EFFECT OF GROWTH REGULATORS ON ROOTING OF DIFFERENT TYPES OF PLANTING MATERIALS IN BLACK PEPPER (*Piper nigrum.* L.)

By

GIGI ELIZABETH CLARA FRANCIS

THESIS

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DECLARATION

I hereby declare that this thesis entitled "Effect of growth regulators on rooting of different types of planting materials in black pepper (*Piper nigrum* L.)" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellanikkara,
15 - 11 - 1988.

Gigi Francis
Gigi Elisabeth Clara Francis

Dr.M.Aravindakshan,
Director,
Centre for Advanced Studies for
Tree Crops and Environmental
Horticulture

College of Horticulture,
Vellanikkara

Dated: 15-11-1988.

CERTIFICATE

Certified that the thesis entitled "Effect of growth regulators on rooting of different types of planting materials in black pepper (Piper nigrum L.)" is a record of research work done independently by Miss.Gigi Elisabeth Clara Francis under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

M. ARAVINDAKSHAN
Chairman
Advisory Committee

To my parents

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Gigi Francis

GIGI ELIZABETH CLARA FRANCIS

CERTIFICATE

We, the undersigned members of the Advisory Committee of Miss. Gigi Elizabeth Clara Francis, a candidate for the degree of Master of Science in Horticulture, agree that the thesis entitled "Effect of growth regulators on rooting of different types of planting materials in black pepper Piper nigrum. L." may be submitted by her in partial fulfilment of the requirement for the degree.

15th NOV 1988

Dr. Abi Cheeran,
Professor,
Plant Pathology

15.11.88

Prof. S. Balakrishnan,
Associate Director of
Research

15/11/88

Mrs. A. K. Babylatha,
Assistant Professor of
Horticulture

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Introduction

INTRODUCTION

The State of Kerala accounts for 96 per cent of the area and production of black pepper in the country. However the productivity has been around 200 gm/standard. One of the reasons for the low productivity is the dearth of superior quality planting materials of high yielding varieties and hybrids. Large scale multiplication of selected clones through vegetative propagation will help to increase production of pepper to a considerable extent. In Kerala, the most commercially accepted method of propagation is by rooted cuttings because of the ease and economy of the operation.

Since large scale multiplication of the cuttings is one of the major and critical inputs in the whole production cycle, a lot of attention is required on various aspects of propagation of pepper by cuttings to obtain maximum number of planting materials. The availability of planting materials often limit the extension of planted area. Systematic studies were therefore undertaken to compare the rooting efficiency of different types of planting materials under varying environmental conditions with growth regulator treatments. The major objectives of the present study were:

(1) To compare the rooting behaviour and the root growth parameters of laterals (plageotrophs) with other types of planting materials viz., runners (stolons), growing shoots (orthotrophs) and hanging shoots (geotrophs).

(2) To find out the effect of different growth regulators on rooting of planting materials.

(3) To study the anatomy of shoots and roots and to relate the anatomical features with root initiation and development.

Review of Literature

REVIEW OF LITERATURE

In pepper, propagation through cuttings continues to be the most widely accepted practice. This is less expensive, more rapid and does not require any special technique or care, more over the genetical purity can be maintained. However, the success in this method is often governed by several factors.

2.1.1 Effect of season on rooting of cuttings

Though it is possible to make cuttings during any time of the year, the season of collection of cuttings has been reported to be one of the key factors determining the success of rooting in many plants.

Nambiar and Kurian (1963) reported 90 to 95 per cent rooting when pepper cuttings from selected mother plants were planted during March and 80 to 90 per cent survival when these rooted cuttings were transplanted two months after rooting. According to Shanthamallish et al. (1974) a maximum sprouting of 78 per cent and rooting of 72 per cent were obtained when cuttings were planted in June. However, increasing trends in both sprouting and rooting were observed when planting was done from March to June and that will depend upon the climatic factors prevailing in that tract. Since break of dormancy in March caused mobilisation of starch along with enhanced auxin activity, rooting from March to July was better, the highest being in June. Nambiar *et al*. (1978) reported that February-March is the most ideal season for raising pepper nursery under northern Kerala conditions. For air layering June to August was found to be most ideal.

Dolar (1960) obtained about 50 per cent success in marcotting of young shoots when done with the onset of monsoon.

2.1.2 Selection of mother plants for cuttings

Pillai and Sasikumaran (1977) reported that the superiority of mother plants selected for taking cuttings should be studied for atleast one season and preferably for three seasons. He also stressed the importance of age of mother plants for selection of cuttings. Young plants of age about five years produced healthy robust and vigorous shoots which struck roots easily compared to shoots from plants of 10 or 15 years. It has been proved in many plants that cuttings taken from old mature plants are difficult to root while cuttings from young plants root easily (Basu *et al*., 1985).

2.1.3 Physiological stage of cuttings on rooting

In several plants cuttings are taken either from vegetative or flowering shoot, irrespective of the fact that rooting potential varies between these two types. Large scale cultivation of improved varieties of pepper is mainly handicapped by the inadequate availability of planting materials. Of paramount importance for securing maximum success in rooting and post transplant survival of rooted cuttings is the selection of cuttings of proper maturity and of the right physiological stage of growth.

Sanford (1955) in Sarawak found that immature vines struck roots better compared to mature ones. John (1955) found that semi herbaceous cuttings were the best planting materials owing to its active metabolic state and also favourable C:N ratio.

Garayar and Corbera (1957) stated that the most ideal shoots for propagation were those that ceased elongation after the removal of terminal buds. According to them progenies raised from terminal cuttings were faster in growth and fruited within three years. The plants from basal shoot cuttings took five years to fruit. The plants from basal shoot though bushy were largely unproductive.

Abraham (1959) reported that the removal of top fruiting lateral branches was highly detrimental to the productivity of mother vines and therefore, runner shoots originating from the base of the vine were to be selected as planting materials in pepper.

Hasan and Iljas (1960) obtained dwarf bushy plants by grafting pieces of fruit bearing shoots as scion on the root stocks of *Piper hirsutum* and *Piper arifolium*.

Gillot and Van Dingenen (1960) reported that for vegetative propagation, semi hardwood cuttings were the best planting materials but should be well supplied with nutrients.

Observations made in Philippines showed that when *Piper nigrum* was propagated by marcotting of fruiting branches, the marcots developed into non climbing dwarf plants with bushy habit which were found to be prolific and early bearers (Anon, 1961).

Hughes (1966) reported that single node cuttings of primary wood resulted in 90 to 95 per cent rooting while cuttings of secondary wood rooted poorly resulting bushy plants. Porres (1966) observed that in pepper grafting semi hardwood materials resulted in 70 to 75 per cent success while success was only 10 to 15 per cent in herbaceous material. Choudhury and Phadnis (1971) in their studies found that leaf bud cuttings were superior to hard wood cuttings with or without growth regulator treatments.

Pillai (1977) reported that pepper vines of cv. 'Karimunda' when raised from runners, hanging shoots or laterals, the yield difference was slight in the first four years of bearing. But in the fifth year highest yield was obtained from runners.

Trials conducted by Bavappa and Gurusinghe (1978) indicated that cuttings from primary vines and ground runners were on par in their rooting ability and both could be used for propagation depending upon the availability of the materials. Genetically cuttings from these two types of shoots from the same vine could not be expected to produce any difference. Lateral branches were not useful for propagation since they grow as bushy plants producing only limited canopy.

A study by Nambiar et al. (1978) using pre-rooted cuttings from all the four types of planting materials viz., growing shoots (Orthotrophs), hanging shoots (Geotrophs), runners (Stolons) and laterals (Plageotrophs) revealed that runners were the best planting materials, with respect to rooting and establishment. Chandy and Pillai (1979) reported that pepper vines can be propagated using growing shoots, top shoots, lateral shoots, hanging shoots and runner shoots. Runner shoots were found to be the best planting material. Studies conducted at Pepper Research Station, Panniyur (1980) revealed that maximum flowering and yield could be obtained from vigorous runner shoots as it established in the mainfield quickly and easily.

Pillai (1977) produced bushy plants of black pepper suitable for growing in flower pots. Horizontal side branches or fruiting branches of a 12 year old vine could give about 1 kg green pepper per year after two years. Cardaso et al (1981) also produced bushy plants from horizontal shoots of pepper which yielded 1.76 kg/vine whereas the yield was only 1.65 kg/vine for vertical cuttings.

Irulappan _et al_. (1981) used three nodal cuttings taken from the upper laterals and fruiting branches and single node cuttings from runner shoots for planting. Of these the maximum percentage of rooting (84.3) was recorded in cuttings taken from upper laterals and this was immediately followed by single node cuttings taken from runner shoots (76.0 per cent).

2.1.4 Effect of position of cuttings

Variation in rooting percentage of cuttings taken from different portions of the shoots were studied by many workers. In black pepper semiherbaceous cuttings taken from the middle portion of the stem rooted better than the herbaceous cuttings from soft terminal portion or woody cuttings from the hard suberised portions of the shoots. The percentage of rooting and sprouting in semi herbaceous, woody and herbaceous cuttings were 38, 27, 26 and 36, 39, 18 respectively (Shanthamalliah *et al*., 1974).

Middle one third portion of the runner shoots was found to be the best planting material for better rooting, growth and final yield when compared to top one third and lower one third portion Nambiar *et al*. 1978)

2.1.5 Effect of number of nodes in cutting

There are differences in opinion among different workers regarding the number of nodes to be retained in the stem cuttings used for planting. Alimirante (1955) observed that cuttings with seven nodes rooted first but those with five nodes survived better and produced vigorous plants. High percentage of success was obtained with single node leafless cuttings, but survival was high when leaf was retained (Indian Counsil of Agricultural Research, 1956). According to Kurup (1956) vertically planted single node cuttings with about 2" stem above and below nodes without leaves induced growth more rapidly but the percentage of survival was less. Gillot and Van Dingenen (1960) found that orthotropic cuttings with a single node and a basal internode or a plageotropic internode with a orthotropic node and a plageotropic internode with or without an orthotropic heel were the best planting materials for vegetative multiplication. One year old orthotropic cuttings of about 60 cm long and with five to seven nodes were found to be the best planting material in pepper (Institute of Research in Tropical Agronomy and Tissue Culture, 1965).

There is wide variation in the source of planting material and size of cuttings used in different countries. In Malaysia, cuttings with five to seven nodes taken from actively growing terminal vines alone are used for planting (Kiow and Chou, 1973) while in India two to three node cuttings collected from the ground runners are generally preferred as planting material (Central Plantation Crop Research Institute, 1976).

In pepper hybrid Panniyur-I, Nambiar *et al*.(1978) conducted a study on rooting behaviour with four to six node cuttings and two node cuttings. They found that two node cuttings were the best planting materials resulting maximum rooting and field establishment.

Bavappa and Gurusinghe (1981) developed a rapid multiplication technique in pepper by raising one node cuttings and they advocated this method whenever planting material is scare.

2.1.6 Effect of growth regulators on rooting of cuttings

The discovery of naturally occurring auxins like IAA (Indole-acetic acid) and synthetic auxins like IBA (Indole butyric acid) was a milestone in the history of propagation and was of real value in stimulating the production of adventitious roots in stem cuttings in several horticultural plants (Linder, 1939).

Grace (1939) tested a series of indole and naphthalene substituted acids and reported that IBA was the most effective auxin in inducing roots in stem cuttings among the indole series. Indole series in general were more effective than the naphthalene series. Audus (1959) stressed the commercial use of IAA, IBA and NAA for better rooting and establishment of cuttings in horticultural crops. Besides these, the combination of the above auxins with 2,4-D (2, 4 dichloro phenoxy acetic acid) and various chemical preparations like 'rootone' 'hormodin' and 'seradix' are also used in lesser extent.

Several studies have been carried out to study the effect of growth regulators on rooting of cuttings in pepper.

Cooper (1955) noticed 75 per cent rooting on 21st day when leaf cuttings of pepper with petiole and bud were treated with IBA at 2 mg/lit and planted in coirdust media. Winters and Musik (1963) found that rooting of laterals markedly improved by treatment with 'rootone' and resulted bushy plants. Leite and Inforzato (1966) obtained maximum rooting of 62.5 per cent when base of the pepper cuttings were immersed in NAA 50 mg/lit, while IAA at the same concentration resulted mainly shooting. According to Hurov (1967), black pepper cuttings when dipped in 0.2 per cent IBA and placed in rooting media recorded the best results. This was also confirmed by Larcher (1970) who found that three node cuttings dipped in 0.2 per cent IBA before planting improved rooting percentage, root number and root length compared to untreated cuttings.

Choudhury and Phadnis (1971) obtained best results in rooting of leaf bud cuttings with Seradix-B, IBA + NAA at 25 or 50 ppm and IBA at 50 ppm. Trials conducted at Pepper Research Station, Panniyur, Kerala (1981) revealed that when basal portion of pepper cuttings were treated with IBA 1000 ppm it induced better rooting compared to those treated with Seradix-B_1, B_2 or B_3.

Studies by Irulappan et al. (1981) in Tamil Nadu revealed the highest percentage of rooting (84.3) of upper lateral cuttings treated with IBA 5000 ppm as against low percentage (31.3) in control. Other promising treatments included the single node runners treated with IBA 2500 ppm and 7500 ppm which produced 76 per cent and 72.6 per cent of rooting respectively.

Pillai et al. (1982) conducted a study using two node cuttings of pepper dipped in 1000 ppm IBA for 15 to 60 seconds and then planting in a rooting medium. Cuttings dipped for 45 seconds produced highest percentage of rooting on 20th and 90th day of observation. However, the shoot and leaf development was maximum in control. Hedge (1983) reported that three node cuttings treated with IBA 25 and 50 ppm rooted better than those treated with IBA 25 ppm + NAA 50 ppm or IBA 50 ppm + NAA 25 ppm.

2.1.7 Method of application of growth regulators

Williams (1943) experimented with the cuttings of certain broad leaved evergreens using commercial hormone preparations such as 'hormodin' and 'rootone' by soaking and dusting method to promote rooting of cuttings. The result of the studies indicated that the cuttings treated with solution forms resulted in higher percentage of rooting than dust treatments.

Zimmerman (1949) stated that though there are different methods of treating the cuttings with hormones, dipping the cuttings in a concentrated solution for a short period was the easiest and convenient to practice, where large number of cuttings were to be handled.

Audus (1959) after studying the effect of growth regulators on rooting of cuttings concluded that the growth regulators could be applied in various form viz., powder, concentrated dip, dilute solution dip, or as paste. The effectiveness of these treatments often varied with plant species and type of chemical used.

Cardaso (1960) working on pepper reported that treating the basal portion of the cutting with a solution of Seradix A resulted 65 per cent success, very high concentration was found to be injurious. Dipping the ends of cuttings in seradix powder also revealed some beneficial effect on rooting.

2.1.8 Effect of rooting media

A wide range of rooting media have been tried by many workers for the rooting studies of various horticultural species. Plants difficult to root might be greatly influenced by rooting medium, not only in the percentage of cuttings rooted, but also in the quality of root system formed (Long, 1932). The generally recommended media for rooting of cuttings are sand, peat, moss (Smith, 1944).

It was reported that heeled cuttings of lateral shoots produced maximum rooting when planted in a rooting medium of 90 per cent sand and 10 per cent leaf mold (Anon, 1938). According to Richards (1955) pepper and betel cuttings produced more roots and shoots when planted in dust and fibre than in sand or soil. Propagation studies in black pepper by Konstantinov and Bodrova (1962) indicated that plants trained on poles covered with damp sphagnum moss rooted well at the nodes.

2.1.9 Environmental conditions on rooting of cuttings

The planting environment of the cutting for rooting should ensure their maintenance without affecting the conditions of cutting at the same time enabling them to initiate and develop new roots. Studies by O'Rourke (1940) and Garner (1944) indicated that cuttings subjected to intermittent mist at high light intensity rooted better as it prevented desication. Hess and Synder (1957) studied the beneficial effects of mist on rooting of cuttings. The major environmental conditions that influence the rooting of cuttings are light, relative humidity and temperature (Garner *et al*., 1976).

Creech (1955) reported that single node cuttings of black pepper when planted in a close propagating case with low light intensity and high humidity resulted 88 per cent rooting. An early and maximum rooting was obtained when the cuttings were planted in washed sawdust or prepared soil taken in a Trinidad type cacao propagator kept under 95-100 per cent relative humidity and 20 to 30 per cent light intensity (Garayar and Corbera, 1957).

Tarasenko and Ermakov (1966) noticed that mist under plastic film resulted maximum rooting in terms of percentage, number and length of roots. The length of shoots was also maximum in this case compared to cuttings planted in frames without mist or glass house or open conditions with mist. Hughes (1966) described the use of a glass covered mist chamber for the rooting of cuttings in black pepper. Single node cuttings of primary wood resulted 90 to 95 per cent rooting while rooting was poor in secondary wood.

Kamp (1969) compared the rooting and field establishment of black pepper cuttings by three methods viz., bush bed, bamboo pot and mist propagator, and found that bush bed was the best method with regard to the above aspects. Mist propagator was also equally good but the cost of establishment was higher.

Senanayake and Kirthisingh (1983) stated that cuttings of black pepper planted under 50 per cent shade and providing irrigation once in three days gave maximum number of roots with highest dry weight of shoots and roots.

2.2 Anatomical studies on rooting of cuttings

Anatomical studies in relation to type of cuttings and their root initiation in black pepper are seem to be meagre. The few works conducted are mainly confined to the general anatomy of shoots and roots.

2.2.1 Structure of stem

Bond (1931) described the presence of an endodermis in the aerial stem of pepper and is developed only in association with the outer ring of vascular bundles. It is with inconspicuous casparian thickening on the outer side of the cortical bundles and was continuous over rays and outer vascular bundles. According to him endodermis is a vestigial structure of no primary importance in the internal economy of the stem.

Metcalfe and Chalk (1950) reported that stem structure of pepper showed characters of both monocots and dicots. The vascular bundles were arranged in a definite pattern in two layers; outer ring considering of cortical bundles and inner ring of medullary bundles. Vascular bundles were found to be open and a distinct cambium present in both cortical and medullary bundles.

Garner and Beakbane (1968) observed an outer epidermis which was found to be continuous over the rays and outer vascular bundles. According to them secondary growth in pepper was typical to that of dicotyledonous vine and vascular bundles remained descrete even after the secondary thickening.

Datta and Dasgupta (1977) studied in detail the vasculature of genus Piper and compared it with those of genus Peperomia and genus Chlorenthus. According to them the number of peripheral bundles was 20 to 24 and medullary bundles 9 to 12 in Piper nigrum. Each xylem had mostly 3 to 9 trachea ry elements and enclosing a group of pareochymatous cells (mostly 8 to 18) forming a semilunar patch.

2.2.2 Development of roots

According to Hartman and Kester (1972) formation of adventitious roots from stem cuttings took place in three stages in general; first - dedifferentiation and rapid division of some parenchymatous cells to produce root initials; secondly establishment of a recognisable root primordium with a meristematic root apex from these cells; and finally development of vascular connection and emergence of root primordium by rupturing the cortical tissue of stem.

It was reported that in some plants pre-formed root initials were present in the intact stem even before cuttings were made and lie dormant until the stem were made into cuttings and placed under favourable conditions (Carlson, 1938, 1950; Carpenter, 1961 and Hartman and Kester, 1972).

Priestly and Swingle (1929) described the origin of roots in stem cuttings as from a group of meristematic cells namely root initials which were localised just outside and between the vascular bundles in many plants.

Different views exist with regard to the emergence of growing root through the Cortex. It has been reported that some hydrolytic ensymes are involved which dissolves away the cortical cells (Bonnet, 1969; Bell and Mc Cully, 1970; Karas and Mc Cully, 1973). According to Mc Cully (1975) again hydrolytic ensymes played major role in the penetration of roots and the role of mechanical pressure very negligible.

2.2.3 Structure of root

In most of the dicotyledonous roots cortex is mainly constituted of parenchyma cells and these cells are some times arranged in radial rows, particularly in the inner layers (Fahn, 1974).

Datta and Dasgupta (1977) studied the arrangement of vascular bundles in the root of Piper evolved from a central cores of trecheary elements to a continuous ring or radiating tracheary plates.

Materials and Methods

MATERIALS AND METHODS

The present series of studies were carried out in the Centre for Advanced Studies on Hymid Tropical Tree Crops, College of Horticulture, Vellanikkara during the periods from March 1987 to January, 1988. The studies mainly consisted of the following two aspects.

3.1 Propagation through cuttings

The cuttings were taken from 10 year old healthy vines of black pepper cv. Panniyur-1 maintained under the KADP Project in the main campus of Kerala Agricultural University.

3.1.1 Selection and preparation of planting materials

The cuttings were prepared during March 1987 from all the four types of shoots vis. runners (stolons) growing shoots (orthotrophs) and hanging shoots (geotrophs) and laterals (plageotrophs) (Plate 1). The middle portion of the shoots were selected to prepare cuttings.

Since the laterals failed to root during March, the studies were repeated during June, three months after harvest.

Two nodal cuttings were taken from runners (stolons), growing shoots (orthotrophs) and hanging shoots (geotrophs). The cuttings were made just below a node leaving 1 cm in the basal portion. The leaf blades were removed carefully keeping the base of petiole intact and cuttings were made into bundles of fifty each, for treating with growth regulators at various concentrations. In the case of laterals, three nodal cuttings were used for planting.

3.1.2 Preparation of nursery

Polythene bags of 250 gauge and 25 x 20 cm size were used for planting the cuttings. The bags were filled with potting mixture consisting of Farm yard manure, sand and top soil in 1:1:1 ratio and required number of 440 bags were arranged in rows under partial shade as well as inside a mist chamber. The temperature and relative humidity inside the mist chamber were adjusted by providing mist for 3 minutes at hourly interval from 8 A.M. to 6 P.M. every day during the course of the investigation (Plate-II).

3.1.3 Effect of growth regulators on rooting of cuttings

The two growth regulators namely IAA, IBA and their combination each at a concentration of 500, 1000, 1500 ppm and a commercial preparation Seradix B were used in

Plate I. Different types of planting materials used for planting

Plate II. Cuttings planted for rooting under mist condition

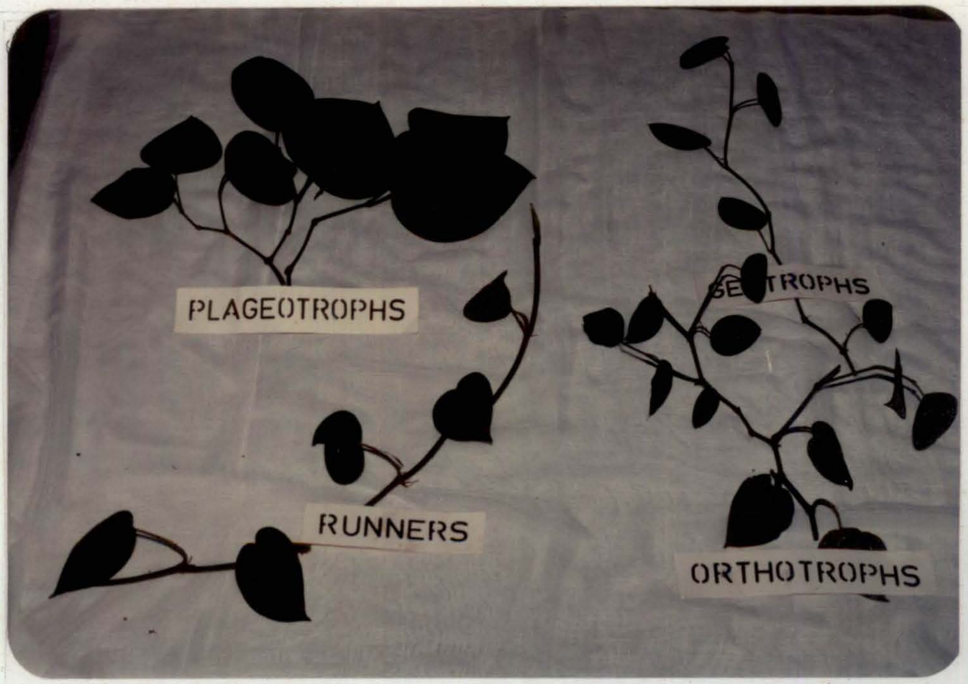

Plate I

Plate II

the present study. The experiment was laid out in CRD. Two hundred cuttings were treated under each of the following eleven treatments.

Treatment details

T_1	-	Control
T_2	-	Seradix-B
T_3	-	IAA 1500 ppm
T_4	-	IAA 1000 ppm
T_5	-	IAA 500 ppm
T_6	-	IBA 1500 ppm
T_7	-	IBA 1000 ppm
T_8	-	IBA 500 ppm
T_9	-	IAA + IBA 1500 ppm
T_{10}	-	IAA + IBA 1000 ppm
T_{11}	-	IAA + IBA 500 ppm

Hundred cuttings each of all the four types of planting materials treated with each of the above chemical were kept under mist and open conditions for rooting.

(i) Preparation of growth regulators

A stock solution of 1500 ppm each of IAA and IBA were prepared separately by dissolving 1.5 g of respective growth regulator in minimum quantity of alcohol and subsequently diluted with glass distilled water and made up the volume to one litre. All the treatment solutions including the IAA and IBA combination of required concentrations were prepared from the stock solutions by adding glass distilled water. The precipitation noticed in the prepared growth regulator solution was overcome by the addition of two to three drops of N/10 sodium hydroxide as suggested by Miller (1963). To prevent precipitation slightly warm distilled water was also used at the time of preparation of treatment solution

(ii) Treatment of cuttings with growth regulators

The cuttings were treated in quick dip method. The basal one inch portion of the cuttings including the nodal region was soaked in respective treatment solution for 45 seconds. For treating with Seradix-B the cut end and basal nodal region were dipped in water first and then smeared with the Seradix powder. The excess powder removed by finger knock. The treated cuttings were planted immediately in the prepared polythene bags at the rate of ten cuttings per bag. The cuttings were watered daily once during the course of the experiment.

3.1.4 Biometric observations

Random samples of 20 cuttings each planted under open and mist conditions were uprooted from all the treatments at triweekly interval from March onwards in the case of runners, growing shoots and hanging shoots. But in the case of laterals the observations were recorded at triweekly intervals from June onwards. The following observations were recorded.

3.1.4.1 Percentage of rooting

The number of cuttings rooted were recorded and the percentage of rooting was worked out.

3.1.4.2 Number of roots

The number of roots produced by cuttings were recorded and the mean was worked out.

3.1.4.3 Length of roots

The length of roots produced by cuttings was measured in centimeters and the mean length was then worked out.

3.1.4.4 Fresh weight of roots

The roots were separated from the cuttings carefully, washed in tap water and subsequently in distilled water to remove the dirt and soil particles adhered on the root surface. Then mean fresh weight of the roots was found out using a chemical balance.

3.1.4.5 Dry weight of roots

The dry weight of roots was recorded using a chemical balance after drying the sample in a cross flow air oven at 70°C ± 2°C for 24 hours.

3.1.4.6 Fresh weight of shoots

The shoots were separated from the cuttings and their fresh weight was found out using a chemical balance.

3.1.4.7 Dry weight of shoots

The separated shoots were dried in a cross flow air oven at 70° ± 2°C for 24 hours and dry weight was found out using a chemical balance.

3.1.4.8 Shoot/root ratio

The mean shoot/root ratio was computed from the fresh weight of shoots and roots.

3.1.5 Statistical analysis

The data was statistically analysed as per the standard procedure suggested by Panse and Sukhatme (1978).

The difference between treatments with regard to percentage of rooting was tested for significance by using chi-square test. When the number of treatment was more than two, chi-square was calculated as

$$\chi^2 = \frac{1}{n_1 n_2} \sum \frac{(an_2 - a' n_1)^2}{a + a'}$$

where,

a = The number of success under each treatment

a' = The number of failure under each treatment

n_1 = The number of success for all the treatments taken together

n_2 = The number of failure for all the treatments taken together

When there were only two treatments, chi-square was calculated as

$$\chi^2 = \frac{(|ad - bc| - \frac{n}{2})^2 \; n}{(a+b)\;(c+d)\;(a+c)\;(b+d)}$$

where,

a and c are the number of success under each treatment, b and d are the number of failures under each treatment and n = a+b + c+d.

The difference among treatments with respect to quantitative characters such as number of roots, length of roots, dry and fresh weight of roots and shoots were tested for significance using analysis of variance.

3.2 Anatomical studies

This study was undertaken in the Department of Wood Science, KFRI, Peechi with an objective to study the structure of stem, root and the stages of development of adventitious roots from the stem cuttings of pepper.

Stem cuttings were prepared separately for anatomical studies from runners, growing shoots (orthotrophs), hanging shoots (geotrophs) and laterals (plageotrophs) in order to find out the variation in anatomical structure of stem and root in these type of planting materials.

To study in detail the stages of root development rooting regions of the cuttings from all treatments were collected. From each treatment of all the four types of planting materials five samples were collected on fifth and tenth day of planting the cuttings. Samples were also collected from those cuttings which failed to root but remained green.

Samples of young and mature roots were collected to study the root anatomy. Young roots were collected in the early stages of root development where as mature roots were collected from cuttings after three months of planting.

(i) Fixation and storage of specimens

FAA was used for fixing the materials as per the methods described by Berlyn and Miksche (1976). Specimens were kept in FAA for a minimum period of 72 hours and then transferred to 50 per cent alcohol for storage. Prior to sectioning, the materials were washed in running water for about 30 minutes to remove traces of the fixative and alcohol.

(ii) Sectioning and staining

Transverse sections of 15 micron thickness were cut using Richert sliding microtome as per standard microtomy suggested for hard woods (Cutler, 1978). Sections were cut both from nodal and internodal region for comparison. For cutting the cross section of roots, the pith of tapioca (<u>Manihot esculenta</u>) stem was used as the supporting material. Roots were inserted into small longitudmal grooves made in the soft pith of split stem. Transverse sections of 15 micron thickness were cut using this technique from both young and mature roots.

The following staining methods were used for staining the sections.

(1) Toluidine Blue 'O' in citrate buffer at pH 4.5 (O' Brien et al., 1964).

(2) Safranin-Bismark Brown (Berlyn and Miksche, 1978) and safranin alone (Single Staining).

(3) Iodine-Potassium Iodide test for starch (Johansen, 1940).

(4) Sudan III (alcoholic) for lipids (Berlyn and Miksche, 1976).

The original procedure was slightly modified for getting promising results. In Toluidine Blue staining, air drying the sections after differentiation in water, was not satisfactory. Hence the following schedule was adopted.

Section
↓
Toluidine blue stain (5-10 minutes)
↓
Differentiation in water
↓
Dehydration in 25%, 50%, 75% acetone (1 minute each)

↓

Pure Acetone (2 changes)

↓

Pure Xylene (2 changes)

↓

Mount in DPX

For staining root sections this procedure was not satisfactory. Safranin (single staining) and Safranin-Bismark Brown was employed for the purpose as per the following staining schedule.

Sections

↓

Alcohol series (10%, 20%, 30% and 40%)
(1 minute each)

↓

Safranin in 50% alcohol

↓

60% alcohol (2 changes one minute each)

↓

Bismark brown

↓

80% alcohol (2 changes)

↓

95% alcohol

↓

Absolute alcohol (2 changes)

↓

3:1 Alcohol : Xylene

↓

1:1 Alcohol : Xylene

↓

1:3 Alcohol : Xylene

↓

Pure Xylene (2 changes)

↓

Mount in DPX

(iii) Microscopy and photomicrography

The slides were examined using Carl-Zeiss binocular research microscope fitted with objectives of magnification ranging from 3.2 x to 100 x and 10 x eyepieces. To check the presence or absence of crystals cart-Zeiss polarizing microscope was used. Photomicrographs were taken using a photomicrograph system and ORWO black and white negative film of 125 ASA.

Results

RESULTS

The results of the present series of studies on the effect of growth regulators on rooting of different types of planting materials in black pepper are presented in the following pages. Except laterals all other planting materials were planted during March but the former were planted in June.

4.1 Effect of growth regulators and mist

The results of the experiment to find out the effect of growth regulators and mist on rooting of cuttings and other growth characters are summarised below.

