EFFICIENCY OF ROOTING HORMONES ON PROPAGATION OF DIFFERENT BAMBOO SPECIES
(*Dendrocalamus strictus* and *Bambusa vulgaris*)

A

THESIS

SUBMITTED TO

NAVSARI AGRICULTURAL UNIVERSITY

NAVSARI

IN PARTIAL FULFILMENT OF THE REQUIREMENTS

FOR

THE AWARD OF THE DEGREE

OF

MASTER OF SCIENCE (FORESTRY)

IN

AGROFORESTRY

BY

MESARIYA BHAVESHKUMAR DEVENDRABHAI

B. Sc. (Forestry)

DEPARTMENT OF SILVICULTURE AND AGROFORESTRY

ASPEE COLLEGE OF HORTICULTURE AND FORESTRY

NAVSARI AGRICULTURAL UNIVERSITY

NAVSARI

GUJARAT STATE

April – 2013

Registration No. 04-1051-2011

ABSTRACT

Efficiency of rooting hormones on propagation of different bamboo species (*Dendrocalamus strictus* and *Bambusa vulgaris*)

Name of Student	Major Advisor
Mr. Mesariya Bhaveshkumar D.	Dr. M. B. Tandel

DEPARTMENT OF SILVICULTURE AND AGROFORESTRY
ASPEE COLLEGE OF HORTICULTURE AND FORESTRY
NAVSARI AGRICULTURAL UNIVERSITY
NAVSARI – 396 450

ABSTRACT

The present research work was carried out to study the "Efficiency of rooting hormones on propagation of different bamboo species (*Dendrocalamus strictus* and *Bambusa vulgaris*)" during March 2012 to November 2012 at Green House Complex, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari (Gujarat).

The experiment was conducted with Randomized Block Design having twenty one treatment combinations, two bamboo species and three replications. The treatments comprised of four levels of each IBA, NAA and their combinations along with control. In each replication nine cuttings were selected for growth hormone treatments. The rooting hormone solution was poured into the segment cavity of the culm cuttings and the holes were closed by wrapping and tying a polythene strip. The treated culm cuttings were planted with the medium comprised of soil, sand and vermicompost in 2:1:1 ratio, respectively.

Among various concentrations of IBA, NAA and their combinations, NAA 100 ppm proved best treatment for obtaining

higher percentage of sprouting and rooting, number of leaves per plant, number of roots per plant, root length, collar diameter and length of sprout as well as earlier sprouting. The next best treatment in order to response was T_{20}: NAA 75 ppm + IBA 100 ppm.

(M.B.TANDEL)
Assistant Professor (Forestry)
ASPEE College of Horticulture and Forestry
Navsari Agricultural University
Navsari- 396450

CERTIFICATE

This is to certify that the thesis entitled "**EFFICIENCY OF ROOTING HORMONES ON PROPAGATION OF DIFFERENT BAMBOO SPECIES (*Dendrocalamus strictus* and *Bambusa vulgaris*)**" submitted by **Mr. Mesariya Bhaveshkumar Devendrabhai** in partial fulfilment of the requirements for the award of the degree of **MASTER OF SCIENCE (FORESTRY)** in the subject of **AGROFORESTRY** of Navsari Agricultural University is a record of bona fide research work carried out by him under my guidance and supervision and that the thesis has not been previously formed the basis for the award of any degree, diploma or has been published for other similar title. All the assistance and help received during the course of the investigation have been duly acknowledged by him.

Tandel M.B

Place : Navsari **(M. B. Tandel)**

Date : 20.04.2013 Major Advisor

DECLARATION

This is to declare that the whole of the research work reported here in the thesis for the partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE** in **FORESTRY** by the undersigned is the result of investigation done under the guidance and supervision of **Dr. M. B. Tandel**, Assistant Professor (Forestry), ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari and no part of the work has been submitted for any other degree so far.

