee pulp compost or vermicompost were

prepared in accordance with the treatments and were filled in polythene bags and placed in the naturally ventilated poly house.

3.5.3 Design and layout of experiment

Simple completely randomized design was adopted for the experiment. There were thirteen treatments of different rooting media used singly or in combination. Each of the treatment consisted of 100 cuttings replicated thrice. The experiment was conducted in naturally ventilated poly house.

3.5.4 Treatment and planting of cuttings

The growth regulator formulations viz., IBA, 1000 ppm which had shown the highest success in rooting in experiment I of the present study was used as a standard pre-treatment to all cuttings. The method of treatment and planting is same as described earlier.

3.5.5 Treatment details

T ₁	Soil:Sand:FYM (2:1:1)
T ₂	Soil:Sand:FYM:SD (1:1:1:1)
T ₃	Soil:Sand:FYM:SD (2:1:1:1)
T ₄	Soil:Sand:FYM:SD (3:1:1:1)
T ₅	Soil:Sand:FYM:CD (1:1:1:1)
T ₆	Soil:Sand:FYM:CD (2:1:1:1)
T ₇	Soil:Sand:FYM:CD (3:1:1:1)
T ₈	Soil:Sand:FYM:CPC (1:1:1:1)
T ₉	Soil:Sand:FYM:CPC (2:1:1:1)
T ₁₀	Soil:Sand:FYM:CPC (3:1:1:1)
T ₁₁	Soil:Sand:FYM:VC (1:1:1:1)
T ₁₂	Soil:Sand:FYM:VC (2:1:1:1)
T ₁₃	Soil:Sand:FYM:VC (3:1:1:1)

Where, FYM= Farm yard manure,
SD= Saw dust,
CD= Coir dust,
CPC= Coffee pulp compost and
VC= Vermicompost.

3.5.6 Observations recorded

The observations on stem leaves and root characters were recorded in the same way as described for Experiment-I.

3.5.7 Analysis of physico-chemical properties of the medium

3.5.7.1 p^H

Soil p^H was determined by potentiometric method in 1.0:2.5 soil water suspension using p^H meter having a glass-calomel combined electrode (Jackson, 1967).

3.5.7.2 Water holding capacity (WHC)

Water holding capacity was estimated using oven dry method and the results are expressed in percentage.

3.5.7.3 Electrical conductivity (ds/m)

An electrical conductivity of soil samples was measured in soil-water extract of 1:2.5 ratio using conductivity bridge (Jackson, 1967) and expressed in ds/m.

3.5.8 Nutrient status of the medium

3.5.8.1 Available Nitrogen (kg/ha)

Available nitrogen was determined by modified alkaline potassium permanganate method as described by Subbaiah and Asija (1956). Available Nitrogen was calculated by using formula

$$\text{Available N (kg/ha)} = \frac{\text{Sample TV} - \text{Blank TV} \times \text{N of H}_2\text{SO}_4 \times 0.0014}{\text{Weight of soil}} \times 2 \times 10^6 \times 1.12$$

TV - Titre Value N - Normality

3.5.8.2 Available Phosphorous (kg/ha)

The available phosphorous in soil was extracted by using Bray's extractant reagent. The ammonium molybdate solution and stannous chloride solution was added to this filtrate solution. The aliquot was taken and estimated by using spectrophotometer. Standard solutions of P with concentration of 0, 0.1, 0.2, 0.4, 0.6, 0.8 and 1.0 ppm were prepared by following the same procedure but without using soil sample.

$$\text{Available P (kg/ha)} = \frac{\text{Graph ppm}}{10^6} \times \frac{\text{Vol. of extractant}}{\text{Wt. of soil}} \times \frac{\text{Vol. made}}{\text{Aliquot taken}} \times 2 \times 10^6 \times 2.29$$

3.5.8.3 Available Potassium (kg/ha)

The available potassium was extracted from soil by using neutral normal ammonium acetate solution and the aliquot was fed to calibrated flame photometer for K estimation. 0, 10, 20, 30 and 40 ppm of K standard solution was pipetted out to volumetric flask from 100 ppm of potassium standard solution (Black, 1965). These samples were fed to flame photometer to obtain flame photometer reading (graph ppm).

Available K (kg/ha)

$$= \frac{\text{Graph ppm}}{10^6} \times \frac{\text{Vol. of extractant}}{\text{Wt. of soil}} \times \frac{\text{Vol. made}}{\text{Aliquot taken}} \times 2 \times 10^6 \times 1.12$$

3.4.8 Statistical analysis

The experimental data recorded on various parameters during the investigation were analyzed statistically by adopting Fischer's method of analysis of variance as outlined by Gomez and Gomez 1976. The interpretation of data was done by using the critical difference value calculated at 0.05 probability level. The level of significance was expressed at 0.05 probability.

EXPERIMENTAL RESULTS

IV EXPERIMENTAL RESULTS

The results of the present investigation on the “Effect of media and growth regulators on rooting of Black pepper (*Piper nigrum*) cuttings” are presented in this chapter under the following headings.

4. 1 Effect of growth regulators rooting of black pepper cuttings.

4. 1.1 Shoot parameters

4. 1.1.1 Days taken for the first sprout to appear

The data pertaining to days taken for the first sprout to appear as influenced by different growth regulators are depicted in table 1 and illustrated through Fig. 1.

The growth regulators significantly influenced the number of days taken for the first sprout to appear. Earliest sprouting (17.40 days) was observed in the cuttings treated with IBA 1000 ppm, followed by IBA 500 ppm (19.27 days). Whereas delayed sprouting (24.47 days) of cuttings was noticed in untreated control (T_1).

4. 1.1.2 Number of leaves per cuttings

The data pertaining to number of leaves per cutting as influenced by growth regulators at the different stages of growth are presented in table 1 and Fig. 2.

4.1.1.2.1 Number of leaves per cuttings at 30 days after planting

Growth regulators with different concentrations caused significant variation with respect to number of leaves per cutting at 30 days after planting. The number of leaves was maximum in IBA 1000 ppm (1.53) followed by IBA 500 ppm, (1.13), which was on par with NAA 250 ppm (1.07), while the minimum number of leaves were recorded in untreated cuttings (0.40).

Table 1: Effect of growth regulators on days taken for first sprouting and number of leaves of black pepper cuttings.

Treatment	Days to sprout	Number of leaves		
		30 DAP	60 DAP	75 DAP
T ₁ – Control	24.47	0.40	1.40	2.20
T ₂ – IBA 500 ppm	19.27	1.13	2.07	3.60
T ₃ – IBA 1000 ppm	17.40	1.53	2.47	4.20
T ₄ – IBA 1500 ppm	19.93	0.80	1.87	3.13
T ₅ – NAA 250 ppm	19.60	1.07	2.00	3.47
T ₆ – NAA 500 ppm	19.80	0.87	1.93	3.20
T ₇ – NAA 1000 ppm	20.60	0.67	1.60	2.80
T ₈ – IAA 1000 ppm	19.80	0.93	1.93	3.27
T ₉ – NAA + IBA 250 ppm	20.13	0.73	1.73	3.07
T ₁₀ – NAA + IBA 500 ppm	20.60	0.67	1.67	2.87
T ₁₁ – NAA + IBA 1000 ppm	21.87	0.53	1.53	2.40
F- test	**	**	**	**
S Em ±	0.61	0.06	0.08	0.13
C D 5%	1.78	0.18	0.24	0.38

** Highly significant

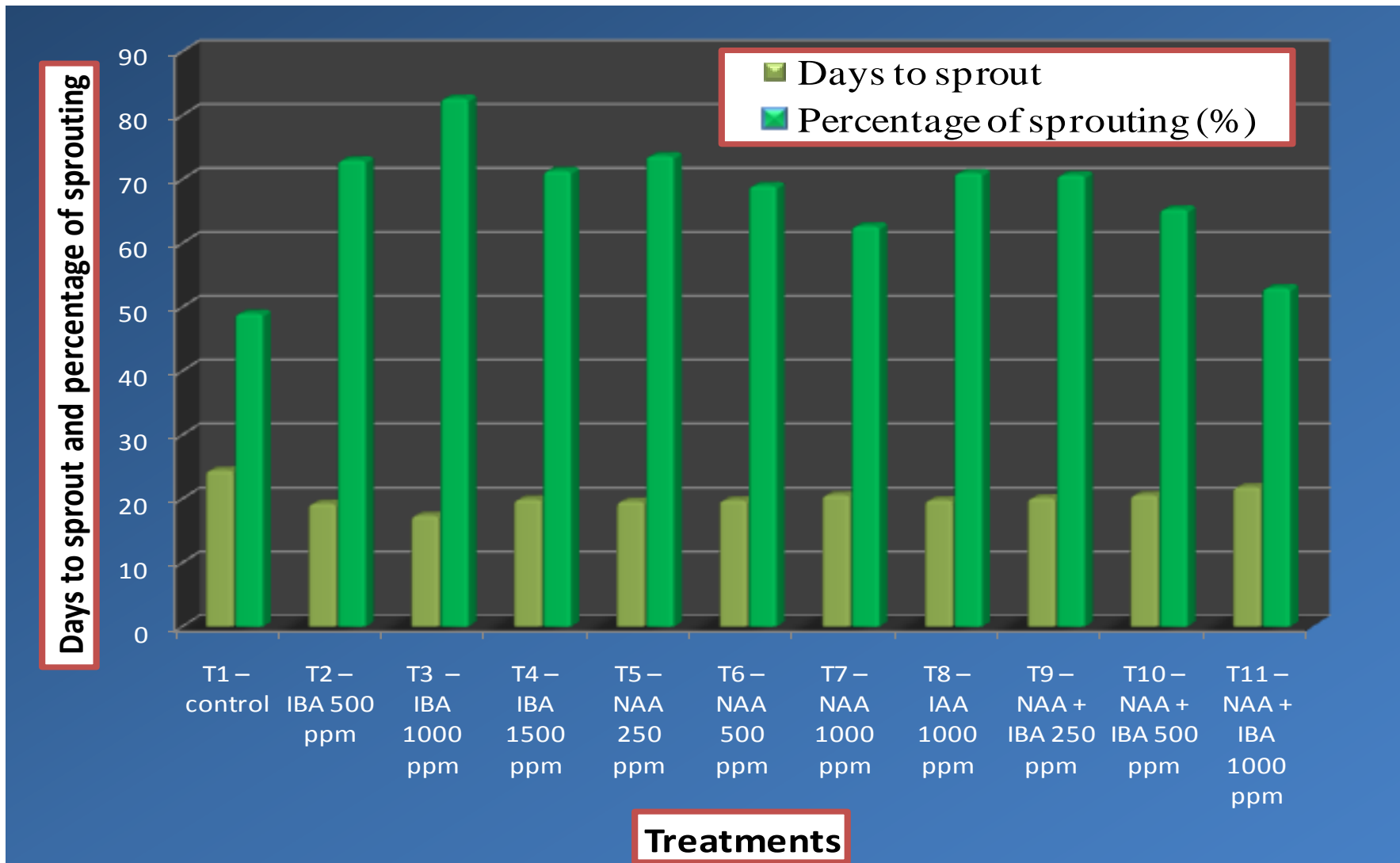


Figure 1: Effect of growth regulators on days to sprout and percentage of sprouting of black pepper cuttings.

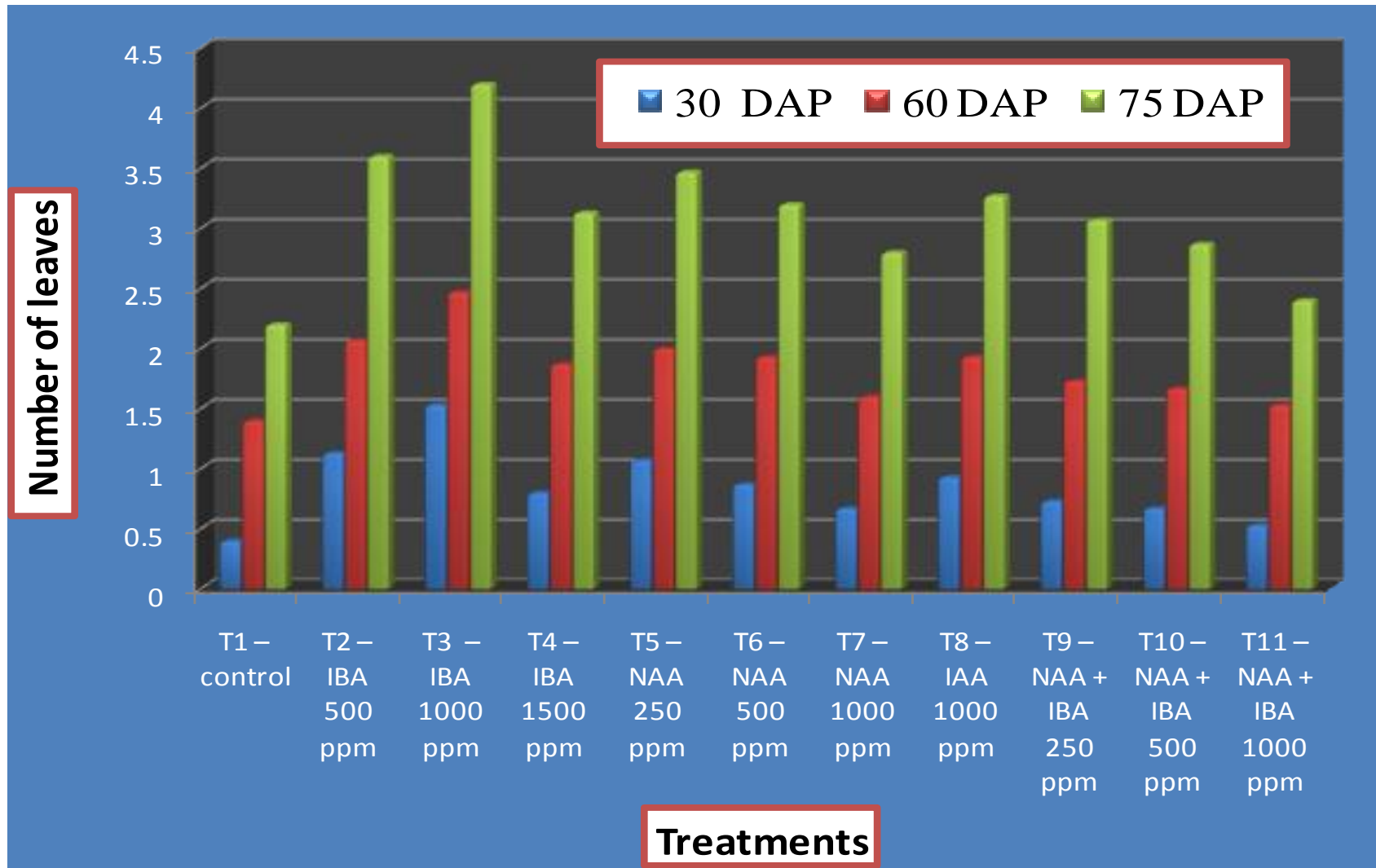


Figure 2: Effect of growth regulators on number of leaves of black pepper cuttings.