4.1.1 Percentage of rooting

The data furnished in Tables 1a, 2a, 3a, and 4a clearly indicated that under mist conditions, all the planting materials produced maximum rooting when treated with IBA 1000 ppm. Treating the cuttings with IBA 1500 ppm, IAA 1500 ppm and Seradix-B also were effective in rooting (Plate III to X). Irrespective of the type of material, open condition was less conducive for best rooting. Pooled analysis of the data tabulated in Tables 1b, 2b, 3b and 4b again indicated that

Table 1a. Effect of growth regulators on rooting of cuttings under mist and open (runners)

Treatment	No.of cuttings sampled	Number of cuttings rooted		No.of cuttings established		Percentage of initial rooting		Percentage of final establishment	
		3 WAP	6 WAP	9 WAP	12 WAP	3 WAP	6 WAP	9 WAP	12 WAP
Seradix-B									
Mist	20	15	18	11	11	75	90	55	55
Open	20	12	12	8	8	60	60	40	40
IAA 1500 ppm									
Mist	20	15	15	14	12	75	75	70	60
Open	20	11	11	7	6	55	55	35	30
IAA 1000 ppm									
Mist	20	11	13	9	8	55	65	45	20
Open	20	11	10	4	4	55	50	20	20
IAA 500 ppm									
Mist	20	10	13	14	8	50	65	70	40
Open	20	5	9	7	4	25	45	35	20
IBA 1500 ppm									
Mist	20	13	14	12	10	65	70	60	50
Open	20	9	11	8	8	45	55	40	40
IBA 1000 ppm									
Mist	20	17	19	16	16	85	95	80	80
Open	20	13	14	12	12	55	70	60	60
IBA 500 ppm									
Mist	20	13	14	9	8	65	70	45	40
Open	20	7	10	5	4	35	50	25	20
IAA + IBA 1500 ppm									
Mist	20	11	16	12	10	55	80	60	50
Open	20	10	9	8	2	50	45	40	10
IAA + IBA 1000 ppm									
Mist	20	14	15	10	8	70	75	50	40
Open	20	7	10	8	4	35	50	40	20
IAA + IBA 500 ppm									
Mist	20	7	15	10	9	35	75	50	45
Open	20	4	10	8	2	20	50	40	10
Control									
Open	20	6	12	8	3	30	60	40	15
Mist	20	5	8	3	1	25	40	15	5
			Chi square values			45.8**	84.32**	44.59**	18.77**

WAP = Weeks after planting
** = Significant at 1% level

Table 1(b). Effect of growth regulators on rooting of cutting (runners)

Treatment	Numbers of cuttings sampled	Number of cuttings rooted				Percentage of rooting			
		3 WAP	6 WAP	9 WAP	12 WAP	3 WAP	6 WAP	9 WAP	12 WAP
Seradix-B	40	27	30	19	19	67.5	75	47.5	47.5
IAA 1500 ppm	40	26	26	21	18	65.0	65	52.5	45.0
IAA 1000 ppm	40	22	23	13	12	55.0	57.5	32.5	30.0
IAA 500 ppm	40	15	22	21	12	37.5	55	52.5	30.0
IBA 1500 ppm	40	22	25	20	18	55.0	62.5	50.0	45.0
IBA 1000 ppm	40	30	33	28	28	75.0	82.5	70.0	70.0
IBA 500 ppm	40	20	24	14	12	50.0	60.0	35.0	30.0
IAA + IBA 1500 ppm	40	21	25	20	12	52.5	62.5	45.0	30.0
IAA + IBA 1000 ppm	40	21	25	18	12	52.5	62.5	45.0	27.5
IAA + IBA 500 ppm	40	11	25	18	11	27.5	62.5	45.0	27.5
Control	40	11	20	11	4	27.5	50.0	27.5	10.0
		Chi-Square value				37.9**	55.2**	23.8**	19.5 NS

Table 1(c). Effect of mist on rooting of cuttings (runners)

Treatments	Weeks after planting	Number of cuttings sampled	Number of cuttings rooted	Percentage rooting	χ^2 value
Mist	3	220	132	60.00	13.13**
Open	3	220	94	42.70	
Mist	6	220	164	74.54	24.43**
Open	6	220	114	51.81	
Mist	9	220	125	56.81	24.83**
Open	9	220	78	35.45	
Mist	12	220	103	46.81	21.64**
Open	12	220	55	25.00	
Mean				59.54	
				38.74	

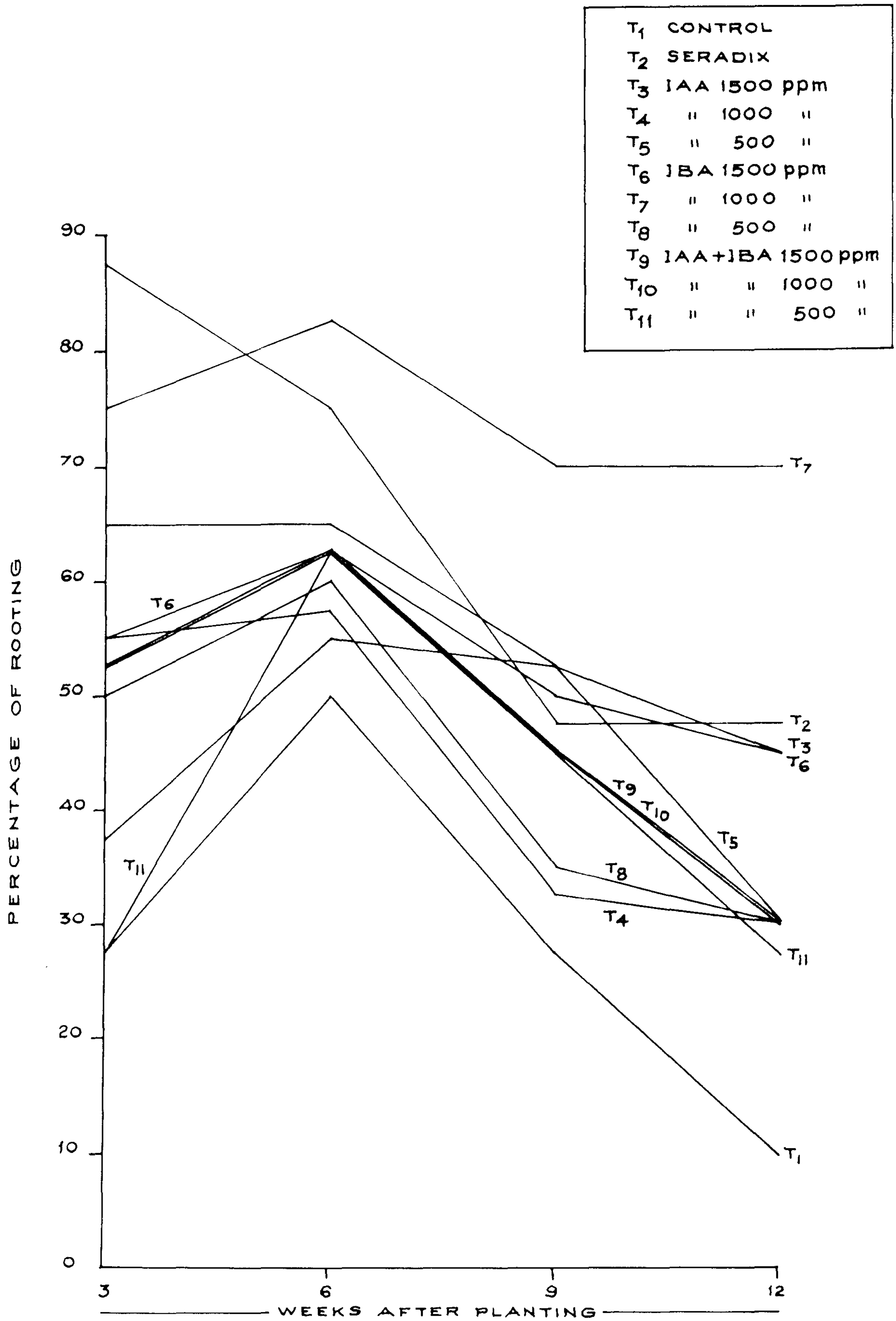

FIG. 1. EFFECT OF GROWTH REGULATORS ON ROOTING OF CUTTINGS IN RUNNERS (STOLONS).

Table 2a. Effect of growth regulators on rooting of cuttings under mist and open (growing shoots)

Treatment	No.of cuttings sampled	No.of cuttings rooted		No.of cuttings established		Percentage of initial rooting		Percentage of final establishment	
		3 WAP	6 WAP	9 WAP	12 WAP	3 WAP	6 WAP	9 WAP	12 WAP
Seradix-B									
Mist	20	10	17	14	14	50	85	70	70
Open	20	5	15	6	6	25	75	30	30
IAA 1500 ppm									
Mist	20	15	20	11	11	75	100	55	55
Open	20	9	13	6	5	45	65	30	25
IAA 1000 ppm									
Mist	20	17	14	9	9	85	70	45	45
Open	20	10	12	4	4	50	60	20	20
IAA 500 ppm									
Mist	20	14	11	10	9	70	55	50	45
Open	20	7	12	5	5	35	60	25	25
IBA 1500 ppm									
Mist	20	16	19	12	12	80	95	60	60
Open	20	10	16	5	5	50	80	25	25
IBA 1000 ppm									
Mist	20	20	20	17	17	100	100	85	85
Open	20	13	14	12	12	65	70	60	60
IBA 500 ppm									
Mist	20	13	15	9	9	65	75	45	45
Open	20	10	12	5	5	50	60	25	25
IAA + IBA 1500 ppm									
Mist	20	15	16	8	8	75	80	40	40
Open	20	11	12	7	4	55	60	35	20
IAA + IBA 1000 ppm									
Mist	20	10	14	9	8	50	70	45	40
Open	20	3	6	9	4	15	30	45	20
IAA + IBA 500 ppm									
Mist	20	12	8	7	7	60	40	35	35
Open	20	1	6	10	3	5	30	50	15
Control									
Mist	20	6	14	8	6	30	70	40	30
Open	20	3	9	5	3	15	45	25	15
			Chi square value			38.45**	69.54**	44.59**	74.10**

WAP = Weeks after planting

** = Significant at 1% level

Table 2(b). Effect of growth regulators on rooting of cuttings (growing shoot)

Treatment	No.of cuttings sampled	Number of cuttings rooted				Percentage of rooting			
		3 WAP	6 WAP	9 WAP	12 WAP	3 WAP	6 WAP	9 WAP	12 WAP
Seradix-B	40	15	32	20	20	37.5	80.0	50.0	50.0
IAA 1500 ppm	40	24	33	17	16	60.0	82.5	42.5	40.0
IAA 1000 ppm	40	27	26	13	13	67.5	65.0	32.5	32.5
IAA 500 ppm	40	21	23	15	14	52.5	57.5	37.5	35.0
IBA 1500 ppm	40	26	35	17	17	65.0	87.5	42.5	42.5
IBA 1000 ppm	40	33	34	29	29	82.5	85.0	72.5	72.5
IBA 500 ppm	40	23	27	14	14	57.5	67.5	35.0	35.0
IAA + IBA 1500 ppm	40	26	28	15	12	65.0	70.0	37.5	30.0
IAA + IBA 1000 ppm	40	13	20	18	12	32.5	50.0	45.0	30.0
IAA + IBA 500 ppm	40	13	14	17	10	32.5	35.0	42.5	25.0
Control	40	9	23	13	9	22.5	57.5	32.5	22.5
		Chi-square value				13.77^{NS}	48.16^{**}	29.42^{**}	44.9^{NS}

Table 2(c). Effect of mist on rooting of cuttings (growing shoots)

Treatments	Weeks after planting	Number of cuttings sampled	Number of cuttings rooted	Percentage rooting	χ^2 value
Mist	3	220	148	67.27	39.68**
Open	3	220	82	37.27	
Mist	6	220	168	76.36	17.29**
Open	6	220	127	57.72	
Mist	9	220	114	51.81	12.89**
Open	9	220	74	33.63	
Mist	12	220	110	50.00	28.20**
Open	12	220	56	25.45	
Mean				61.36	
				38.51	

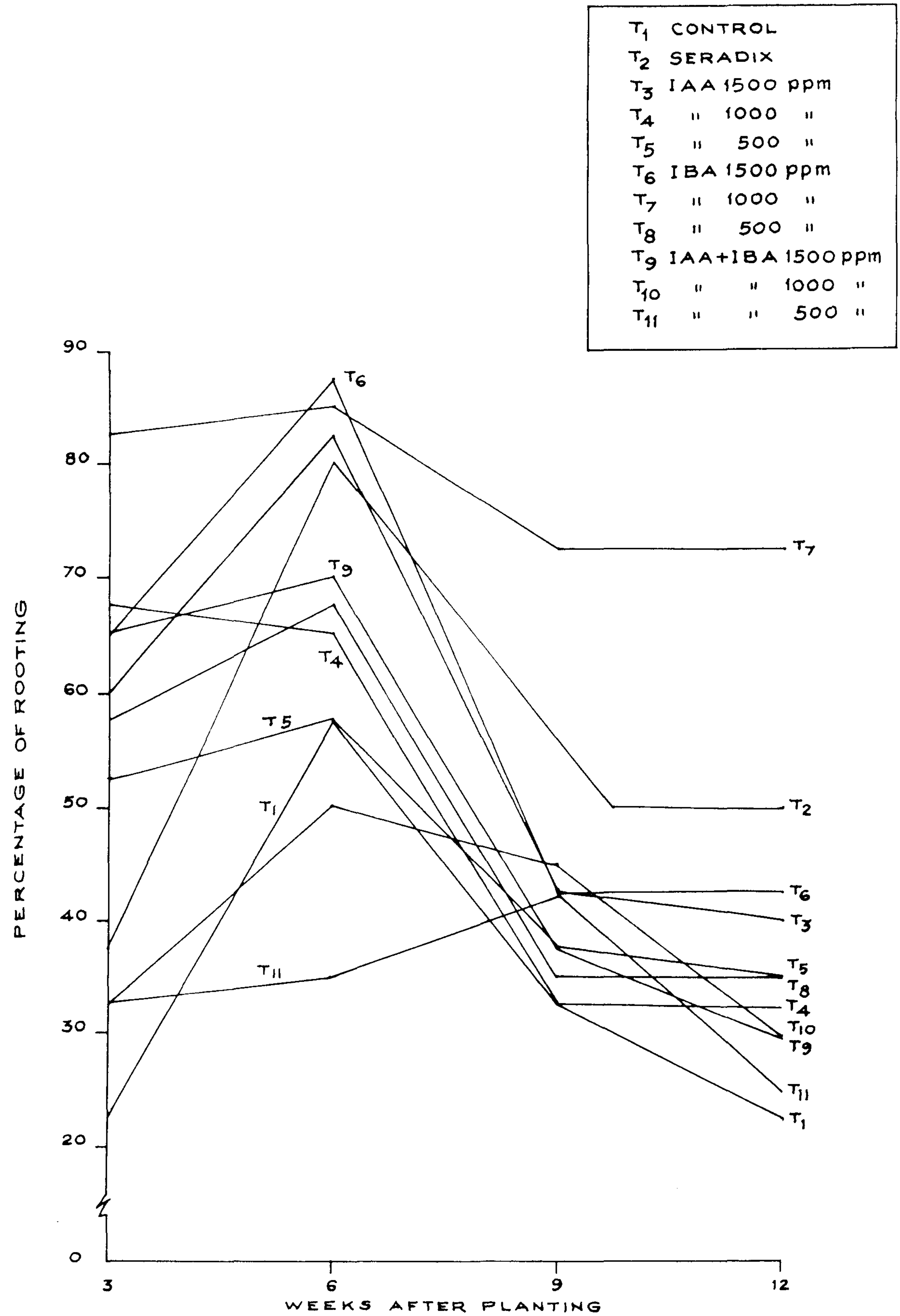

FIG. 2. EFFECT OF GROWTH REGULATORS ON ROOTING OF CUTTINGS IN GROWING SHOOTS (ORTHOTROPHS).

Table 3a. Effect of growth regulators on rooting of cuttings under mist and open (hanging shoots)

Treatment	No.of cuttings sampled	No.of cuttings rooted		No.of cuttings established		Percentage of initial rooting		Percentage of final establishment	
		3 WAP	6 WAP	9 WAP	12 WAP	3 WAP	6 WAP	9 WAP	12 WAP
Seradix-B									
Mist	20	11	14	13	13	55	70	65	65
Open	20	8	7	6	6	40	35	30	30
IAA 1500 ppm									
Mist	20	14	14	12	10	70	70	60	50
Open	20	8	10	10	4	40	50	50	20
IAA 1000 ppm									
Mist	20	8	9	7	6	40	45	35	30
Open	20	6	7	5	4	30	35	25	20
IAA 500 ppm									
Mist	20	10	10	8	8	50	50	40	40
Open	20	5	8	5	5	25	40	25	25
IBA 1500 ppm									
Mist	20	13	16	12	12	65	80	60	60
Open	20	8	13	8	5	40	65	40	25
IBA 1000 ppm									
Mist	20	16	18	16	16	80	90	80	80
Open	20	9	15	10	9	45	75	50	45
IBA 500 ppm									
Mist	20	13	10	9	9	65	50	45	45
Open	20	9	8	8	5	45	40	40	25
IAA + IBA 1500 ppm									
Mist	20	9	13	8	8	45	65	40	40
Open	20	7	9	8	4	35	45	40	20
IAA + IBA 1000 ppm									
Mist	20	6	12	9	7	38	60	45	45
Open	20	3	9	6	4	15	45	30	20
IAA + IBA 500 ppm									
Mist	20	13	10	9	6	65	50	45	30
Open	20	8	8	6	3	40	40	30	15
Control									
Mist	20	8	9	6	4	40	45	30	30
Open	20	5	7	5	3	25	35	25	15
		Chi square value				43.64**	42.19**	29.4**	51.44**

WAP = Weeks after planting
** = Significant at 1% level

Table 3(b). Effect of growth regulators on rooting of cutting (hanging shoots)

Treatment	No.of cuttings sampled	Number of cuttings rooted				Percentage of rooting			
		3 WAP	6 WAP	9 WAP	12 WAP	3 WAP	6 WAP	9 WAP	12 WAP
Seradix-B	40	19	21	19	19	47.5	52.5	47.5	47.5
IAA 1500 ppm	40	22	24	22	14	55.0	60.0	55 0	35.0
IAA 1000 ppm	40	14	16	12	10	35.0	40.0	30.0	25.0
IAA 500 ppm	40	15	18	13	13	37.5	45.0	32.5	32.5
IBA 1500 ppm	40	21	29	20	17	52.5	72.5	50.0	42.5
IBA 1000 ppm	40	25	33	26	25	62.5	82.5	65.0	62.5
IBA 500 ppm	40	22	18	17	14	55.0	45.0	42.5	35.0
IAA + IBA 1500 ppm	40	16	22	16	12	40.0	55.0	40.0	30.0
IAA + IBA 1000 ppm	40	9	21	15	11	22.5	52.5	37.5	27.5
IAA + IBA 500 ppm	40	21	18	15	9	52.5	45.0	37.5	22.5
Control	40	13	16	11	9	32.5	40.0	27.5	22.5
		Chi-Square value				15.15 NS	19.70**	21.58**	43.45**

Table 3(c). Effect of mist on rooting of cutting (hanging shoots)

Treatments	Weeks after planting	Number of cuttings sampled	Number of cuttings rooted	Percentage rooting	χ^2 value
Mist	3	220	121	55.0	18.61^{**}
Open	3	220	76	34.54	
Mist	6	220	135	61.36	10.56^{**}
Open	6	220	101	49.50	
Mist	9	220	109	49.54	3.11^{NS}
Open	9	220	77	35.00	
Mist	12	220	101	45.90	24.05^{**}
Open	12	220	52	23.63	
Mean				52.95	
				34.75	

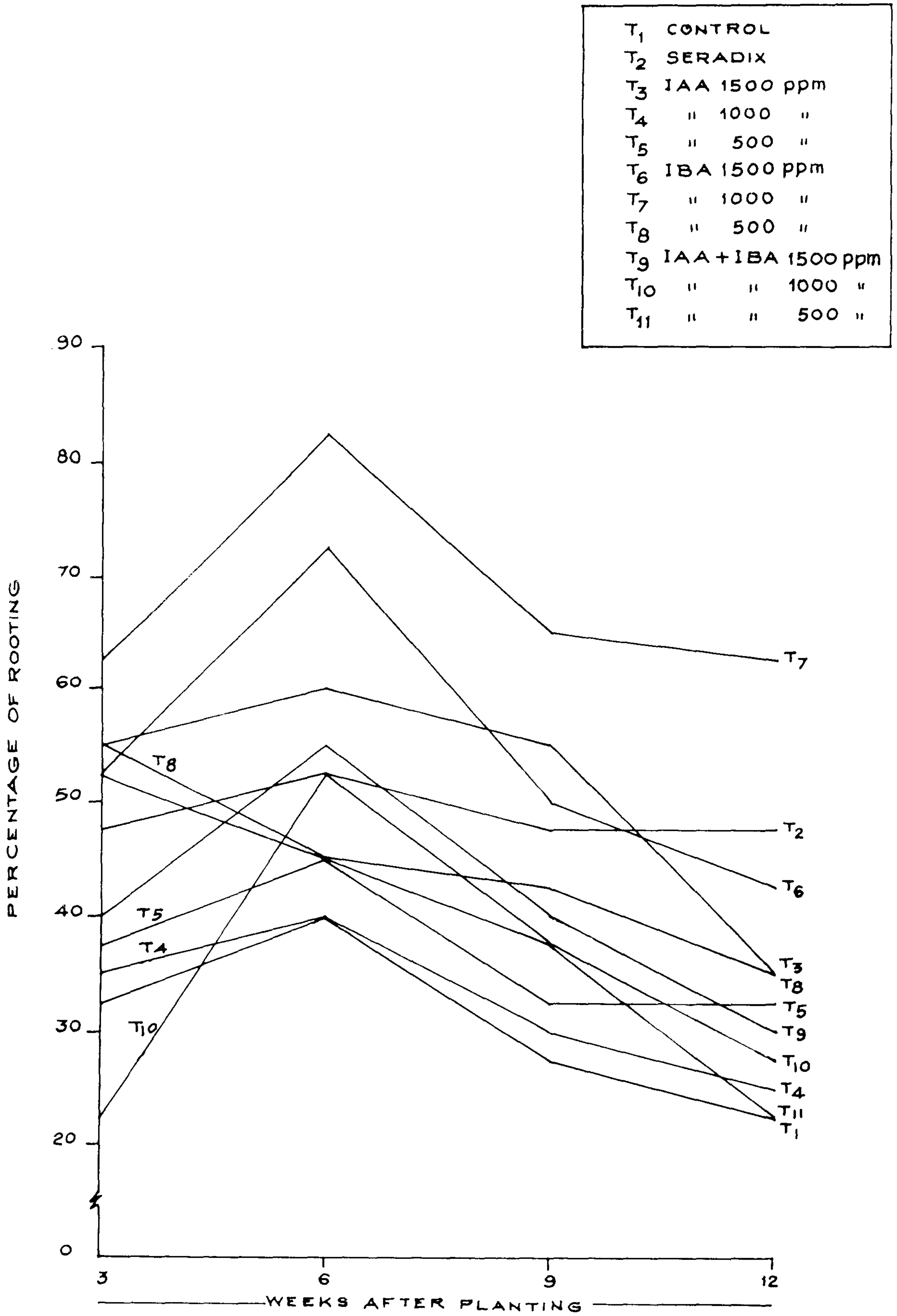

FIG. 3. EFFECT OF GROWTH REGULATORS ON ROOTING OF CUTTINGS IN HANGING SHOOTS (GEOTROPHS).

Table 4a. Effect of growth regulators on rooting of cuttings under mist and open (laterals)

Treatment	No.of cuttings sampled	No.of cuttings rooted		No.of cuttings established		Percentage of initial rooting		Percentage of final establishment	
		3 WAP	6 WAP	9 WAP	12 WAP	3 WAP	6 WAP	9 WAP	12 WAP
Seradix-B									
Mist	20	-	12	14	12	-	60	70	60
Open	20	-	10	12	9	-	50	60	45
IAA 1500 ppm									
Mist	20	-	12	12	11	-	60	60	55
Open	20	-	6	8	7	-	30	40	35
IAA 1000 ppm									
Mist	20	-	10	8	7	-	50	40	35
Open	20	-	2	6	5	-	10	30	25
IAA 500 ppm									
Mist	20	-	8	9	8	-	40	45	40
Open	20	-	4	5	5	-	20	25	25
IBA 1500 ppm									
Mist	20	-	12	13	12	-	60	65	60
Open	20	-	8	9	9	-	40	45	45
IBA 1000 ppm									
Mist	20	-	16	17	15	-	80	85	75
Open	20	-	12	14	11	-	60	70	55
IBA 500 ppm									
Mist	20	-	10	10	8	-	50	50	40
Open	20	-	8	8	4	-	40	40	20
IAA + IBA 1500 ppm									
Mist	20	-	11	10	9	-	55	50	45
Open	20	-	2	8	5	-	10	40	25
IAA + IBA 1000 ppm									
Mist	20	-	10	9	7	-	50	45	35
Open	20	-	2	7	3	-	10	35	15
IAA + IBA 500 ppm									
Mist	20	-	9	11	6	-	45	55	30
Open	20	-	2	9	3	-	10	45	15
Control									
Mist	20	-	3	4	5	-	15	20	25
Open	20	-	1	2	2	-	5	10	10
Chi square value							58.26**	49.30**	45.65**

WAP = Weeks after planting

** = Significant at 1% level

Table 4(b). Effect of growth regulators on rooting of cutting (laterals)

Treatment	No. of cuttings sampled	Number of cuttings rooted				Percentage of rooting			
		3 WAP	6 WAP	9 WAP	12 WAP	3 WAP	6 WP	9 WAP	12 WAP
Seradix-B	40	1	22	26	21	2.5	55.0	65.0	52.5
IAA 1500 ppm	40	3	18	20	18	7.5	45.0	50.0	45.0
IAA 1000 ppm	40	1	12	14	12	2.5	30.0	35.0	30.0
IAA 500 ppm	40	0	12	14	13	0	30.0	35.0	32.5
IBA 1500 ppm	40	4	20	22	21	10.0	50.0	55.0	52.5
IBA 1000 ppm	40	5	28	31	26	12.5	70.0	77.5	65.0
IBA 500 ppm	40	3	18	18	12	7.5	45.0	45.0	30.0
IAA + IBA 1500 ppm	40	2	13	10	14	5.0	32.5	45.0	35.0
IAA + IBA 1000 ppm	40	0	12	16	10	0	30.0	40.0	25.0
IAA + IBA 500 ppm	40	0	11	20	9	0	27.5	50.0	22.5
Control	40	0	4	6	7	0	10.0	15.0	17.5
		Chi-square value				39.17*	33.08**	25.89**	37.48**

Table 4(c). Effect of mist on rooting of cuttings (laterals)

Treatments	Weeks after planting	Number of cuttings sampled	Number of cuttings rooted	Percentage rooting	χ^2 value
Mist	3	220	11	6.07	0.49 NS
Open	3	220	8	3.63	
Mist	6	220	113	51.36	30.06 **
Open	6	220	57	25.90	
Mist	9	220	117	53.18	7.68 **
Open	9	220	88	40.00	
Mist	12	220	100	45.45	13.34 **
Open	12	220	63	28.63	
Mean				39.01	
				24.54	

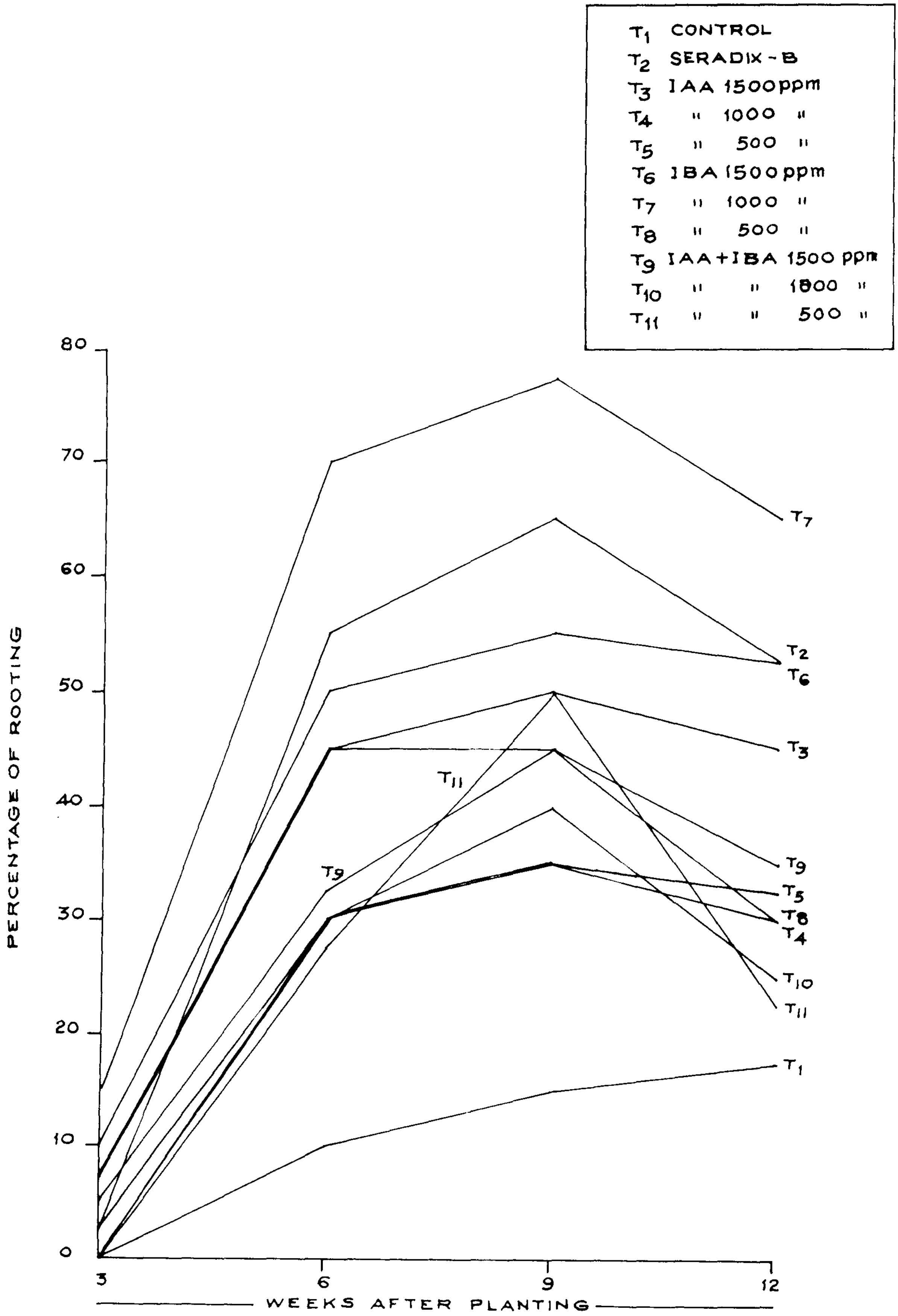

FIG. 4. EFFECT OF GROWTH REGULATORS ON ROOTING OF CUTTINS IN LATERALS (PLAGEOTROPHS).

IBA 1000 ppm was the best treatment. In runners the superiority of this treatment was evident through out the course of study in which rooting observed was 70 per cent. In the case of growing shoots, though IBA 1000 ppm gave 82.5 per cent rooting initially, after six weeks of planting cuttings treated with IBA 1500 ppm produced maximum rooting (87.5 per cent). Hanging shoot cuttings treated with IBA 1000 ppm produced a maximum rooting of 82.5 per cent followed by IBA 1500 ppm, 72.5 per cent. In the case of laterals IBA 1000 ppm produced 77.5 per cent rooting. On the other hand in control rooting was only 10 per cent (Figs.1 to 4).

The pooled data presented in Tables (1c, 2c, 3c and 4c) clearly indicated the beneficial effect of mist on rooting of cuttings in different types of planting materials (Fig.15). In the case of runners and growing shoots the beneficial effect of mist was more pronounced throughout the period of study. Laterals uprooted after three weeks of planting and hanging shoots after nine weeks of planting showed no significant difference between open and mist treatment and it may be due to the climatic variation, but during all other intervals of observation mist significantly increased rooting compared to open conditions.