Place : Navsari

Date : 20.04.2013

(B. D. Mesariya)

Countersigned by

(M. B. TANDEL)
Assistant Professor (Forestry)
ASPEE College of Horticulture & Forestry
Navsari Agricultural University
Navsari- 396450

ACKNOWLEDGEMENT

Firstly, I would like to express my enormous indebtedness and deep sense of gratitude to the GOD for providing me spiritual exuberance ad infinitum.

It gives me immense pleasure to express my deep sense of gratitude to my major advisor Dr. M. B. Tandel, Assistant Professor (Forestry), ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari for his ardent concern, stirring guidance and assiduous assistance during the investigation and in the preparation of this thesis. His fatherly guidance and encouragement buoyed me all along and helped me in every respect in M. Sc. (Forestry) studies and research work. No words are ample to express my thanks to him. Special thanks are reckoned for his counsel, generous guidance and useful suggestion to the minor advisor: Mr. Jayesh Pathak Assistant Professor (Agroforestry), ASPEE College of Horticulture and Forestry N.A.U. Navsari. I am highly grateful to other members of my advisory committee: Dr. B. K. Bhatt, Associate Professor (Agricultural Statistics), Dr. D. B. Jadeja, Professor & Head (Silviculture & Agroforestry), N. A. U. Navsari, for their help and support during my M. Sc. studies. I am also grateful to Dr. S. K. Jha, Mr. M. R. Parmar, Mr. S. M. Patel and Mr. M. K. Desai for their valuable suggestions and help during the studies.

I would like to express my greatest sense of gratitude to Director of Research & Dean P. G. Studies ***Dr. A. N. Sabalpara*** *for approving my research and valuable suggestions offered by them for quality research work.*

I am beholden to the Principal and Dean of our college **Dr. N. L. Patel** *for providing me all the facilities required for the research work.*

I deeply render my gratitude to my seniors Mr. Paresh Gaykwad, Ms. Vishnu Solanki. Though thanks is a taboo in friendship, my conscience does not permit to refrain myself from expressing my heartfelt feeling towards my beloved friends Mr. Umesh Parmar, Mr. Jigar Panchal Mr. Hiren Patel, Mr. Jigar Jani, Mr.Dharamshi Prajapati, Mr. Durga Singh and Ms. Nilam Surve. I am grateful to my contemporaries Mr. Jignesh Bhusara, Mr. Ramesh Sondarva, Mr. Hershal Bhasotiya, Mr. Tufanshi Muniya, Mr. Yuvraj Dindor, Mr. Bhavin Choudhary, Mr. Mayur Bhagora, Mr. Hiraj Patel, Mr. Mittal Patel and many others who are in my heart for their amicable company, warmer affection and co-operation whenever required.

My vocabulary fails to get the words to express my respect and sense of gratitude towards my beloved family members, my father and mother, my sister and my fiancee for their constant inspiration and endorsement and buoyant sharing the challenges in various ways during the period of my M.Sc. studies.

I am thankful to all who helped me directly or indirectly during the course of my study.

Place: Navsari

Date: 20.04.2013

(B. D. Mesariya)

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDIX

INTRODUCTION

I. INTODUCTION

Bamboo is a multipurpose, fast growing woody species, which occupies an important place in the diverse phases of life and culture of the people. It is the most universally useful plant known to man. It is fascinating to the craftsman, poet, artist and scientist alike. Bamboo is said to be poverty alleviator. The multiple uses of bamboos for food, fodder, raw material for pulp and paper industry, handicraft industries, construction, windbreaks and in preventing soil erosion make it ideal choice for social and agroforestry plantations. Bamboo is a cultural feature of South-East Asia. No country in the region is without an indigenous bamboo flora. Its plethora of essential uses has led to the use of terms such as "bamboo culture", "green gold", "poor man's timber", "bamboo friend of the people" and "the cradle to coffin timber".