4.1.1.2.2 Number of leaves per cuttings at 60 days after planting

The number of leaves per cuttings differed significantly among the different concentrations of growth regulators. The treatment IBA 1000 ppm (T_3) recorded significantly the higher number of leaves per plant (2.47), followed by T_2 with IBA 500 ppm (2.07). Number of leaves was lowest in untreated control (1.40).

4.1.1.2.3 Number of leaves per cuttings at 75 days after planting

At 75 days after planting, differences were significant with respect to number of leaves produced per cuttings, among the different growth regulator treatments. Number of leaves per cuttings was maximum in IBA 1000 ppm (4.20) was found significantly superior to rest of the cultivars. The next best treatment was IBA 500 ppm (3.60), which was on par with NAA 250 ppm (3.47). The minimum number of leaves per cutting (2.20) was recorded in untreated control (T_1) which is on par with NAA+IBA 1000 ppm (2.40). As the dose of IBA and NAA increased the number of leaves per cutting decreased at all the stages.

4. 1.1.3 Shoot length (cm)

Data on the mean length of the shoot as a result of treatment with growth regulators at 30, 60 and 75 days after planting are presented in table 2.

4.1.1.3.1 Shoot length at 30 days after planting (cm)

Shoot length at 30 days after planting varied significantly among different growth regulator treatments which ranging from 2.10 cm in control to maximum 3.83 cm in IBA 1000 ppm. IBA 1000 ppm recorded significantly highest shoot length (3.83 cm) over other treatments and it was followed by IBA 500 ppm (3.38 cm) and the lowest shoot length (2.10 cm) was noticed in control.

Table 2: Effect of growth regulators on shoot length of black pepper cuttings

Treatment	Length of new shoot (cm)		
	30 DAP	60 DAP	75 DAP
T ₁ – Control	2.10	4.44	6.17
T ₂ – IBA 500 ppm	3.38	7.57	9.10
T ₃ – IBA 1000 ppm	3.83	8.11	10.40
T ₄ – IBA 1500 ppm	3.13	6.39	8.42
T ₅ – NAA 250 ppm	3.40	7.15	8.96
T ₆ – NAA 500 ppm	3.16	6.47	8.53
T ₇ – NAA 1000 ppm	2.66	5.87	7.97
T ₈ – IAA 1000 ppm	3.20	6.93	8.70
T ₉ – NAA + IBA 250 ppm	3.10	6.38	8.16
T ₁₀ – NAA + IBA 500 ppm	3.06	5.95	8.14
T ₁₁ – NAA + IBA 1000 ppm	2.28	5.83	7.39
F- test	**	**	**
S Em ±	0.09	0.26	0.22
C D 5%	0.25	0.77	0.63

** Highly significant

4.1.1.3.2 Shoot length at 60 days after planting (cm)

The shoot length measured at 60 days after planting ranged between 4.44 cm to 8.11 cm. The maximum shoot length was recorded in IBA 1000 ppm (8.11cm), which was on par with IBA 500 ppm (7.57 cm). The minimum shoot length (4.44 cm) was noticed in untreated control.

4.1.1.3.3 Shoot length at 75 days after planting (cm)

Shoot length at 75 days after planting varied significantly among different growth regulator treatments ranging from 6.17 cm to 10.40 cm. Significantly the higher shoot length was recorded in IBA 1000 ppm (10.40 cm). IBA 500 ppm (9.10 cm), NAA 250 ppm (8.96 cm), IAA 1000 ppm (8.70 cm) and NAA 500 ppm (8.53 cm) were found at par with respect to their shoot length. The lowest shoot length was recorded in untreated control (6.17 cm).

4. 1.1.4 Sprouting Percentage

The data pertaining to sprouting percentage as influenced by growth regulators at the different stages of growth are presented in Table 3 and Fig. 1.

4.1.1.4.1 Sprouting percentage at 30 days after planting

The significant differences were noticed with different concentrations of growth regulators. IBA 1000 ppm (T₃) recorded the maximum percentage of sprouting (40 %), followed by (T₅) NAA 250 ppm (31.33 %). Whereas, control (T₁) recoded the minimum percentage of sprouting (12.33 %).

4.1.1.4.2 Sprouting Percentage at 60 days after planting

Sprouting percentage differed significantly among the growth regulator treatments. A treatment with IBA 1000 ppm (T₃) recorded significantly the maximum sprouting percentage (67 %), which was on par with NAA 250 ppm (64.67 %). Sprouting percentage was minimum in untreated control (30.33 %).

Table 3: Effect of growth regulators on Percentage of sprouting of black pepper cuttings.

Treatment	Percentage of sprouting		
	30 DAP	60 DAP	75 DAP
T ₁ – Control	12.33	30.33	49.00
T ₂ – IBA 500 ppm	30.33	57.67	73.00
T ₃ – IBA 1000 ppm	40.00	67.00	82.67
T ₄ – IBA 1500 ppm	28.67	55.67	71.33
T ₅ – NAA 250 ppm	31.33	64.67	73.67
T ₆ – NAA 500 ppm	24.33	49.00	69.00
T ₇ – NAA 1000 ppm	19.33	40.00	62.67
T ₈ – IAA 1000 ppm	28.33	52.00	71.00
T ₉ – NAA + IBA 250 ppm	27.00	50.00	70.67
T ₁₀ – NAA + IBA 500 ppm	22.33	47.33	65.33
T ₁₁ – NAA + IBA 1000 ppm	14.33	35.33	53.00
F- test	**	**	**
S Em ±	1.54	2.37	2.06
C D 5%	4.51	6.96	6.04

** Highly significant

4.1.1.4.3 Sprouting Percentage at 75 days after planting

The significant differences were manifested regarding different concentrations of growth regulators. IBA 1000 ppm (T₃) recorded the maximum percentage of sprouting (82.67 %), followed by (T₅) NAA 250 ppm (73.67 %). Whereas, control recoded the minimum percentage of sprouting (49 %).

4. 1.1.5 Fresh and dry weights of shoots (g)

The data regarding fresh and dry weights of shoots as influenced by growth regulators are presented in table 4.

Fresh and dry weights of shoots were found to be significantly the highest in IBA 1000 ppm (11 and 3.52 g, respectively), which is on par with IBA 500 ppm (10.01 g and 3.22 g respectively), followed by NAA 250 ppm (9.90 g and 2.70 g respectively), while it was minimum in control (8.16 g and 1.57 g respectively).

4. 1.2 Root Parameters

4. 1.2.1 Days taken to root initiation

The perusal of data presented in Table 5 and Fig.3 clearly indicates the significant effect of growth regulators on number of days taken for rooting of black pepper cuttings.

An early rooting (35.47 days) was observed in cuttings dipped in (T₃) IBA 1000 ppm, followed by (T₂) IBA 500 ppm (38.67 days). Whereas, delayed rooting was noticed in (T₁) untreated control (44.27 days) which was on par with (T₁₁) IBA+NAA 1000 ppm (42.67 days).

4. 1.2.2 Rooting Percentage

The data on percentage of cuttings rooted at the end of 75 days after planting as influenced by different growth regulator treatments are presented in table 5 and Fig. 3.

Table 4: Effect of growth regulators on fresh and dry weight of shoots of black pepper cuttings.

Treatment	Fresh weight (g)	Dry weight (g)
T ₁ – Control	8.16	1.57
T ₂ – IBA 500 ppm	10.01	3.22
T ₃ – IBA 1000 ppm	11.00	3.52
T ₄ – IBA 1500 ppm	9.82	2.14
T ₅ – NAA 250 ppm	9.90	2.70
T ₆ – NAA 500 ppm	9.83	2.37
T ₇ – NAA 1000 ppm	9.10	2.04
T ₈ – IAA 1000 ppm	9.89	2.54
T ₉ – NAA + IBA 250 ppm	9.19	2.10
T ₁₀ – NAA + IBA 500 ppm	9.19	2.08
T ₁₁ – NAA + IBA 1000 ppm	8.68	1.86
F- test	**	**
S Em ±	0.37	0.20
C D 5%	1.07	0.58

** Highly significant

Table 5: Effect of growth regulators on days taken to root initiation and percentage of rooting of black pepper cuttings.

Treatment	Days taken to root initiation	Percentage of rooting
T ₁ – Control	44.27	43.33
T ₂ – IBA 500 ppm	38.67	66.67
T ₃ – IBA 1000 ppm	35.47	70.00
T ₄ – IBA 1500 ppm	40.00	56.67
T ₅ – NAA 250 ppm	38.80	63.33
T ₆ – NAA 500 ppm	39.60	60.00
T ₇ – NAA 1000 ppm	40.27	43.33
T ₈ – IAA 1000 ppm	38.93	60.00
T ₉ – NAA + IBA 250 ppm	40.67	53.33
T ₁₀ – NAA + IBA 500 ppm	41.07	50.00
T ₁₁ – NAA + IBA 1000 ppm	42.67	43.33
F- test	**	**
S Em ±	1.06	2.66
C D 5%	3.12	7.80

** Highly significant

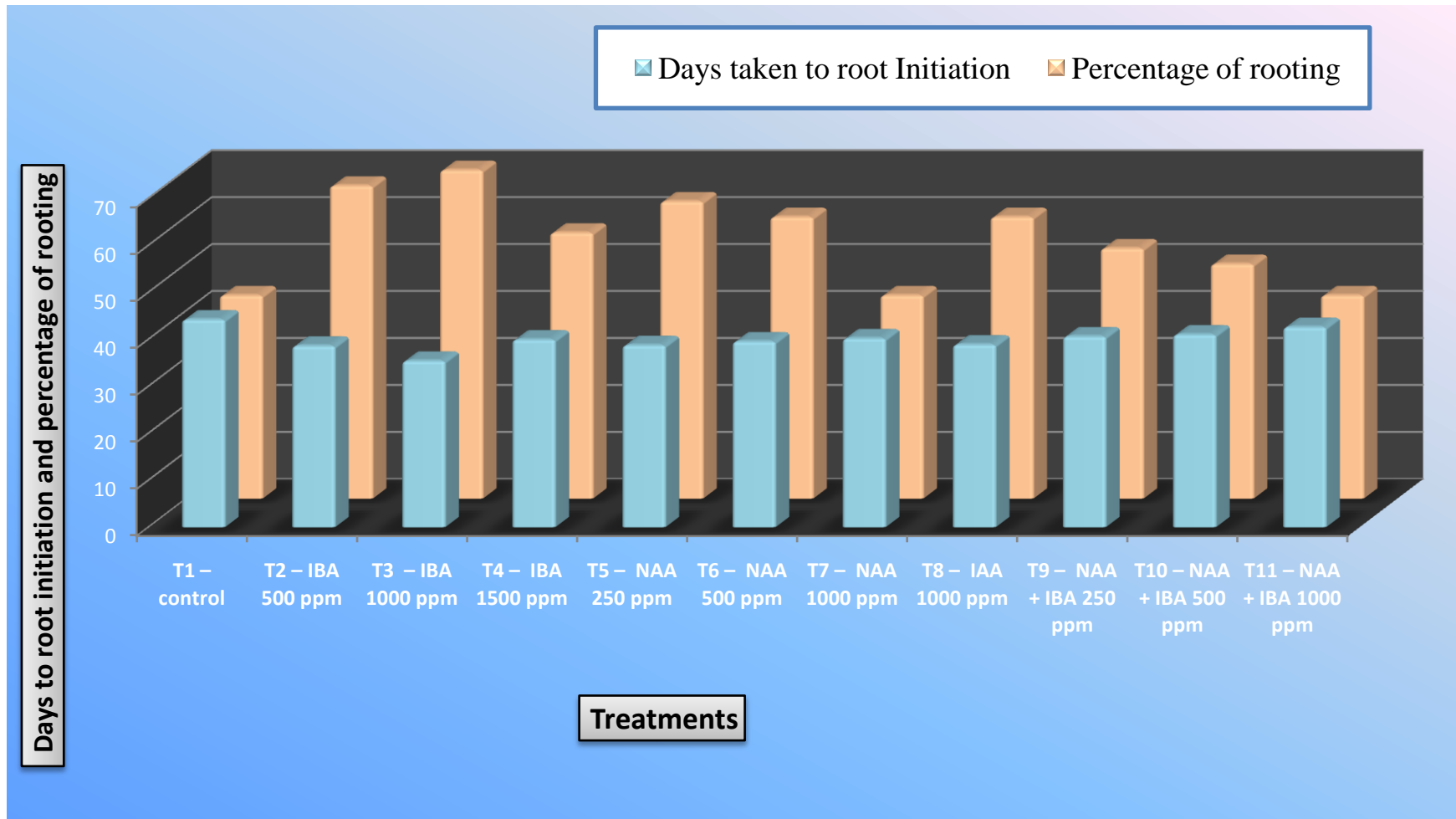


Figure 3: Effect of growth regulators on root initiation and rooting percentage of black pepper cuttings.

It is seen that all the growth regulator treatments significantly promoted rooting in cuttings. The highest (70 %) rooting was recorded in cuttings treated with IBA 1000 ppm (T₃) as against the least (43.33 %) percentage of rooting in untreated cuttings (T₁ and T₁₁). The next promotive effect in this regard was by treatment of IBA and NAA at 500 ppm and 250 ppm which recorded 66.67 and 63.33 per cent respectively. The use of higher concentrations of both IBA, NAA and combination of NAA+IBA were not appreciable for black pepper cuttings.