The data furnished in Tables 1a, 2a and 3a also revealed that maximum rooting was observed after six weeks of

Plate III. Effect of growth regulators on rooting of cuttings in runners (sixth week of planting under mist condition)

T_1 - Control
T_2 - Seradix-B
T_3 - IAA 1500 ppm
T_4 - IAA 1000 ppm
T_5 - IAA 500 ppm
T_6 - IBA 1500 ppm
T_7 - IBA 1000 ppm
T_8 - IBA 500 ppm
T_9 - IAA + IBA 1500 ppm
T_{10} - IAA + IBA 1000 ppm
T_{11} - IAA + IBA 500 ppm

Plate IV. Effect of growth regulators on rooting of cuttings in runners (sixth week of planting under open condition)

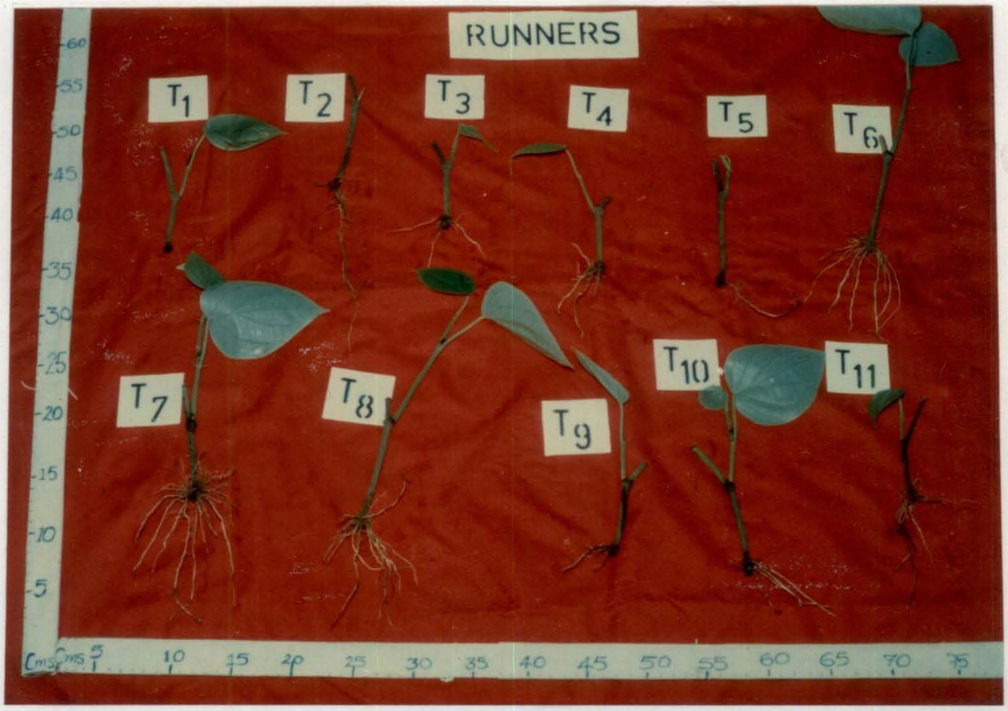

Plate III

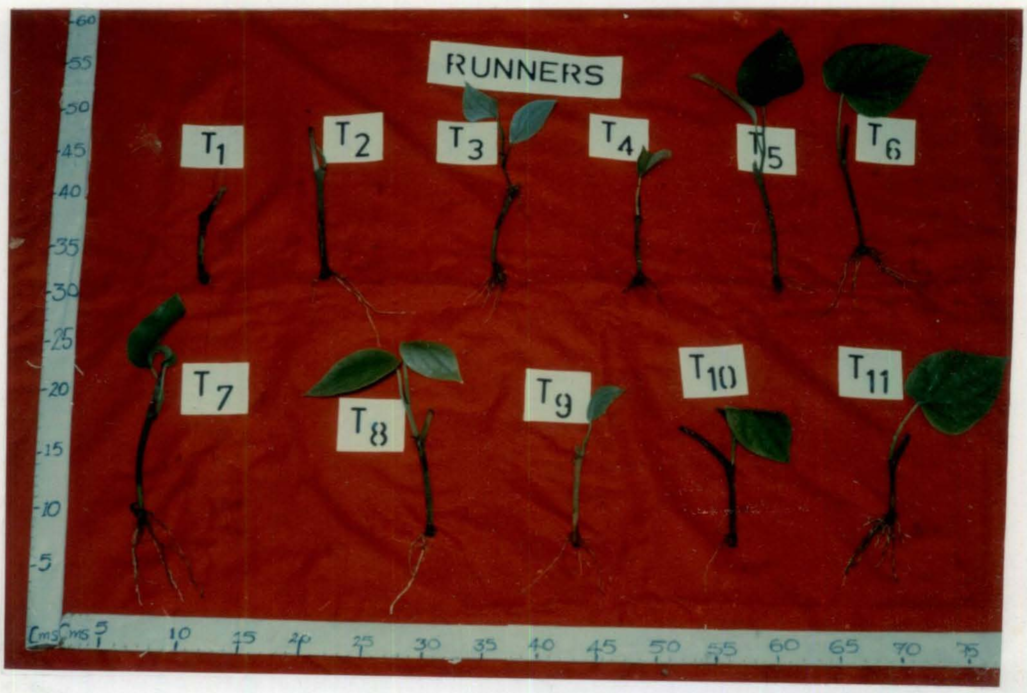

Plate IV

Plate V. Effect of growth regulators on rooting of cuttings in orthotrophs (sixth week of planting under mist condition)

T_1 - Control
T_2 - Seradix-B
T_3 - IAA 1500 ppm
T_4 - IAA 1000 ppm
T_5 - IAA 500 ppm
T_6 - IBA 1500 ppm
T_7 - IBA 1000 ppm
T_8 - IBA 500 ppm
T_9 - IAA + IBA 1500 ppm
T_{10} - IAA + IBA 1000 ppm
T_{11} - IAA + IBA 500 ppm

Plate VI. Effect of growth regulators on rooting of cuttings in orthotrophs (sixth week of planting under open condition)

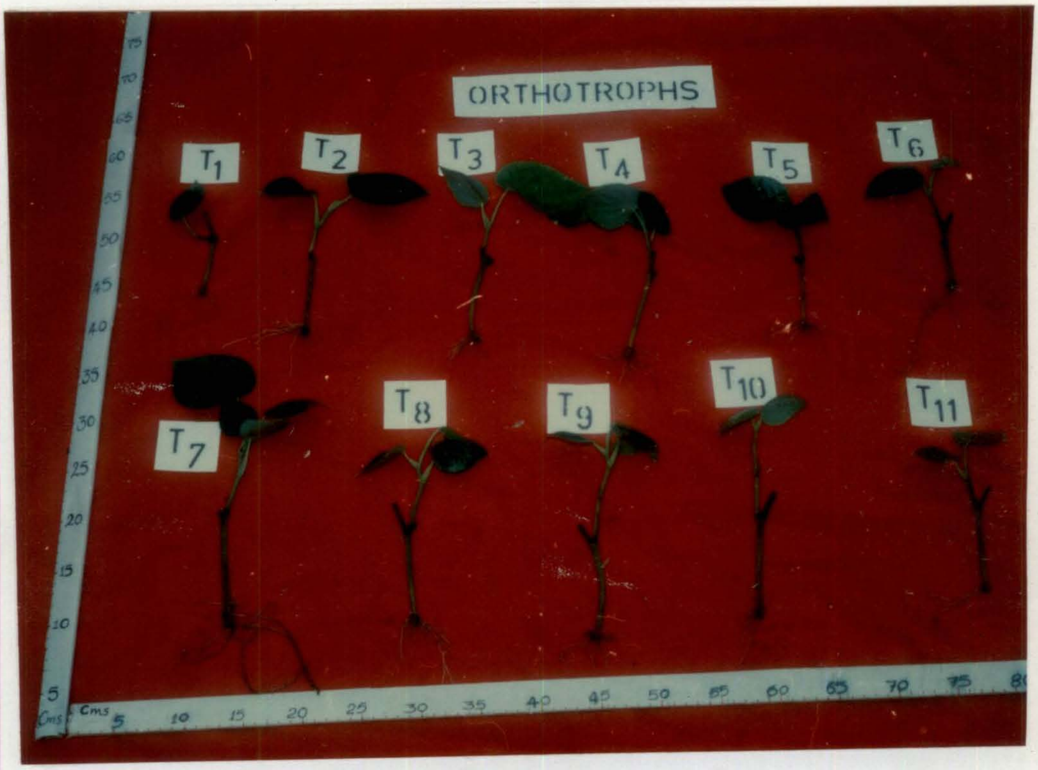

Plate V

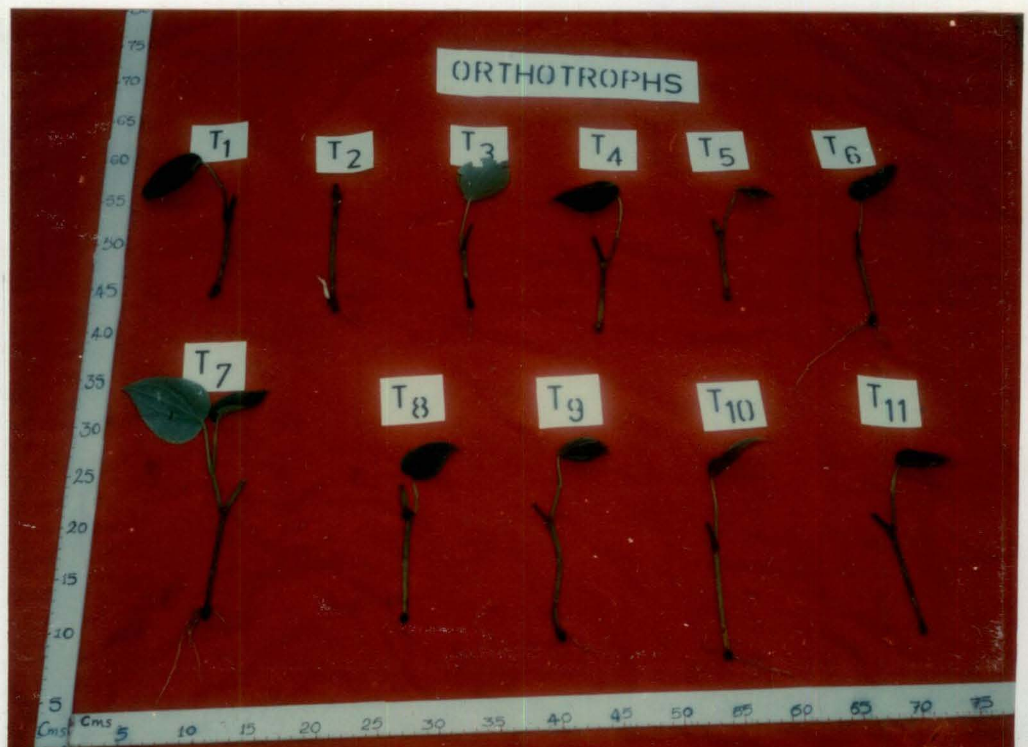

Plate VI

Plate VII. Effect of growth regulators on rooting of cuttings in geotrophs (sixth week of planting under mist condition)

T_1 - Control
T_2 - Seradix-B
T_3 - IAA 1500 ppm
T_4 - IAA 1000 ppm
T_5 - IAA 500 ppm
T_6 - IBA 1500 ppm
T_7 - IBA 1000 ppm
T_8 - IBA 500 ppm
T_9 - IAA + IBA 1500 ppm
T_{10} - IAA + IBA 1000 ppm
T_{11} - IAA + IBA 500 ppm

Plate VIII. Effect of growth regulators on rooting of cuttings in geotrophs (sixth week of planting under open condition)

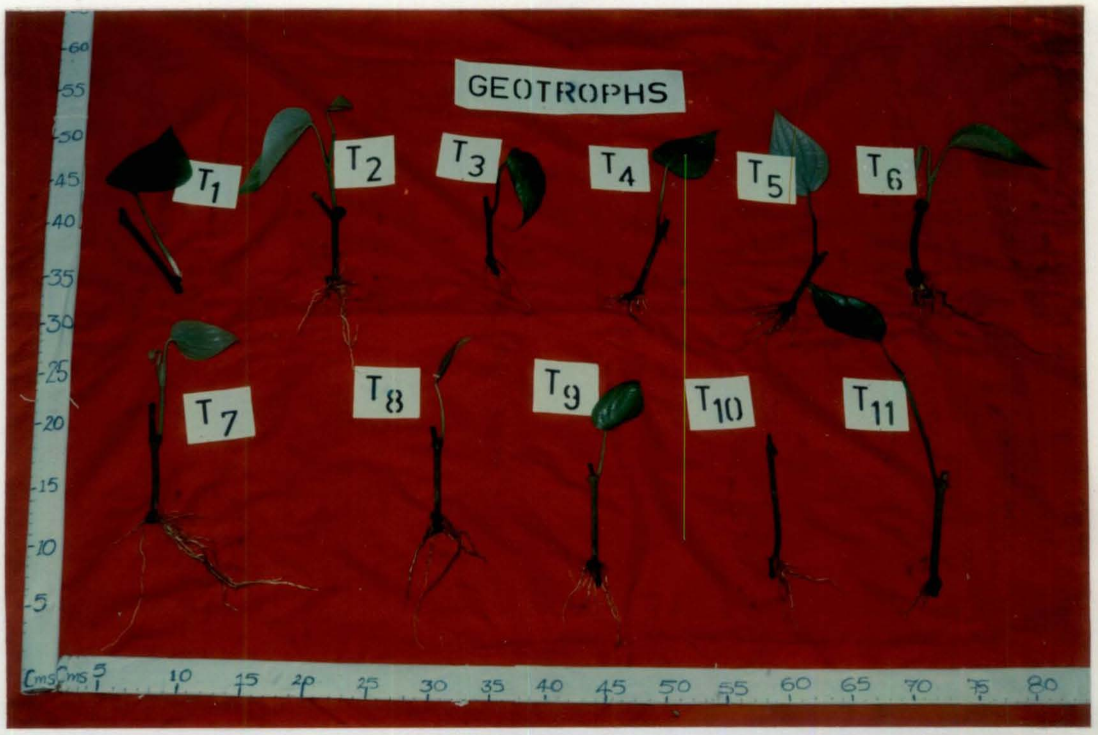

Plate VII

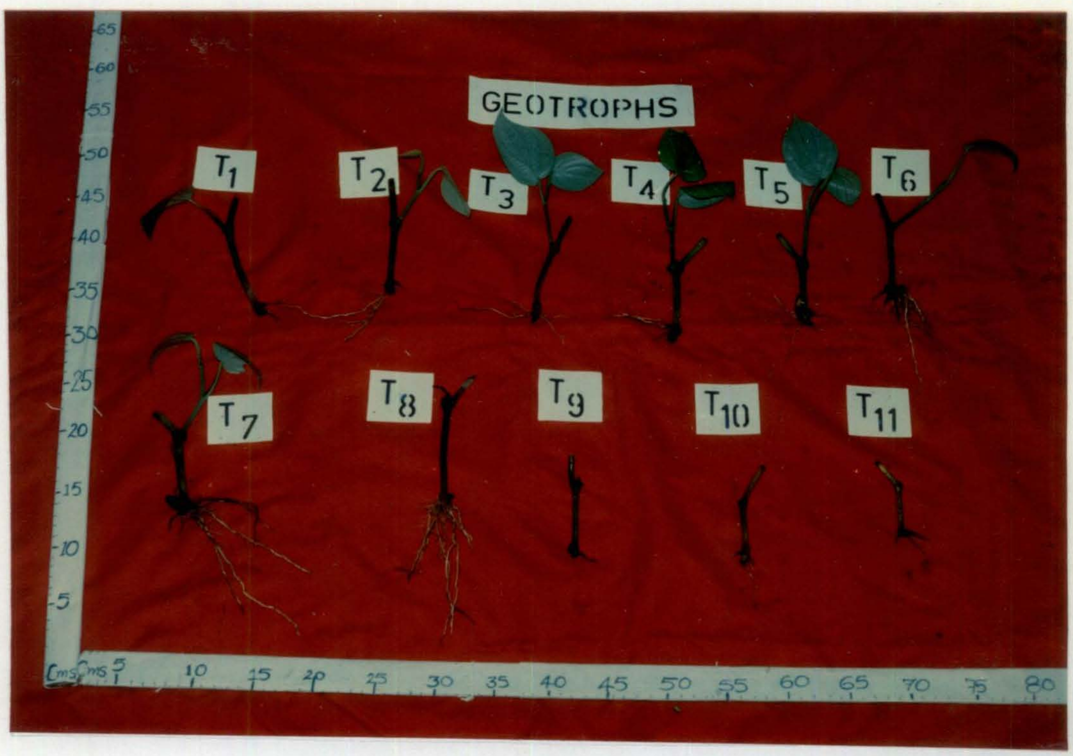

Plate VIII

Plate IX. Effect of growth regulators on rooting of cuttings in plageotrophs (Ninth week of planting under mist condition)

T_1 - Control
T_2 - Seradix-B
T_3 - IAA 1500 ppm
T_4 - IAA 1000 ppm
T_5 - IAA 500 ppm
T_6 - IBA 1500 ppm
T_7 - IBA 1000 ppm
T_8 - IBA 500 ppm
T_9 - IAA + IBA 1500 ppm
T_{10} - IAA + IBA 1000 ppm
T_{11} - IAA + IBA 500 ppm

Plate X. Effect of growth regulators on rooting of cuttings in plageotrophs (Ninth week of planting under open condition)

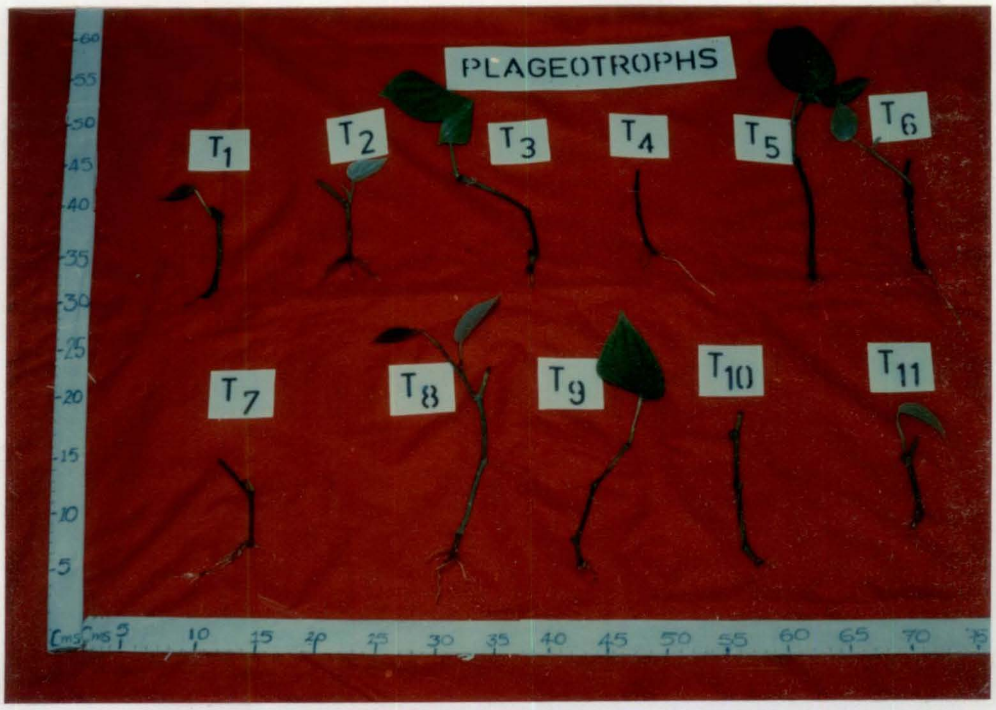

Plate IX

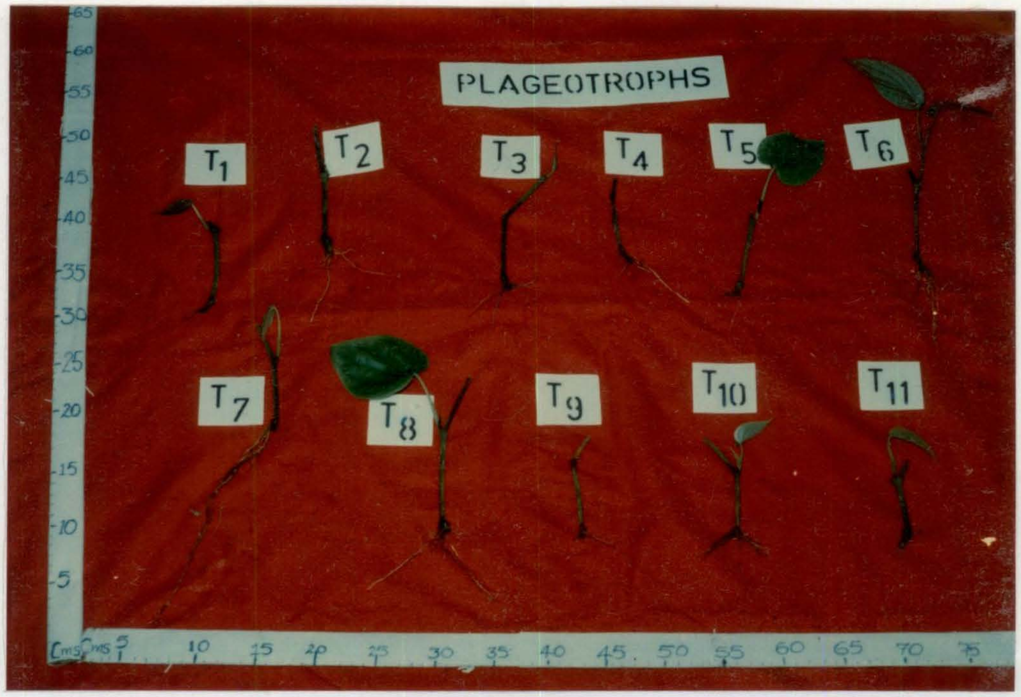

Plate X

planting in the case of runners, growing shoots and hanging roots, whereas laterals produced maximum rooting after nine weeks of planting (Fig.18, Plate XIII and XIV). It is interesting to note that after three weeks of planting the effect of growth regulators was more pronounced in the case of runners only whereas in growing shoots and hanging shoots the treatment effects were found to be non-significant in the earliest stage. In all the treatments laterals did not produce any roots upto three weeks (Plate XI and XII). Later, the growth regulator treatments were found to give higher percentage of rooting when compared with control both under mist and open condition.

4.1.2 Number of roots

The results of the analysis of the data on the effect of growth regulators and mist on number of roots produced by cuttings are presented in Tables 5a to 8c.

In all types of planting materials under mist, mean number of roots per cutting was found to be highest with IBA 1000 ppm followed by Seradix-B, IBA 1500 ppm and IAA 1500 ppm. Tables furnished (5b, 6b, 7b and 8b) with pooled data on the effect of growth regulators on number of roots produced by cuttings indicated that all the treatments differed significantly with regard to this parameter. Runners treated

Table 5(a). Effect of growth regulators on number of roots per cutting under mist and open (runners)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B					
Mist	9.4	11.8	8.1	10.4	10.0
Open	7.1	6.1	5.8	5.5	6.1
IAA 1500 ppm					
Mist	8.0	10.4	8.0	9.3	8.9
Open	6.6	5.8	6.4	6.0	6.2
IAA 1000 ppm					
Mist	6.3	8.8	6.3	8.0	8.9
Open	4.5	5.8	6.5	5.3	5.5
IAA 500 ppm					
Mist	5.6	7.6	7.8	6.6	6.9
Open	3.4	4.6	6.3	5.3	5.8
IBA 1500 ppm					
Mist	5.6	10.7	8.8	9.9	10.2
Open	5.0	7.0	6.3	6.1	6.2
IBA 1000 ppm					
Mist	10.8	15.2	10.1	12.5	12.2
Open	7.8	7.8	6.5	6.8	7.2
IBA 500 ppm					
Mist	8.0	7.6	8.5	8.0	8.0
Open	5.3	4.7	6.6	5.5	5.5
IAA + IBA 1500 ppm					
Mist	3.2	9.9	8.5	7.3	7.2
Open	4.7	6.7	6.8	7.5	6.4
IAA + IBA 1000 ppm					
Mist	5.9	8.8	7.2	6.6	7.1
Open	2.7	5.1	5.8	4.0	4.4
IAA + IBA 500 ppm					
Mist	3.5	9.5	5.9	5.8	6.1
Open	1.8	6.7	4.0	4.0	4.8
Control					
Mist	4.8	5.4	5.1	5.0	5.0
Open	2.3	4.2	4.3	3.6	3.6
CD	5.6**	4.6**	NS	6.3**	
SEm ±	2.1	1.7	2.2	2.3	

WAP = Weeks after planting
CD = Critical difference
** = Significant at 1% level
NS = Not significant

Table 5(b). Effect of growth regulators on number of roots per cutting (runners)

Treatments	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B	8.3	9.6	7.2	8.2	8.3
IAA 1500 ppm	7.4	8.4	7.5	8.2	7.8
IAA 1000 ppm	5.3	7.5	6.3	7.1	6.5
IAA 500 ppm	4.8	6.4	7.3	6.2	6.2
IBA 1500 ppm	5.3	9.3	7.8	8.3	7.7
IBA 1000 ppm	9.5	12.0	8.8	10.2	10.1
IBA 500 ppm	7.0	6.3	7.2	7.2	6.9
IAA + IBA 1500 ppm	3.9	8.8	7.8	7.3	6.9
IAA + IBA 1000 ppm	4.8	7.3	6.5	5.8	6.1
IAA + IBA 500 ppm	2.8	8.3	5.4	5.5	5.5
Control	3.8	4.9	4.9	4.5	4.5
CD	3.6**	3.2**	NS	4.2**	
SEm ±	1.4	1.2	1.2	1.8	

Table 5(c). Effect of mist on numbers of roots per cutting (Runners)

Treatments	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Mist	6.9	9.9	7.8	8.8	8.4
Open	5.3	6.3	6.1	5.8	5.9
CD	1.2**	1.2**	1.1**	1.2**	
SEm ±	0.5	0.5	0.4	0.5	

WAP = Weeks after planting
** = Signi icant at 1% level
CD = Critical difference

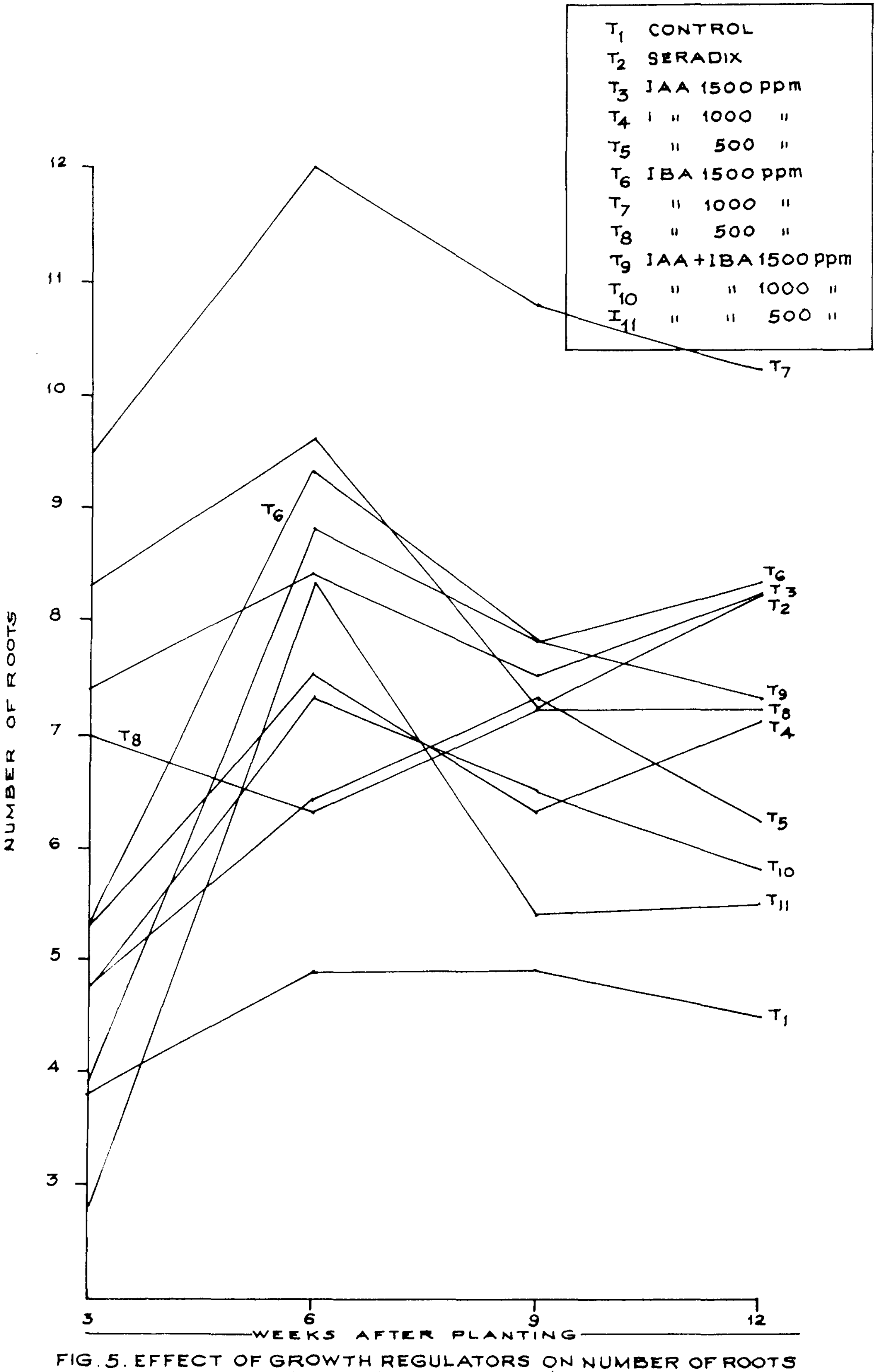

FIG. 5. EFFECT OF GROWTH REGULATORS ON NUMBER OF ROOTS PER CUTTING IN RUNNERS (STOLONS).