Bamboo is monocotyledonous perennial grasses and most diverse group of plants in the grass family and the most primitive sub-family belonging to sub family Bambusoidae of the family (Gramineae). They are distinguished by having woody culms, complex branching, robust rhizome system and infrequent flowering, Cultivation of bamboo has attracted a great deal of interest in recent years. The National Bamboo Mission (NBM) envisages covering an area of 1.7 lakh hectare which will require over 70 million plants in India (Haridasan and Tewari, 2008). In addition the requirements from other governmental and non-governmental organisation and farmers are also very high and require immediate attention for propagation of quality bamboos on large scale.

In India, there are 23 genera and 130 species of bamboo, occupying about 10.05 million ha of land, which contribute about 12.80 % of the forest area of the country (Sharma, 1987). Propagation of bamboo is mainly carried out by seeds and most of the bamboo species come under flowering after 20-120 years which limit their propagation (Mandal and Subramanian, 1992). Seed viability is for short period of time, which further restricts their propagation (Tewari, 1992). Vegetative propagation has potential to capture traits of superior candidate plus clumps or genotypes by producing genetically true to type plants to mother plant as well as production of planting material without depending upon seed.

Flowering cycle of the *Dendrocalamus strictus* is 35-40 years. The clump or plant dies after flowering without setting any seed thus making vegetative propagation a must in *Dendrocalamus strictus*, *Bambusa bamboos*, *Bambusa arundinacea* and *Bambusa vulgaris*. The species is therefore propagated vegetatively by branch and culm cuttings. Rooting of culm cuttings is however, affected by a number of factors like species, age, season, position, source of planting material, auxin levels, growing condition, *etc.*, which act independently as well as in combination (Joshi *et al.* 2012).

Propagation of Bamboos is normally done vegetatively through offshoots and rhizomes. Most of the bamboo species flower after long duration (20-60 years) and therefore the seeds are not readily available. There are few reports (Seethalakshmi *et al.* 1983; Surendran *et al.* 1983) suggesting that bamboo culm cutting can be used for propagation after treatment with growth regulating substance leads to induction of shoots and roots at the node region of the cutting and they can be used as planting materials. Thus culm cutting can be used for propagation and will be relatively more convenient, economical and large number of planting material will be available in short time.

Large structure of bamboos of the genera *Bambusa* and *Dendrocalamus* are well known to be very important in the rural economy of Nepal (Stapleton, 1982), being multipurpose species which provide constructional materials, animal fodder, fuelwood, food and woven products for agricultural and domestic purpose, as well as baskets for transport of most commodities beyond the road heads in the hills. They have been selected by the community forestry development project as priority species requiring particular attention (Tystjarvi, 1981).

Planting large bamboos has in the past been severely restricted by lack of seed, lack of knowledge concerning satisfactory vegetative propagation techniques and a complete lack of knowledge of the distribution, uses and site requirements of Nepalese species. Considerable knowledge has been gained of the most important species including their flowering and seeding habits and also the potential for propagating them from short culm sections as well as by the traditional rhizome plus long culm section used almost exclusively in Nepal until very recently (Stapleton, 1985a).

Short culm cuttings offer many advantages over the traditional cuttings, (Stapleton, 1985b). An average clump may provide only about five traditional cuttings each year without a severe reduction in clump vigour and productivity, while up to one or two hundred culm cuttings can be taken without affecting clump productivity or disturbing the rhizome system at all by short culm cuttings. Traditional cuttings can weigh up to 40 kg each, making transport extremely difficult while short culm cutting weighs about half a kilogramme or less. Traditional cuttings retain certain advantages however (Stapleton and Tamrakar, 1984): nursery facilities are not required, survival is very good even under extremely arduous condition, protection against grazing animals is much easier and establishment is potentially a little quicker.