4. 1.2.3 Number of primary roots per cutting

The data pertaining to the mean number of roots per cutting as influenced by different growth regulator treatments are presented in Table 6 and Fig. 4.

The data revealed that growth regulators promoted more number of primary roots per cutting as compared to control. The treatment IBA 1000 ppm (T₃) had recorded maximum number of primary roots (7.28) followed by T₂ treatment with IBA 500 ppm (6.11), while the minimum number of primary roots (1.78) was recorded in control. The remaining treatments have recorded the increase in number of primary roots and were in the range of 1.89-5.67 per cutting.

4. 1.2.4 Length of the roots (cm)

The data pertaining to the root length as influenced by different growth regulator treatments are presented in table 6 and Fig. 4.

The different concentrations of growth regulators tried were able to induce significant differences among the treatments with respect to longest primary root. IBA 1000 ppm treated cuttings developed significantly longest primary roots (18.18 cm) followed by IBA 500 ppm (17.09 cm) while, shortest primary root length were observed in the control (10.93 cm). The remaining treatments have recorded significant

Table 6: Effect of growth regulators on number of primary roots and root length of black pepper cuttings.

Treatment	Number of primary roots	Root length (cm)
T ₁ – Control	1.78	10.93
T ₂ – IBA 500 ppm	6.11	17.09
T ₃ – IBA 1000 ppm	7.28	18.18
T ₄ – IBA 1500 ppm	5.11	15.15
T ₅ – NAA 250 ppm	5.67	16.93
T ₆ – NAA 500 ppm	5.11	16.41
T ₇ – NAA 1000 ppm	3.33	14.55
T ₈ – IAA 1000 ppm	5.44	16.76
T ₉ – NAA + IBA 250 ppm	4.89	15.32
T ₁₀ – NAA + IBA 500 ppm	4.00	14.85
T ₁₁ – NAA + IBA 1000 ppm	1.89	12.27
F- test	**	**
S Em ±	0.25	0.34
C D 5%	0.73	1.01

** Highly significant

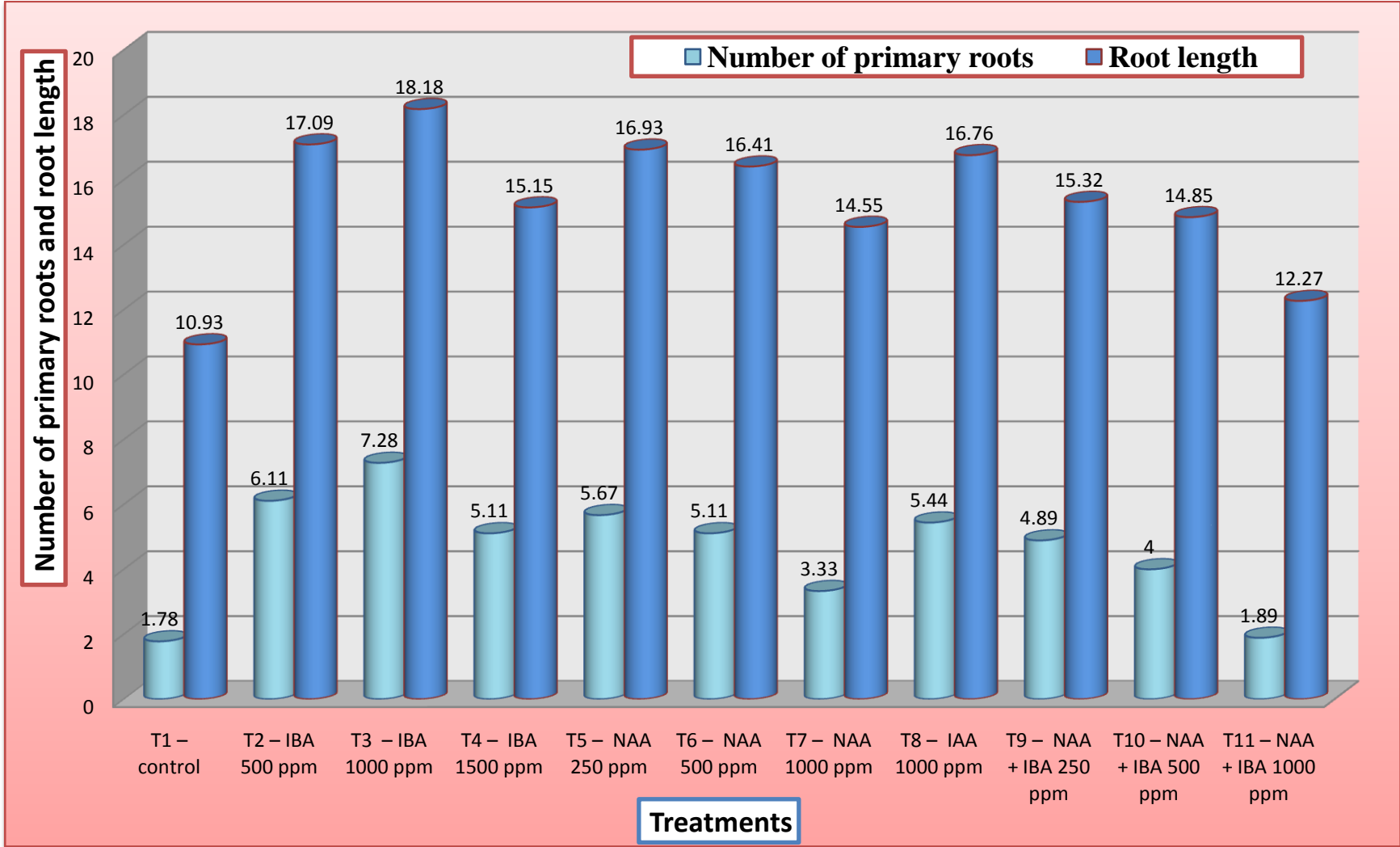


Figure 4: Effect of growth regulators on number of primary roots and root length of black pepper cuttings.

increase in length of primary root and were in the range of 12.27 -16.93 cm per rooted cutting.

4.1.2.5 Fresh weight of roots per cutting (g)

The fresh weight of roots as influenced by growth regulators is presented in table 7.

Significant differences were observed among the different growth regulators with regard to the fresh weight of roots. The maximum fresh weight of roots was recorded in the cuttings treated with IBA 1000 ppm (2.71 g), followed by IBA 500 ppm (2.34 g) and untreated control recorded the minimum (1.30 g).

4.1.2.6 Dry weight of roots per cutting (g)

The dry weight of roots as influenced by growth regulators is presented in table 7.

Significant differences were observed among the different growth regulators with regard to the dry weight of roots. The maximum dry weight of roots was recorded in the cuttings that were treated with IBA 1000 ppm (1.02 g), followed by IBA 500 ppm (0.91 g) and while untreated control recorded the minimum (0.49 g) dry weight of roots.

4.1.3 Biochemical analysis

The data on sugar content in rooted black pepper cuttings as influenced by growth regulators are given in table 8 and Fig. 5.

4.1.3.1 Reducing Sugars

The shoots selected for cuttings contained 0.83 per cent reducing sugars (initial) before they were treated and planted for rooting. The sugar level showed a marginal decline as the rooting process continued. At the end of 75 days after planting, IBA 1000 ppm treated cuttings registered

Table 7: Effect of growth regulators on fresh and dry weight of roots of black pepper cuttings.

Treatment	Fresh weight (g)	Dry weight (g)
T ₁ – Control	1.30	0.49
T ₂ – IBA 500 ppm	2.34	0.91
T ₃ – IBA 1000 ppm	2.71	1.02
T ₄ – IBA 1500 ppm	2.03	0.77
T ₅ – NAA 250 ppm	2.32	0.89
T ₆ – NAA 500 ppm	2.27	0.85
T ₇ – NAA 1000 ppm	1.67	0.68
T ₈ – IAA 1000 ppm	2.29	0.87
T ₉ – NAA + IBA 250 ppm	1.99	0.76
T ₁₀ – NAA + IBA 500 ppm	1.80	0.76
T ₁₁ – NAA + IBA 1000 ppm	1.41	0.54
F- test	**	**
S Em ±	0.14	0.04
C D 5%	0.40	0.11

** Highly significant

significantly the lowest reducing sugars (0.56) followed by IBA 500 ppm (0.60) while the highest reducing sugars was observed under control (0.74).

4.1.3.2 Non Reducing Sugars

In case of non-reducing sugars, the initial sugar content of cutting before planting was 1.63 per cent. The value changed marginally during the process of rooting. At the end of 75 days after planting, the cuttings treated with IBA 1000 ppm registered significantly the lowest reducing sugars (1.10) followed by IBA 500 ppm (1.16) while the highest reducing sugars was observed in the control (1.44).

4.1.3.3 Total Sugars

The initial total sugar content of cutting before planting was 2.46 per cent. Its content changed marginally due to metabolic process of rooting. At the end of 75 days after planting, IBA 1000 ppm treated cuttings registered significantly the lower total sugars (1.66) followed by IBA 500 ppm (1.75) while the highest reducing sugars was observed under control (2.18).

4.2 Effect of rooting medias on rooting of black pepper cuttings.

4. 2.1 Shoot parameters

4. 2.1.1 Days taken for the first sprout to appear

The data related to number of days taken for first sprout to appear in black pepper cuttings raised under different rooting media are furnished in table 9.

The data showed that the performance of different rooting medias differed significantly with each other. Among various rooting media, soil + sand + FYM + vermicompost (1:1:1:1) recorded minimum (15.93 days) for sprouting and is on par with soil + sand + FYM + vermicompost in 2:1:1:1 proportion (16.20 days), soil + sand + FYM + coir dust in 1:1:1:1 proportion (16.53 days), soil + sand + FYM + coir dust in 2:1:1:1 proportion (16.87

Table 8: Effect of growth regulators on sugar content of black pepper cuttings.

Treatment	Reducing Sugar (%)	Non-Reducing Sugar (%)	Total Sugar (%)
T ₁ – Control	0.74	1.44	2.18
T ₂ – IBA 500 ppm	0.60	1.16	1.75
T ₃ – IBA 1000 ppm	0.56	1.10	1.66
T ₄ – IBA 1500 ppm	0.63	1.22	1.85
T ₅ – NAA 250 ppm	0.60	1.16	1.76
T ₆ – NAA 500 ppm	0.62	1.19	1.81
T ₇ – NAA 1000 ppm	0.69	1.33	2.02
T ₈ – IAA 1000 ppm	0.61	1.17	1.78
T ₉ – NAA + IBA 250 ppm	0.65	1.27	1.92
T ₁₀ – NAA + IBA 500 ppm	0.67	1.30	1.98
T ₁₁ – NAA + IBA 1000 ppm	0.70	1.36	2.06
F- test	**	**	**
S Em ±	0.01	0.02	0.02
C D 5%	0.02	0.05	0.07
Initial value	0.83	1.63	2.46

** Highly significant

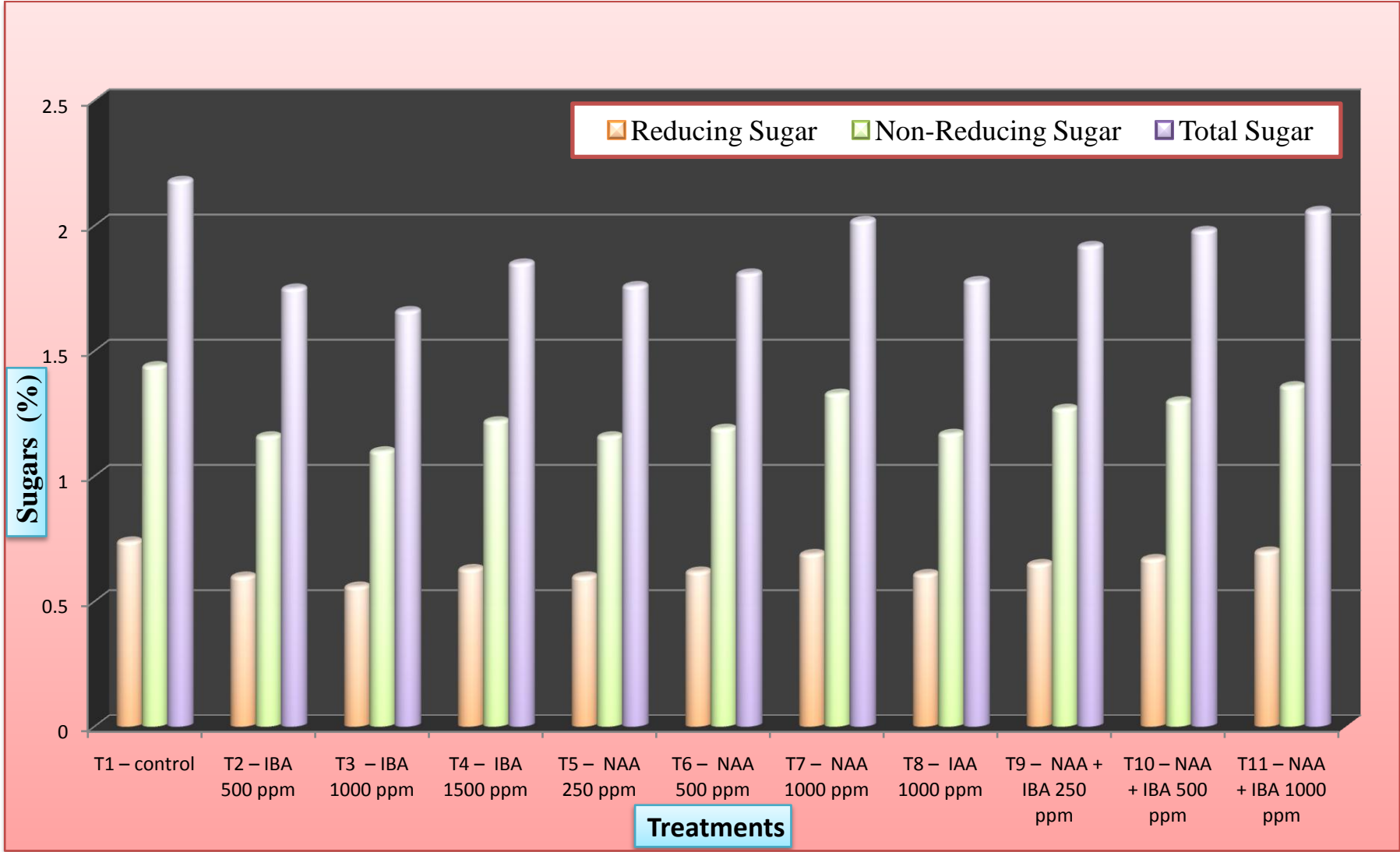


Figure 5: Effect of growth regulators on sugar content of black pepper cuttings.

days) and soil + sand + FYM + vermicompost (3:1:1:1) (16.93 days). While, maximum number of days taken for first sprout to appear was in soil + sand + FYM (2:1:1) (18.07 days). Rest of the medias recorded the number of days taken for first sprout to appear in the range of 17.33 – 17.87 days.