Table 6 (a). Effect of growth regulators on number of roots per cutting under mist and open (growing shoots)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B					
Mist	7.3	9.8	11.7	12.2	10.2
Open	4.2	6.3	8.0	7.1	6.4
IAA 1500 ppm					
Mist	7.2	8.2	6.1	11.1	8.1
Open	5.0	6.0	8.5	6.4	6.4
IAA 1000 ppm					
Mist	6.4	7.3	9.3	9.8	8.2
Open	5.2	5.2	7.0	6.0	5.8
IAA 500 ppm					
Mist	6.6	6.2	10.2	8.5	7.8
Open	4.7	4.7	7.6	6.0	6.7
IBA 1500 ppm					
Mist	8.0	9.2	12.5	12.0	10.4
Open	4.8	6.6	9.0	7.8	7.0
IBA 1000 ppm					
Mist	10.3	11.9	16.5	14.0	13.2
Open	6.9	7.2	9.4	8.7	8.0
IBA 500 ppm					
Mist	6.3	6.8	11.0	7.8	8.0
Open	4.4	5.9	7.4	5.4	5.7
IAA + IBA 1500 ppm					
Mist	5.4	7.0	8.5	6.8	6.9
Open	5.0	5.0	7.0	5.5	5.6
IAA + IBA 1000 ppm					
Mist	5.4	5.5	9.2	7.8	6.9
Open	4.0	4.3	7.1	5.0	5.1
IAA + IBA 500 ppm					
Mist	5.8	6.5	9.1	6.8	7.1
Open	0.0	4.5	6.4	6.3	5.7
Control					
Mist	4.6	5.6	8.0	6.8	6.2
Open	3.3	3.3	6.0	4.6	4.3
CD	NS	4.7**	5.2**	5.8**	
SEm ±	2.5	1.7	1.8	2.2	

WAP = Weeks after planting
CD = Critical difference
** = Significant at 1% level
NS = Not significant

Table 6(b). Effect of growth regulators on number of roots per cutting (growing shoots)

Treatments	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B	6.2	8.2	10.5	10.7	8.9
IAA 1500 ppm	6.4	7.4	6.7	9.6	7.5
IAA 1000 ppm	6.0	6.3	8.4	8.6	7.3
IAA 500 ppm	6.0	5.4	9.3	7.6	7.1
IBA 1500 ppm	6.8	8.0	11.4	10.7	9.2
IBA 1000 ppm	8.9	9.9	13.6	11.9	11.1
IBA 500 ppm	5.5	6.4	9.7	7.0	7.1
IAA + IBA 1500 ppm	5.2	6.1	7.8	6.4	6.4
IAA + IBA 1000 ppm	5.0	5.1	8.1	6.8	6.3
IAA + IBA 500 ppm	5.6	5.6	7.5	6.7	6.3
Control	4.2	4.7	7.2	6.1	5.5
CD	NS	3.0**	3.7**	3.7**	
SEm ±	1.5	1.2	1.3	1.4	

Table 6 (c) Effect of mist on number of roots per cutting (growing shoots)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Mist	7.0	7.9	10.7	10.2	9.0
Open	5.0	5.6	7.6	6.6	6.2
CD	1.2**	1.0**	1.3**	1.4**	
SEm ±	0.5	0.4	0.5	0.6	

WAP = Weeks after planting
** = Significant at 1% level
CD = Critical difference
NS = Not significant

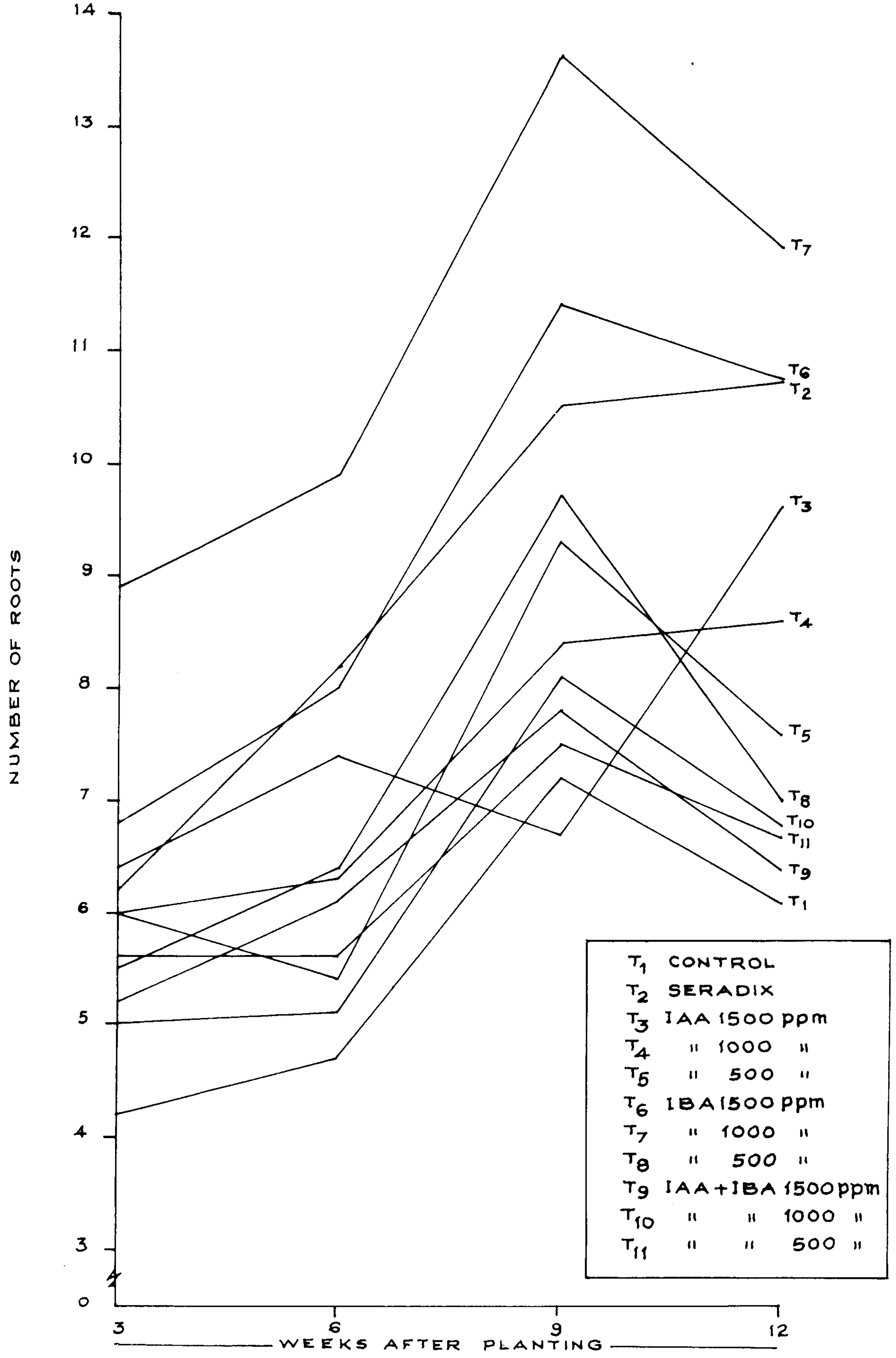

FIG. 6. EFFECT OF GROWTH REGULATORS ON NUMBER OF ROOTS PER CUTTING IN GROWING SHOOTS (ORTHOTROPHS).

with IBA 1000 ppm produced maximum mean number of roots (10.2) followed by Seradix-B (8.3) and IBA 1500 ppm (7.7). A similar trend was observed in the growing as well as in hanging shoots. They produced a maximum mean number of 13.7 and 12.4 roots respectively under IBA 1000 ppm treatment. In these materials the open condition control produced lowest number of roots 5.6 and 4.4 respectively. In the case of laterals IBA 1000 ppm treatment showed its superiority over all other treatments, after nine weeks of planting it produced 13.7 roots on an average (Fig.5 to 8).

The results of the pooled analysis of the observations furnished in Tables 5c, 6c, 7c and 8c on the effect of mist on the number of roots produced by cuttings clearly indicated the superiority of mist on this parameter (Fig.13). Runners under mist produced an average of 8.3 roots compared to 5.8 under open condition. In growing shoots and hanging shoots through out the course of study the effect of mist was found to be highly significant while in laterals during the time of initial observation the effect of mist was found to be non significant due to the seasonal variation, but later on mist significantly influenced root production.

With regard to this parameter also runners exhibited significant difference between the treatments through out the period of study but in the other three types of planting

Table 7(a). Effect of growth regulators on number of roots per cutting under mist and open (hanging shoots)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B					
Mist	7.2	9.0	11.2	10.6	9.5
Open	5.7	6.2	6.6	5.8	6.1
IAA 1500 ppm					
Mist	8.5	10.1	12.0	11.5	10.5
Open	6.5	6.0	7.1	6.5	6.5
IAA 1000 ppm					
Mist	6.7	7.0	9.5	8.0	7.8
Open	3.3	5.0	6.0	5.5	4.9
IAA 500 ppm					
Mist	6.9	6.4	9.1	8.1	7.6
Open	5.2	3.1	7.2	5.0	5.1
IBA 1500 ppm					
Mist	7.8	8.5	12.1	10.9	9.8
Open	4.5	7.5	7.5	6.6	6.5
IBA 1000 ppm					
Mist	9.1	12.8	13.6	13.9	12.4
Open	6.8	9.3	10.7	8.5	8.8
IBA 500 ppm					
Mist	5.6	5.6	8.5	6.5	6.5
Open	3.8	3.8	6.3	4.0	4.5
IAA + IBA 1500 ppm					
Mist	5.6	7.7	9.6	7.2	7.5
Open	5.7	5.5	6.0	5.0	5.5
IAA + IBA 1000 ppm					
Mist	5.0	5.8	8.0	7.4	6.5
Open	4.6	4.8	7.1	4.2	5.2
IAA + IBA 500 ppm					
Mist	7.4	6.7	7.4	6.8	7.1
Open	4.6	4.8	6.8	4.3	5.1
Control					
Mist	4.1	5.1	6.2	5.0	5.1
Open	2.6	4.1	3.6	3.0	3.3
CD	NS	4.1**	3.8**	5.0**	
SEm ±	2.6	1.5	1.3	1.9	

WAP = Weeks after planting
CD = Critical difference
NS = Not Significant
** = Significant at 1% level

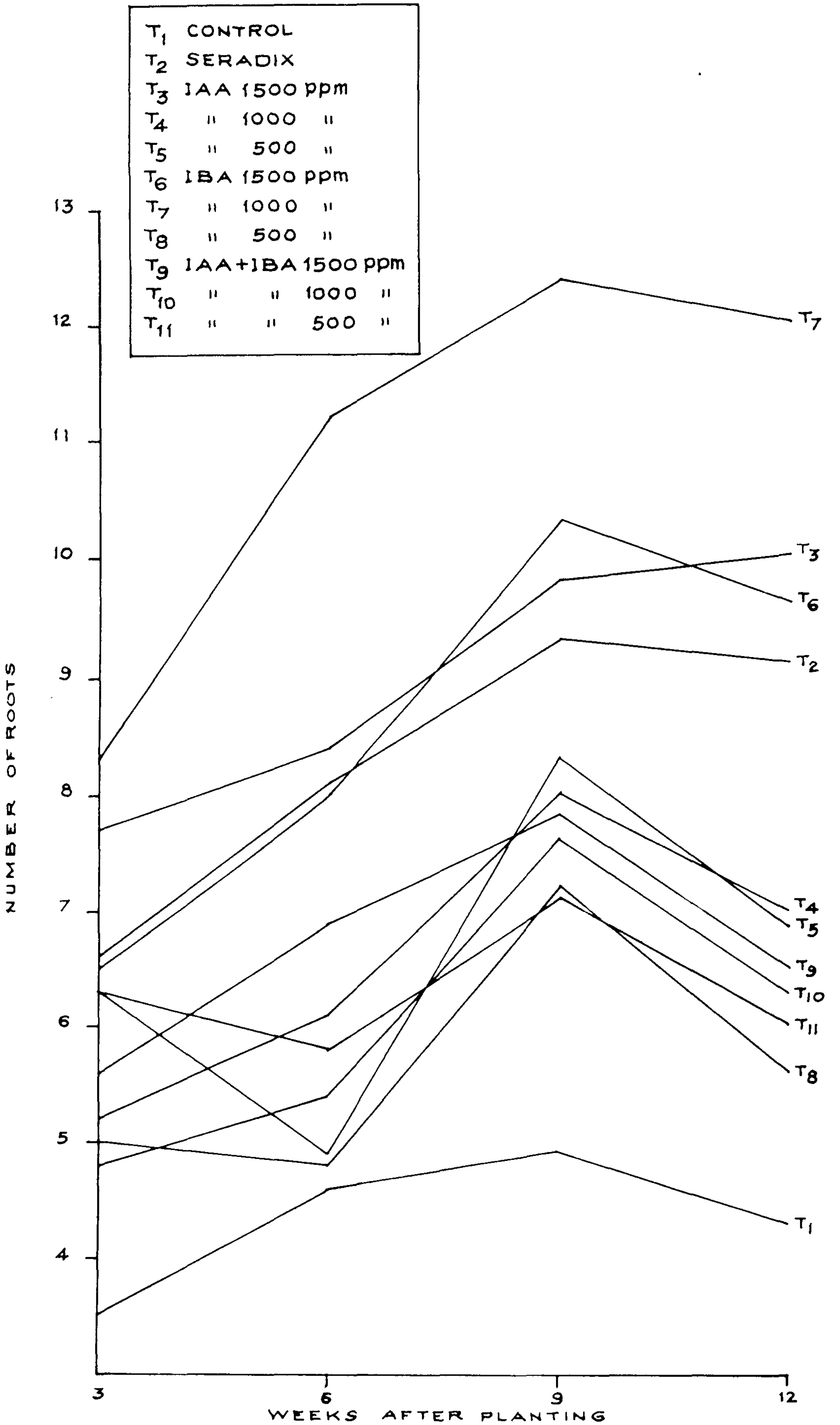

FIG. 7. EFFECT OF GROWTH REGULATORS ON NUMBER OF ROOTS PER CUTTING IN HANGING SHOOTS (GEOTROPHS).

Table 7(b). Effect of growth regulators on number of roots per cutting (hanging shoots)

Treatments	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B	6.6	8.1	9.3	9.1	8.3
IAA 1500 ppm	7.7	8.4	9.8	10.0	9.0
IAA 1000 ppm	5.3	6.1	8.0	7.0	6.6
IAA 500 ppm	6.3	4.9	8.3	6.9	6.6
IBA 1500 ppm	6.5	8.0	10.3	9.6	8.6
IBA 1000 ppm	8.3	11.2	12.4	12.0	11.0
IBA 500 ppm	5.0	4.8	7.2	5.6	5.6
IAA + IBA 1500 ppm	5.6	6.8	7.3	6.5	6.6
IAA + IBA 1000 ppm	4.8	5.4	7.6	6.3	6.0
IAA + IBA 500 ppm	6.3	5.8	7.1	6.0	6.3
Control	3.5	4.6	4.9	4.3	4.3
CD	NS	2.8**	2.8**	3.4**	
SEm ±	1.5	1.0	1.0	1.2	

Table 7(c). Effect of mist on number of roots per cutting (hanging shoots)

Treatments	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Mist	7.0	8.2	10.4	9.5	8.8
Open	5.0	5.8	7.0	5.7	5.9
CD	1.3**	1.1**	1.1**	1.3**	
SEm ±	0.5	0.4	0.4	0.5	

WAP = Weeks after planting   CD = Critical difference
** = Significant at 1% level   NS = Not significant

Table 8(a). Effect of growth regulators on number of roots per cutting under mist and open (laterals)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B					
Mist	-	6.9	12.0	11.8	10.2
Open	-	6.3	10.4	8.0	8.2
IAA 1500 ppm					
Mist	-	5.1	11.5	11.0	9.2
Open	-	5.0	9.2	7.7	7.3
IAA 1000 ppm					
Mist	-	5.3	10.3	8.2	7.9
Open	-	4.5	10.1	7.2	7.2
IAA 500 ppm					
Mist	-	5.1	11.1	7.3	7.8
Open	-	4.0	8.4	5.0	5.8
IBA 1500 ppm					
Mist	-	6.4	12.0	10.8	9.7
Open	-	5.5	9.0	7.0	7.1
IBA 1000 ppm					
Mist	-	8.9	15.6	13.0	12.5
Open	-	6.5	11.3	8.9	8.9
IBA 500 ppm					
Mist	-	5.1	10.3	7.5	7.6
Open	-	2.7	8.0	5.0	5.2
IAA + IBA 1500 ppm					
Mist	-	4.2	10.0	9.0	7.7
Open	-	1.5	8.2	7.0	5.5
IAA + IBA 1000 ppm					
Mist	-	5.0	9.1	8.0	7.3
Open	-	3.5	9.7	6.3	6.5
IAA + IBA 500 ppm					
Mist	-	4.6	9.1	8.6	7.5
Open	-	2.5	6.5	4.3	4.4
Control					
Mist	-	3.3	6.5	4.2	4.6
Open	-	-	4.5	4.0	4.2
CD	-	NS	6.0**	6.5**	
SEm ±	-	2.6	2.6	2.7	

WAP = Weeks after planting
CD = Critical difference
** = Significant at 1% level
NS = Not Significant

Table 8(b). Effect of growth regulators on number of roots per cutting (laterals)

Treatments	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B	-	6.3	11.3	10.1	9.3
IAA 1500 ppm	-	5.1	10.6	9.8	8.5
IAA 1000 ppm	-	5.2	10.3	7.8	7.8
IAA 500 ppm	-	4.8	10.1	6.4	7.1
IBA 1500 ppm	-	6.1	10.8	9.2	8.6
IBA 1000 ppm	-	7.9	13.7	11.3	10.9
IBA 500 ppm	-	4.1	9.3	6.6	6.6
IAA + IBA 1500 ppm	-	3.8	9.2	8.2	7.1
IAA + IBA 1000 ppm	-	4.2	9.3	7.5	7.2
IAA + IBA 500 ppm	-	4.3	8.0	7.2	6.4
Control	-	3.3	5.8	4.1	4.4
CD	-	4.1*	3.6**	3.9**	
SEm ±	-	1.5	1.6	1.5	

Table 8(c). Effect of Mist on number of roots per cutting (laterals)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Mist	-	5.8	11.3	9.8	8.9
Open	-	4.9	9.1	7.8	7.0
CD	-	NS	1.1**	1.3**	
SEm ±	-	0.5	0.4	0.5	

WAP = Weeks after planting CD = Critical difference
** = Significant at 1% level NS = Not significant

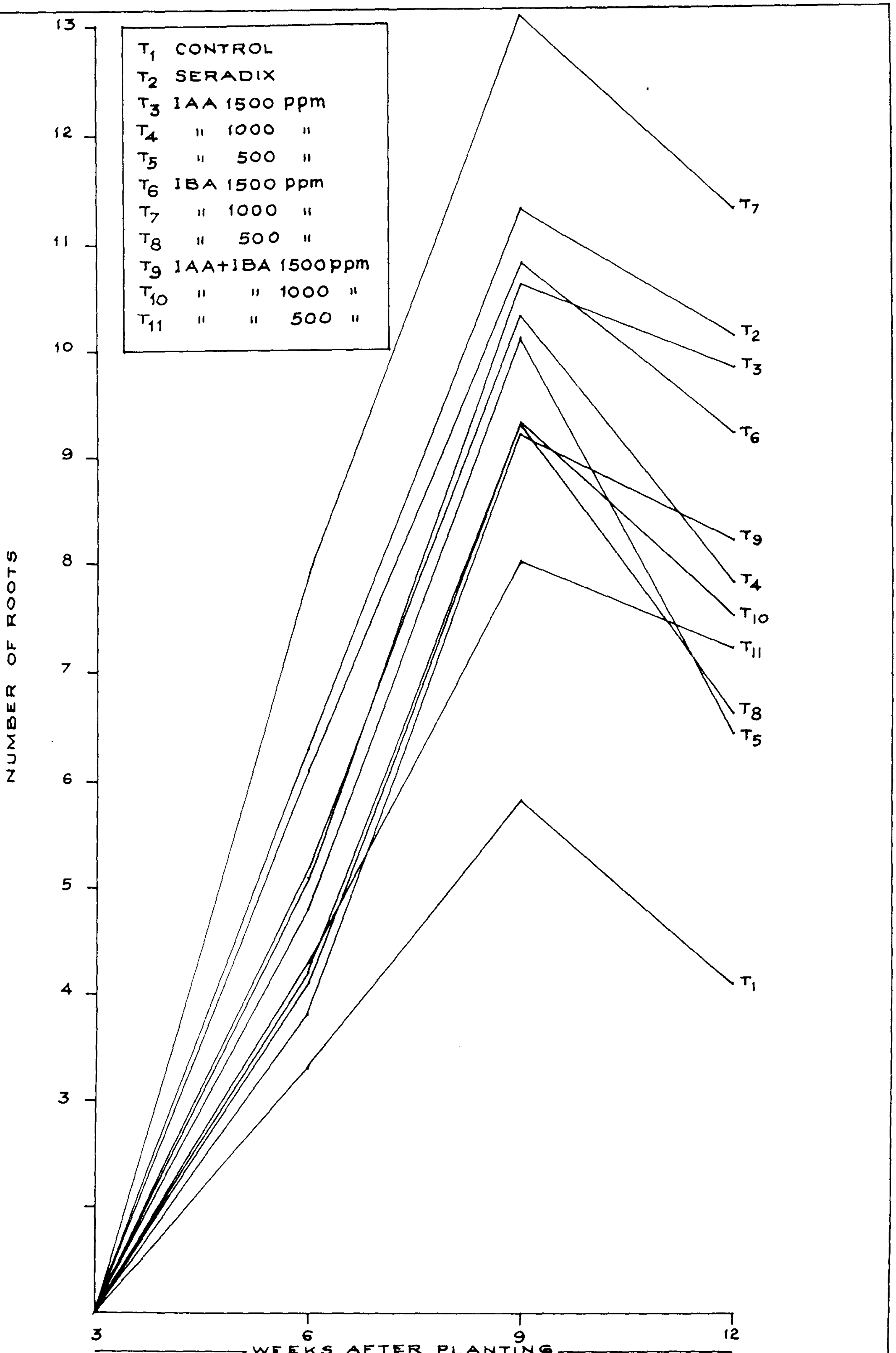

FIG. 8. EFFECT OF GROWTH REGULATORS ON NUMBER OF ROOTS PER CUTTING IN LATERALS (PLAGEOTROPHS).

Plate XIII. Effect of IBA on rooting of different types of planting materials (sixth week of planting under mist condition)

1. IBA 1500 ppm
2. IBA 1000 ppm
3. IBA 500 ppm

Plate IX. Effect of IBA on rooting of different types of planting materials (sixth week of planting under open condition)

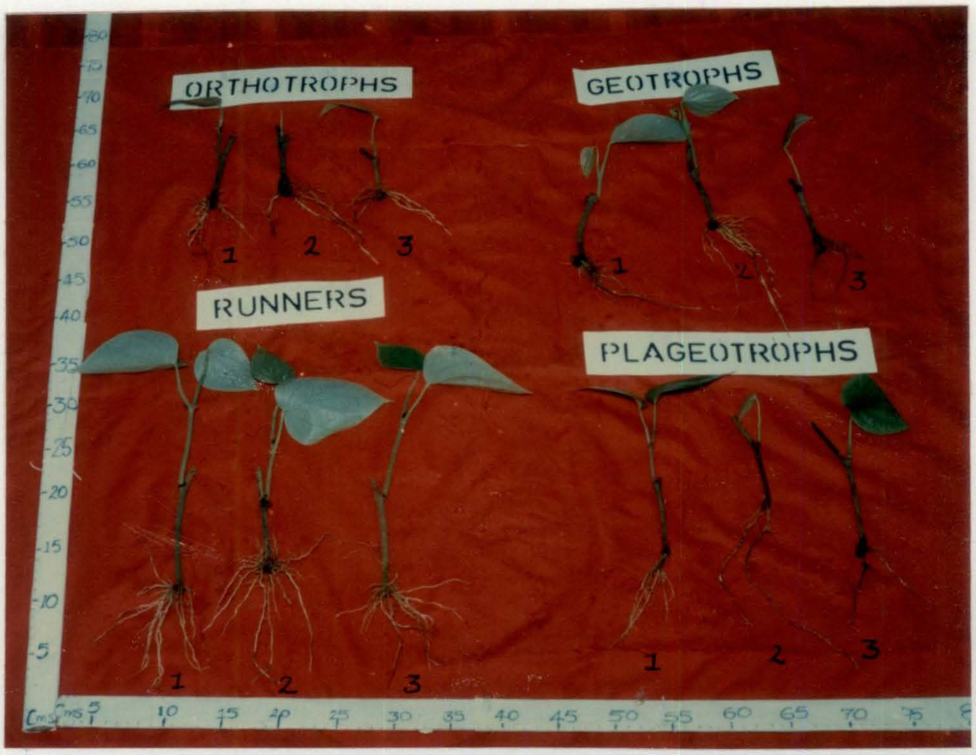

Plate XIII

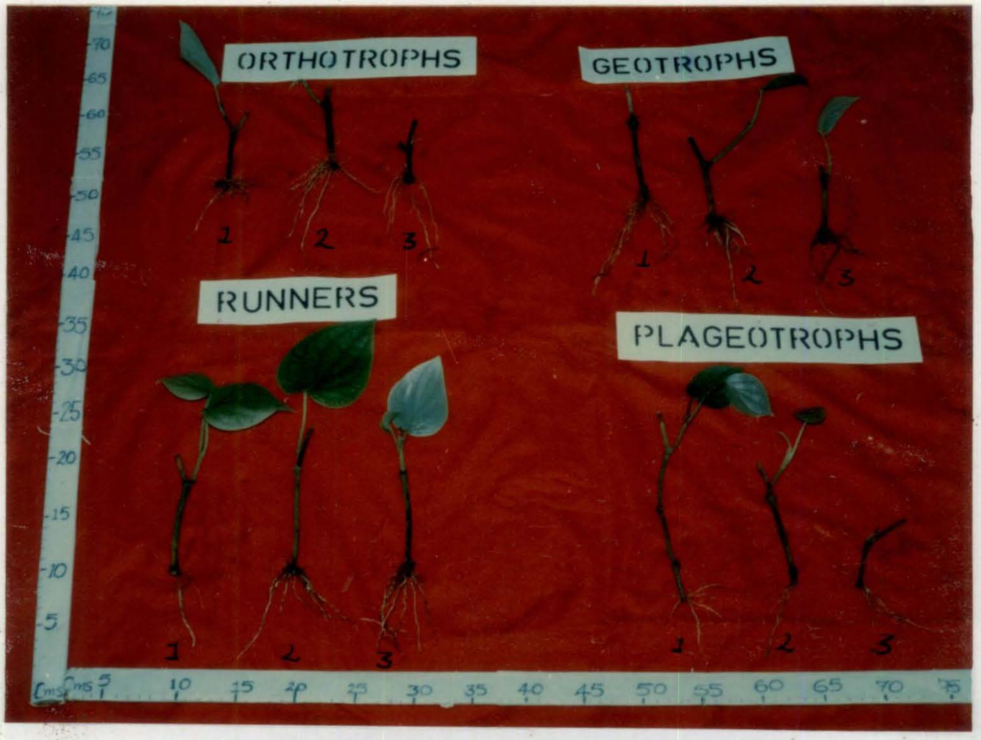

Plate XIV

Plate XI. Effect of IBA on rooting of different types of planting materials (third week of planting under mist condition)

1. IBA 1500 ppm
2. IBA 1000 ppm
3. IBA 500 ppm

Plate XII. Effect of IBA on rooting of different types of planting materials (third week of planting under open condition)

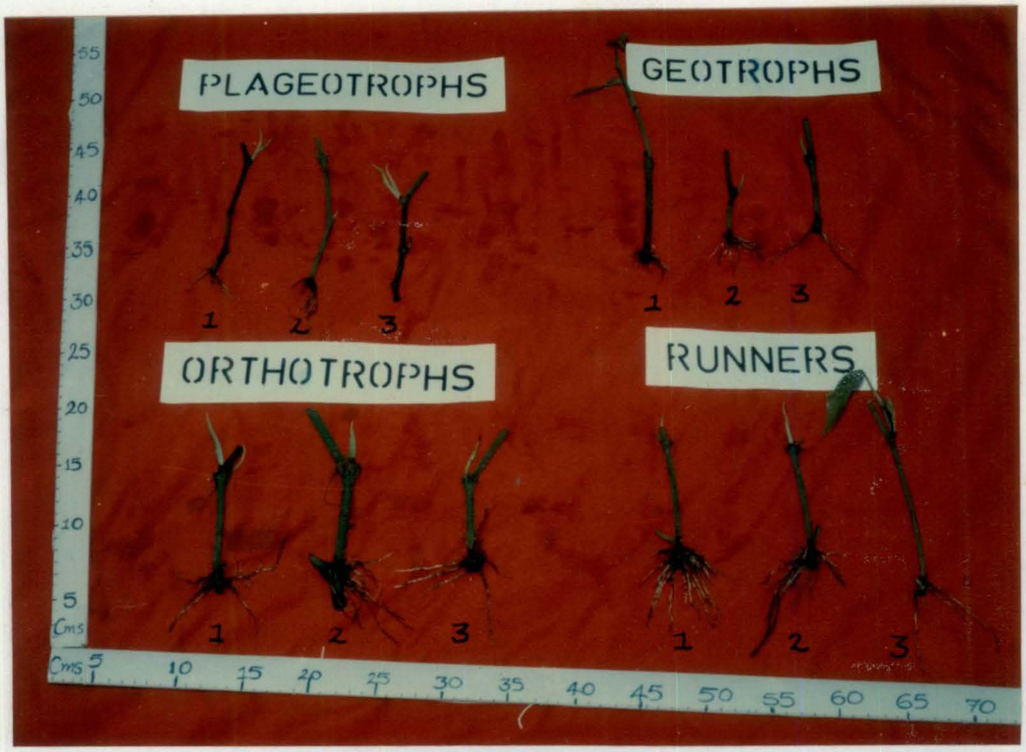

Plate XI

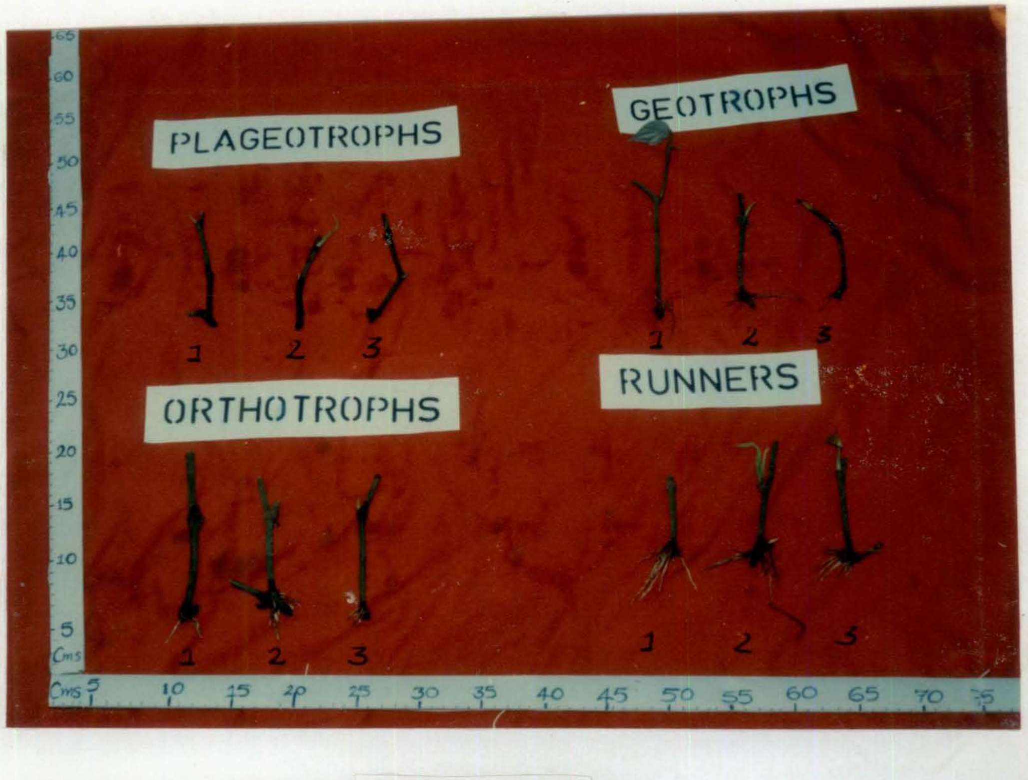

Plate XII

materials all the growth regulator treatments under mist and open were found to be on par with respect to number of roots produced during the first interval of observation. In runners after six weeks of planting and in growing shoots and laterals after nine weeks of planting the IBA, 1000 ppm treatment showed significant increase in root production compared to all other treatments (Fig.16). The maximum number of roots produced by these materials during the above periods were 15.1, 12.5 and 12.1 respectively. In the case of hanging shoots after twelve weeks of planting though there existed significant difference among the treatments, IBA 1000 and 1500 ppm, Seradix-B and IAA 1500 ppm under mist were found to be on par. The pooled data on effect of mist on number of roots produced indicated that in growing shoots the effect was less significant after six weeks of planting but during the later stages it was highly significant.