Culm cuttings are preferred as planting materials for nursery raising of large sized and thick walled bamboo species. However, raising bamboos by culm cutting is destructive process as it requires many culms to be harvested which ultimately affects the clump productivity. Contrary, branch cutting, if used carefully as propagating material can be less destructive and cost effective (Banik, 2008). Further, branch cuttings could also be useful approach due to ease in its availability and handling. The present study was thus an effort to study the rooting pattern of different bamboo species using culm cutting as propagation material.

Propagation through culm cuttings is the most feasible and advantageous method over traditional methods. A few traditional cuttings can be obtained per clump each year while several hundred 1-2 nodal culm cuttings can be extracted throughout the year without affecting the clump productivity or disturbing the rhizome systems. Medina *et al.* (1962) propagated *B. vulgaris* var. vittata through culm cuttings.

The advantage of branch cuttings of bamboos are that farmers in large numbers, can easily adopt it. Propagules can be obtained without cuttings of culm and are easy in their handling. The present study describes efficient vegetative propagation technique via culm cutting in *Dendrocalamus strictus* and *B. vulgaris* with the following objectives;

i. To find out best rooting hormones for bamboo.
ii. To evaluate the effect of different growth hormones on sprouting of bamboo.
iii. To find out optimum level of rooting hormones to be used for rooting of bamboo.
iv. To develop macro propagation technique for bamboo.

REVIEW

OF

LITERATURE

II. REVIEW OF LITREATURE

Many plants are propagated commercially through vegetative means. In vegetative propagation, vegetative parts of the plant are used for propagation. It is possible because all the living cells of a plant have a capacity to regenerate into a full plant under favorable environmental conditions. The plants produced through vegetative means are therefore genetically identical and similar to the mother plant, possessing all the characteristics of the mother plant. Vegetative methods produce genetically identical individual plants. Raising of plants through cuttings is a simple, quick and cheap method of plant propagation. Many kinds of plants can be propagated through cuttings.

A cutting is any part of a plant, which when put in suitable propagation medium becomes an individual plant in its own right, similar to the mother plant part. Most plants are raised by stem cuttings, but in some cases plants can also be propagated from their leaves, buds or root cutting. The plant part to be used as cutting chiefly depends upon the growing habit of the plant. However, any plant part taken for cutting, it must reproduce into full plant. As the rooted cuttings will be identical to its parent, great care should be taken while selecting the parent plant from which cuttings are to be taken. A poor growing, spindly plants are unlikely to produce a prized specimen from a cutting. Similarly, diseased or unhealthy plants also do not produce good cuttings. Therefore, healthy and strong growing plants should be selected if these are to be utilized for the preparation of cuttings.

2.1 Effect of auxins on *Bamboo species*

McClure (1966) stressed the need for new rooted shoots to develop before success had been obtained and showed that only inside the dormant buds is the meristematic tissue capable of achieving this. In this way bamboos differ from dicotyledonous plants which can produce roots from the ample supply of meristematic tissue widely distributed as inter-fascicular cambium. Understanding of this is fundamental for successful propagation in bamboos. He also noted the need for sufficient reserves in the culms, necessitating the use of older material.

Seethalakshmi *et al.* (1983) revealed that lateral branch and culm cutting of commercial bamboo when treated with particular growth promoting substance than it rooted and survived while the control failed to root. Coumarin, NAA and a mixture of coumarin and IAA gave the highest percentage of rooting as well as survival after transplanting in the field. Branch and culm material are more economical and convenient to develop large scale vegetative propagation of bamboos than the conventionally used offset and rhizome material.

Nath *et al.* (1986) utilised one year old, two noded culm cutting of *Bambusa balcooa, B. tulda, B. vulgaris,* *Dendrocalamus hamiltonii* ~~and *Teniostachyum*~~ *dullooa* for vegetative propagation. Internodal cavities of the culm cutting were filled with different chemicals (IAA, NAA, GA_3, Boric acid and Kinetin) alone or in combination in different concentration and planted horizontally. Induction of shoots and roots were observed after 10-15 days of planting. Best result with respect to induction of shoots and roots were observed when treatments were made with IAA + Kinetin in *B. balcooa, D. hamilitoni* and *B. vulgaris*, whereas NAA + Kinetin gave best result in *B. tulda* and *T. dulloa*. The study further indicates that culm cuttings can be utilised for vegetative propagation of the bamboo species mentioned above in different season of the year when irrigation facilities are available.