4. 2.1.2 Number of leaves per cutting

The data on the number of leaves per cutting raised under various rooting media is given in table 9.

A linear increase in number of leaves per cutting was observed with increase in days from 30 DAP to 75 DAP. The cuttings raised in treatment T₁₁ with soil + sand + FYM + vermicompost (1:1:1:1) recorded the maximum number of leaves per cutting (6.70) which is significantly different from the rest of rooting medias. The next best rooting media was soil + sand + FYM + vermicompost in 2:1:1:1 proportion (6.23). The least number of leaves (4.20) was observed in cuttings raised under soil + sand + FYM (2:1:1) at the end of 75 days after planting.

4. 2.1.3 Shoot length (cm)

The data pertaining to length of shoot as influenced by different rooting media is presented in table 10.

A linear increase in length of shoot was observed with increase in days from 30 DAP to 75 DAP. The cuttings rose under soil + sand + FYM + vermicompost (1:1:1:1) recorded the maximum length of sprout (20.26 cm) which is significantly different from the rest and is followed by soil + sand + FYM + vermicompost in 2:1:1:1 proportion (18 cm). Whereas the shortest length of shoot (10.42 cm) was recorded in soil + sand + FYM (2:1:1) at the end of 75 days after planting.

Table 9: Effect of rooting media on number of leaves and days taken for first sprouting of black pepper cuttings.

Treatment	Days to sprout	Number of leaves (DAP)		
		30	60	75
T ₁ - SOIL: SAND: FYM (2:1:1)	18.07	1.45	2.43	4.20
T ₂ - SOIL: SAND: FYM : SD (1:1:1:1)	17.07	1.75	3.17	5.60
T ₃ - SOIL: SAND: FYM : SD (2:1:1:1)	17.43	1.68	3.10	5.37
T ₄ - SOIL: SAND: FYM : SD (3:1:1:1)	17.80	1.65	2.97	5.10
T ₅ - SOIL: SAND: FYM : CD (1:1:1:1)	16.53	1.92	3.30	5.90
T ₆ - SOIL: SAND: FYM : CD (2:1:1:1)	16.87	1.85	3.17	5.70
T ₇ - SOIL: SAND: FYM : CD (3:1:1:1)	17.33	1.78	3.03	5.43
T ₈ - SOIL: SAND: FYM : CC (1:1:1:1)	17.53	1.72	2.93	5.23
T ₉ - SOIL: SAND: FYM : CC (2:1:1:1)	17.67	1.68	2.80	5.07
T ₁₀ - SOIL: SAND: FYM : CC (3:1:1:1)	17.87	1.62	2.67	4.68
T ₁₁ - SOIL: SAND: FYM : VC (1:1:1:1)	15.93	1.98	3.63	6.70
T ₁₂ - SOIL: SAND: FYM : VC (2:1:1:1)	16.20	1.95	3.37	6.23
T ₁₃ - SOIL: SAND: FYM : VC (3:1:1:1)	16.93	1.85	3.13	5.70
F- test	**	**	**	**
S Em ±	0.38	0.05	0.07	0.12
C D 5%	1.12	0.13	0.21	0.35

FYM- Farm Yard Manure

SD- Saw Dust

CD- Coir Dust

CC- Coffee pulp Compost

VC- Vermicompost

DAP- Days After Planting

** Highly significant

Table 10: Effect of rooting media on shoot length of black pepper cuttings.

Treatment	Length of new shoot (cm)		
	30 DAP	60 DAP	75 DAP
T ₁ - SOIL: SAND: FYM (2:1:1)	3.72	7.83	10.42
T ₂ - SOIL: SAND: FYM : SD (1:1:1:1)	4.45	9.93	15.21
T ₃ - SOIL: SAND: FYM : SD (2:1:1:1)	4.27	9.39	14.52
T ₄ - SOIL: SAND: FYM : SD (3:1:1:1)	4.09	8.63	12.64
T ₅ - SOIL: SAND: FYM : CD (1:1:1:1)	4.83	10.25	17.71
T ₆ - SOIL: SAND: FYM : CD (2:1:1:1)	4.69	9.93	16.99
T ₇ - SOIL: SAND: FYM : CD (3:1:1:1)	4.25	9.40	15.77
T ₈ - SOIL: SAND: FYM : CC (1:1:1:1)	4.39	9.13	13.32
T ₉ - SOIL: SAND: FYM : CC (2:1:1:1)	4.10	8.68	12.97
T ₁₀ - SOIL: SAND: FYM : CC (3:1:1:1)	3.79	8.19	12.12
T ₁₁ - SOIL: SAND: FYM : VC (1:1:1:1)	5.78	11.80	20.26
T ₁₂ - SOIL: SAND: FYM : VC (2:1:1:1)	5.20	10.93	18.00
T ₁₃ - SOIL: SAND: FYM : VC (3:1:1:1)	4.61	10.03	16.03
F- test	**	**	**
S Em ±	0.17	0.23	0.45
C D 5%	0.50	0.66	1.31

FYM- Farm Yard Manure

SD- Saw Dust

CD- Coir Dust

CC- Coffee pulp Compost

VC- Vermicompost

DAP- Days After Planting

** Highly significant

4. 2.1.4 Sprouting percentage

The data pertaining to sprouting percentage as influenced by rooting media at the different stages of growth are presented in table 11 and Fig. 6.

4. 2.1.4.1 Sprouting percentage at 30 days after planting

The significant differences were manifested regarding different rooting media. Soil + sand + FYM + vermicompost (1:1:1:1) recorded maximum percentage of sprouting (50.33 %), followed by soil + sand + FYM + vermicompost in 2:1:1:1 proportion (48 %). soil + sand + FYM + coir dust (1:1:1:1) (44 %). Whereas, control (T₁) recoded the minimum sprouting (37.67 %).

4. 2.1.4.2 Sprouting percentage at 60 days after planting

Sprouting percentage differed significantly among the different rooting media. soil + sand + FYM + vermicompost (1:1:1:1) recorded significantly the maximum Sprouting percentage (78.67 %), followed by soil + sand + FYM + vermicompost in 2:1:1:1 proportion (75.67). Sprouting percentage was minimum in control (T₁) (66.67 %).

4. 2.1.4.3 Sprouting Percentage at 75 days after planting

The significant differences were manifested regarding different rooting media. The media (T₁₁) soil + sand + FYM + vermicompost (1:1:1:1) recorded maximum percentage of sprouting (85.33 %), followed by (T₁₂) soil + sand + FYM + vermicompost in 2:1:1:1 proportion (82.33 %). Whereas, control (T₁) recoded the minimum percentage of sprouting (76 %).

4. 2.1.5 Fresh and dry weights of shoots (g)

The data regarding fresh and dry weights of shoots (g) as influenced by rooting media are presented in Table 12.

Fresh and dry weights of shoots were found to be the highest (17.47 g and 6.65 g respectively) in the media containing soil + sand + FYM +

Table 11: Effect of rooting media on percentage of sprouting of black pepper cuttings.

Treatment	Percentage of sprouting (%)		
	30 DAP	60 DAP	75 DAP
T ₁ - SOIL: SAND: FYM (2:1:1)	37.67	66.67	76.00
T ₂ - SOIL: SAND: FYM : SD (1:1:1:1)	43.00	72.00	79.33
T ₃ - SOIL: SAND: FYM : SD (2:1:1:1)	41.67	70.33	78.67
T ₄ - SOIL: SAND: FYM : SD (3:1:1:1)	39.67	68.67	76.67
T ₅ - SOIL: SAND: FYM : CD (1:1:1:1)	44.00	74.00	81.67
T ₆ - SOIL: SAND: FYM : CD (2:1:1:1)	42.33	72.67	81.00
T ₇ - SOIL: SAND: FYM : CD (3:1:1:1)	40.00	71.00	79.67
T ₈ - SOIL: SAND: FYM : CC (1:1:1:1)	41.67	70.67	78.00
T ₉ - SOIL: SAND: FYM : CC (2:1:1:1)	40.00	69.00	77.33
T ₁₀ - SOIL: SAND: FYM : CC (3:1:1:1)	38.33	67.33	76.33
T ₁₁ - SOIL: SAND: FYM : VC (1:1:1:1)	50.33	78.67	85.33
T ₁₂ - SOIL: SAND: FYM : VC (2:1:1:1)	48.00	75.67	82.33
T ₁₃ - SOIL: SAND: FYM : VC (3:1:1:1)	45.00	71.67	80.67
F- test	**	**	**
S Em ±	0.77	0.70	0.99
C D 5%	2.25	2.03	2.88

FYM- Farm Yard Manure

SD- Saw Dust

CD- Coir Dust

CC- Coffee pulp Compost

VC- Vermicompost

DAP- Days After Planting

** Highly significant

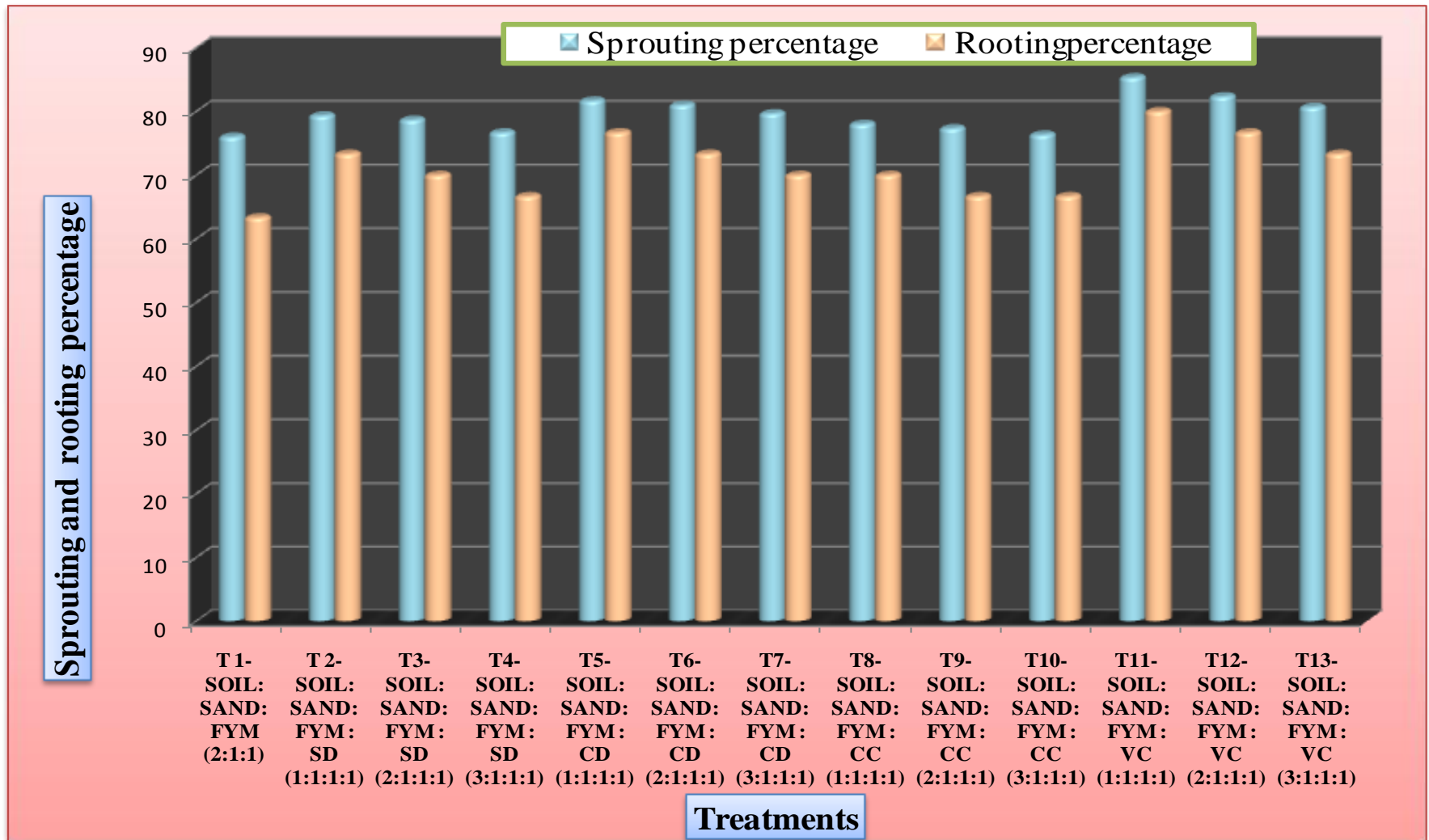


Figure 6: Effect of media on sprouting and rooting percentage of black pepper cuttings.

Table 12: Effect of rooting media on fresh and dry weight of shoots of black pepper cuttings.