4.1.3 Length of roots

The effect of different growth regulators and mist on the length of roots produced by cuttings are tabulated in Tables 9a, 10a, 11a and 12a. It is evident from the data that in general in all the planting materials, IBA 1000 ppm tended to produce longer roots followed by Seradix-B, IAA 1500 ppm and IBA 1500 ppm though the treatment effect was not significant. This effect was more pronounced under mist. In runners,

Table 9(a). Effect of growth regulators on length of roots (cm) per cutting under mist and open (runners)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B					
Mist	3.5	15.3	18.5	23.8	15.3
Open	1.9	6.7	10.1	14.5	8.3
IAA 1500 ppm					
Mist	2.6	9.5	16.5	24.5	16.4
Open	1.8	4.1	9.6	14.6	7.6
IAA 1000 ppm					
Mist	2.0	7.8	12.1	18.5	10.1
Open	1.9	4.0	9.7	6.1	5.5
IAA 500 ppm					
Mist	2.3	7.2	12.4	17.0	9.8
Open	3.6	4.4	7.5	15.0	7.7
IBA 1500 ppm					
Mist	3.2	9.0	17.8	25.4	13.9
Open	1.9	4.6	7.8	14.6	7.3
IBA 1000 ppm					
Mist	5.6	13.4	22.3	28.7	17.6
Open	3.0	5.8	10.6	15.0	8.7
IBA 500 ppm					
Mist	2.0	7.5	14.4	20.9	11.2
Open	1.8	4.2	7.9	12.6	6.7
IAA + IBA 1500 ppm					
Mist	2.1	7.0	14.2	22.6	11.5
Open	2.3	4.1	9.3	8.0	5.9
IAA + IBA 1000 ppm					
Mist	2.7	6.5	13.6	20.9	10.9
Open	2.0	4.2	7.7	8.9	5.7
IAA + IBA 500 ppm					
Mist	1.6	6.5	13.2	19.4	10.2
Open	1.3	5.7	7.5	2.9	4.4
Control					
Mist	1.8	5.7	11.7	15.7	8.8
Open	1.8	4.6	6.1	7.1	4.9
CD	1.7**	4.4**	8.9**	16.0**	
SEm ±	0.7	1.6	3.5	3.9	

WAP = Weeks after planting
CD = Critical difference
** = Significant at 1% level

Table 9(b). Effect of growth regulators on length of roots (cm) per cutting (runners)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B	2.8	11.9	15.0	19.6	12.3
IAA 1500 ppm	2.3	7.3	14.2	21.2	11.3
IAA 1000 ppm	1.9	6.2	11.3	14.4	8.5
IAA 500 ppm	2.7	6.1	10.8	16.4	9.0
IBA 1500 ppm	2.7	7.2	14.2	20.7	11.2
IBA 1000 ppm	4.5	10.2	18.5	22.9	14.0
IBA 500 ppm	2.0	6.2	12.1	18.2	9.6
IAA + IBA 1500 ppm	2.2	5.9	12.3	20.2	10.2
IAA + IBA 1000 ppm	2.5	5.6	10.9	16.9	9.6
IAA + IBA 500 ppm	1.5	6.2	10.7	16.4	8.7
Control	1.5	5.3	10.2	13.6	7.6
CD	1.1**	3.1**	5.5**	NS	
SEm ±	0.4	1.2	2.7	2.5	

Table 9(c). Effect of mist on length of roots (cm) per cutting (runners)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Mist	2.9	9.0	15.6	22.7	12.5
Open	2.2	4.8	8.7	12.8	7.1
CD	0.4**	1.2**	1.8**	2.3**	
SEm ±	0.2	0.5	0.7	1.0	

WAP = Weeks after planting CD = Critical Difference
** = Significant at 1% level NS = Not significant

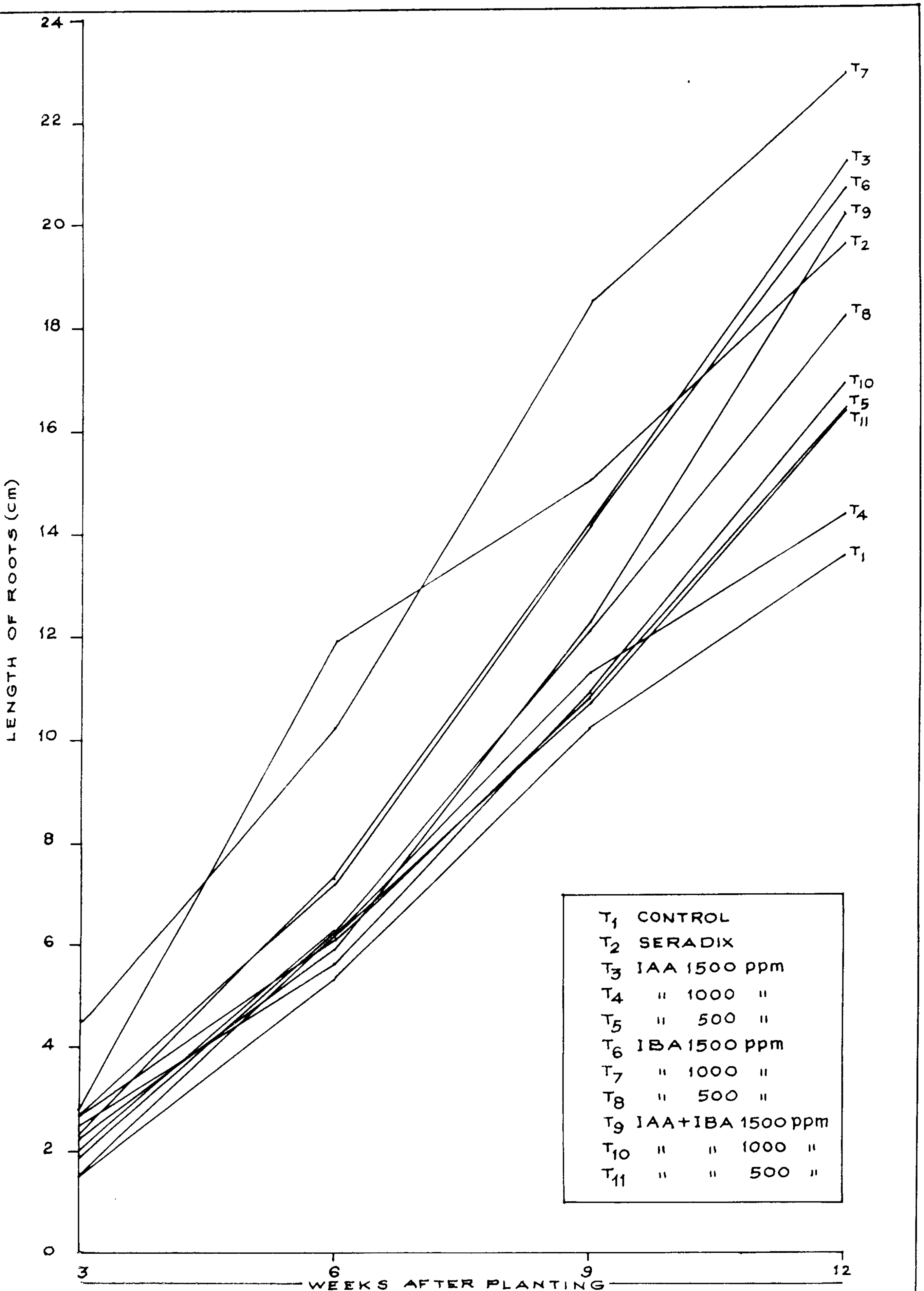

FIG. 9. EFFECT OF GROWTH REGULATORS ON LENGTH OF ROOTS PER CUTTING IN RUNNERS (STOLONS).

Table 10(a). Effect of growth regulators on length of roots (cm) per cutting under mist and open (growing shoots)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B					
Mist	6.2	12.8	21.8	30.9	17.9
Open	3.6	7.9	16.0	25.0	13.2
IAA 1500 ppm					
Mist	4.9	9.6	12.3	29.7	14.2
Open	2.7	7.0	16.0	20.0	11.5
IAA 1000 ppm					
Mist	4.2	9.9	15.5	25.5	13.7
Open	2.0	7.7	12.6	16.5	9.7
IAA 500 ppm					
Mist	4.3	7 6	15.8	24.2	13.0
Open	3.2	7.5	12.0	18.7	10.4
IBA 1500 ppm					
Mist	6.5	10.8	20.4	35.2	18.3
Open	3.2	8.4	15.2	28.0	13.8
IBA 1000 ppm					
Mist	7.7	15.3	27.8	35.7	21.7
Open	5.2	8.9	15.7	25.0	13.8
IBA 500 ppm					
Mist	4.4	9.6	16.0	27.0	14.3
Open	3.3	6.4	15.7	28.0	13.4
IAA + IBA 1500 ppm					
Mist	4.0	8.8	16.6	27.0	14.1
Open	3.8	6.3	11.2	24.0	11.4
IAA + IBA 1000 ppm					
Mist	4.7	7.8	16.2	27.0	13.9
Open	3.0	7.3	12.9	24.0	11.8
IAA + IBA 500 ppm					
Mist	4.2	8.0	16.7	22.5	12.9
Open	2.5	7.8	11.5	17.6	9.9
Control					
Mist	4.1	5.1	13.4	16.8	9.9
Open	1.7	4.3	8.4	10.4	6.2
CD	NS	6.0**	5.1**	10.6**	
SEm ±	4.3	2.2	2.0	4.1	

WAP = Weeks after planting
CD = Critical difference
** = Significant at 1% level

Table 10(b). Effect of growth regulators on length of roots (cm)/cutting (growing shoots)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B	5.3	10.5	20.0	29.1	16.3
IAA 1500 ppm	4.1	8.5	13.4	26.7	13.2
IAA 1000 ppm	3.4	8.9	14.3	22.4	12.3
IAA 500 ppm	4.0	7.6	14.0	22.3	12.1
IBA 1500 ppm	5.2	9.7	18.9	33.1	16.8
IBA 1000 ppm	6.8	12.7	22.9	31.3	18.4
IBA 500 ppm	3.9	8.2	15.9	27.4	13.9
IAA + IBA 1500 ppm	3.9	7.8	14.0	26.0	13.9
IAA + IBA 1000 ppm	4.3	7.6	14.5	26.0	13.1
IAA + IBA 500 ppm	4.1	7.9	13.6	21.0	11.7
Control	3.3	4.8	11.5	14.7	8.6
CD	NS	3.7**	4.0**	6.9**	
SEm ±	1.4	1.5	1.6	2.6	

Table 10(c). Effect of mist on length of roots (cm) per cutting (growing shoots)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Mist	5.2	9.9	18.5	28.8	15.6
Open	3.4	7.3	13.3	22.6	11.7
CD	1.1**	1.3**	1.6**	2.7**	
SEm ±	0.5	0.5	0.6	1.1	

WAP = Weeks after planting   CD = Critical difference
** = Significant at 1% level   NS = Not significant

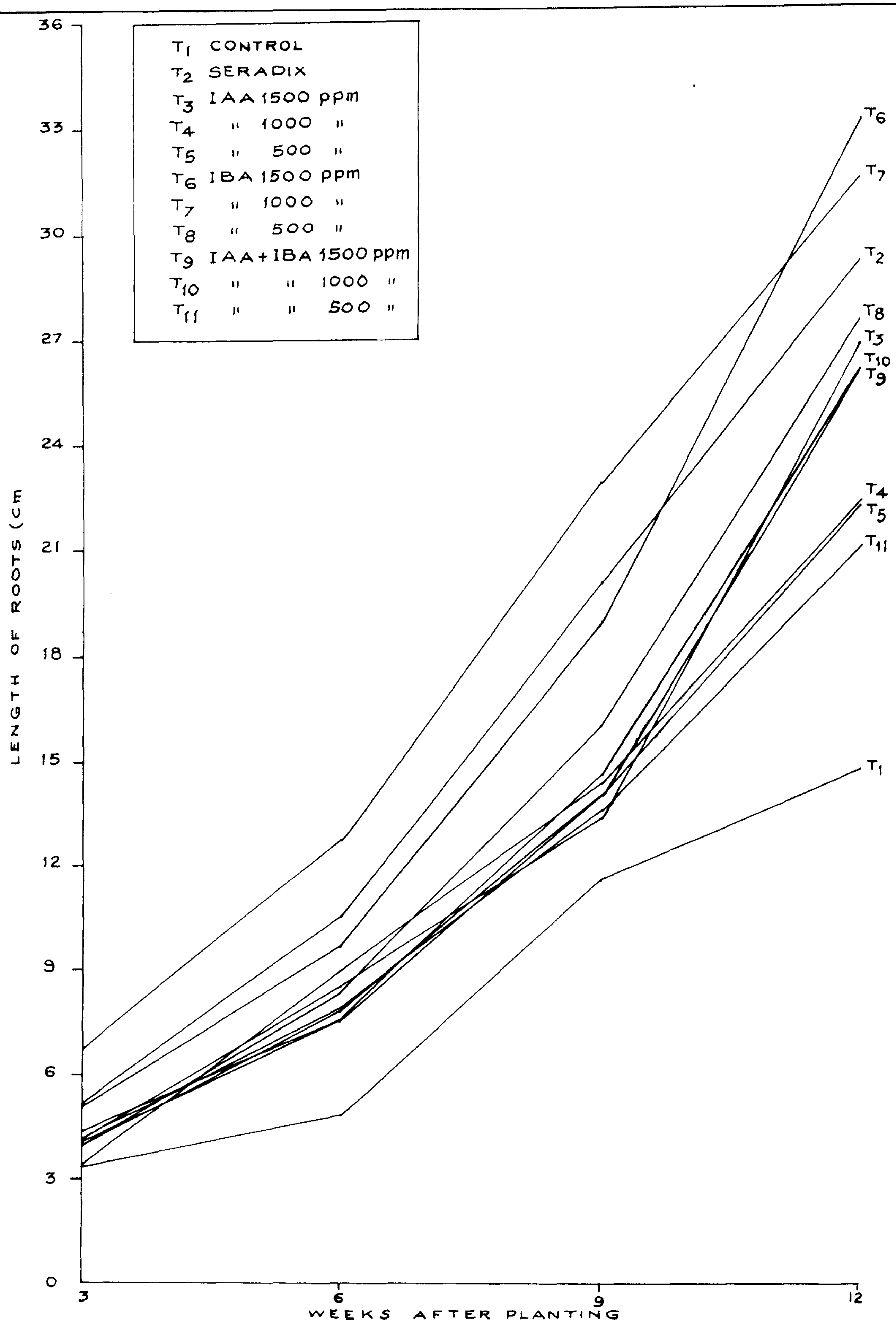

FIG. 10. EFFECT OF GROWTH REGULATORS ON LENGTH OF ROOT PER CUTTING IN GROWING SHOOTS (ORTHOTROPHS).

growing and hanging shoots, the highest mean lengths recorded were 17.6 cm, 21.6 cm,21.7 cm respectively under IBA 1000 ppm with mist. In laterals also the above treatment was found to be highly significant (20.4 cm) compared to IAA + IBA combination treatments and control. The pooled data furnished in Tables 9b, 10b, 11b and 12b also showed the superiority of IBA 1000 ppm on this root parameter. In runners a maximum mean length of 14.3 cm was recorded while control resulted minimum of 7.6 cm. When cuttings of growing shoots, hanging shoots and laterals were treated with IBA 1000 ppm, mean root lengths observed were 18.4 cm, 17.9 cm and 11.1 cm respectively (Fig.9 to 12). IAA 1500 ppm was found to be the second best treatment.

The results of the pooled analysis of the data on the effect of mist on length of roots produced by cuttings revealed the beneficial effect of mist on the production of longer roots (Table 9c, 10c, 11c and 12c and Fig.14). In laterals where the effect of mist was very much pronounced, the mean length of roots under mist and open conditions were found to be 19.4 cm and 8.3 cm respectively. Under mist runners produced a mean root length of 12.6 cm while growing shoots and hanging shoots produced respectively 15.6 cm and 15.3 cm.

It is evident from the data that in all the four types of planting materials the length of roots increased from the

Table 11(a). Effect of growth regulators on length of roots (cm) per cutting under mist and open (hanging shoots)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B					
Mist	4.9	11.5	20.1	32.6	17.3
Open	3.0	6.0	12.1	16.6	6.9
IAA 1500 ppm					
Mist	5.1	10.0	17.9	27.5	15.2
Open	3.6	6.3	11.6	17.1	7.2
IAA 1000 ppm					
Mist	3.8	7.9	16.4	24.6	13.2
Open	2.2	5.8	10.3	19.4	9.5
IAA 500 ppm					
Mist	3.7	7.9	15.8	23.2	12.6
Open	3.3	5.3	8.7	13.0	7.6
IBA 1500 ppm					
Mist	5.0	11.8	24.2	29.9	17.8
Open	3.9	7.2	11.6	16.4	9.8
IBA 1000 ppm					
Mist	6.9	18.2	27.1	34.6	21.7
Open	4.3	8.9	13.1	19.4	11.5
IBA 500 ppm					
Mist	4.4	8.2	15.9	26.0	13.7
Open	3.1	6.4	11.6	11.6	8.1
IAA + IBA 1500 ppm					
Mist	4.9	9.3	15.5	26.4	14.1
Open	4.1	7.1	10.0	16.1	9.4
IAA + IBA 1000 ppm					
Mist	4.6	7.1	14.8	25.1	12.9
Open	3.4	5.1	10.4	12.9	7.9
IAA + IBA 500 ppm					
Mist	4.5	7.8	13.9	20.5	11.7
Open	3.7	5.0	10.6	11.6	7.7
Control					
Mist	6.5	4.9	10.5	12.4	8.6
Open	1.9	2.4	6.1	6.3	4.2
CD	NS	4.2**	5.8**	9.4**	
SEm ±	1.8	1.5	2.1	3.6	

WAP = Weeks after planting
CD = Critical difference
** = Significant at 1% level
NS = Not significant

Table 11(b). Effect of growth regulators on length of roots (cm) per cutting (hanging shoots)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B	4.2	9.7	16.8	27.6	14.5
IAA 1500 ppm	4.6	8.5	15.0	24.6	13.1
IAA 1000 ppm	3.1	7.0	13.9	22.5	11.6
IAA 500 ppm	3.6	6.0	13.1	10.3	10.7
IBA 1500 ppm	4.6	9.0	19.2	25.9	14.8
IBA 1000 ppm	5.9	14.0	21.3	30.3	17.9
IBA 500 ppm	3.9	7.4	13.2	15.2	10.2
IAA + IBA 1500 ppm	4.6	8.4	12.1	21.2	11.6
IAA + IBA 1000 ppm	4.2	6.2	13.0	20.7	11.0
IAA + IBA 500 ppm	4.2	6.6	12.6	17.5	10.2
Control	4.8	3.8	8.3	10.4	6.8
CD	NS	3.2**	5.2**	8.4**	
SEm ±	1.0	1.1	2.0	3.0	

Table 11 (c). Effect of mist on length of roots (cm) per cutting (hanging shoots)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Mist	5.0	10.2	18.6	27.3	15.3
Open	3.5	1.3	10.8	15.3	8.9
CD	0.8**	1.2**	1.7**	2.5**	
SEm ±	0.4	0.5	0.7	1.1	

WAP = Weeks after planting CD = Critical difference

** - Significant at 1% level NS = Not significant

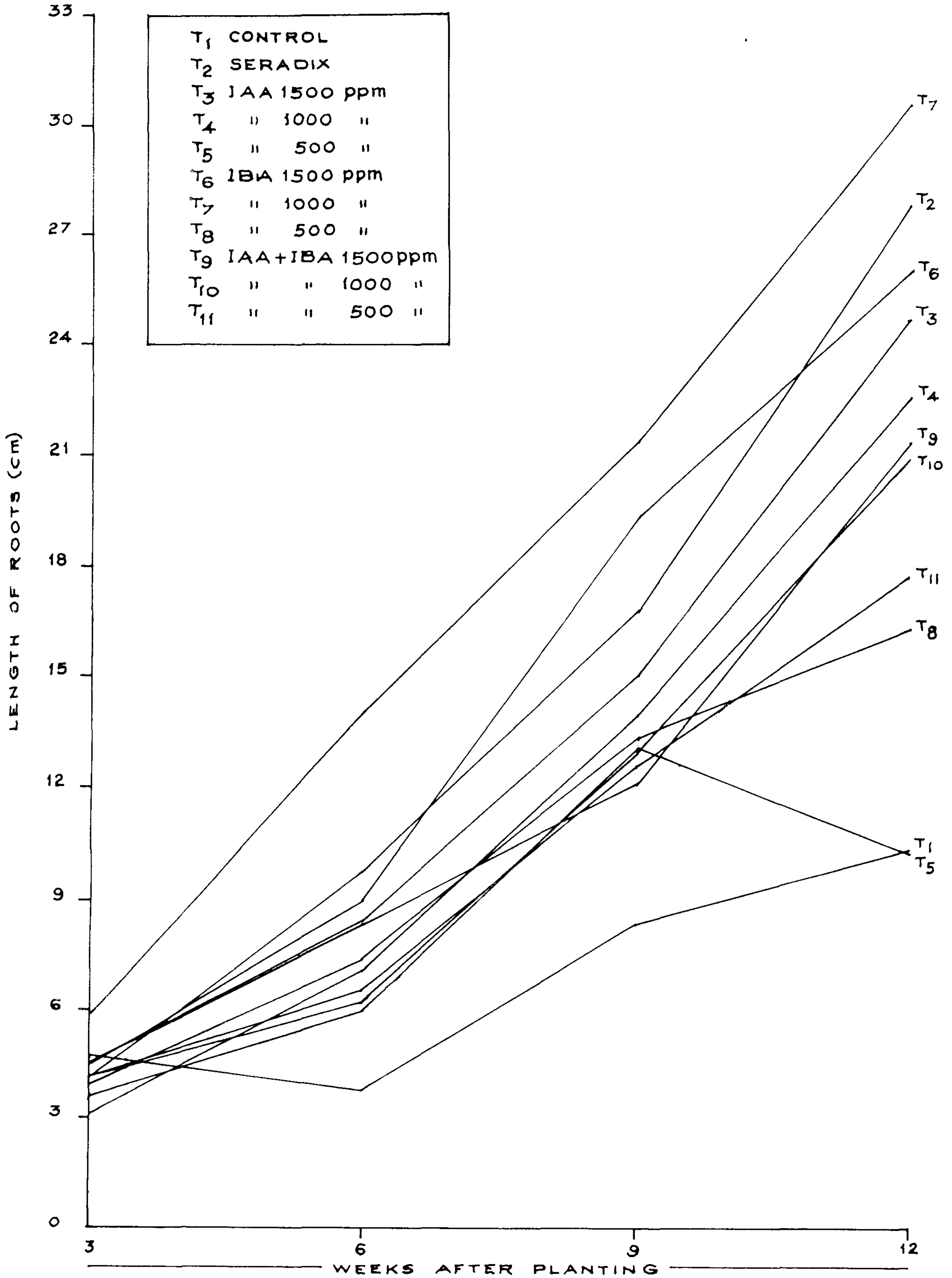

FIG. 11. EFFECT OF GROWTH REGULATORS ON LENGTH OF ROOTS PER CUTTING IN HANGING SHOOTS (GEOTROPHS).

Table 12(a). Effect of growth regulators on length of roots (cm) per cutting under mist and open (laterals)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B					
Mist	-	7.1	14.3	28.9	16.8
Open	-	6.7	8.6	11.4	8.9
IAA 1500 ppm					
Mist	-	8.4	16.0	30.6	18.4
Open	-	5.8	8.6	12.4	6.7
IAA 1000 ppm					
Mist	-	5.6	12.6	22.8	13.7
Open	-	3.5	6.2	10.0	6.6
IAA 500 ppm					
Mist	-	4.9	11.2	23.9	13.3
Open	-	3.7	5.8	10.0	6.5
IBA 1500 ppm					
Mist	-	7.7	15.4	28.2	17.2
Open	-	5.7	10.3	15.1	7.1
IBA 1000 ppm					
Mist	-	8.1	20.3	29.3	19.3
Open	-	5.7	10.7	15.6	7.4
IBA 500 ppm					
Mist	-	5.6	10.0	23.8	13.2
Open	-	6.4	7.8	9.6	7.3
IAA + IBA 1500 ppm					
Mist	-	5.9	10.8	21.2	9.5
Open	-	4.5	6.4	9.4	6.8
IAA + IBA 1000 ppm					
Mist	-	4.6	11.7	23.8	13.4
Open	-	3.6	4.0	7.5	5.0
IAA + IBA 500 ppm					
Mist	-	3.2	11.5	22.3	12.4
Open	-	2.7	4.9	8.0	5.2
Control					
Mist	-	2.5	8.2	11.5	7.4
Open	-	1.5	5.4	6.4	4.4
CD	-	7.3**	7.3**	10.6**	
SEm ±	-	3.1	3.2	3.1	

WAP = Weeks after planting
CD = Critical difference
** = Significant at 1% level

Table 12(b). Effect of growth regulators on length of roots (cm)/cutting (laterals)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B	-	6.9	11.6	21.4	13.4
IAA 1500 ppm	-	7.5	13.0	23.5	14.7
IAA 1000 ppm	-	5.2	9.9	17.5	10.9
IAA 500 ppm	-	4.5	9.3	18.5	7.5
IBA 1500 ppm	-	6.8	13.3	22.6	14.3
IBA 1000 ppm	-	7.0	15.9	23.5	15.5
IBA 500 ppm	-	5.0	9.0	19.1	11.8
IAA + IBA 1500 ppm	-	5.7	8.8	17.0	10.5
IAA + IBA 1000 ppm	-	4.4	8.3	18.9	10.5
IAA + IBA 500 ppm	-	3.1	8.5	17.5	9.8
Control	-	2.2	7.2	10.0	6.5
CD		3.51**	5.2**	8.8*	
SEm ±		1.5	2.2	3.4	

Table 12(c). Effect of mist on length of roots (cm) per cutting (laterals)

Treatments	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Mist	-	6.3	13.8	25.6	19.3
Open	-	5.2	7.7	11.8	8.2
CD	-	NS	1.4**	2.0**	
SEm ±	-	0.4	0.6	0.7	

WAP = Weeks after planting   CD = Critical difference
** - Significant at 1% level   * - Significant at 5% level

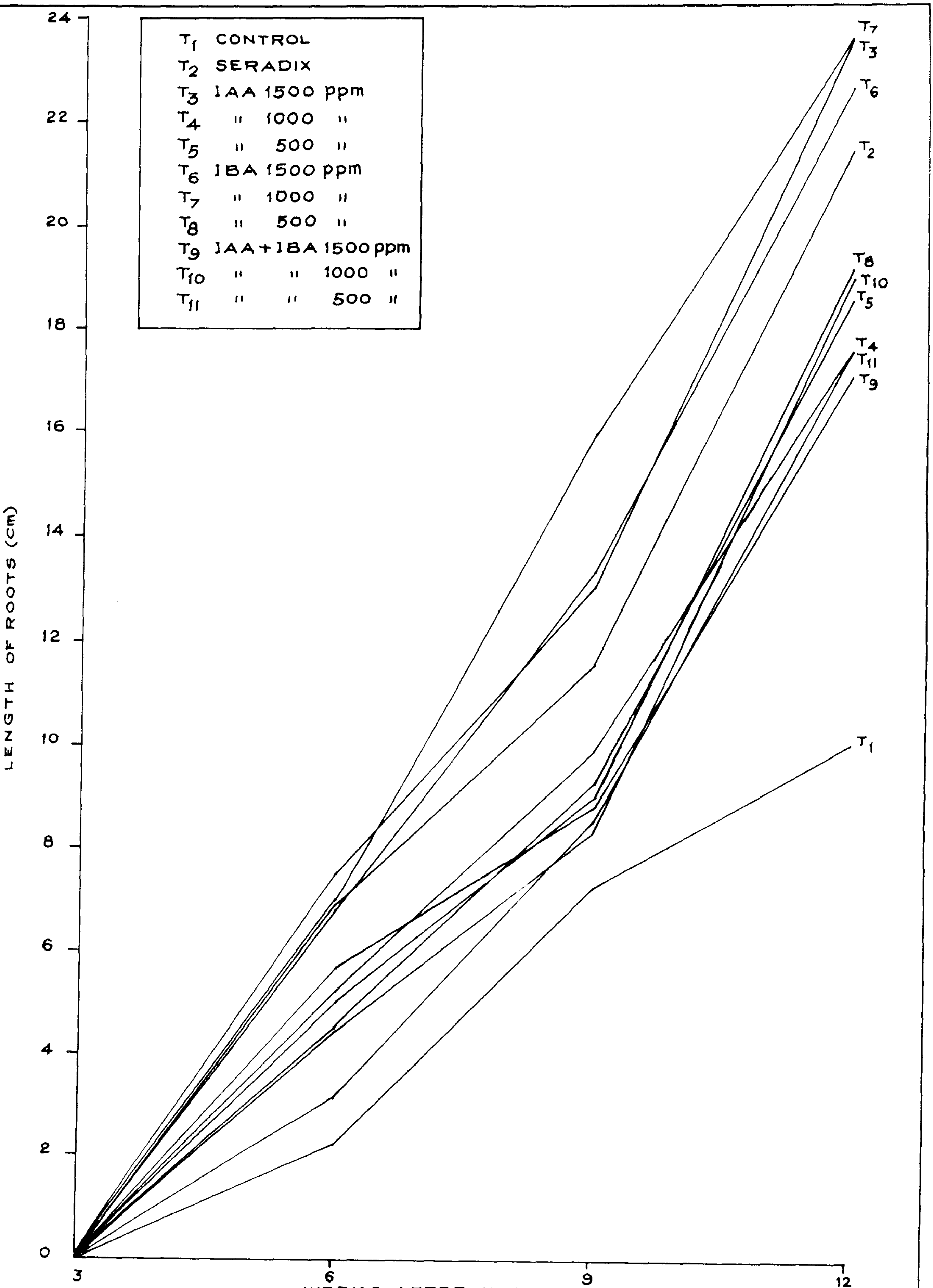

FIG. 12. EFFECT OF GROWTH REGULATORS ON LENGTH OF ROOTS PER CUTTING IN LATERALS (PLAGEOTROPHS).

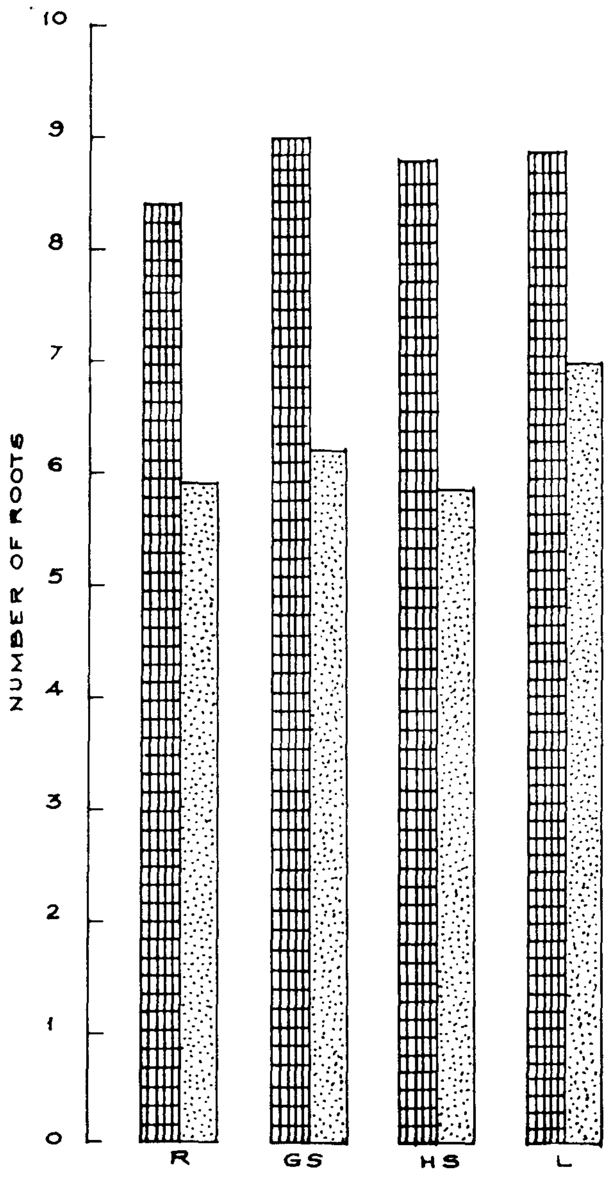

FIG. 13. EFFECT OF MIST ON MEAN-NUMBER OF ROOTS PER CUTTING.