Saharia and Sen (1990) noted that culm cutting of bamboo can be used successfully as an alternative method of vegetative propagation for large scale plantation. Survival per cent of culm cutting varies significantly for different species. Cutting of two years old bamboo culms give higher survival percentage than one year or three year old culm cuttings.

Kumar *et al.* (1990) stated that the cuttings treated with NAA and Coumarin as well as distilled water responded to flower development, but those treated with boric acid did not show any indication of flowering. None of the cuttings responded to rooting. However, an enhancement in the flower production was discernible under different treatments as compared to control. The August planted cuttings did not produce any flowering but rooted, sprouted and showed rhizomegenesis as reported earlier, whereas the production of flowering in November planted culm cuttings as well as in mother clumps showed that the entire mother clump reached in induced state spontaneously between August and November.

Kumar *et al.* (1991) carried out a study of eight months i.e., August to March on vegetative propagation of *Dendrocalamus strictus* through macro-proliferation was extended by another four months i.e., April to July in order to study the growth behaviour in full one year. It was found that sufficient number of field plantable propagules can be developed through seedling multiplication. The propagules thus produced planted in the field established well and showed Culm formation in six months.

Kumar (1991) developed technology for production of field planting stock in *D. strictus* on mass scale. The advantage of this technology is that it is simple, easy, quick and involves the use of locally available materials. The planting stock developed with this technology, planted in the field established well and have shown vigorous growth and culm formation in 6 months. A plan has been developed to produce 36,000 field plantable seedlings of *D. strictus* through macro proliferation every year for several years without seed. Depending upon the facilities available the target for production of planting stock can be increased in the multiples of 36,000 each year. The dependence on bamboo seed is totally eliminated for mass production of field plantable bamboo planting stock from second year onwards. The planting stocks developed through macro proliferation remain small in size which is additional advantage as these are easy to handle and transport.

Nath and Das (1995) studied the vegetative propagation of *Dendrocalamus membranaceus* through seedling proliferation and juvenile culm cuttings at seedling stage with a view to obtain plantable saplings in massive numbers. It was observed that mother stock seedlings can be multiplied more than nineteen times without addition of fertilizer within one year. Rooting and sprouting from juvenile culm cuttings were inducted by growth promoting substance though differentially. Successful sprouting and rooting of culm segments collected from *D. membranaceus* seedlings had further augmented the availability of planting stock.

Agnihotri and Ansari (2000) carried out a study to investigate adventitious rhizogenesis in culm branch cutting of *Bambusa vulgaris* var. striata and *Dendrocalamus strictus* as influenced by seasonal variation, size of cutting, IAA treatment and their all possible interaction. Adventitious rhizogenesis in both species was found to be season specific and the cutting size and IAA treatment helped in optimizing rooting behaviour during responsive warm season of the year. April x 100 ppm IAA x Double or triple nodal cutting and

February x 100 ppm IAA x Double nodal cutting were recommended for large scale vegetative propagation of *B. vulgaris* var. striata and *D. strictus*, respectively.

Singh *et al.* (2002) worked on the suitability of culm and culm-branch cutting for adventious rooting under the influence of various auxin treatments in view of the problem of inadequate adventitious rhizogenesis in *Bambusa nutans*. Induction and growth of adventitious rhizogenesis in both type of cutting was noted to be more in April than May. However, culm cutting exhibited markedly better adventitious root formation and growth, compared to culm-branch cuttings. The cutting responded more positively to exogenous auxin treatments in the month of May and administration for 24h of 2.0 mM indole 3-butyric acid consistently enhanced adventitious rooting in both months.