Treatment	Fresh weight of shoot (g)	Dry weight of shoot (g)
T ₁ - SOIL: SAND: FYM (2:1:1)	10.66	4.02
T ₂ - SOIL: SAND: FYM : SD (1:1:1:1)	13.03	5.08
T ₃ - SOIL: SAND: FYM : SD (2:1:1:1)	12.66	4.85
T ₄ - SOIL: SAND: FYM : SD (3:1:1:1)	11.87	4.50
T ₅ - SOIL: SAND: FYM : CD (1:1:1:1)	15.00	5.77
T ₆ - SOIL: SAND: FYM : CD (2:1:1:1)	14.07	5.31
T ₇ - SOIL: SAND: FYM : CD (3:1:1:1)	12.83	4.99
T ₈ - SOIL: SAND: FYM : CC (1:1:1:1)	11.96	4.53
T ₉ - SOIL: SAND: FYM : CC (2:1:1:1)	11.67	4.44
T ₁₀ - SOIL: SAND: FYM : CC (3:1:1:1)	11.18	4.26
T ₁₁ - SOIL: SAND: FYM : VC (1:1:1:1)	17.47	6.65
T ₁₂ - SOIL: SAND: FYM : VC (2:1:1:1)	15.03	6.02
T ₁₃ - SOIL: SAND: FYM : VC (3:1:1:1)	13.80	5.25
F- test	**	**
S Em ±	0.37	0.14
C D 5%	1.08	0.40

FYM- Farm Yard Manure

SD- Saw Dust

CD- Coir Dust

Coffee pulp Compost

VC- Vermicompost

** Highly significant

vermicompost in 1:1:1:1 proportion, followed by soil + sand + FYM + vermicompost in 2:1:1:1 proportion (15.03 g and 6.02 g respectively), while, it was least (10.66 g and 4.02 g respectively) in control (T₁).

4.2.2 Root parameters

4. 2.2.1 Days taken to root initiation

The perusal of data presented in Table 13 clearly indicates the significant effect of rooting media on number of days taken for rooting of black pepper cuttings.

An early rooting (33.07 days) was observed in cuttings planted in the media containing soil + sand + FYM + vermicompost (1:1:1:1), which is on par with treatments soil + sand + FYM + vermicompost in 2:1:1:1 proportion (33.47 days) and soil + sand + FYM + vermicompost in 3:1:1:1 proportion (34.13 days). While, significantly delayed rooting was noticed in control (T₁) (39.13 days).

4. 2.2.2 Rooting Percentage

The data on percentage of cuttings rooted at the end of 75 days after planting as influenced by different rooting medias are presented in table 13 and Fig. 6.

It was observed that, all the cuttings pretreated with growth regulator and planted in different rooting media significantly promoted rooting in cuttings. The highest rooting (80 %) was noted in cuttings raised in the media containing soil + sand + FYM + vermicompost (1:1:1:1), which is on par with soil + sand + FYM + vermicompost in 2:1:1:1 proportion (76.67 %), soil + sand + FYM + coir dust in 1:1:1:1 proportion (76.67 %), soil + sand + FYM + vermicompost in 3:1:1:1 proportion (73.33 %), soil + sand + FYM + saw dust (1:1:1:1) with rooting percentage of 73.67. The minimum (63.33 %) was recorded in the control.

Table 13: Effect of rooting media on days taken to root initiation and percentage of rooting of black pepper cuttings.

Treatment	Days taken to root initiation	Percentage of rooting (%)
T ₁ - SOIL: SAND: FYM (2:1:1)	39.13	63.33
T ₂ - SOIL: SAND: FYM : SD (1:1:1:1)	34.80	73.33
T ₃ - SOIL: SAND: FYM : SD (2:1:1:1)	35.27	70.00
T ₄ - SOIL: SAND: FYM : SD (3:1:1:1)	35.80	66.67
T ₅ - SOIL: SAND: FYM : CD (1:1:1:1)	35.87	76.67
T ₆ - SOIL: SAND: FYM : CD (2:1:1:1)	36.13	73.33
T ₇ - SOIL: SAND: FYM : CD (3:1:1:1)	37.87	70.00
T ₈ - SOIL: SAND: FYM : CC (1:1:1:1)	37.00	70.00
T ₉ - SOIL: SAND: FYM : CC (2:1:1:1)	37.60	66.67
T ₁₀ - SOIL: SAND: FYM : CC (3:1:1:1)	38.13	66.67
T ₁₁ - SOIL: SAND: FYM : VC (1:1:1:1)	33.07	80.00
T ₁₂ - SOIL: SAND: FYM : VC (2:1:1:1)	33.47	76.67
T ₁₃ - SOIL: SAND: FYM : VC (3:1:1:1)	34.13	73.33
F- test	**	*
S Em ±	0.40	3.20
C D 5%	1.17	9.31

FYM- Farm Yard Manure

SD- Saw Dust

CD- Coir Dust

Coffee pulp Compost

VC- Vermicompost

** Highly significant

* Significant

LEGEND

Growth regulator formulations

- T₁ – Control
- T₂ – IBA 500 ppm
- T₃ – IBA 1000 ppm
- T₄ – IBA 1500 ppm
- T₅ – NAA 250 ppm
- T₆ – NAA 500 ppm
- T₇ – NAA 1000 ppm
- T₈ – IAA 1000 ppm
- T₉ – NAA + IBA 250 ppm
- T₁₀ – NAA + IBA 500 ppm
- T₁₁ – NAA + IBA 1000 ppm

Rooting media

- T₁- SOIL: SAND: FYM (2:1:1)
- T₂- SOIL: SAND: FYM : SD (1:1:1:1)
- T₃- SOIL: SAND: FYM : SD (2:1:1:1)
- T₄- SOIL: SAND: FYM : SD (3:1:1:1)
- T₅- SOIL: SAND: FYM : CD (1:1:1:1)
- T₆- SOIL: SAND: FYM : CD (2:1:1:1)
- T₇- SOIL: SAND: FYM : CD (3:1:1:1)
- T₈- SOIL: SAND: FYM : CC (1:1:1:1)
- T₉- SOIL: SAND: FYM : CC (2:1:1:1)
- T₁₀- SOIL: SAND: FYM : CC (3:1:1:1)
- T₁₁- SOIL: SAND: FYM : VC (1:1:1:1)
- T₁₂- SOIL: SAND: FYM : VC (2:1:1:1)
- T₁₃- SOIL: SAND: FYM : VC (3:1:1:1)

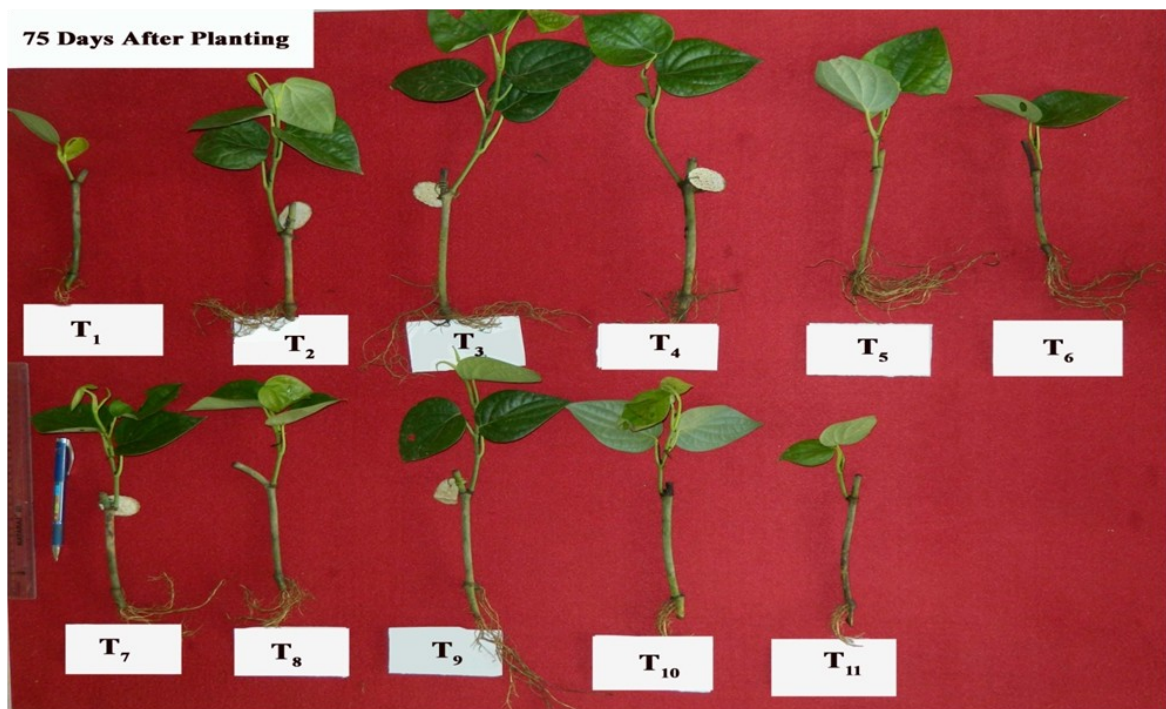


Plate 4: Effect of growth regulators on rooting of black pepper cuttings.



Plate 5: Effect of media on rooting of black pepper cuttings.

4. 2.2.3 Number of primary roots per cutting

The data pertaining to the mean number of roots per cutting as influenced by different rooting media are presented in Table 14 and Fig. 7.

The data revealed that rooting media promoted more number of primary roots per cutting as compared to control. The treatment (T₁₁) soil + sand + FYM + vermicompost (1:1:1:1) had promoted development of the maximum number of primary roots (11.07), followed by T₁₂ soil + sand + FYM + vermicompost in 2:1:1:1 proportion (10.13) while the least number of primary roots (7.60) was recorded in control.

4. 2.2.4 Length of the root (cm)

The data pertaining to the mean number of roots per cutting as influenced by different rooting media treatments are presented in table 14 and illustrated in Fig. 7.

The different composition of rooting media tried were able to induce significant differences among the treatments with respect to the primary root length. The media (T₅) comprising of soil + sand + FYM + coir dust (1:1:1:1) registered significantly longest primary root length (26.79 cm), followed by soil + sand + FYM + coir dust in 2:1:1:1 proportion (24.27 cm). While, shortest primary root length was observed under control (17.78 cm). The remaining treatments have favoured significant increase in length of primary root and were in the range of 18.57 to 24.17cm per rooted cutting.

4.2.2.5 Fresh weight of roots per cutting (g)

The fresh weight of roots as influenced by rooting media is presented in Table 15.

Significant differences were observed among the different rooting media with regard to the fresh weight of roots. The maximum fresh weight of roots (5.08 g) was recorded in the cuttings that were planted in soil + sand +

Table 14: Effect of rooting media on number of primary roots and root length of black pepper cuttings.

Treatment	Number of primary roots	Root length (cm)
T ₁ - SOIL: SAND: FYM (2:1:1)	7.60	17.78
T ₂ - SOIL: SAND: FYM : SD (1:1:1:1)	8.73	22.77
T ₃ - SOIL: SAND: FYM : SD (2:1:1:1)	8.37	22.05
T ₄ - SOIL: SAND: FYM : SD (3:1:1:1)	7.97	19.37
T ₅ - SOIL: SAND: FYM : CD (1:1:1:1)	9.73	26.79
T ₆ - SOIL: SAND: FYM : CD (2:1:1:1)	9.53	24.17
T ₇ - SOIL: SAND: FYM : CD (3:1:1:1)	9.10	21.47
T ₈ - SOIL: SAND: FYM : CC (1:1:1:1)	8.33	20.16
T ₉ - SOIL: SAND: FYM : CC (2:1:1:1)	8.20	19.49
T ₁₀ - SOIL: SAND: FYM : CC (3:1:1:1)	8.00	18.57
T ₁₁ - SOIL: SAND: FYM : VC (1:1:1:1)	11.07	24.27
T ₁₂ - SOIL: SAND: FYM : VC (2:1:1:1)	10.13	23.23
T ₁₃ - SOIL: SAND: FYM : VC (3:1:1:1)	9.33	22.17
F- test	**	**
S Em ±	0.25	0.47
C D 5%	0.73	1.36

FYM- Farm Yard Manure

SD- Saw Dust

CD- Coir Dust

Coffee pulp Compost

VC- Vermicompost

** Highly significant

Table 15: Effect of rooting media on fresh and dry weight of roots of black pepper cuttings.

Treatment	Fresh weight (g)	Dry weight (g)
T ₁ - SOIL: SAND: FYM (2:1:1)	2.64	0.99
T ₂ - SOIL: SAND: FYM : SD (1:1:1:1)	3.44	1.34
T ₃ - SOIL: SAND: FYM : SD (2:1:1:1)	3.20	1.21
T ₄ - SOIL: SAND: FYM : SD (3:1:1:1)	3.01	1.14
T ₅ - SOIL: SAND: FYM : CD (1:1:1:1)	4.33	1.65
T ₆ - SOIL: SAND: FYM : CD (2:1:1:1)	4.07	1.50
T ₇ - SOIL: SAND: FYM : CD (3:1:1:1)	3.83	1.37
T ₈ - SOIL: SAND: FYM : CC (1:1:1:1)	3.38	1.28
T ₉ - SOIL: SAND: FYM : CC (2:1:1:1)	3.16	1.14
T ₁₀ - SOIL: SAND: FYM : CC (3:1:1:1)	2.76	1.02
T ₁₁ - SOIL: SAND: FYM : VC (1:1:1:1)	5.08	1.96
T ₁₂ - SOIL: SAND: FYM : VC (2:1:1:1)	4.52	1.77
T ₁₃ - SOIL: SAND: FYM : VC (3:1:1:1)	4.17	1.62
F- test	**	**
S Em ±	0.12	0.05
C D 5%	0.36	0.14