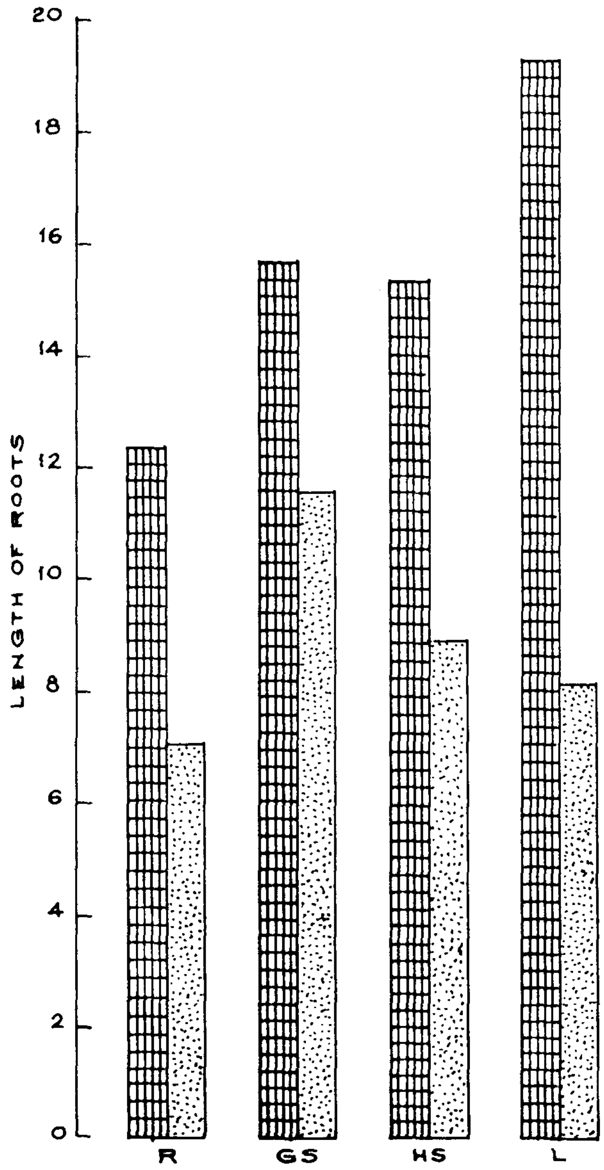

FIG. 14. EFFECT OF MIST ON MEAN-LENGTH OF ROOTS PER CUTTING

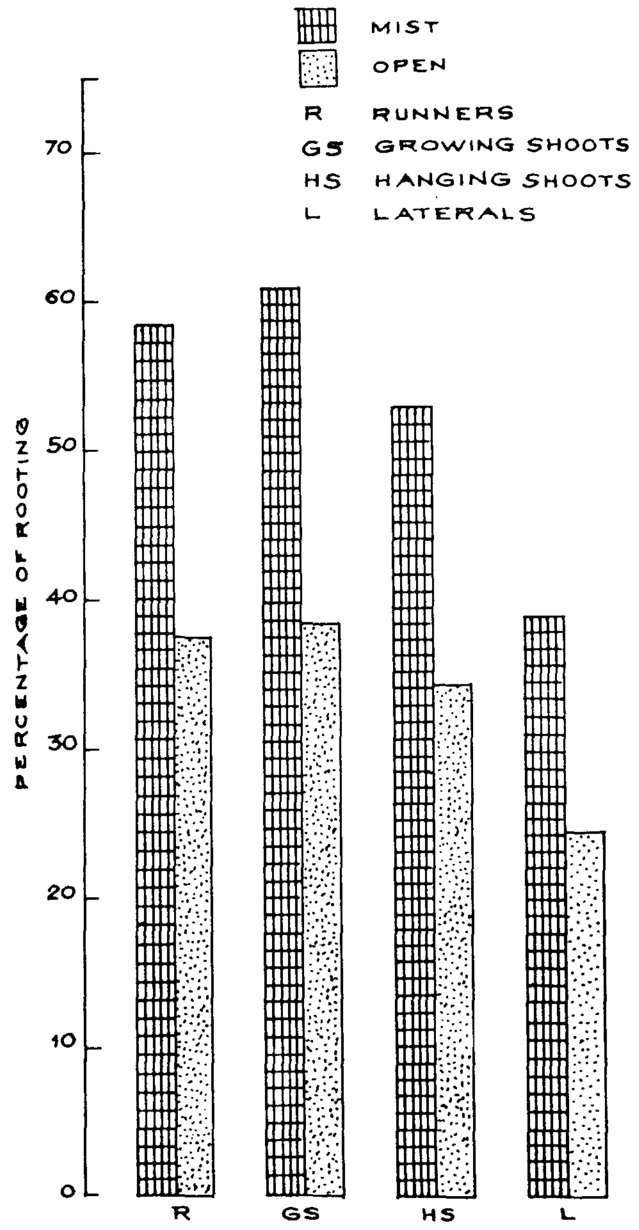

FIG. 15. EFFECT OF MIST ON ROOTING OF CUTTING.

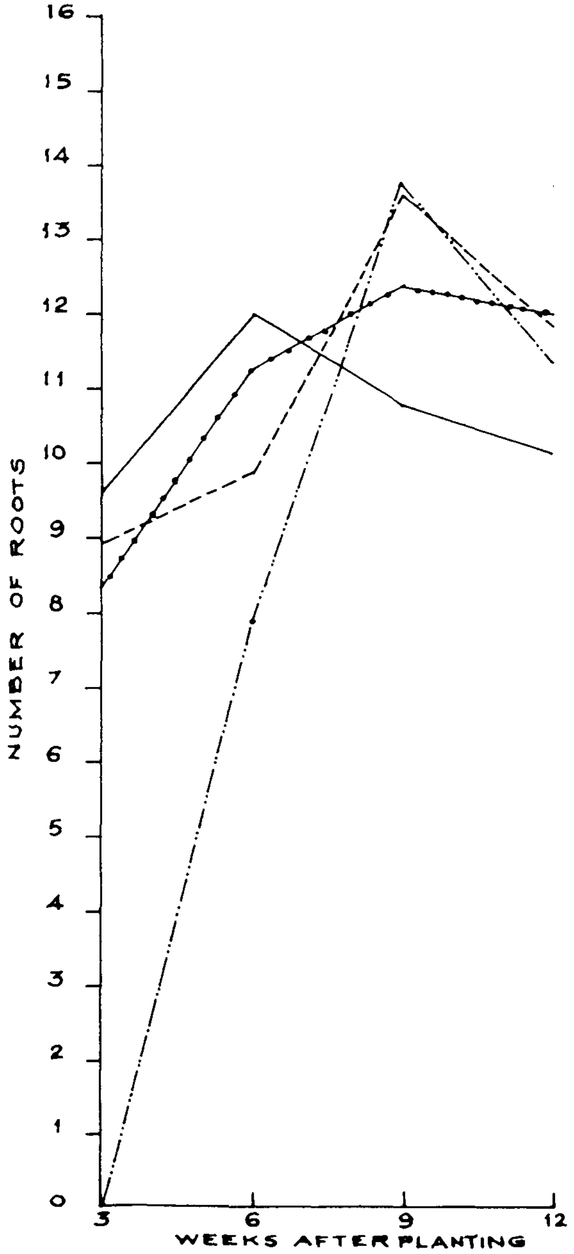

FIG. 16. EFFECT OF IBA 1000ppm ON NUMBER OF ROOTS PER CUTTING.

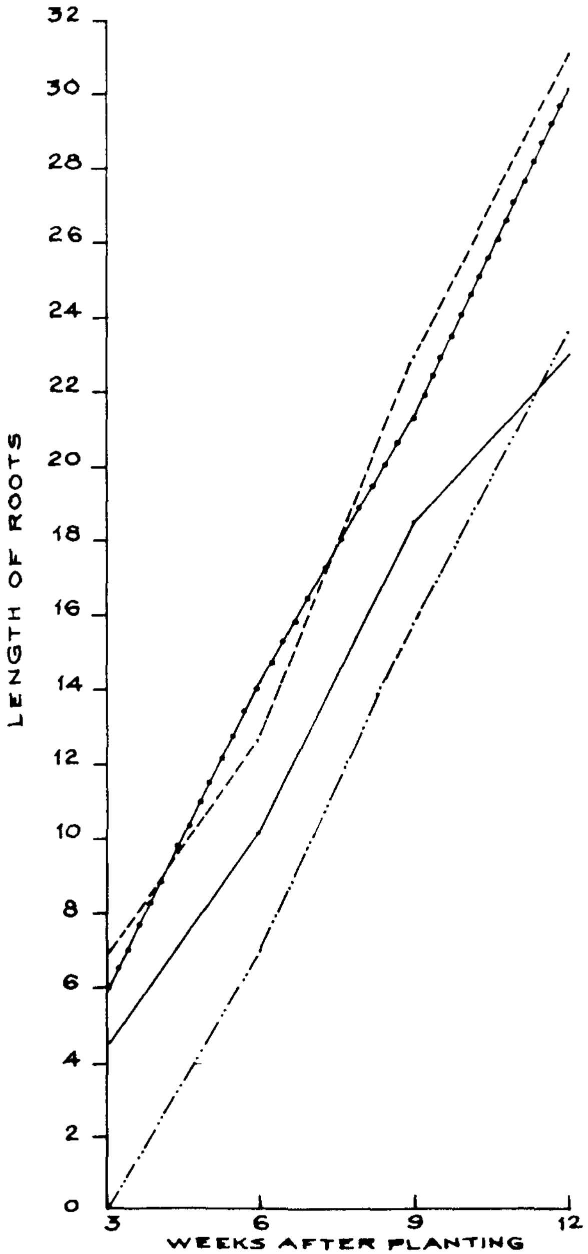

FIG. 17. EFFECT OF IBA 1000 ppm ON LENGTH OF ROOTS PER CUTTING.

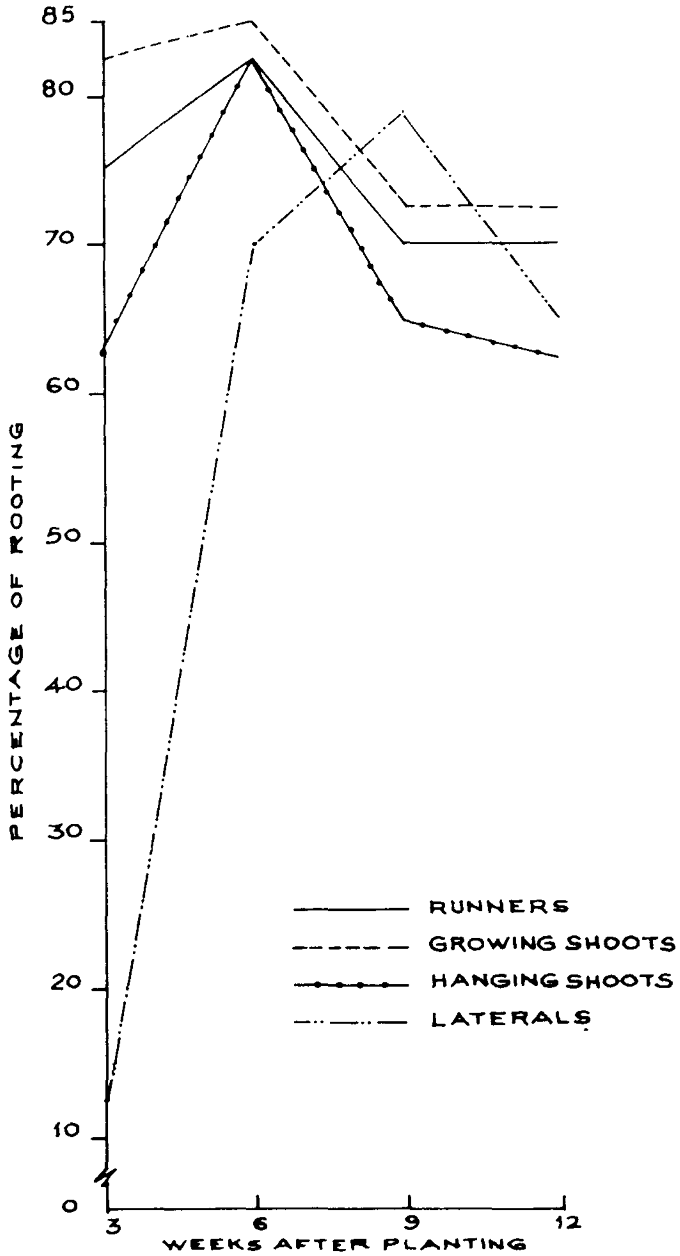

FIG. 18. EFFECT OF IBA 1000 ppm ON ROOTING OF CUTTING.

initial stage to the final stage of observation. In runners at the earliest stage itself effect of best growth regulator under mist was highly pronounced. During third week of planting a length of 5.6 cm was noticed and finally after twelve weeks the length was 28.8 cm, though the effect of growth regulator was not significant in the final stage of observation. In growing shoots and hanging shoots though the treatments did not differ significantly in the initial stage upto three weeks of planting at all other intervals it was found to be significant. In laterals most significant effect of the best treatment was noticed after nine weeks of planting and up to three weeks of planting they did not produce any roots either under mist or open (Fig.17).

4.1.4 Fresh weight of roots

The results of the data on the effect of growth regulators and mist on fresh weight of roots per cutting are presented in the Tables 13 to 16.

Runners, under mist recorded a maximum mean fresh weight of 324.7 mg when treated with IBA 1000 ppm. After nine weeks and twelve weeks of planting though there was no significant difference between the treatment, IBA 1000 ppm and 1500 ppm treatments resulted in more fresh weight values.

Growing shoots showed a maximum mean fresh weight of 353 mg, when treated with IBA 1000 ppm under mist condition.

Table 13. Effect of growth regulators on fresh weight of roots (mg) per cutting under mist and open (runners)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B					
Mist	85.8	240.3	270.3	370.4	241.8
Open	55.7	139.2	230.2	280.5	176.5
IAA 1500 ppm					
Mist	69.4	276.7	290.0	359.3	243.9
Open	46.5	136.4	248.9	289.4	180.3
IAA 1000 ppm					
Mist	86.6	218.2	268.0	301.5	218.6
Open	42.5	109.5	255.0	270.6	169.4
IAA 500 ppm					
Mist	78.6	217.4	258.0	298.5	213.2
Open	34.2	117.8	225.0	260.2	159.4
IBA 1500 ppm					
Mist	108.6	279.0	317.5	390.4	301.0
Open	53.3	177.6	280.5	275.6	196.8
IBA 1000 ppm					
Mist	139.1	387.0	317.8	454.5	324.7
Open	88.6	268.9	289.6	320.5	241.9
IBA 500 ppm					
Mist	60.7	238.2	249.8	325.3	218.6
Open	37.3	112.5	250.8	250.0	162.7
IAA + IBA 1500 ppm					
Mist	65.4	22.9	239.1	299.9	206.9
Open	35.6	119.3	250.3	240.0	161.3
IAA + IBA 1000 ppm					
Mist	80.6	219.7	238.5	300.9	209.9
Open	32.1	108.0	240.8	238.0	154.8
Control					
Mist	49.3	148.0	155.4	170.4	130.8
Open	30.0	80.2	99.0	110.5	79.9
CD	89.0*	167.9*	NS	NS	
SEm ±	33.9	101.0	62.0	121.4	

WAP = Weeks after planting
CD = Critical difference
** = Significant at 1% level
NS = Not significant

Table 14. Effect of growth regulators on fresh weight of roots (mg) per cutting under mist and open (growing shoots)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B					
Mist	72.7	287.5	387.4	399.5	286.3
Open	36.5	129.7	240.7	320.6	181.9
IAA 1500 ppm					
Mist	96.9	258.2	360.5	398.4	278.5
Open	40.1	129.7	258.0	268.6	174.1
IAA 1000 ppm					
Mist	92.0	207.5	320.8	322.6	235.5
Open	31.3	111.1	250.2	258.0	162.7
IAA 500 ppm					
Mist	76.5	178.8	300.0	316.0	217.6
Open	30.7	97.6	245.2	260.4	158.5
IBA 1500 ppm					
Mist	110.4	310.8	397.4	419.6	337.2
Open	54.3	157.7	280.0	356.5	212.1
IBA 1000 ppm					
Mist	121.5	378.2	447.3	465.1	353.1
Open	84.0	178.9	367.0	375.1	251.3
IBA 500 ppm					
Mist	80.3	229.1	298.2	340.6	234.5
Open	31.5	105.0	280.8	258.5	168.9
IAA + IBA 1500 ppm					
Mist	67.6	178.9	300.8	315.6	215.7
Open	38.3	108.3	280.1	241.2	167.0
IAA + IBA 1000 ppm					
Mist	79.1	191.2	288.0	311.0	217.5
Open	30.1	103.1	228.0	300.0	165.4
IAA + IBA 500 ppm					
Mist	60.1	192.4	230.6	300.0	195.7
Open	29.3	78.3	195.6	220.0	105.8
Control					
Mist	41.9	145.8	184.5	189.6	140.5
Open	19.2	91.8	112.1	120.5	85.9
CD	161.3*	174.5**	249.1*	NS	
SEm ±	71.3	77.3	73.4	100.7	

WAP = Weeks after planting
CD = Critical difference
** = Significant at 1% level
NS = Not significant

Table 15. Effect of growth regulator on fresh weight of roots (mg) per cutting under mist and open (hanging shoots)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B					
Mist	87.1	244.9	266.5	376.3	243.7
Open	50.7	136.4	210.5	290.5	172.0
IAA 1500 ppm					
Mist	87.9	250.2	288.6	379.4	251.5
Open	55.4	130.2	299.8	280.2	191.4
IAA 1000 ppm					
Mist	77.1	212.6	270.2	310.4	217.6
Open	29.9	111.2	241.4	255.6	159.5
IAA 500 ppm					
Mist	75.4	210.0	259.4	325.4	317.5
Open	30.3	126.8	234.8	250.3	160 6
IBA 1500 ppm					
Mist	82.9	289.9	327.5	390.5	272.7
Open	48.6	169.7	288.7	280.4	196.8
IBA 1000 ppm					
Mist	22.6	356.6	337.2	460.4	319.2
Open	85.5	187.0	287.2	311.1	217.8
IBA 500 ppm					
Mist	71.0	222.5	282.1	330.5	272.2
Open	36.7	135.3	280.6	251.6	176.0
IAA + IBA 1500 ppm					
Mist	74.8	192.5	244.6	315.6	206.8
Open	26.3	120.6	240.3	268.5	163.9
IAA + IBA 1000 ppm					
Mist	68.0	157.1	238.0	306.5	192.4
Open	40.2	110.1	244.5	300.0	173.7
IAA + IBA 500 ppm					
Mist	59.0	174.5	210.8	303.0	186.8
Open	33.7	101.5	215.5	289.4	160.0
Control					
Mist	45.2	150.8	157.0	175.5	132.1
Open	18.9	85.2	112.1	115.0	82.8
CD	84.4*	133.3**	NS	NS	
SEm ±	36.1	56.9	65.9	94.0	

WAP = Weeks after planting
CD = Critical difference
** = Significant at 1% level
NS = Not significient

Table 16. Effect of growth regulators on fresh weight of roots (mg) per cutting under mist and open (laterals)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B					
Mist	-	86.4	249.9	260.0	198.8
Open	-	42.6	199.4	200.0	147.3
IAA 1500 ppm					
Mist	-	91.4	233.2	240.0	188.2
Open	-	39.9	233.0	195.0	155.9
IAA 1000 ppm					
Mist	-	70.7	215.0	220.0	168.5
Open	-	21.6	163.5	180.0	121.7
IAA 500 ppm					
Mist	-	69.5	211.1	211.0	163.8
Open	-	26.8	182.0	188.0	132.3
IBA 1500 ppm					
Mist	-	88.0	289.9	299.9	225.9
Open	-	43.0	210.9	261.1	171.7
IBA 1000 ppm					
Mist	-	127.7	294.1	350.0	257.3
Open	-	49.2	250.1	279.9	193.1
IBA 500 ppm					
Mist	-	60.6	219.8	230.0	170.2
Open	-	40.9	185.8	205.1	143.9
IAA + IBA 1500 ppm					
Mist	-	58.8	214.2	221.8	164.9
Open	-	32.0	244.7	202.0	159.6
IAA + IBA 1000 ppm					
Mist	-	75.6	202.0	211.0	162.8
Open	-	30.5	176.0	175.2	127.2
IAA + IBA 500 ppm					
Mist	-	65.3	189.3	270.0	158.2
Open	-	22.1	167.1	170.0	119.7
Control					
Mist	-	36.1	150.2	160.1	115.4
Open	-	20.9	82.4	99.9	67.7
CD	-	127.4*	NS	154.7**	
SEm ±	-	37.5	88.6	52.6	

WAP = Weeks after planting
CD = Critical difference
** = Significant at 1% level
NS = Not significant

Mean fresh weight was found to be lowest for control particularly under open condition (85.9 mg). There was no significant difference between IBA 1000 and 1500 ppm and Seradix-B treatments on the sixth week of observation with respect to fresh root weight. In hanging shoots also the superiority of IBA treatment with respect to this parameter was evident from the data. Under mist the mean maximum fresh weight (319.2 mg) was observed for IBA 1000 ppm followed by IBA 1500 ppm (272.7 mg) and IBA 500 ppm (272.2 mg). With regard to fresh weight of roots the laterals recorded significant differences among treatments on six weeks and twelve weeks of planting. However, the difference was not statistically significant on ninth week of planting. The mean fresh weight values of 257.3 mg and 193.1 mg respectively for IBA 1000 ppm under mist and open conditions were recorded followed by IBA 1500 ppm and Seradix-B treatments, under mist condition. In different planting materials the treatments differed significantly with regard to fresh weight of roots. In general, all the treatments under mist resulted in more fresh weight compared to treatments under open conditions.

4.1.5 Fresh weight of shoots

The results on the effect of growth regulators and mist on fresh weight of shoots per cuttings are tabulated in Tables 17 to 20.

Table 17. Effect of growth regulators on fresh weight of shoots (mg) per cutting under mist and open (runners)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B					
Mist	204.3	724.9	1531.8	1691.2	1038.8
Open	46.8	293.9	856.5	1889.9	759.3
IAA 1500 ppm					
Mist	363.6	693.3	1001.2	2136.9	1048.8
Open	187.6	559.3	773.5	1143.2	665.9
IAA 1000 ppm					
Mist	252.3	640.5	765.8	2310.5	992.2
Open	115.8	449.4	693.2	1775.8	758.6
IAA 500 ppm					
Mist	250.7	602.4	777.0	730.9	591.7
Open	102.0	329.7	674.5	1705.3	702.9
IBA 1500 ppm					
Mist	140.8	568.5	1135.0	1144.4	747.2
Open	23.0	394.0	710.1	1537.2	675.1
IBA 1000 ppm					
Mist	234.6	659.4	1535.7	1393.7	1022.0
Open	102.4	310.5	1254.8	1599.6	816.8
IBA 500 ppm					
Mist	311.9	570.2	1168.2	659.8	677.5
Open	133.2	602.0	983.4	1634.9	838.4
IAA + IBA 1500 ppm					
Mist	121.0	629.6	1204.1	762.8	679.4
Open	84.2	593.1	746.1	1322.3	686.4
IAA + IBA 1000 ppm					
Mist	291.1	785.0	1061.3	1168.8	826.5
Open	107.2	426.1	859.4	1488.3	720.3
IAA + IBA 500 ppm					
Mist	171.83	623.4	1007.8	697.0	624.9
Open	11.60	413.1	721.7	1140.6	574.6
Control					
Mist	167.7	547.6	654.3	1162.5	633.0
Open	45.5	172.1	568.1	1278.3	516.0
CD	146.3**	434.9*	NS	1208.9*	
SEm ±	52.8	161.5	313.7	455.6	

WAP = Weeks after planting
CD = Critical difference
** = Significant at 1% level
NS = Not significant

Table 18. Effect of growth regulators on fresh weight of shoots (mg) per cutting under mist and open (growing shoots)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B					
Mist	122.2	913.9	1101.3	1512.7	914.0
Open	38.7	457.2	1614.4	1139.5	812.5
IAA 1500 ppm					
Mist	185.0	656.9	1347.3	1679.5	967.2
Open	142.6	323.6	1627.3	1712.7	951.6
IAA 1000 ppm					
Mist	114.2	815.2	1375.1	1036.8	835.3
Open	137.2	533.2	1138.4	1503.7	828.1
IAA 500 ppm					
Mist	131.0	715.0	1775.8	791.7	853.3
Open	54.1	316.2	777.8	1734.9	720.8
IBA 1500 ppm					
Mist	128.3	666.2	1577.3	1477.3	962.3
Open	142.6	405.5	3046.0	1953.4	1136.9
IBA 1000 ppm					
Mist	164.6	614.6	2068.0	1876.3	1180.9
Open	112.9	323.5	1443.7	2566.0	1358.1
IBA 500 ppm					
Mist	322.5	487.3	1508.6	1005.2	830.9
Open	68.9	301.4	1356.6	1830.0	889.2
IAA + IBA 1500 ppm					
Mist	175.7	485.7	1119.0	1707.9	872.1
Open	105.4	793.0	1006.1	810.3	678.7
IAA + IBA 1000 ppm					
Mist	141.2	1072.6	1393.9	713.1	830.2
Open	69.6	559.6	1163.2	593.4	596.5
IAA + IBA 500 ppm					
Mist	143.8	1191.0	1562.5	544.5	860.5
Open	86.0	613.6	835.6	778.6	578.4
Control					
Mist	143.5	484.0	579.9	721.6	482.3
Open	36.5	337.7	597.2	1680.7	663.0
CD	191.0**	NS	744.7**	NS	
SEm ±	77.1	270.5	278.8	728.0	

WAP = Weeks after planting
CD = Critical difference
** = Significant at 1% level
NS = Not significant

Table 19. Effect of growth regulators on fresh weight of shoots (mg) per cutting under mist and open (hanging shoots)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B					
Mist	170.3	688.0	1269.0	1471.1	899.5
Open	57.1	299.4	1512.8	1947.1	1043.1
IAA 1500 ppm					
Mist	177.0	439.5	887.8	1056.6	640.0
Open	71.1	823.4	1856.4	1335.7	1021.2
IAA 1000 ppm					
Mist	149.1	279.9	1006.1	1023.5	614.5
Open	49.0	562.4	1421.6	1468.2	875.2
IAA 500 ppm					
Mist	164.9	672.3	972.6	1587.2	849.1
Open	34.1	185.3	1831.9	1473.8	880.8
IBA 1500 ppm					
Mist	124.0	560.3	1052.2	1772.9	877.2
Open	48.7	256.0	1789.4	1068.6	790.4
IBA 1000 ppm					
Mist	196.4	685.8	1720.6	1582.1	1046.1
Open	64.5	326.2	1512.5	1084.9	747.0
IBA 500 ppm					
Mist	230.0	806.2	1007.6	960.8	751.2
Open	63.1	284.9	977.3	734.1	514.0
IAA + IBA 1500 ppm					
Mist	280.4	317.4	992.0	1877.5	866.8
Open	77.2	238.7	771.1	744.6	457.9
IAA + IBA 1000 ppm					
Mist	232.7	715.4	1830.0	1471.8	1062.2
Open	17.1	215.3	810.0	750.6	448.4
IAA + IBA 500 ppm					
Mist	132.3	822.6	1044.0	1128.3	781.7
Open	16.8	298.3	778.7	1171.5	566.3
Control					
Mist	94.3	471.9	581.4	1802.5	737.3
Open	52.6	238.7	788.6	997.5	519.3
CD	121.5**	NS	829.9**	NS	
SEm ±	44.8	223.2	299.4	448.5	

WAP = Weeks after planting
CD = Critical difference
** = Significant at 1% level
NS = Not significant

Table 20. Effect of growth regulator on fresh weight of shoots (mg) per cutting under mist and open (laterals)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B					
Mist	24.9	279.7	1128.9	1734.4	785.7
Open	23.1	134.5	1019.3	1338.5	628.8
IAA 1500 ppm					
Mist	27.2	873.5	1314.5	1550.8	948.3
Open	17.9	57.9	1066.6	696.2	459.9
IAA 1000 ppm					
Mist	23.1	491.6	765.7	738.4	504.7
Open	7.4	72.4	760.0	740.2	395.0
IAA 500 ppm					
Mist	24.6	631.8	996.5	646.8	574.9
Open	7.1	46.8	1295.3	732.3	520.4
IBA 1500 ppm					
Mist	20.7	762.6	866.2	1247.7	724.3
Open	5.4	76.7	843.9	680.4	402.6
IBA 1000 ppm					
Mist	24.4	690.6	1293.9	1145.6	788.6
Open	17.0	68.2	824.6	1379.9	572.4
IBA 500 ppm					
Mist	30.5	88.4	909.3	846.3	468.5
Open	13.6	69.3	2041.3	776.7	725.2
IAA + IBA 1500 ppm					
Mist	77.6	677.2	753.8	772.7	570.3
Open	28.8	77.1	1613.3	1171.0	720.5
IAA + IBA 1000 ppm					
Mist	59.8	762.8	696.3	597.9	354.2
Open	7.2	94.5	1527.3	757.2	596.5
IAA + IBA 500 ppm					
Mist	21.6	390.3	715.1	603.9	432.5
Open	3.6	22.2	1097.1	778.6	475.4
Control					
Mist	36.8	303.9	384.8	690.2	353.9
Open	15.8	37.8	400.8	413.1	220.6
CD	35.4**	653.2**	NS	1000.7*	
SEm ±	13.4	246.1	480.3	346.9	

WAP = Weeks after planting
CD = Critical difference
** = Significant at 1% level
NS = Not significant

In runners a maximum mean fresh weight of 1048.8 mg was observed when treated with IAA 1500 ppm under mist condition. During the third week of observation IAA 1500 ppm showed significant increase in fresh weight but later on treatments IAA 1000 ppm, Seradix-B and IBA 1000 ppm were on par with regard to this parameter. For growing shoots during sixth and twelth week of observation there was no significant difference between treatments, but a maximum mean fresh weight of 1358.1 mg was recorded when treated with IBA 1000 ppm under open condition.

In hanging shoots during the early stages, up to six weeks combination treatments such as IAA + IBA 1500 ppm and 1000 ppm produced maximum fresh weight, 280.4 mg and 232.7 mg respectively. But later, on ninth week, IBA 1000 ppm and Seradix-B treatments with mist produced more fresh weight. On the last observation there were no statistical difference in shoot weights but maximum shoot weights were recorded in treated cuttings.

In laterals root production was not started up to three weeks of planting but a significant difference between the treatments were observed in fresh weight of shoots. Combination treatments IAA + IBA 1500 ppm and 1000 ppm under mist produced higher shoot weights. A mean maximum fresh weight of 948.3 mg was produced by cuttings treated with IAA 1500 ppm under mist

Table 21. Effect of growth regulators on dry matter content of roots (mg) per cutting under mist and open (runners)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B					
Mist	17.9	54.0	60.0	80.9	53.2
Open	10.6	31.9	51.8	62.3	39.2
IAA 1500 ppm					
Mist	15.7	62.0	64.6	79.6	19.9
Open	10.6	30.5	55.6	64.3	40.3
IAA 1000 ppm					
Mist	19.9	49.3	59.8	67.0	49.2
Open	12.3	24.3	56.7	47.5	35.2
IAA 500 ppm					
Mist	17.6	46.3	57.3	66.3	46.9
Open	8.1	25.8	49.9	57.0	35.2
IBA 1500 ppm					
Mist	24.6	62.0	70.5	89.7	61.7
Open	12.1	37.9	62.3	61.5	43.5
IBA 1000 ppm					
Mist	31.1	85.9	69.8	100.9	71.9
Open	20.1	59.8	64.4	71.2	53.8
IBA 500 ppm					
Mist	12.9	52.9	54.3	72.4	48.1
Open	8.5	22.8	55.7	55.5	35.6
IAA + IBA 1500 ppm					
Mist	14.7	49.6	51.7	66.6	45.7
Open	8.2	26.5	55.7	53.4	36.0
IAA + IBA 1000 ppm					
Mist	18.2	48.8	52.7	66.8	46.6
Open	7.2	24.0	53.5	52.8	34.6
IAA + IBA 500 ppm					
Mist	13.8	92.1	45.6	69.3	42.7
Open	6.2	39.2	46.7	66.6	39.7
Control					
Mist	11.1	32.7	34.5	36.7	28.8
Open	6.8	17.8	22.1	-	15.6
CD	20.0*	36.6**	NS	NS	
SEm ±	7.6	13.9	22.6	26.7	

WAP = Weeks after planting
CD = Critical difference
** = Significant at 1% level
NS = Not significant

Table 22. Effect of growth regulators on dry matter content of roots (mg) per cutting under mist and open (growing shoots)

Treatments	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B					
Mist	22.1	63.8	86.0	88.3	65.1
Open	8.3	28.8	51.7	71.2	40.0
IAA 1500 ppm					
Mist	22.0	43.1	80.1	88.2	58.5
Open	9.1	40.4	57.3	60.1	41.8
IAA 1000 ppm					
Mist	20.9	29.9	71.2	71.3	48.3
Open	7.1	23.4	55.5	57.3	35.9
IAA 500 ppm					
Mist	17.4	78.1	64.4	69.8	57.5
Open	7.0	36.3	54.5	57.4	38.8
IBA 1500 ppm					
Mist	25.1	45.5	87.3	93.2	62.9
Open	10.1	23.1	59.6	52.6	36.4
IBA 1000 ppm					
Mist	27.1	84.6	105.6	108.5	81.5
Open	19.1	40.3	81.4	82.9	55.7
IBA 500 ppm					
Mist	16.0	50.8	66.2	75.6	52.2
Open	7.4	23.7	62.4	57.4	37.7
IAA + IBA 1500 ppm					
Mist	15.4	39.1	66.8	70.1	47.9
Open	8.7	24.3	62.2	53.6	37.2
IAA + IBA 1000 ppm					
Mist	17.9	42.4	64.0	69.1	48.4
Open	8.8	22.9	48.3	66.7	36.2
IAA + IBA 500 ppm					
Mist	13.6	42.7	51.2	66.7	43.6
Open	-	19.4	45.7	56.3	40.4
Control					
Mist	9.5	32.4	41.0	42.7	31.3
Open	4.4	20.4	24.9	26.8	19.1
CD	26.4*	39.4**	54.4*	NS	
SEm ±	9.5	15.2	17.6	22.1	

WAP = Weeks after planting
CD = Critical difference
** = Significant at 1% level
NS = Not significant

Table 23. Effect of growth regulators on dry matter content of roots (mg) per cutting under mist and open (hanging shoots)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B					
Mist	21.5	54.8	59.2	83.6	54.8
Open	11.5	30.3	46.7	64.7	38.3
IAA 1500 ppm					
Mist	19.9	55.9	64.1	84.3	56.1
Open	12.6	28.9	66.6	56.8	41.2
IAA 1000 ppm					
Mist	17.5	47.3	60.0	68.9	48.4
Open	6.9	24.8	53.6	57.4	35.7
IAA 500 ppm					
Mist	17.1	46.6	56.2	72.2	48.0
Open	6.9	25.7	52.2	55.6	35.1
IBA 1500 ppm					
Mist	18.0	64.4	72.7	86.7	60.7
Open	11.1	38.3	63.9	62.3	43.9
IBA 1000 ppm					
Mist	27.9	79.2	74.9	102.3	71.1
Open	19.5	41.7	62.6	75.9	49.9
IBA 500 ppm					
Mist	8.3	44.4	62.7	74.0	47.4
Open	16.1	27.3	62.2	56.0	40.4
IAA + IBA 1500 ppm					
Mist	17.1	43.6	54.3	70.2	46.3
Open	6.0	26.7	53.4	59.6	36.4
IAA + IBA 1000 ppm					
Mist	15.5	37.0	52.8	79.5	46.2
Open	7.6	24.5	54.2	66.6	38.2
IAA + IBA 500 ppm					
Mist	13.1	38.7	46.5	69.7	42.0
Open	8.2	22.5	46.0	64.3	40.8
Control					
Mist	10.3	33.4	34.8	37.1	28.9
Open	4.3	18.9	20.5	25.5	17.3
CD	20.2*	29.7**	NS	NS	
SEm ±	8.1	10.7	17.3	21.7	

WAP = Weeks after planting
CD = Critical difference
** = Significant at 1% level
NS = Not significant

Table 24. Effect of growth regulators on dry matter content of roots (mg) per cutting under mist and open (laterals)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B					
Mist	-	19.3	53.9	57.8	43.6
Open	-	9.5	44.3	44.5	32.8
IAA 1500 ppm					
Mist	-	20.9	52.4	53.2	42.0
Open	-	8.9	52.3	52.7	37.9
IAA 1000 ppm					
Mist	-	15.8	47.8	48.5	37.4
Open	-	4.9	36.3	39.9	27.0
IAA 500 ppm					
Mist	-	15.4	46.8	46.5	36.2
Open	-	6.0	40.5	41.8	29.4
IBA 1500 ppm					
Mist	-	19.5	64.4	66.7	50.2
Open	-	9.5	46.6	58.0	38.0
IBA 1000 ppm					
Mist	-	28.4	65.2	77.8	57.1
Open	-	10.9	55.1	62.0	42.7
IBA 500 ppm					
Mist	-	22.6	48.7	50.4	40.5
Open	-	9.1	41.1	44.8	31.7
IAA + IBA 1500 ppm					
Mist	-	13.2	47.3	47.8	36.1
Open	-	7.1	54.1	54.9	38.7
IAA + IBA 1000 ppm					
Mist	-	16.8	46.1	46.8	36.6
Open	-	6.7	38.5	38.8	28.0
IAA + IBA 500 ppm					
Mist	-	14.7	43.9	46.9	35.2
Open	-	4.9	37.0	37.7	26.5
Control					
Mist	-	8.5	32.6	32.7	24.6
Open	-	-	18.3	18.9	18.6
CD	-	26.7	NS	34.5*	
SEm ±	-	9.6	19.8	10.2	

WAP = Weeks after planting
CD = Critical difference
** = Significant at 1% level
NS = Not significant

condition while the lowest fresh weight was observed for control treatment under open condition.