FYM- Farm Yard Manure

SD- Saw Dust

CD- Coir Dust

Coffee pulp Compost

VC- Vermicompost

** Highly significant

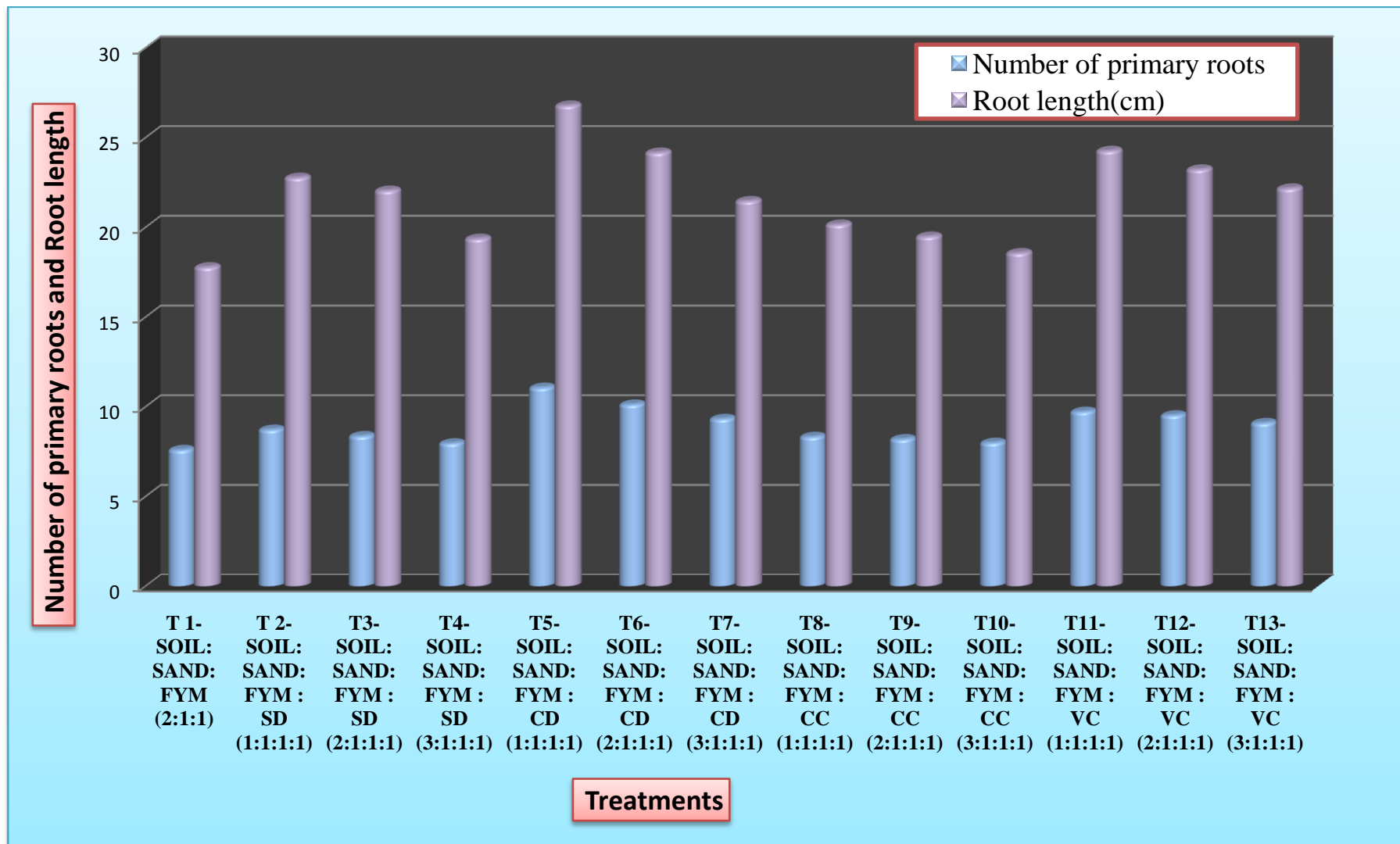


Figure 7: Effect of media on number of primary roots and root length of black pepper cuttings.

FYM + vermicompost (1:1:1:1), followed by soil + sand + FYM + vermicompost in 2:1:1:1 proportion (4.52 g) and control (T₁) recorded the minimum (2.64 g) weight.

4.2.2.6 Dry weight of roots per cutting (g)

The dry weight of roots as influenced by rooting media is presented in Table 15.

Significant differences were observed among the different rooting media compositions with regard to the dry weight of roots. The maximum dry weight of roots (1.96 g) was recorded in the cuttings that were planted in soil + sand + FYM + vermicompost (1:1:1:1), followed by soil + sand + FYM + vermicompost in 2:1:1:1 proportion (1.77 g) and while control recorded the least (0.99 g) weight.

4.2.3 Biochemical analysis

The data pertaining to chlorophyll content of leaf at 75 days after planting are presented in the Table 16 and Fig. 8.

4.2.3.1 Chlorophyll content of leaf

4.2.3.1.1 Chlorophyll- a

Significant differences were observed among different rooting media compositions for chlorophyll content of leaf. Chlorophyll-a content was maximum (1.39 mg/g) in soil + sand + FYM + vermicompost (1:1:1:1), followed by soil + sand + FYM + vermicompost in 2:1:1:1 proportion (1.26 mg/g), whereas minimum chlorophyll- a content (0.35 mg/g) was recorded in control.

4.2.3.1.2 Chlorophyll- b

Chlorophyll-b content of leaf varied significantly among different composition of rooting media. The treatment (T₁₁) soil + sand + FYM + vermicompost (1:1:1:1) recorded highest (0.59 mg/g), followed by 0.53 mg/g

Table 16: Effect of rooting media on chlorophyll content of black pepper cuttings.

Treatment	Chlorophyll content (mg/ 100 g fresh weight)		
	Chlorophyll “ a”	Chlorophyll “b”	Total Chlorophyll
T ₁ - SOIL: SAND: FYM (2:1:1)	0.35	0.13	0.49
T ₂ - SOIL: SAND: FYM : SD (1:1:1:1)	0.89	0.40	1.29
T ₃ - SOIL: SAND: FYM : SD (2:1:1:1)	0.92	0.28	1.20
T ₄ - SOIL: SAND: FYM : SD (3:1:1:1)	0.77	0.32	1.09
T ₅ - SOIL: SAND: FYM : CD (1:1:1:1)	1.22	0.46	1.75
T ₆ - SOIL: SAND: FYM : CD (2:1:1:1)	1.06	0.41	1.47
T ₇ - SOIL: SAND: FYM : CD (3:1:1:1)	0.84	0.35	1.19
T ₈ - SOIL: SAND: FYM : CC (1:1:1:1)	0.89	0.30	1.19
T ₉ - SOIL: SAND: FYM : CC (2:1:1:1)	0.75	0.35	1.10
T ₁₀ - SOIL: SAND: FYM : CC (3:1:1:1)	0.55	0.20	0.75
T ₁₁ - SOIL: SAND: FYM : VC (1:1:1:1)	1.39	0.59	1.99
T ₁₂ - SOIL: SAND: FYM : VC (2:1:1:1)	1.26	0.53	1.79
T ₁₃ - SOIL: SAND: FYM : VC (3:1:1:1)	1.02	0.49	1.51
F- test	**	**	**
S Em ±	0.07	0.03	0.06
C D 5%	0.21	0.09	0.16

FYM- Farm Yard Manure

SD- Saw Dust

CD- Coir Dust

Coffee pulp Compost

VC- Vermicompost

** Highly significant

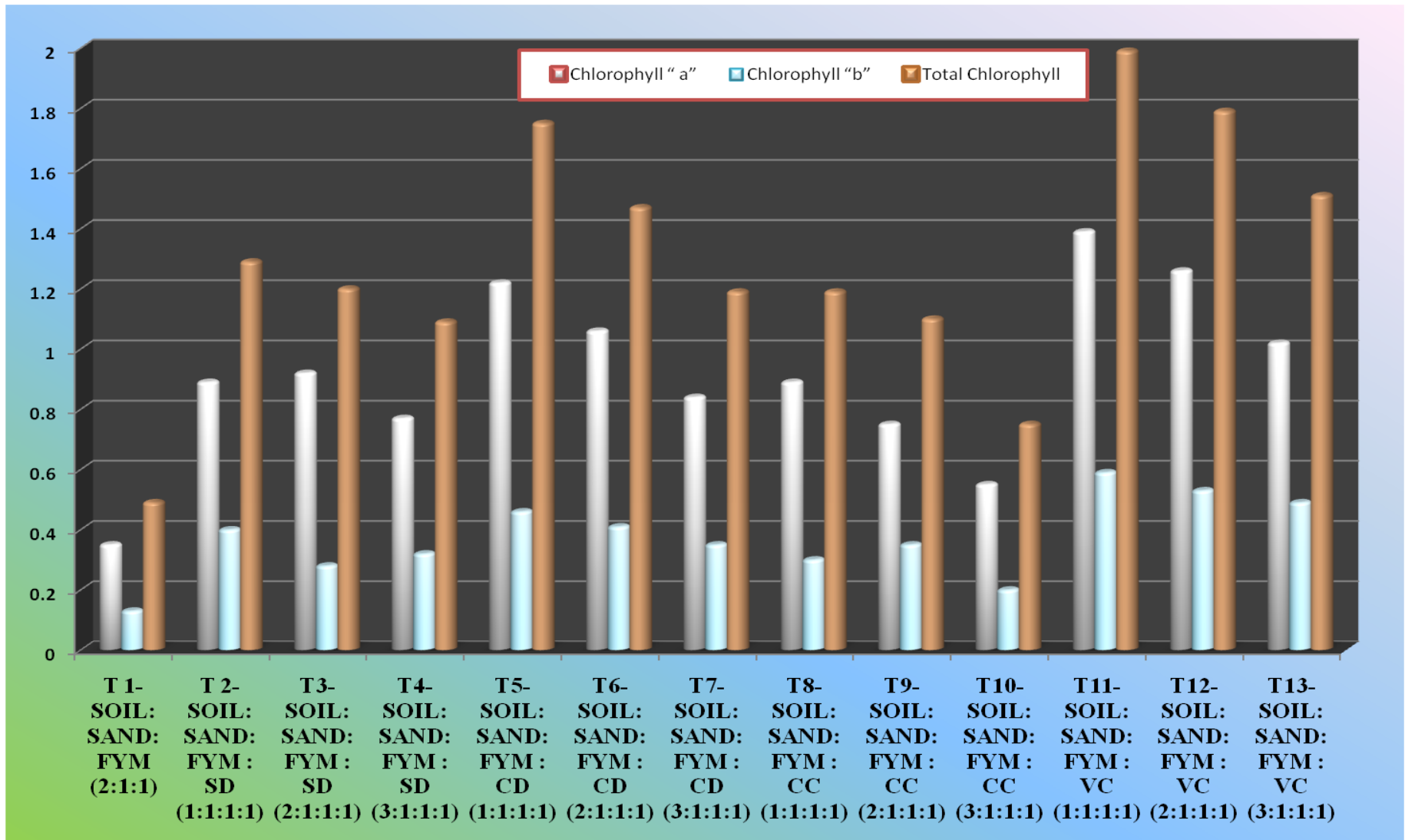


Figure 8: Effect of media on Chlorophyll content of black pepper cuttings.

in soil + sand + FYM + vermicompost (2:1:1:1) however, it was minimum in control (0.13 mg/g).

4.2.3.1.3 Total chlorophyll

Total chlorophyll content of leaf varied significantly among the different rooting media compositions. The maximum total chlorophyll content (1.99 mg/g) was recorded in the treatment soil + sand + FYM + vermicompost (1:1:1:1), followed by 1.79 mg/g in soil + sand + FYM + vermicompost (2:1:1:1). The minimum total chlorophyll content (0.49 mg/g) was recorded in control.

DISCUSSION

V. DISCUSSION

Propagation is the natural mechanism by which plants regenerate. Plant perpetuates in nature through seeds or through vegetative parts or special and modified organs.

Asexual propagation of plants is essentially the reproduction of plant material from vegetative organs so that the offspring will contain the exact characteristics of the parent plant with regards to genotypes and health status (Macdonald, 1996). Perpetuation of plants by vegetative means is sometimes easiest, quicker and economical method. In several horticultural crops different methods of vegetative propagation are employed depending upon their suitability in multiplying a particular plant species. Among the different methods of vegetative propagation, cuttings are the most popular and widely used method. Propagating a plant by means of cutting is a simple, quick and cheapest method wherein no complex interaction of stock and scion is involved.

Vegetative propagation can be made more effective with the use of plant growth regulators that have been exploited profitably to alter plant archetype to achieve higher yields and quality in intended species. These are the chemical substances which are needed in small quantity for fine tuning of various physiological processes. It has been widely demonstrated that extremely minute concentrations of plant growth substances have the potential to regulate several phases of plant growth and development spanning from seed germination, growth, flowering, fruiting and seed formation through development and senescence. Of the different groups, auxins were the first class of growth regulators discovered. Notably, auxins have been in use for initiation of rooting in cuttings of various horticultural crops. Among them, the most widely used are indole butyric acid (IBA) and naphthalene acetic acid (NAA). Several horticultural crops have been successfully propagated by cuttings by use of such auxins under suitable environmental conditions.

There is no universal or ideal rooting mix for cuttings. An appropriate propagation medium depends on the species, cutting type, season, propagation system, cost and availability of the medium components are other considerations. An ideal propagation media should hold and provide moisture for cuttings, to permit penetration and exchange of air and to create dark environment at the base of the cuttings (Hartmann *et al.*, 2002).

Black pepper (*Piper nigrum*) can be propagated through seeds and vegetatively through semi hardwood cuttings. Indole-3-butyric acid (IBA) is still the most widely used synthetic auxin for rooting in stem cuttings and to increase the success percentage of cuttings (Gasper and Hofinger, 1989; Al-Saqri and Alderson, 1996). As information available on optimum concentration of growth regulators and locally available substrates as rooting media for regeneration of *Piper nigrum* by semi hardwood cuttings is meager, it was felt to develop a rapid, convenient, easy and economically viable method for raising *Piper nigrum* for commercial planting.

Hence, an investigation entitled “Effect of growth regulators and media on rooting of black pepper (*Piper nigrum*) cuttings” was taken up and the results obtained from two investigations are discussed under this chapter.

5.1 Experiment – I

5.1 Effect of growth regulators on rooting of black pepper cuttings.

5.1.1 Shoot parameters

The data (Table 1, 2, 3 and 4) clearly indicated the favourable and significant influence of growth regulators on all shoot parameters as compared to control. IBA was superior to NAA. The combination of IBA and NAA at different concentrations was not so effective in respect of shoot parameters studied.

Cuttings treated with growth regulators recorded early sprouting only in lower or medium concentrations of growth regulators (IBA and NAA) indicating deleterious effect at higher concentration than optimum or

threshold values of growth regulators. However IBA at 1000 ppm concentration recorded early sprouting, maximum per cent sprouting, length of shoot, number of leaves, fresh and dry weight of shoots as compared to control. These results are in conformity with Chandramouli (2001) in *Bursera penicillata*, Kempe gowda (2006) in long pepper and Diwaker (2010) in guggal.

Early sprouting (17.40 days) and highest percentage (82.67) of sprouting was recorded in the treatment IBA 1000 ppm (Fig. 1). This may be due to better utilization of stored carbohydrates, nitrogen and other factors with the aid of growth regulators (Chandramouli, 2001). In all the growth regulators tested, linear increase in the parameters was observed in all the concentrations. However, linearity was more prominent with high values only at optimum concentration. Similar findings were also reported by Patil and Shirol (1991) and Rajarama (1997). Further, stored food materials with the aid of growth regulators have hastened the sprouting thereby enhancing the utilization of carbohydrates (Haissig and Davies, 1984).

With regard to number of leaves, cuttings treated with IBA at 1000 ppm and 500 ppm performed better (4.2 and 3.6 leaves per cutting, respectively) over other treatments (Fig. 2). Chandramouli (2001) observed similar trend and attributed it to activation of shoot growth which probably might have increased number of nodes that led to development of more number of leaves under mist conditions.

Cuttings treated with IBA at 1000 ppm have recorded the maximum shoot length when compared to other treatments. Similar findings were also reported by Kempe gowda *et al.* (2006) in long pepper and attributed it to the auxins activated shoot growth which might have resulted in elongation of stems through cell division accounting in higher number of leaves and shoot length.

Different concentrations of IBA caused significant difference over control with regard to fresh and dry weight of shoots. The maximum fresh

and dry weight of shoots was recorded with IBA 1000 ppm. The results reported by Kempe Gowda *et al.* (2006) in long pepper followed the similar trend. This may be due to auxin activated the stem and leaf growth which might have resulted in elongation of stem and number of leaves through cell division and cell elongation accounting for higher fresh and dry weights.

5.1.2 Root parameters

Adventitious root formation is a developmental process involving sequences of histological events with each stage having different requirement for growth substances like auxins, cytokinins and gibberllic acid (Eriksen and Mohammed, 1974, Smith and Thorpe, 1975).

An early root induction was observed in all the cuttings treated with growth regulators especially with IBA as compared to NAA, IAA and in combination of IBA and NAA. IAA was also quite helpful in inducing early rooting compared to control which took maximum number of days for root induction in black pepper cuttings. Similar trend was observed in respect of rooting percentage also.

Earliest rooting (35.47 days) and maximum rooting (70 %) were observed when the cuttings were treated with IBA 1000 ppm, which differed significantly from rest of the treatments (Fig. 4). An early sprouting and higher shoot parameters at initial stages might have brought early and better rooting. Duhamel (1958) reported that hormone like substances were formed in developing bud, which transfer through phloem to the base of the cuttings, where these stimulate rooting. Further, stored food materials with the aid of growth regulators might have hastened the rooting (Haissig and Davies, 1984).

A similar increase in rooting percentage of Indian lavender stem cuttings applied with growth regulators (IBA and NAA) has also been reported by earlier workers (Somappa, 1979, Chandramouli, 2001 and Swetha, 2005). The results obtained are in line with those of Diwakar *et al.* (2010) in guggul.

Significant effect of growth regulators has been observed on number and quality of roots produced in black pepper cuttings as compared to control (Fig. 3). Cuttings treated with IBA (1000 ppm) recorded the maximum number of roots (7.28) and length of the root (18.18 cm). It can be ascribed to enhanced hydrolysis of carbohydrates caused by auxin treatment (Rajarama, 1997). Further, Krishnamurthy (1981) opined that auxins would bring about various physiological changes, but the mechanism by which these changes are brought about is not fully understood except for the effect of auxin on cell elongation. The better response to IBA (1000 ppm) may be attributed to increased rate of respiration, accumulation of higher level of amino acids at their bases, 48 hours after the treatment than untreated cuttings.

In the present investigation, among different growth regulators IBA 1000 ppm showed better results followed by IBA 500 ppm with respect to various growth parameters that were under consideration. This effect may be due to its slow translocation property or slow destruction by auxin destroying enzyme system (Debnath and Maiti, 1990). The beneficial effect of higher concentrations of IBA on rooting of cuttings is supposed to be due to its instability at lower concentrations at the site of application (Thimmappa and Bhattacharjee, 1990 in scented geranium). Similar opinions were also held by Gupta (1995) in white oleander and Singh (2001) in jasmine.

Somappa (1979) obtained increased root length and thickness in IBA treated cuttings in Indian lavender. Similar results were also reported by several workers (Smitha, 2005 and Diwakar, 2010). It may be attributed to the action of auxin activity which might have caused hydrolysis and translocation of carbohydrate and nitrogenous substances at the base of cuttings and resulted in accelerated cell elongation and cell division (Singh *et al.*, 2003). Another possible reason may be early formation of roots and efficient utilization of reserved food materials, which might have resulted in elongated growth of roots in treated cuttings (Ghatnatti, 1997).



Plate 6: Effect of different concentrations of IBA on rooting of black pepper cuttings.

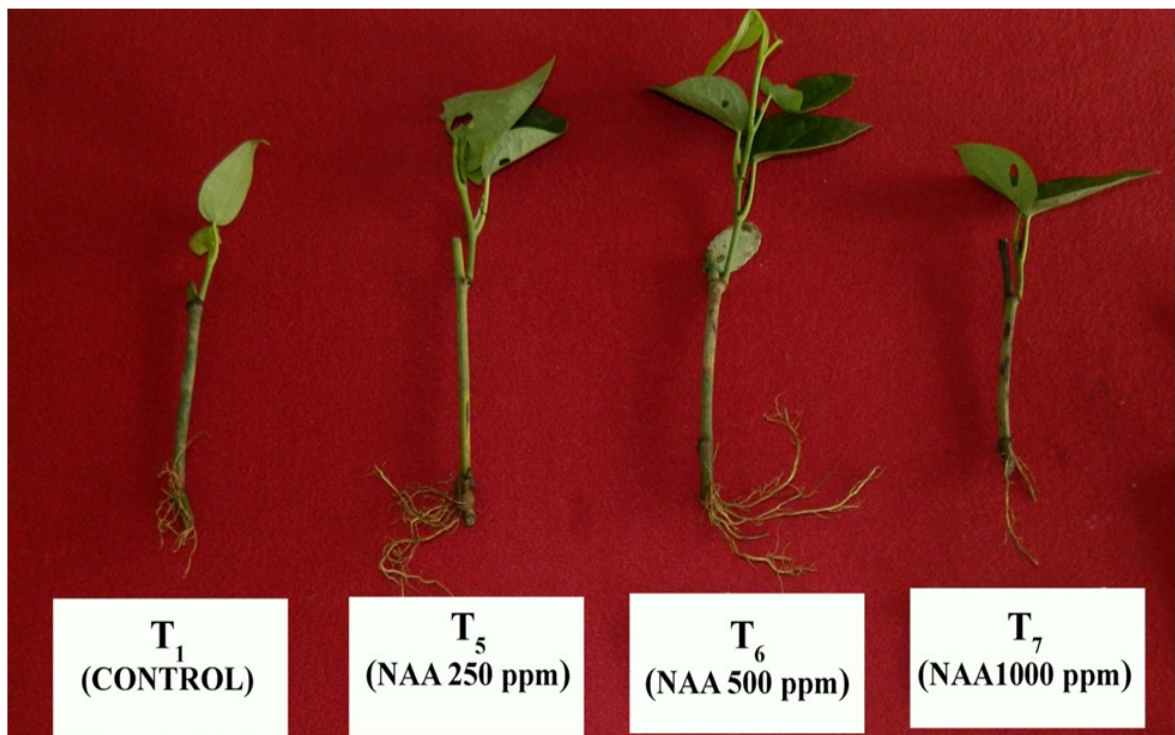


Plate 7: Effect of different concentrations of NAA on rooting of black pepper cuttings.

The growth regulator treatments increased the fresh and dry weight of induced roots. The maximum fresh and dry weight of roots (2.71 and 1.02 g, respectively) was observed in IBA 1000 ppm followed by IBA at 500 ppm each (Table 8). Swetha (2005) obtained higher fresh and dry weight in IBA treated cuttings of Indian lavender. The maximum fresh and dry weight of roots in cuttings treated with IBA 1000 ppm can be very well related to higher number of roots, length and thickness of the roots obtained with the same treatment (Table 5). Similar results were reported by earlier workers (Ghosh and Basu, 1974, Patil and Shirol, 1991 and Singh *et al.*, 2003). It is obvious that auxin treatment induced higher number of primary and secondary roots, that might have also resulted in elongation of these roots through cell division (Debnath and Maiti, 1990) and consequently accounting for higher fresh and dry weight of roots.

In general, IBA 1000 ppm and IBA 500 ppm have been found to induce significant rooting in black pepper cuttings. The basis for this may be enhanced hydrolysis of nutrient reserves (mainly starch) by auxin treatments. According to Nanda *et al.* (1968) enhanced hydrolysis activity in the presence of exogenously applied hormones was responsible for the increased rooting in auxin treated cuttings. The cuttings which received IBA at 1000 ppm excelled over all the other treatments in all the root characters, and it was followed by IBA 500 ppm.

In addition to growth regulators the better rooting can be attributed to the favourable conditions prevailing in poly houses like high temperature (30-35° C) and high relative humidity (85-90 %) and is responsible for reduced transpiration and respiration rate associated with higher photosynthetic activity which promoted better rooting in cuttings (Hartmann and Kester, 1986).

5.1.3 Biochemical analysis

The physiological state of cuttings exerts a strong influence on development of roots and shoots from cuttings. This may be mainly related to sugars.

Reducing sugars, non reducing sugars and total sugars marginally changed during the process of rooting in both untreated and treated cuttings (Fig. 5). IBA 1000 ppm treated cuttings had least total sugars (1.66 %), reducing sugar (0.56 %) and non reducing sugars (1.10 %). This may be due to enhanced depletion of sugars by hydrolysis and their utilization during root initiation as reported by Hegde (1981) in black pepper.

The steady decline of sugars during the initiation and growth of roots indicates breakdown of carbohydrates during root development. Arslonov (1979) noted a rise in catalase and peroxidase activity which accompanied break down of carbohydrates in lemon cuttings. According to Somappa (1979), exogenous application of auxins produced changes in the redox regime and this resulted in utilization of stored food substances for quicker root formation in Indian lavender cuttings. Similar trend was noticed by earlier workers viz., Patil and Shirol (1991) in oleander and Singh (1992) in *Callistemon lanceolatus*.

The fact that relatively higher total sugar and lower starch content of cuttings was essential for good rooting was reported by earlier workers (Nanda *et al.*, 1971 and Reuveni and Adato, 1974).

5.2 Experiment – II

5.2 Effect of rooting media on rooting of black pepper cuttings.

5.2.1 Shoot parameters

Among the various rooting media studied in the present investigation, there were significant differences in shoot characters among the different rooting media (Table 9 to 12).

The earliest sprouting (15.93 days) and the maximum per cent sprouting (85.33 %) was observed in the media (Table 11) comprised of soil + sand + FYM + Vermicompost (1:1:1:1 v/v). This might be due to the presence of growth promoting substances in vermicompost which helped in better

utilization of stored carbohydrates, nitrogen and other factors. These results are in conformity with Gavrilov (1963) who reported that vermicompost could be a definitive source of plant growth regulators produced by interactions between microorganisms and earthworms, which could contribute significantly to enhancement of plant growth.

The treatment, soil + sand + FYM + Vermicompost (1:1:1:1 v/v) had a profound influence on length of new shoot and number of leaves (Table 10) per cutting (20.26 cm and 6.70 respectively). The above mentioned shoot parameters combined, led to higher fresh and dry weight of shoot (17.47 g and 6.65 g, respectively). This may be attributed due to the excellent structure, porosity and nutrients (Appendix 1) in available form such as nitrate nitrogen and soluble phosphorus might have been the main reasons for excellent growth in media comprising of vermicompost (Edwards and Neuhauser, 1988). Further, Atiyeh et al., (2001), reported that the amounts of nitrate nitrogen in the planting media increased with the increasing vermicompost concentrations. Also, Shi-wei and Fu-zhen, (1991) reported that vermicompost might have greatly increased surface areas, providing more micro sites for microbial decomposing organisms and strong adsorption and retention of nutrients which might have resulted in better growth of cuttings.

Reddy (1998) also observed that the length and weight of the shoots of *Catharanthus rosus* and *Oriza sativa* showed significant increase when they were applied with the casts of *Perionyx*. These results are in conformity with earlier workers Vadiraj *et al.* (1992) in cardamom seedlings, Siddagangaiah *et al.* (1996) in vanilla, Thankamani *et al.* (1996) in black pepper and Venkateshan *et al.* (2010) in *Gymnemma sylvestris*.

5.2.2 Root parameters

The present study indicated that, significant influence of rooting media on increasing the rooting percentage of black pepper cuttings propagated under naturally ventilated polyhouse.

The effect was marked in rooting media *viz.*, soil + sand + FYM + vermicompost (1:1:1:1 v/v) with 80%, soil + sand + FYM + vermicompost (2:1:1:1 v/v) with 76.67 % and soil + sand + FYM + coir dust (1:1:1:1 v/v) with 76.67 per cent (Fig. 6). Similar views were reported by earlier workers Siddagangaiah *et al.* (1996) in vanilla and Shirol *et al.* 2001 in dwarf poinsettia. This can be attributed due to the better physico-chemical properties of vermicompost consisting media like optimum water retention capacity (57.35 %) and near neutral p^H (7.60). As it is also a source of plant growth regulators, it had resulted in highest rooting percentage (Appendix 1). These results are in conformity with views of Edwards and Burrows (1988) who reported that vermicompost is finely divided peat-like materials with high porosity, aeration, drainage, water-holding capacity. Also, Gavrilov (1963) reported that vermicompost could be a definitive source of plant growth regulators.

The earliest rooting (33.07 days) was observed in the cuttings pretreated with IBA 1000 ppm and raised in the media, soil + sand + FYM + vermicompost (1:1:1:1 v/v) which differed significantly from rest of the treatments. An early sprouting and higher shoot parameters in initial stages might have brought earliness and better rooting (Table 15). Further, stored food materials with the aid of growth regulators and better physico-chemical properties of the media had hastened the rooting (Haissig and Davies, 1984). These results are in conformity with Gavrilov (1963) who reported that vermicomposts could be a definitive source of plant growth regulators.