4.1.6 Dry matter content

The data presented in Tables 21 to 28 indicated the effect of different growth regulators at varying concentrations and mist on dry matter content of roots and shoots produced by different types of planting materials.

In all the planting materials, under mist the maximum mean dry content of roots was noticed for treatment with IBA 1000 ppm followed by IBA 1500 ppm and Seradix-B. The runners, growing shoots and hanging shoots did not produce any significant difference in the dry matter production of roots during the twelth week of observation while laterals did not produce any significant difference during the ninth week.

The effect of different growth regulators on dry matter content of the shoots revealed that in runners a maximum mean dry matter content of 174.7 mg was obtained when cuttings were treated with Seradix-B under mist condition while the lowest (85.9 mg) was recorded for control particularly under open condition. In growing shoots and hanging shoots IBA 1000 ppm resulted a maximum mean dry matter content of 197.4 mg and 178.8 mg respectively under mist while in laterals IBA 1500 ppm produced highest dry matter content of shoots (166.8 mg).

Table 25. Effect of growth regulators on dry matter content of shoots (mg) per cutting under mist and open (runners)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B					
Mist	34.0	106.1	114.0	281.7	108.9
Open	8.3	40.6	142.6	286.9	119.6
IAA 1500 ppm					
Mist	60.6	115.0	166.9	356.1	174.7
Open	31.2	93.2	128.8	176.2	99.6
IAA 1000 ppm					
Mist	42.1	106.7	127.3	385.0	165.3
Open	19.3	75.0	115.4	296.1	126.5
IAA 500 ppm					
Mist	42.7	100.7	129.6	127.2	100.1
Open	24.8	54.9	112.4	284.1	119.1
IBA 1500 ppm					
Mist	18.4	95.1	190.2	190.0	123.4
Open	3.7	65.4	118.3	249.8	109.3
IBA 1000 ppm					
Mist	39.1	114.9	255.8	232.0	160.5
Open	17.1	54.7	204.9	267.1	136.0
IBA 500 ppm					
Mist	52.1	95.0	194.7	109.9	112.9
Open	22.2	100.2	163.8	272.4	139.7
IAA + IBA 1500 ppm					
Mist	20.5	104.6	200.5	127.0	113.2
Open	13.7	99.3	124.2	219.9	114.3
IAA + IBA 1000 ppm					
Mist	48.5	120.8	158.6	146.4	118.6
Open	14.4	66.5	143.2	247.8	118.2
IAA + IBA 500 ppm					
Mist	29.3	104.2	167.4	115.9	104.2
Open	1.9	68.8	120.1	169.5	90.0
Control					
Mist	27.9	91.7	113.8	193.7	106.7
Open	7.6	28.7	94.6	212.8	85.9
CD	24.1**	NS	NS	199.7*	
SEm ±	8.9	26.6	47.3	72.3	

WAP = Weeks after planting
CD = Critical difference
** = Significant at 1% level
NS = Not significant

Table 26. Effect of growth regulators on dry matter content of shoots (mg) per cutting under mist and open (growing shoots)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B					
Mist	18.8	148.2	176.3	252.0	148.8
Open	6.5	75.9	268.9	189.9	135.3
IAA 1500 ppm					
Mist	27.5	109.5	224.6	277.9	159.8
Open	23.8	53.9	258.0	285.2	155.2
IAA 1000 ppm					
Mist	19.1	108.1	229.1	171.1	131.9
Open	22.8	88.9	189.7	301.1	150.6
IAA 500 ppm					
Mist	17.2	120.1	295.8	130.7	142.5
Open	9.0	39.3	129.5	147.2	81.3
IBA 1500 ppm					
Mist	21.3	110.7	202.8	246.8	160.4
Open	23.7	67.5	340.9	324.8	196.5
IBA 1000 ppm					
Mist	27.3	105.3	344.5	312.6	197.4
Open	18.8	53.8	240.5	415.6	182.2
IBA 500 ppm					
Mist	51.4	81.5	251.3	167.2	137.9
Open	11.5	50.2	225.9	304.9	148.1
IAA + IBA 1500 ppm					
Mist	29.8	80.9	189.4	162.2	115.6
Open	17.5	131.9	167.6	134.9	113.0
IAA + IBA 1000 ppm					
Mist	23.5	109.9	234.5	118.9	121.7
Open	9.6	94.5	193.9	99.7	99.4
IAA + IBA 500 ppm					
Mist	24.0	198.4	260.2	90.8	143.2
Open	14.2	102.2	138.1	129.6	96.0
Control					
Mist	23.9	80.4	96.6	120.3	80.3
Open	5.8	56.2	99.2	260.0	105.3
CD	30.5*	NS	121.4**	251.3*	
SEm ±	12.3	39.9	43.3	101.3	

WAP = Weeks after planting
CD = Critical difference
** = Significant at 1% level
NS = Not significant

Table 27. Effect of growth regulators on dry matter content of shoots (mg) per cutting under mist and open (hanging shoots)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B					
Mist	28.4	114.6	211.4	245.1	149.9
Open	9.5	49.6	250.6	323.8	158.4
IAA 1500 ppm					
Mist	29.5	86.2	147.3	175.8	109.7
Open	11.8	137.6	309.2	222.5	170.3
IAA 1000 ppm					
Mist	24.8	46.7	167.6	170.5	102.4
Open	8.2	83.4	236.8	244.6	143.2
IAA 500 ppm					
Mist	29.4	112.1	162.0	408.7	178.0
Open	4.7	31.2	304.8	245.5	146.5
IBA 1500 ppm					
Mist	20.6	93.4	175.4	295.4	146.2
Open	8.1	42.6	273.6	148.0	125.8
IBA 1000 ppm					
Mist	32.7	114.7	286.7	261.6	178.8
Open	11.1	54.3	252.0	180.7	124.5
IBA 500 ppm					
Mist	37.8	134.5	167.9	159.9	125.0
Open	10.5	47.1	162.8	121.6	85.5
IAA + IBA 1500 ppm					
Mist	47.0	52.8	186.8	311.7	149.6
Open	12.9	39.8	128.4	116.4	74.4
IAA + IBA 1000 ppm					
Mist	38.6	117.7	254.9	245.2	164.1
Open	2.9	35.9	135.1	125.2	74.8
IAA + IBA 500 ppm					
Mist	22.3	137.1	173.9	187.9	130.3
Open	2.8	49.7	115.8	195.2	90.9
Control					
Mist	15.7	77.1	98.1	300.2	122.7
Open	9.8	39.4	131.0	166.4	86.6
CD	20.4**	NS	135.4	NS	
SEm ±	7.5	40.2	50.7	77.5	

WAP = Weeks after planting
CD = Critical difference
** = Significant at 1% level
NS = Not significant

Table 28. Effect of growth regulators on dry matter content of shoots (mg) per cutting under mist and open (lateral)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP	Mean
Seradix-B					
Mist	4.1	46.6	188.0	289.0	141.2
Open	3.8	31.7	161.3	147.2	86.0
IAA 1500 ppm					
Mist	4.6	116.9	218.5	327.1	166.8
Open	2.9	9.8	177.0	116.0	76.4
IAA 1000 ppm					
Mist	3.8	88.8	131.4	122.9	86.7
Open	1.2	12.0	125.7	123.5	65.6
IAA 500 ppm					
Mist	9.5	105.3	165.9	107.6	97.05
Open	1.1	22.1	142.9	121.9	72.0
IBA 1500 ppm					
Mist	3.2	130.4	143.7	207.4	121.2
Open	0.9	14.9	140.6	111.1	66.9
IBA 1000 ppm					
Mist	4.2	98.6	215.6	190.9	127.6
Open	2.8	11.4	136.1	211.1	90.4
IBA 500 ppm					
Mist	4.9	173.1	151.2	140.9	117.5
Open	2.2	10.9	276.7	129.5	104.8
IAA + IBA 1500 ppm					
Mist	13.0	111.2	125.7	129.5	94.9
Open	3.5	13.6	268.4	195.1	120.2
IAA + IBA 1000 ppm					
Mist	10.1	114.9	114.9	99.6	84.9
Open	1.2	15.9	254.4	126.2	99.4
IAA + IBA 500 ppm					
Mist	3.7	64.9	119.0	100.5	72.0
Open	0.7	3.8	183.0	129.7	79.3
Control					
Mist	6.1	50.6	67.5	114.9	59.7
Open	2.6	6.3	66.9	68.9	36.2
CD	NS	117.7**	NS	135.6*	
SEm ±	3.9	44.3**	74.0	53.6	

WAP = Weeks after planting
CD = Critical difference
** = Significant at 1% level
NS = Not significant

4.1.7 Shoot/root ratios

Tables 29 to 32 furnished with the data on shoot/root ratio of different types of planting materials at triweekly intervals revealed that in runners, growing shoots and hanging shoots the shoot/root ratio was higher after three weeks and six weeks of planting under mist compared to open. Later on during ninth week of observation ratio tended to increase under open and became almost equal to that of under mist condition. Finally after twelve weeks of planting higher ratio was observed under open.

In laterals after six weeks of planting the shoot/root ratio was found to be high under mist but later on after ninth and twelth weeks of observation the shoot weight decreased considerably and hence resulted in a low ratio. The reduction in shoot weight under mist during later stages might be due to the increased leaf fall observed.

4.2 Anatomical studies

4.2.1 Anatomy of the stem

In order to understand the initiation and development of roots in stem cuttings and to identify the tissue origin of the root primordia, the structure of the stem was studied in detail. The details are presented below.

Table 29. Shoot/root ratio at triweekly intervals (runners)

Treatments	3 WAP	6 WAP	9 WAP	12 WAP
Seradix-B				
Mist	2.3	3.0	5.6	4.5
Open	0.8	1.7	3.7	6.7
IAA 1500 ppm				
Mist	5.2	2.5	3.4	5.9
Open	4.0	4.1	3.1	3.9
IAA 1000 ppm				
Mist	2.9	2.9	2.8	7.6
Open	2.7	4.1	2.7	6.5
IAA 500 ppm				
Mist	3.2	2.7	3.0	2.4
Open	2.9	2.8	3.0	6.5
IBA 1500 ppm				
Mist	1.3	2.0	3.5	2.9
Open	0.4	2.2	2.5	5.7
IBA 1000 ppm				
Mist	1.6	1.7	4.8	3.0
Open	1.1	0.8	4.3	5.0
IBA 500 ppm				
Mist	5.1	2.3	4.6	2.0
Open	3.5	5.3	3.9	6.5
IAA + IBA 1500 ppm				
Mist	1.8	2.8	5.0	2.5
Open	2.3	4.9	2.9	5.5
IAA + IBA 1000 ppm				
Mist	3.6	3.5	4.4	3.8
Open	3.3	3.9	3.5	6.2
IAA + IBA 500 ppm				
Mist	2.8	3.4	4.9	2.2
Open	0.4	2.5	3.2	3.8
Control				
Mist	3.4	3.7	4.2	6.8
Open	1.5	2.1	5.7	11.5

Table 30. Shoot/root ratio at triweekly intervals (growing shoot)

Treatments	3 WAP	6 WAP	9 WAP	12 WAP
Seradix-B				
Mist	1.6	3.1	2.8	3.8
Open	1.0	3.5	6.7	3.5
IAA 1500 ppm				
Mist	1.9	2.5	3.7	4.2
Open	3.5	2.5	6.3	6.3
IAA 1000 ppm				
Mist	1.2	3.9	4.3	3.2
Open	4.3	4.8	4.5	5.8
IAA 500 ppm				
Mist	1.7	4.0	5.9	2.5
Open	1.7	3.2	3.1	6.6
IBA 1500 ppm				
Mist	1.1	2.1	3.9	3.5
Open	2.6	2.5	7.3	5.4
IBA 1000 ppm				
Mist	1.3	1.6	4.6	4.0
Open	1.3	1.8	1.6	6.8
IBA 500 ppm				
Mist	4.5	2.1	5.0	2.9
Open	2.1	2.8	4.8	7.0
IAA + IBA 1500 ppm				
Mist	2.6	2.7	3.7	5.4
Open	2.7	7.3	3.5	3.3
IAA + IBA 1000 ppm				
Mist	1.7	5.6	4.8	2.2
Open	2.3	5.4	5.0	1.9
IAA + IBA 500 ppm				
Mist	2.3	6.1	6.7	1.8
Open	2.9	7.8	4.2	3.5
Control				
Mist	3.4	3.3	3.1	3.8
Open	1.9	3.6	5.3	13.9

Table 31. Shoot/root ratio at triweekly intervals (hanging shoots)

Treatments	3 WAP	6 WAP	9 WAP	12 WAP
Seradix-B				
Mist	1.9	2.8	4.7	3.9
Open	1.1	2.2	7.1	6.7
IAA 1500 ppm				
Mist	2.0	1.7	3.0	2.7
Open	1.2	6.3	6.1	4.7
IAA 1000 ppm				
Mist	1.9	1.3	3.7	3.3
Open	1.6	5.0	5.8	5.7
IAA 500 ppm				
Mist	2.1	3.2	3.7	4.8
Open	1.1	1.4	7.8	5.8
IBA 1500 ppm				
Mist	1.5	1.9	3.2	4.5
Open	1.0	1.5	6.2	3.8
IBA 1000 ppm				
Mist	1.6	1.9	5.1	3.4
Open	0.7	1.7	5.2	3.4
IBA 500 ppm				
Mist	3.2	3.6	3.5	2.9
Open	1.7	2.1	3.4	2.9
IBA + IBA 1500 ppm				
Mist	3.7	1.6	4.0	5.9
Open	2.9	1.9	3.2	2.7
IBA + IBA 1000 ppm				
Mist	3.4	4.5	7.6	8.8
Open	0.4	1.9	3.3	2.5
IBA + IBA 500 ppm				
Mist	2.2	4.7	4.9	3.7
Open	0.5	2.9	3.6	4.0
Control				
Mist	2.0	3.1	3.7	10.2
Open	2.7	2.8	7.0	8.6

Table 32. Shoot/root ratio at triweekly intervals (laterals)

Treatment	3 WAP	6 WAP	9 WAP	12 WAP
Seradix-B				
Mist	-	3.2	4.5	6.6
Open	-	3.1	5.1	6.6
IAA 1500 ppm				
Mist	-	9.5	5.6	6.9
Open	-	1.4	4.5	3.5
IAA 1000 ppm				
Mist	-	6.9	3.5	3.3
Open	-	3.3	4.6	4.1
IAA 500 ppm				
Mist	-	9.0	4.7	3.0
Open	-	1.7	7.1	3.8
IBA 1500 ppm				
Mist	-	8.6	2.9	4.1
Open	-	1.7	4.0	2.6
IBA 1000 ppm				
Mist	-	5.4	4.4	3.2
Open	-	1.3	3.3	4.9
IBA 500 ppm				
Mist	-	12.9	4.1	3.6
Open	-	1.6	10.9	3.7
IAA + IBA 1500 ppm				
Mist	-	11.5	3.5	3.4
Open	-	2.4	6.5	5.8
IAA + IBA 1000 ppm				
Mist	-	10.0	3.4	2.8
Open	-	3.1	8.6	4.3
IAA + IBA 500 ppm				
Mist	-	5.9	3.5	2.8
Open	-	1.0	6.5	4.5
Control				
Mist	-	8.4	2.5	4.3
Open	-	1.8	4.8	4.1

The outer most layer of a young stem with primary growth was the epidermis. The epidermal cells were tabular in shape and appeared almost rectangular in a cross sectional view. Epidermal hairs were sparse, simple and uniseriate and were usually seen developed from shallow depressions in the layer (Plate XV.A). Below the epidermis were ten to fifteen layers of unevently thick walled cells of collenchyma mixed with patches of sclerenchyma. The inner part of the ground tissue was constituted by thin walled, isodiametric parenchyma cells. An endodermis with less distinct casparian thickenings was usually present.

There were two rings of vascular bundles present. The outer ring (cortical) consisted of 35 to 46 bundles separated from the inner ring (medullary) by a continuous sinuous zone of sclerenchyma (Plate XV.B and C). This layer was of uneven thickness. Portions of the ring closer to the periphery were 5 to 6 cells thick, whereas rest of the portions were 6 to 8 cells thick. Medullary bundles were also arranged in a definite circle and vary in number from 9 to 15. Xylem vessels were arranged in U-shaped groups within the bundles. Sclerenchyma patches were present on the outerside of the bundles capping the phloem or sometimes forming a more or less continuous layer.

Plate XV. Anatomy of the stem

A	Cross sectional view of stem showing epidermal hairs. Note the hairs arising froms shallow depressions in the epidermal layer (at arrow) X 40.96x
B and C	Cross sections of the stem showing two rings of vascular bundles. The outer ring (Cortical) separated from the inner ring (medullary) by a continuous sinuous zone of sclerenchyma layer (at arrow) X 12.70x
D	Mucilage canal with wide lumen and surrounding epithelial cells X 80x
E	Transverse section of the stem with secondary thickening. Note larger and radially elongated vascular bundles. X 40.96x
F	Transverse section of the stem with secondary growth to show the interfascicular parenchyma appearing rectangular and radially elongated. X 51.20x

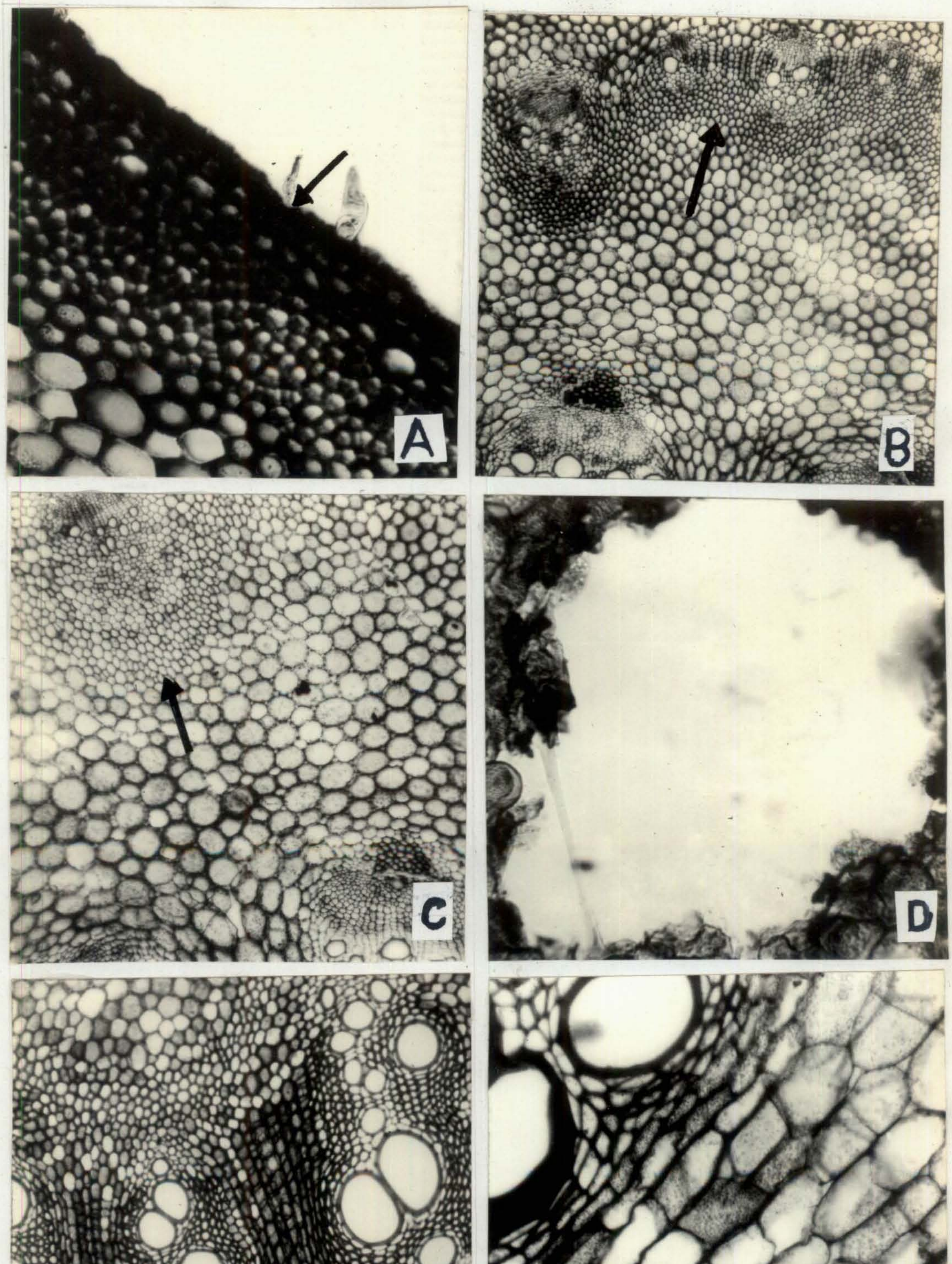

Plate XV

Mucilage canals with wide lumina and surrounded by distinct epithelial cells were seen present in the ground tissue (Plate XV.D). There was one large central canal accompanied by 5 to 10 peripheral ones seen outside the circle of medullary vascular bundles.

Starch was present in the form of minute granules in the parenchyma cells of cortex and pith, however, the distribution was uneven.

The epithelial cells surrounding mucilage canals contained higher amount of starch as compared to rest of the cells. Oil globules were numerous in the parenchyma tissue. The cortical parenchyma normally contained larger globules. Crystals have not been observed in the ground tissue.

4.2.2 Secondary growth of the stem

In stems showing secondary thickening, the epidermis was found to be replaced by a multilayered periderm formed from a cork cambium which originated just below the epidermis. Cork cells were suberized and were arranged compactly in radial rows. Cup-shaped lenticels, which were the structurally differentiated portions of the periderm were also present. They were characterised by a relatively loose arrangement of cells with more intercellular spaces.

As a result of the activity of a vascular cambium the bundles in a mature stem appeared larger and radially elongated in the cross section (Plate XV.E). The cambium was not distinct in the interfascicular region, but it was distinct in the fascicular region. Parenchyma cells in the interfascicular region appeared rectangular and radially elongated (Plate XV.F).

4.2.3 Development of roots

In pepper stem cuttings, roots are produced usually from the nodal regions or less frequently from the callus. No preformed root primordia were observed in fresh cuttings nor in planted stem cuttings that failed to root. Materials collected 5 and 10 days after planting the cuttings showed roots or root primordia at various stages of development. The degree of development of the primordia in cuttings differed not only between different treatments but also between different types of planting materials and individual cuttings. In general, three steps have been recognised in the development of roots from cuttings, they are

i) dedifferentiation and rapid division of few parenchymatous cells to produce root initials;

ii) establishment of a recognizable root primordium with a meristematic root apex from these cells; and

iii) development of vascular connection and emergence of root primeridum by rupturing the cortical tissue of the stem.

4.2.3.1 Cell divisions

A small group of interfascicular parenchyma lying between the cortical bundles were divided resulting in smaller cells. These cells were distributed almost at the same level as the cambium and phloem tissues of the adjacent cortical bundles (Plate XVI. A and B). Sometimes two or more groups of such root initials could also be found between different pairs of vascular bundles in a single transverse section and opposite to each group, the sinuous ring of sclerenchyma was discontinuous (Plate XVI. C and D). Anticlinal and periclinal divisions were observed in the initials as a result of which the groups of initials became easily distinguishable from rest of the cortical cells. The initials differed in their stainability also. In cuttings which failed to produce roots, no cell division was noticed.

4.2.3.2 Establishment of a root primordium

Further divisions, both anticlinal and periclinal resulted in a dome-shaped mass of meristematic cells (Plate XVI. E and F). The size of these cells was considerably

Plate XVI. Development of roots

A and B	Cross sections of the stem showing the interfascicular region of cortical bundles. Note the isodiametric (Fig.A) or radially flattened (Fig.B) cells resulting from active cell divisions at arrows X 80x
C, D	Cross sections of the stem showing the discontinuity in the sinuous layer of sclerenchyma. Note that the thickness of the layer is reduced (Fig.C) and a gap is developed (Fig.D) below the differentiating primoridum X 51.20x
E	Dome shaped mass of meristematic cells resulting from anticlinal and periclinal divisions. X 20.16x
F	Enlarged dome shaped primordium. X 20.16x

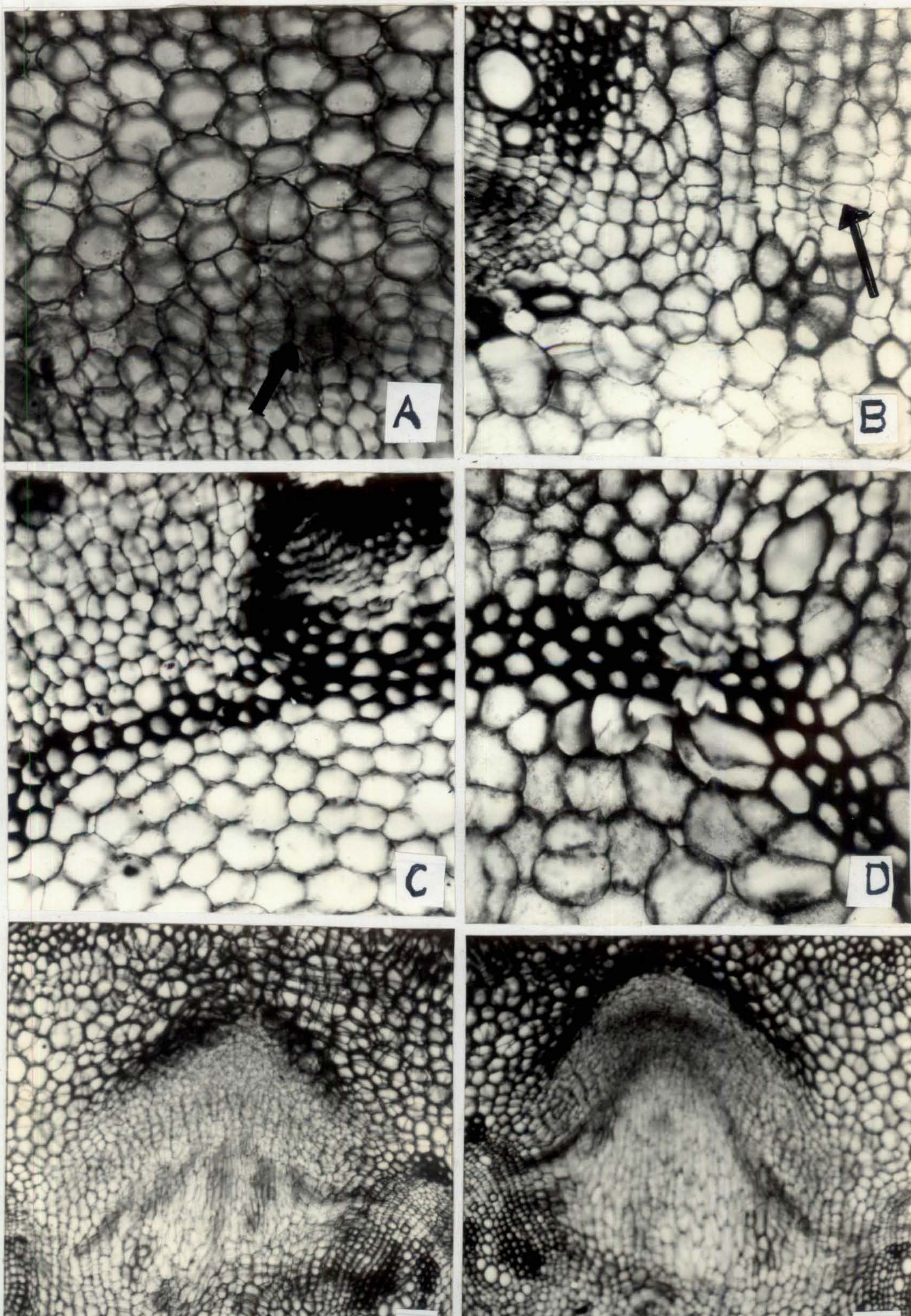

Plate XVI

Plate XVII. Development of roots

A A developing primordium showing the outer most layer consisting of densely stained columnar cells (at arrow). X 20.16x.

B The root tissue showing a distinct primordial epidermis (at arrow) even after the emergence of the root. X 51.20x.

C Root primordium, before its emergence with distinct and well developed root cap consisting of many layers of cells (at arrow). X 20.16x

D Developing root primordium showing differentiation of vascular tissue. Note that a connection is established with adjacent vascular bundles X 20.16x.

E A developing primordium before its emergence. Note a layer of darkly stained substances along with some disorganized cells on its outer side X 51.20x.

F An emerged root showing at its base the ruptured cortical tissue and a layer of periderm covering the point of emergence (at arrow). X 51.20x.

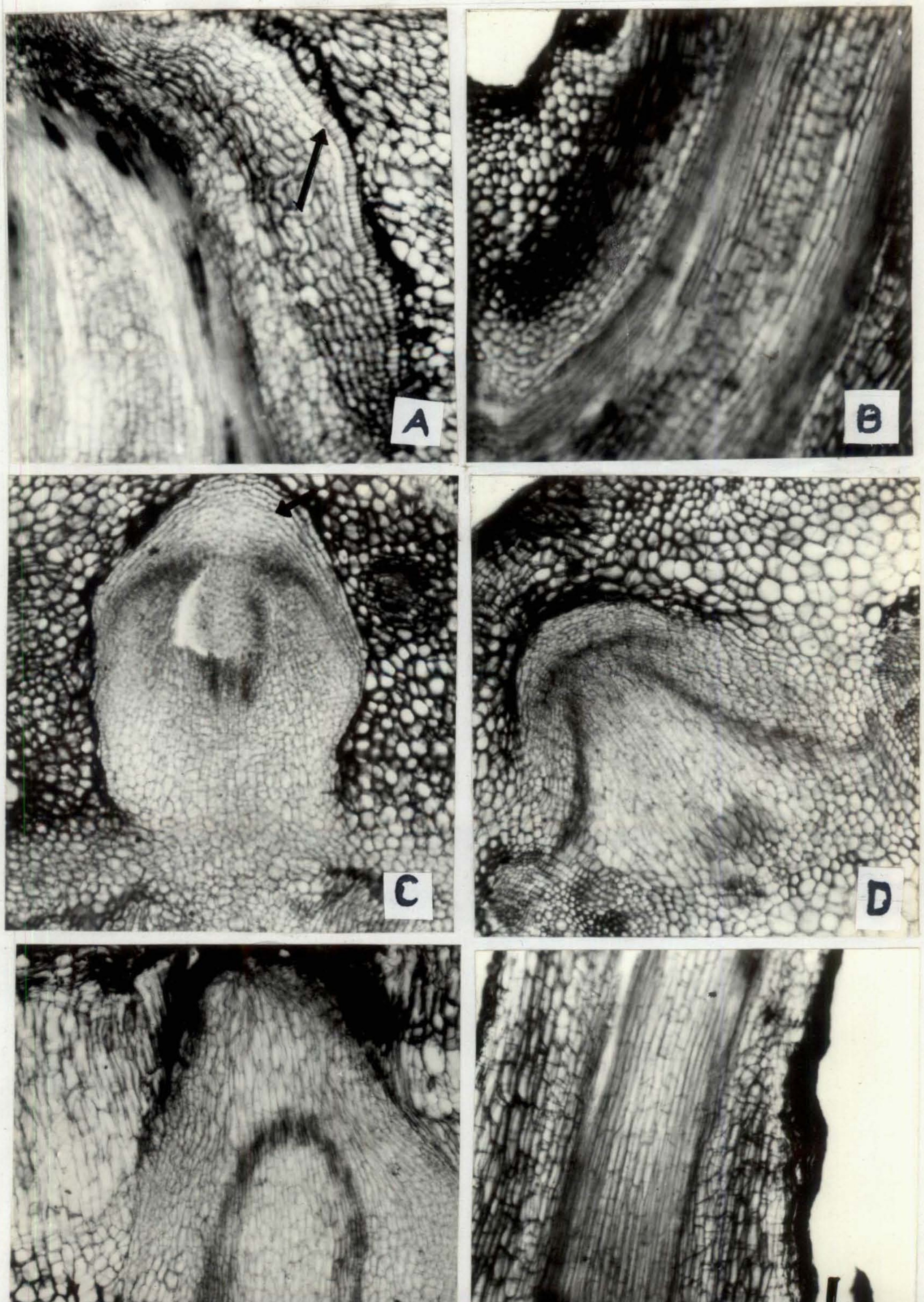

Plate XVII

reduced and the arrangement was more definite as compared to the surrounding cortical parenchyma cells. The dome shaped primordium enlarged further without establishing connection with the surrounding parenchyma cells. At this stage the outermost layer of the primordium was usually distinct at the flanks of the meristematic dome and it consisted of densely stained columnar cells (Plate XVII.A). This primordium epidermis continued to delimit the root tissue from stem cortex even after the emergence of a young root (Plate XVII.B). The inner cells of the root parmordium were thin walled with dense cytoplasmic contents and were arranged in less definite layers. The root primordium, before its emergence, also showed a distinct and well developed root cap consisting of many layers of cells. The cells of the root cap showed poor stainability and were definitely arranged (Plate XVII.C).

4.2.3.3 Development of vascular connection and emergence of root

Accompanying the growth of the primordium, differentiation of meristemic cells began at the proximal end. The nearly isodiametric cells of the meristem were found to elongate radially (with reference to the stem axis). Differentiation of vascular tissues was also observed at the base of the primordium, at first connecting the provascular tissues to the xylem and phloem of the cortical bundles and proceeding further acropetally (Plate XVII.D). The elongation of the primordium was usually in the radial direction. However, in some samples it curved tangentially before emerging out from the stem especially when vascular traces were situated against its path. It was observed that the growth of the primordium resulted crushing down of some parenchyma cells especially those contiguous to the meristem. A layer of darkly stained substances along with some disorganised cells was found lining the primordium on its outer side (Plate XVII.E). The outer cortex was found ruptured at the point of emergence of root and the exposed cells found suberised. In some samples a distinct periderm was found covering the stem around the point of root emergence (Plate XVII.F).

4.2.4 Anatomy of root

4.2.4.1 Young root

A young root revealed the following anatomical features. The outermost layer of the root was the epidermis. It was constituted by closely packed cells with rather thin but suberised walls. Finger like, unicellular root hairs were arising from some epidermal cells. Below the epidermis 8 to 10 layers of the parenchyma arranged in less distinct radial rows constituted the root cortex (Plate XVIII.A).

Plate XVIII. Anatomy of root

A Cross section of a young root showing seven vascular strands. Note also a developing lateral root. X 20.16x

B Enlarged view of root section. The xylem elements forming discrete strands alternating with equal number of phloem groups X 51.20x

C Cross sectional view of mature root showing well developed xylem tissue and pith. Phloem arcs can also be seen. X 20.16x

D Portion of secondary vascular tissue separated by broad strips of parenchyma cells. Note an arc of phloem (at arrow) and Cambium is indistinct. X 51.20x.

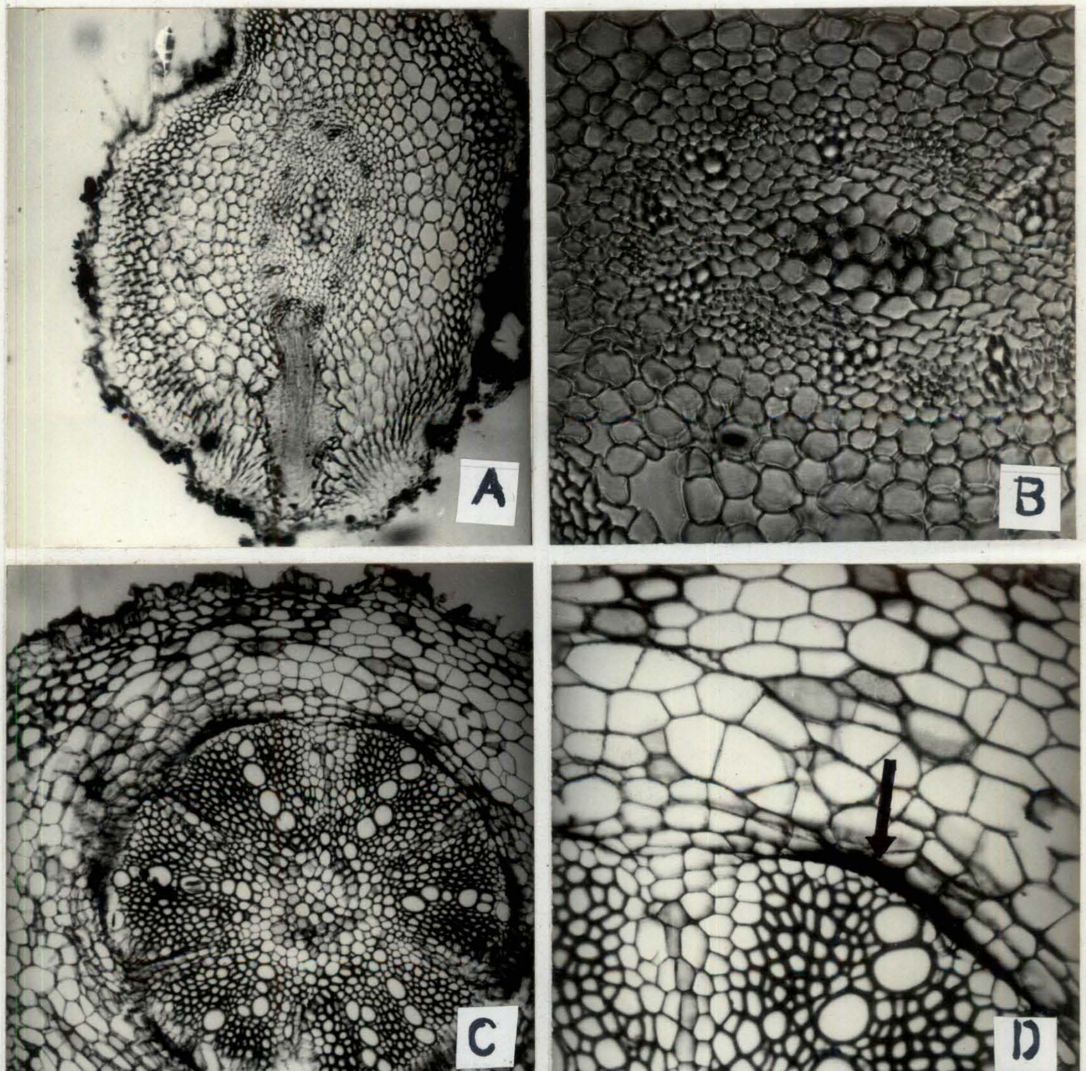

Plate XVIII

Cells of the cortex varied in their size and shape. In general smaller cells were seen towards the periphery and larger ones towards the inner cortex. A distinct endodermis was seen characterised by cells with casparian thickenings on their anticlinal walls. Below the endodermis was the pericycle usually a single layer in thickness.

The inner part of the root was occuped by the vascular tissue and the associated parenchyma. The xylem elements formed discrete strands alternating with equal number of phloem groups and were arranged in a circle immediately below the pericycle. Each xylem group was constituted by larger radially arranged cells and was exarch. The phloem groups were constituted by smaller cells. The number of xylem strands ranged from three to six. However, in some thicker roots as many as seven vascular strands were observed (Plate XVIII.B). A distinct pith consisting of parenchyma was usually present in young roots. However, mucilage canals were not found.

4.2.4.2 Mature root

A mature root showed a well developed stele with a discontinuous cylinder of xylem surrounding a small pith (Plate XVIII.C). The secondary xylem occupied major part of the stele and was composed of vessels and fibres. In contrast to the young roots, phloem occurred as narrow arcs on the outer side of the wedge-shaped xylem patches (Plate XVIII.D). The cambial layers were however not readily recognisable. The patches of secondary xylem were separated by broad strips of radially elongated cells as observed in a mature stem. The endodermis was found intact even at this stage. The cortical cells of a mature root appeared in a transverse section to be tangentially more stretched as compared to a young root. The outer most few layers of cortex differed in their stainability from rest of the cortical cells.

Discussion

DISCUSSION

Black pepper, one of the most important cash crops of Kerala, is propagated commercially by vegetative means. For increasing the production of pepper in the country large scale replanting of the senile and poor yielding vines and also extensive new plantings with high yielding types are required. Type of planting materials and time of taking cuttings are some of the important factors to be considered while propagating pepper (Nambiar and Kurian, 1963; Shathamalliah *et al.*, 1974; and Nambiar *et al.*, 1978). Traditionally in Kerala the runner shoots produced from the base of the plants are being used commercially as planting materials, though often other stem portions such as growing shoots (orthotrophs), hanging shoots (geotrophs) and laterals (plageotrophs) are also used. By these means the availability of planting materials can also be increased (Pillai, 1977; Bavappa and Gurushinghe, 1978; Nambiar *et al.*, 1978; and Chandy and Pillai, 1979). Application of various growth regulators at proper concentration have been found to increase the rooting percentage in pepper (Cooper, 1955; Leite and Inforzato, 1966; Hurov, 1967; Choudhury and Phadnis, 1971; Package of Practice, KAU, 1982; Irulappan *et al.*, 1981; Pillai *et al.*, 1982 and Hedge, 1983).

5.1 Effect of growth regulators on rooting of cuttings

The process of root generation in cuttings in a wide range of difficult to root plant species could be accelerated with the use of root promoting substances at proper concentrations. The results of the present study clearly indicated that in all the four types of planting materials the growth regulators significantly increased the rooting. Among the growth regulators tried viz., Seradix-B, IBA, IAA and IAA + IBA combination, IBA at 1000 ppm resulted in maximum success. The results of the present study thus confirms the earlier findings of Pepper Research Station, Panniyur (1981) and Pillai et al. (1982). The effectiveness of auxin in general and IBA in particular for induction of rooting of cuttings have been well amplified by several workers in many spice crops and a variety of other horticultural crops (Nicholas and Pryde, 1958; Hurov, 1967; and Sympson and Chin, 1980).

The rooting efficiency of growth regulators are generally assessed by the number of roots produced by the cutting, length and weight of roots, since these parameters ultimately decide the final percentage of establishment of rooted cuttings in the main field (Hartman and Kester, 1972). In the present study also there was a clear indication of the beneficial effect of IBA 1000 ppm on all the above root growth parameters.

Pillai et al (1982) also stressed the positive effect of IBA 1000 ppm on the rooting of cuttings in pepper. In the treated cuttings number, length and weight of the roots had increased by more than 100 per cent compared to the untreated cuttings and hence the treated cuttings developed a good root system which finally resulted in their quick growth and establishment in the mainfield. The external application of growth regulators would have perhaps increased the meristematic activity and root differentiation (Pontikis et al., 1979). Moreover, the production of more number of roots in auxin treated cuttings is often attributed to the mobilisation of more reserve food materials from the terminal to the basal portion of the cutting (Strydom and Hartman, 1960).

In most of the plant species sprouting of shoot is an indication of root initiation in cuttings (Hartman and Kester, 1972) Aishabi (1981) also found that cuttings that produced shoots earlier failed to root on several occasions. However, in pepper from the present study it is observed that the initial sprouts of shoots is not a clear indication of root strike.

In the initial stages fresh weight of shoot was observed to be maximum in cuttings treated with IAA + IBA 1500 and 1000 ppm and control however, later on fresh weight was found to be more in cuttings treated with IBA 1000 ppm and Seradix-B. The initial set back in shoot growth in IBA treatment might be due to the more utilisation of carbohydrate for root production and resultant exhaustion of stored carbohydrate in the planting material for shoot growth. Further the dominance of the axillary buds would have been inhibited by the applied auxins at the base of the cuttings. After the roots have established, they might have started absorbing nutrients from the soil and this accounted for the recoupment of shoot growth rate later in these treatments (Pillai *et al*., 1982).

5.2 Effect of mist on rooting of cuttings

The pooled analysis of the data indicated the beneficial effect of mist on rooting of cuttings in all the four types of planting materials. The significant effect of mist on rooting of pepper cuttings was also reported by earlier workers (Creech, 1955; Hughes, 1966 and Kamp, 1969). In all the types of planting materials the superiority of mist was also clearly apparent with respect to other root growth parameter viz., number, length, fresh weight and dry matter production of roots. The beneficial effect of mist could be attributed to the presence of high humidity which prevents descication and keeps the cuttings cool thus reducing transpiration and respiration rates. This results in a condition most ideal for rooting and sprouting (Bose *et al*., 1972; Singh, 1976 and 1980 and Singh and Motilal, 1981).

Mist had a depressing effect on the shoot/root ratio in the final stage. It was clear from the results that after twelve weeks of planting higher ratio values were observed under open condition. This reduction in shoot weight under mist during later stages might be due to the increased leaf fall observed.

Mist helps significantly root initiation and development in all the four types planting materials. However once rooting has taken place, further retension of the cuttings in the mist chamber does not appear to be condusive for pepper since the incidence of diseases were more.

5.3 Rooting of cuttings in different types of planting materials

The present study was carried out using four different types of planting materials viz., runners, growing shoots (orthotrophs), hanging shoots (geotrophs) and laterals (plageotrophs). From the results of the present study it could thus be seen that there was not much difference among the planting materials with regard to their rooting ability, though laterals were found to be shy rooters in the initial stages, they could also be used as planting materials as they produce dwarf bushy plants.

As far as rooting success was concerned there was not much difference between the cuttings from growing shoots, henging shoots and runners (Bevappa and Gurusinghe, 1978); Pillai, 1977; Nambiar et al., 1978 and Chandy and Pillai, 1979). The suitability of semiherbaceous cuttings is due to their active metabolic state and also a favourable C:N ratio as has been reported by Hartman and Kester (1972). All the planting materials except laterals rooted readily during March. Maximum sprouting and rooting observed when planting was done from March to June and poor rooting during winter season from November to February could be explained due to bud dormancy. The break of dormancy in March might be due to the mobilisation of starch because of enhanced auxin content (Shathamalliah et al., 1974). The failure of laterals to root during March might be due to the lack of food reserves in the cuttings as they were taken immediately after harvest. During the flushing season i.e. during June the lateral cuttings also rooted satisfactorily.

It is interesting to note in the present study that three weeks after planting the effect of growth regulators on rooting percentage and other root growth parameters was significant in runners only and in growing shoots and hanging shoots the effect was not found to be significant. At this stage laterals revealed very poor rooting under mist as well as open condition. Early rooting is a very desirable attribute as it will substantially reduce casuality of the rooted cuttings in the nursery and an early initiated and well developed root system ensures their quick establishment in the transplanted main field (Pillai _et al_., 1982). Use of pre rooted cuttings of runners was found to be the best planting materials with regard to rooting and establishment (Nambiar _et al_., 1978; Chandy and Pillai, 1979 and Package of Practice, KAU, 1986).

In the case of runners, growing shoots and hanging shoots rooting was completed by the end of six weeks of planting where as in laterals rooting was generally delayed and it has gone upto nine weeks for completion.

In all the planting materials the initial rooting recorded a higher percentage, while ultimately the percentage of establishment showed a reduction. This would indicate that in pepper there are factors which interfere in the growth of roots after the initial root strike. Lack of production of sufficient number of roots or the improper development of roots and vigrous vegetative growth could be the reason attributed to this phenomenon. Moreover, pepper roots in the initial stages are prone to fungal pathogens like *Phtophthora*, *Pythium* and *Rhizoctonia* resulting poor establishment. Identifying the exact factors for the reduction in the establishment of rooted cuttings will be helpful to obtain maximum success in rooting of cutting.

5.4 Anatomy in relation to rooting

5.4.1 Anatomy of the stem

The stem anatomy of pepper shows the characters of both monocots and dicots. The vascular bundles are scattered in the ground tissue in many members of Piperaceae as in monocots (Metcalfe and Chalk, 1950). In *Piper nigrum* the arrangement is more definite as the bundles are arranged in two distinct layers an outer ring of cortical bundles and an inner ring of medullary bundles. Even in monocots, Zimmerman and Tomlinson (1972) recognised the existence of an 'inner' and 'outer' vascular systems based on the three dimensional course of the vascular bundles. But unlike monocots the vascular bundles are open in pepper as a distinct cambium is present in both cortical and medullary bundles. Thus the stem structure in pepper is anomalous among the dicots and bears some resemblance to that of monocots (Metcalfe and Chalk, 1950).

Endodermis is developed to varying degrees in different species of *Piper*. According to Bond (1931) the endodermis in the aerial stem of *Piper* is developed always in association with the outer ring of vascular bundles. In some species the endodermis forms a continuous cylinder around the bundles, in others it is replaced by a layer of relatively large cells with no casparian thickenings; in a third group of species it is present but inconsistently distributed. In the présent study it is noticed that the endodermis with inconspicuous casparian thickenings is present on the outer side of the cortical bundles in *Piper nigrum*. The cell size is almost similar to other cortical cells. Bond (1931) believes that the endodermis is a vestigial structure of no primary importance in the internal economy of the stem. He observed that endodermis was continuous over the rays and outer vascular bundles in the stem of *Piper nigrum*. Similar observations were also made by Garner and Beakbane(1968).

During the secondary growth in woody perennials the cambium becomes a continuous cylinder and the secondary vascular tissues are produced all along the circumference. In some herbaceous plants and dicotyledonous vines a modified form of secondary thickening takes place. Here the cambium does not extend laterally beyond the limits of primary xylem and phloem of the bundle or the formation of vascular tissues is restricted to the fascicular region. In the interfascicular region either some parenchyma tissue or no tissue is formed (Esau, 1965). In the present study it is found that the secondary growth in pepper is typical to that of dicotyledonous vines. The vascular bundles remain discrete even after the secondary thickening as observed by Garner and Beakbane (1968). Secondary growth of this type is sometimes treated as normal and someties as anomalous. According to Esau (1965) a clear delimitation of anomalous growth is difficult and depends on how narrowly the normal type is circumscribed.

5.4.2 Development of roots

In general the formation of adventitious roots takes place after the cuttings are planted. However, in some plants preformed root initials are reported to be present in the intact stem even before the cuttings are made (Carlson, 1938 and 1950) Hartman and Kester, 1972). These pre-formed initials generally lie dormant until the stems are made into cuttings and planted under favourable environmental conditions for rooting (Carpenter, 1961). It is also known that the species having pre-formed initials root easily as compared to the rest (Eames and Mac Daniels, 1947 and Fahn, 1974). In pepper no pre-formed initials have been observed. The dedifferentiation of interfascicular parenchyma into root initials and establsihment of a root primordium are the developments subsequent to planting, as in majority of other species. Thus the failure of stem cuttings to root is traceable to the lack of initiating cell divisions and not due to any anatomical barrier as reported to be present in some other species (Ciampi and Gellini, 1958 and Beakbane, 1941).

The origin of roots in stem cuttings is from groups of meristematic cells namely root initials which are localized usually just outside and between the vascular bundles in many herbaceous plants (Priestley and Swingle, 1929). Root initials can arise from a layer of parenchymatous cells inside the fibre sheath as in carnation (Stangler, 1949) or from the parenchymatous cells of the phloem as in Cucurbita pepo, Nerium oliander, Lycopersicon esculentum and Hedera helix (Petri et al., 1960 and Girouard, 1967). Root primordia are also reported to originate from various other tissues like non differentiated phloem and cambium between the vascular bundles, interfascicular cambium and pericycle, parenchymatous interruptions in the secondary xylem formed by leaf gaps or even from the epidermal, cortical or pith tissues (Fahn, 1974). It is observed that in pepper the root primordia originate from interfascicular parenchyma between the cortical vascular bundles. No primondia are found originating from the vicinity of the medullary bundles. According to Esau (1965) the adventitious primordium develops from cells near the periphery of the vascular system in younger organs and from inner tissues in mature ones.

One peculiar feature of the pepper stem is the presence of a continuous sinuous ring of sclerenchyma found on the innerside of the cortical bundles. It is interesting to note that prior to the formation of root initials a gap develops in the ring against each group of initials, so that the pith of the developing root and that of the stem are interconnected. The significance of this histological change during the development of roots is not fully understood. However, it is presumed that a continuity between the ground tissues of the stem and root may be of some importence in the transfer and storage of metabolites as starch and lipids are commonly found stored in the parenchyma tissue in pepper. The gap in the sclerenchymatous ring probably develops by the transformation of some of the thick walled cells. Thinning of the cell walls and loss of lignin stainability have been observed during the lateral root development in a few species although opinions differ with regard to the possibility of delignification (Mc Cully, 1975).

Karas and Mc Cully (1973) observed that in corn the cells of the primordium epidermis are distinctive, being columnar and are densely cytoplasmic. These cells have been found to secrete a PAS-positive mucilage lining the outer side of the emerging primordium (Mc Cully, 1975). In pepper also primordium epidermis shows similar characters. A layer of densely stained material is also evident surrounding the growing primordium. During the early development in corn the epidermal cells of the primordium divide only anticlinally, later on divide perclinally and this produces root cap initials (Bell and Mc Cully, 1970). The daughter cells of these divisions show poor stainability and before the lateral root emerges out it has a fully developed root cap. The root cap in pepper is apparently a product of periclinal divisions as evident from the arrangement of cells in radiating rows. The cells are poorly stained as in corn.

The growth of the developing root through the stem cortex of pepper is in the radial direction and is brought about by cell divisions at the apex and elongation and maturation of cells at the proximal end. Occasionally the primordium curves tangentially before emergence especially when some vascular traces passes across its path. It has been observed in certain species that the adventitious roots originating in older stems grow obliquely through outer tissues probably because of the resistance offered by sclerenchyma outside it (Tomlinson, 1961 and Esau, 1965).

With the maturation of proximal cells the primordium receives the vascular supply from the contiguous bundles. Usually the parenchyma cells at the proximal end of the primordium differentiate into vascular elements so as to provide the connection (Esau, 1965). The differentiation of pro vascular tissues of the primordium in pepper is acropetal compared to other species. The penetration of the young roots through stem cortex involves breakdown of a few cortical cells. Different views exist with regard to the passage of a growing root through the cortex. The involvement of hydrolytic enzymes which dissolve some of the cortical cells had been speculated by early workers. More recent works (Bonnet, 1969; Bell and Mc Cully, 1970; Karas and Mc Cully, 1973) also suggest that hydrolytic enzymes are involved in the penetration of the root and the role of mechanical pressure may be negligible (Mc Cully, 1975). Although in the present study evaluation of the role of enzymes and mechanical factors was not possible, evidences suggest that the importence of mechanical pressure cannot be totally ruled out. The final phase of the emergence of young roots in pepper involves rupture of a few cortical layers and epidermis. The exposed cells are subsequently suberised or covered by a periderm.

5.4.3 Anatomy of the root

In most of the dicotyledons the cortex of the root mainly consists of parenchyma cells. These cells are sometimes arranged in radial rows particularly in the inner layers (Fahn, 1974). In pepper, the cortical cells are arranged in less distinct radial rows. The radial arrangement is the result of cell division during the process of formation of cortex (Heimsch, 1960). Repeated anticlinal divisions results in the increased tangential dimension of cortex while periclinal divisions add to the number of cell layers in radial direction (Fahn, 1974).

In the root vascular system the phloem occurs in the form of strands distributed near the periphery of vascular cylinder beneath the pericycle. The xylem either forms discrete strands, alternating with the phloem strands or occupies the centre and then as in many plants, xylem appears star shaped in cross section (Esau, 1965 and Fahn, 1974). In pepper, the xylem elements form discrete strands alternating with equal number of phloem groups and are arranged in a circle immediately below the pericycle. Thus a distinct pith is present surrounded by the ring of vascular strands. The number of vascular bundles appears to be variable in pepper. Triarch to hexarch arrangement is more common in thicker roots and in some cases even upto seven vascular strands have been noticed. According to Fahn (1974) the number of protoxylem groups in a root and even the presence or absence of a pith are dependent upon the diameter of the vascular cylinder.

Variation in number of vascular strands in the root within a species and even within the same plant have been reported by Fahn (1974) in monocots and dicots.

As reported earlier (Metcalf and Chalk, 1950), no mucilage canals have been observed in the root of pepper. The mature root usually shows well developed xylem plates surrounding a small pith. As observed by Datta and Dasgupta (1977) the number of tracheary plate varies from five to six in mature roots of *Piper nigrum*.

The success of rooting in the different types of cuttings in general was thus found to be influenced by the anatomical features.

Summary

SUMMARY

The present investigations on the effect of growth regulators on rooting of different types of planting materials and the anatomical studies on initiation and development of roots in black pepper were carried out in the Centre for Advanced Studies on Humid Tropical Crops, College of Horticulture, Vellanikkara. The salient results of the studies are summarised below.

1. In all the planting materials viz., runners (stolons), growing shoots (orthotrophs), hanging shoots (geotrophs) and laterals (plagetrophs) rooting was significantly influenced by growth regulator treatments compared to control. Among all the treatments, IBA 1000 ppm recorded maximum rooting followed by Seradix-B, IAA 1500 ppm and IBA 1500 ppm. With regard to other root growth parameters viz., number, length, fresh weight and dry matter production IBA 1000 ppm was found to be superior.

2. The fresh weight and dry weight of shoots were maximum in combination treatments, such as IAA + IBA 1000 ppm and 1500 ppm during the early stages. However, in the later stages of observation IBA 1000 ppm was found to be good with regard to these parameters.

3. Irrespective of the growth regulator treatments, mist had pronounced effect on rooting and on other root growth parameters in all the types of planting materials. However, mist had depressing effect on shoot weight and shoot/root ratio especially during ninth week after planting.

4. There was not much difference among the planting materials with respect to their rooting ability though the laterals were found to be shy rooters in the initial stages. After three weeks of planting the effect of growth regulators on rooting was significant in runners only and in laterals no rooting was observed at this stage. In the case of runners, growing shoots and hanging shoots maximum rooting was observed after six weeks of planting while laterals produced maximum rooting after nine weeks of planting.

5. In runners, growing shoots and hanging shoots rooting was satisfactory when cuttings were planted during March whereas in laterals, there was very little rooting during this period. Laterals recorded maximum rooting when cuttings were planted in June.

6. The anatomical studies of the stem of black pepper showed the characters of both monocots and dicots. The outermost layer in young stem was the epidermis with

sparse epidermal hairs followed by fifteen layers of collenchyma mixed with sclerenchyma and inner ground parenchymatous tissue. An endodermis with less distinct casparian thickening was present. There were two rings of vascular bundles. Mucilage canals with wide lumina were also seen to be present.

In stems showing secondary thickening, the epidermis was found to be replaced by multilayered periderm. Vascular bundles appeared larger and radially elongated and thus parenchyma cells in the interfascicular region also appeared rectangular and radially elongated. The planting materials were not differing in their stem structure.

7. In pepper stem cuttings roots were produced usually from the nodal regions or less frequently from the callus. No preformed root primordia have been observed. The roots are initiating from a small group of interfascicular parenchyma lying between the cortical bundles. Anticlinal and periclinal divisions of these tissues resulted in a dome-shaped mass of meristematic cells which developed into a root primordium. Accompanying the growth of the primordium differentiation of vascular tissues also take place and finally resulted in the rupture of outer cortex and the root emergence.

8. Outer most layer of young root was the epidermis below which eight to ten layers of parenchyma constitute the root cortex. A distinct endodermis was seen characterised by cells with casparian thickenings on their anticlinal walls. Vascular tissue constituted by equal number of xylem and phloem groups arranged in a circle alternating with each other was seen to be present.

A mature root showed a well developed stele with a discontinuous cylinder of xylem surrounding a small pith. Phloem occurred as narrow arcs on the outerside of the wedge shaped xylem patches. The cambial layers however was not easily recognisable.

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*Originals not seen

Appendix

Appendix-I

Weather data during the period of experimentation

Period	Mean maximum temperature (°C)	Mean minimum temperature (°C)	Mean R.H. (%)	Mean soil temperature (°C)	Sunshine hours
February, 1987	35.6	22.8	57	35.6	10.30
March	36.4	22.2	55	36.2	10.20
April	36.2	25.3	64	37.5	7.97
May	36.1	24.7	66	35.9	8.68
June	30.7	23.7	83	27.6	4.53
July	30.3	23.5	84	25.4	5.67
August	29.6	23.5	87	28.6	3.66
September	31.5	23.9	79	31.1	6.72
October	31.9	23.9	79	30.2	7.66
November	31.6	22.8	77	29.3	8.11
December	31.6	23.3	70	29.3	7.81
January, 1988	32.4	22.0	56	30.4	9.20
February	35.8	23.1	56	36.2	9.80
March	35.7	24.4	67	35.8	10.10
April	35.1	24.3	70	36.8	8.30

EFFECT OF GROWTH REGULATORS ON ROOTING OF DIFFERENT TYPES OF PLANTING MATERIALS IN BLACK PEPPER (*Piper nigrum.* L.)

By

GIGI ELIZABETH CLARAFRANCIS

ABSTRACT OF A THESIS

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ABSTRACT

Systematic studies were carried out in Centre for Advanced Studies, College of Horticulture, Vellanikkara to study different aspects of rooting of cuttings and anatomy of the root initiation and development in black pepper. For propagation studies, four different types of planting materials viz., runners (stolons), growing shoots (orthotrophs), hanging shoots (geogrophs) and laterals (plageotrophs) were treated with Seradix-B, IAA, IBA and IAA + IBA combination each at 500, 1000 and 1500 ppm concentrations planted under mist and open conditions. The results revealed that in all the planting materials IBA 1000 ppm treatment was superior with regard to rooting percentage and other root growth parameters such as number, length, fresh weight and dry matter production of roots.

Regardless of the growth regulator treatments, mist had pronounced influence on root growth in all the planting materials. However, mist decreased the shoot weight and shoot/root ratio particularly in the final stages of observation.

All the planting materials except laterals rooted readily during March but laterals recorded maximum rooting during June. Though there was not much difference among the planting materials with regard to their rooting ability, laterals were shy rooters and produced roots only after six weeks of planting while all other types produced roots readily within three weeks of planting.

For anatomical studies, rooting regions of the cuttings from all the treatments were used. The tissue origin of roots was found to be the parenchyma situated in the interfascicular region and three steps were identified in the process of root development. Structure of the stem and roots were also studied and described.