The different rooting media also influenced the number of primary roots (Fig. 7). The maximum primary roots (11.07) were observed in the treatment soil + sand + FYM + vermicompost (1:1:1:1 v/v). This may be attributed to the excellent structure, porosity and nutrients in available form such as nitrate nitrogen and soluble phosphorus for excellent rooting in vermicompost comprising media. (Edwards and Neuhauser, 1988). Vadiraj *et al.* (1993) also reported more number of primary roots in vermicompost (18.2) when compared to sand (9.8), while studying the effect of

different media on cardamom seedlings. Similar results were reported by Siddagangaiah *et al.* (1996) in vanilla and Venkateshan *et al.*, (2010) in *Gymnemma sylvestris*.

Regarding the length of the longest primary root (Fig. 7), the media comprising soil + sand + FYM + coir dust (1:1:1:1 v/v) registered significantly the longest primary root length (26.79 cm) followed by soil + sand + FYM + coir dust (2:1:1:1 v/v) with 24.27cm, showed better performance as compared to other media. These results are in conformity with Siddagangaiah *et al.* (1996) in vanilla, Singh *et al.* (2003) in jajoba and Rubasinghe *et al.* (2009) in *Chiranta mooni*.

Coir dust has a low particle density indicating it's high specific surface, which contributes to the high adsorption of water and ions. Coir dust has a high water holding capacity (Rubasinghe *et al.* 2009). Increased root length might be attributed to the better texture and porosity of coir dust which probably facilitated easy penetration of roots (Siddagangaiah *et al.*, 1996) and also being a well drained media it promoted better root characters. (Singh *et al.*, 2003).

The fresh and dry weight of roots was significantly higher (5.08 and 1.96 g, respectively) in cuttings raised on soil + sand + FYM + vermicompost (1:1:1:1 v/v). The fresh and dry weight of roots reflects the root parameters recorded. The treatments with better root parameters have higher fresh and dry weights, while treatments with lower root parameters had shown lower fresh and dry weights. Similar views were held by Siddagangaiah *et al.* (1996) in vanilla and Thankamani *et al.* (1996) in black pepper.

5.2.3 Biochemical analysis

In the present investigation, there was only a marginal variation in chlorophyll-a, chlorophyll-b and total chlorophyll content of the cuttings raised in all the treatments (Fig. 8). Cuttings grown in the treatment soil + sand + FYM + vermicompost (1:1:1:1 v/v) recorded the maximum

LEGEND

Growth regulator formulations

T₁ – Control (dipped in distilled water)

T₉ – Naphthalene acetic acid (NAA)+ Indole butyric acid (IBA) 250 ppm

T₁₀ – Naphthalene acetic acid (NAA)+ Indole butyric acid (IBA) 500 ppm

T₁₁– Naphthalene acetic acid (NAA)+ Indole butyric acid (IBA) 1000 ppm

Rooting media

T₁- SOIL: SAND: FYM (2:1:1)

T₅- SOIL: SAND: FYM : CD (1:1:1:1)

T₆- SOIL: SAND: FYM : CD (2:1:1:1)

T₁₁- SOIL: SAND: FYM : VC (1:1:1:1)

T₁₂- SOIL: SAND: FYM : VC (2:1:1:1)

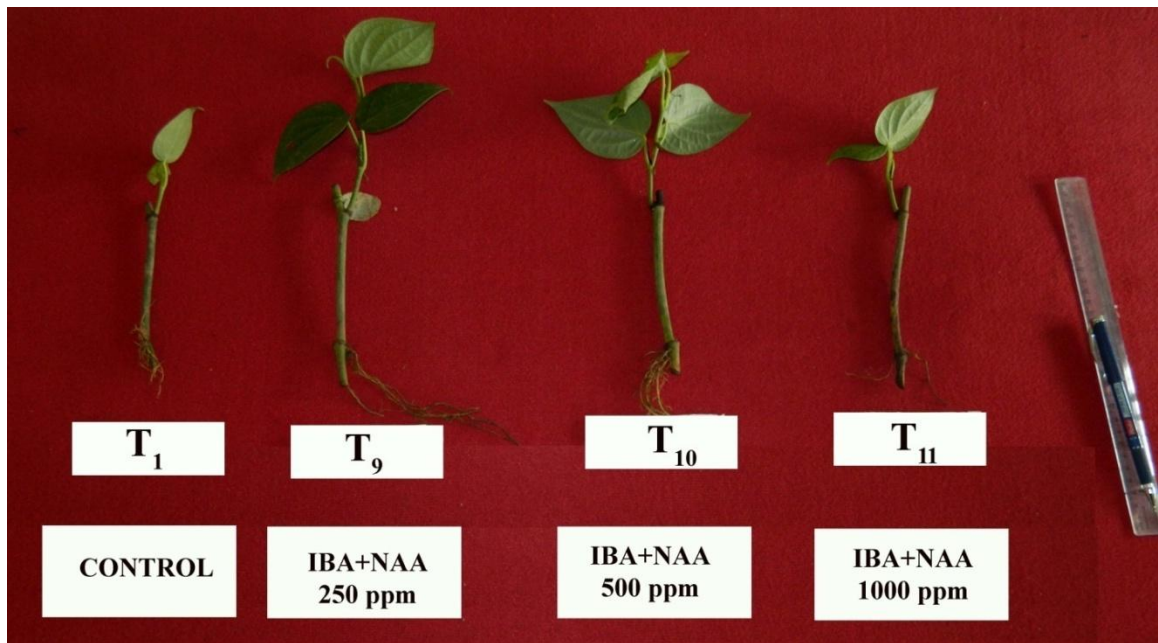


Plate 8: Effect of different concentrations of IBA + NAA on rooting of black pepper cuttings.



Plate 9: Effect of different media on rooting of black pepper cuttings.

chlorophyll-a, chlorophyll-b and total chlorophyll content (1.39 mg/100 g, 0.59 mg/100 g and 1.99 mg/100 g respectively). The superiority of vermicompost can be explained by its ability to supply nutrients like N, P, K, Ca and Mg in available form (Edwards and Neuhauser, 1988). As N and Mg are the important constituents of chlorophyll, higher availability and uptake of these nutrients resulted in higher chlorophyll synthesis in turn leading to higher photosynthesis and growth rate of black pepper cuttings.

Practical application of results

- 1) Higher rooting percentage (70 %) can be obtained by pre-treatment of cuttings with growth regulator IBA (1000 ppm) by quick dip method for 60 seconds.
- 2) Higher rooting percentage (80 %) can be obtained by raising cuttings which were pre-treated with IBA (1000 ppm) in the media of soil + sand + FYM + vermicompost (1:1:1:1 v/v).

Future line of work

- The influence of seasonal variation on rooting of black pepper cuttings need to be tried under open as well as controlled conditions.
- Other methods of application of growth regulators like soaking, powder and paste methods can be studied in propagation of black pepper.
- Standardization of growth regulators and rooting medium for the propagation of black pepper through cuttings under open conditions.
- Development of protocol for large scale multiplication of black pepper through tissue culture.

SUMMARY

VI. SUMMARY

The investigation on “Effect of growth regulators and media on rooting of black Pepper (*Piper nigrum*) cuttings” was carried out at Regional Horticultural Research and Extension Centre, Mudigere, University of Horticultural Sciences, Bagalkot during the year 2011-12 with the following objectives.

1. To study the effect of growth regulators on rooting of black pepper cuttings,
2. To study the effect of media on rooting of black pepper cuttings.

The salient findings of the studies are summarized below.

Experiment 1 - Effect of growth regulators on rooting of black pepper cuttings.

In this experiment, the effect of growth regulators *viz.*, IBA, IAA, NAA and combinations of IBA and NAA on rooting of cuttings were studied and experimented by adapting completely randomized design with three replications. The growth regulator treatments imposed were NAA at 250, 500 and 1000 ppm, IBA at 500, 1000 and 1500 ppm, IAA at 1000 ppm and IBA in combination with NAA at 250, 500 and 1000 ppm and compared with untreated control.

Different shoot parameters such as, days to sprout, number of leaves per cutting, length of shoot, percentage of sprouting, fresh and dry weight registered significantly higher values (17.40 days, 4.20, 10.40cm 82.67 %, 11 g and 3.52 g, respectively) with the cuttings treated with IBA at 1000 ppm.

Root parameters of black pepper cuttings were significantly influenced by IBA at 1000 ppm which recorded minimum days to rooting (35.47 days), higher percentage of rooting (70 %), higher number of primary roots (7.28), maximum length of root (18.18 cm) and higher fresh and dry weight of roots (2.71 g and 1.02 g, respectively) compared to untreated cuttings.

The reducing sugars, non reducing sugars and total sugars content was minimum in cuttings treated with IBA 1000 ppm (0.56 %, 1.10 % and 1.66 % respectively) compared to other concentrations of growth regulators.

The use of higher concentration of growth regulators, especially IBA at 1500 ppm and NAA at 1000 ppm and their combination at 1000 ppm adversely affected the rooting of cuttings indicating higher concentrations of growth regulators may become toxic to black pepper cuttings.

Experiment 2 - Effect of media on rooting of black pepper cuttings.

In this experiment, the effect of locally available substrate *viz.*, saw dust, coir dust, coffee pulp compost and vermicompost along with potting mixture (soil, sand and FYM) as media for rooting of cuttings were studied in completely randomized design with three replications. The cuttings were pretreated with the best growth regulator from the first experiment i.e. IBA 1000 ppm and raised in the different rooting medias *viz.*, Soil, sand and FYM at 1:1:1, 2:1:1 and 3:1:1 proportion respectively and are added separately with one part of saw dust or coir dust or coffee pulp compost or vermicompost to form twelve treatments and compared with control (soil, sand and FYM at 2:1:1 v/v).

The cuttings raised in the media comprising soil + sand + FYM + vermicompost (1:1:1:1 v/v) significantly increased the different shoot parameters of cuttings such as, days to sprout, number of leaves per cutting, length of shoot, percentage of sprouting, fresh and dry weight (15.93 days, 6.70, 20.26 cm 85.33 %, 17.47 g and 6.65 g respectively).

Among the different medias tried, black pepper cuttings raised in the media soil + sand + FYM + vermicompost with 1:1:1:1 (v/v) ratio clearly manifested that, significant increase in the root parameters such as, minimum days to rooting (33.07 days), higher percentage of rooting (80 %), higher number of primary roots (11.07), maximum fresh and dry weight of roots (5.08 g and 1.96 g, respectively). Whereas, the maximum root length

(26.79 cm) was noticed in the media soil + sand + FYM + coir dust (1:1:1:1 v/v). The cuttings raised under control recorded significantly minimum values in respect of all the root parameters.

In general, the cuttings raised in the media comprising of vermicompost as one of the components excelled in all the growth parameters except in root length among the different rooting media. This was followed by coir dust comprising media.

Among the different proportions of rooting media, the cuttings raised in 1:1:1:1 proportions of all the substrates, recorded excellent growth in all the parameters studied as compared to other proportions under investigation.

Conclusion

It was evident in the present study that the percentage of rooting of cuttings would be better if they are pre-treated with growth regulators and kept in better rooting media for favourable rooting. This indicates that cuttings need some physiological stimulation and better environment for favourable rooting. In the present study 80 per cent rooting was obtained by favourable growth regulator treatment when raised in an ideal rooting medium under greenhouse conditions. These technologies would go a long way in improving the 'turnover efficiency' of availability of rooted cuttings per unit time to meet the increasing demands of growers.

In the overall conclusion, it may be summarized that the black pepper planting material can be raised with high success (80 %) by pre-treatment of cuttings with IBA at 1000 ppm and growing in the medium of soil + sand + FYM + vermicompost (1:1:1:1 v/v) in polyhouse conditions. As an alternative, the medium comprising of coir dust can also be used in the places where, vermicompost is scarce and costly. By this way, higher turnover of planting material can be accompanied quite easily.

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* Originals not seen

APPENDICES

APPENDEX-1

Physical and chemical properties of rooting media:

Sample name	p^H	EC (dsm⁻¹)	N (Kgha⁻¹)	P (Kgha⁻¹)	K (Kgha⁻¹)	WHC (%)
T₁	7.12	0.037	195.6	29.8	141.6	44.63
T₂	6.97	0.041	248.5	51.8	205.8	55.89
T₃	7.03	0.019	223.4	45.7	191.7	52.37
T₄	7.07	0.028	200.7	37.2	176.6	50.10
T₅	7.28	0.022	263.4	53.4	263.2	62.01
T₆	7.20	0.031	225.8	46.8	248.4	59.85
T₇	7.15	0.035	205.2	39.7	230.2	54.63
T₈	6.84	0.052	240.3	40.9	201.6	58.36
T₉	6.88	0.029	218.4	34.3	188.7	56.41
T₁₀	6.95	0.022	202.4	30.2	175.6	53.70
T₁₁	7.60	0.019	325.7	65.3	286.8	57.35
T₁₂	7.45	0.039	303.6	54.1	268.0	54.36
T₁₃	7.17	0.047	276.2	42.5	250.8	51.16

APPENDIX- II

The monthly mean meteorological data for the year 2011-12 recorded at RHREC, Mudigere.

Month	Rainfall (mm)	Temperature (°C)		Relative humidity (%)
		Maximum	Minimum	
	2011-12	2011-12	2011-12	2011-12
July, 2011	814.4	25.5	16.80	87.88
August	691.6	26.37	17.11	85.78
September	542.1	26.58	18.26	84.06
October	343.9	26.16	17.90	90.29
November	121.2	26.6	17.36	80.99
December	Nil	26.74	14.98	80.56
January '12	Nil	26.75	14.56	70.32
February	Nil	27.00	15.46	67.15
March	Nil	31.69	19.09	62.18
April	278.6	31.51	18.31	83.34
May	123.2	31.58	18.58	84.49
June	918.4	27.83	18.13	85.71
Total	3833.4	-	-	-
Average	-	27.85	17.21	80.22