Kumar and Pal (2003) conducted a study to estimate the carbohydrate content in bamboo culm in relation to rooting potential. The findings indicate that in *Dendrocalamus strictus*, the carbohydrate content is not directly related to rooting potential of cuttings. Hence, some other factors may be responsible for initiating the rooting in culm cuttings.

Somashekar *et al.* (2004) studied on effect of type of cuttings, concentrations and mode of auxin (IBA) treatments. Leafy culm branch cuttings with shoot apex of 10-

15 cm in length with 2/3 rd trimmed leaves, treated with IBA 2500 ppm (talcum based IBA powder) induced maximum (85.00 %) rooting within 30 days in sand bed medium under intermittent misting, at 30±5^{0}c temperature and 70±5% relative humidity in mist chamber. Whereas, nodal (culm) cuttings of 5-6 cm in length and 3-4 cm in diameter exhibited maximum (80%) rooting by pulse treatment with 2500 ppm IBA solution within 45 days period. Rooted cuttings grew vigorously in 600 cc single cell root trainers containing compost, sand and soil (10:7:3) formation was observed within 4 months period. Further multiplication (3-4 fold) can be achieved by separating tillers (1-2) with roots and rhizome from the four months old rooted cuttings in root trainers. About five hundred plants were produced by these methods. Method described could be used for large scale macro propagation of *Guadua angustifolia*.

Nain *et al.* (2007) conducted an experiment with a view to evolve cloning procedure for *Bambusa multiplex*, *Bambusa tulda* and *Bambusa vulgaris* single node culm cuttings to four different treatments for 24h *viz.*, water or 1, 2 and 4 mM NAA. The treated cuttings were horizontally placed and covered completely with sand in ground beds of low-cost mist chamber. After two months, the cuttings were scored for adventitious rooting percentage, root number and length. Significant influence of graded concentration of NAA on adventitious rhizogenesis was observed. In *B. tulda* and *B.*

vulgaris the treatment of 4 mM NAA to culm cuttings proved superior for root induction while 2 mM was found best for rooting in *B. multiplex*.

Dubey *et al.* (2008) developed a technique for production of quality planting of *B. vulgaris* var. vittata, *B. balcooa, B. bamboos, B. nutans, B. tulda* and *D. hamiltonii* through two noded culm cutting with macro proliferation which yields planting stock with survival rate of 90-100%. Through this simple technique from a single bamboo node to 180 numbers of bamboo saplings (propagules) can be produced in a year (April to March) pending upon the species selected. The best part of the techniques is that it can produce bamboo planting stock round the year without involving many technicalities.

Kaushal *et al.* (2011) studied primary and secondary branch cuttings of eight different bamboo species viz. *Bambusa balcooa, B. bamboos, B. nutans, B. vulgaris, Dendrocalamus asper, D. giganteus and D. hamiltonii* for their rooting potential. Primary branch cuttings were given 200 ppm IBA treatment and control treatment for 8 hours. Secondary branch cuttings were treated with 4000 ppm IBA for one minute. The study revealed following order of rooting: *B. vulgaris* > *B. balcooa* > *D. hamiltonii* > *D. giganteus* > *B. bamboos* > *B. tulda* > *B. nutans* > *D. asper*. Application of 200 ppm IBA was found to enhance the rooting and sprouting parameters. In secondary branch cuttings, all the species except *B. vulgaris* failed to produce root.

Razvi *et al.* (2011) carried out an experiment to develop the farmer's friendly protocol for mass multiplication of *Bambusa vulgaris* through *ex vitro* methods. During the study rooting was obtained in three seasons except winter season and the variation in all the physiological characters with seasons and treatments were significant at $P<0.001$. Maximum average (62.00 %) rooting percentage and (24.41 cm) root length was found in rainy season followed by summer season with average (50.33 %) rooting percentage and (15.31 cm) root length. However, (47.33 %) rooting percentage and (16.80 cm) root length was achieved in spring season. Among the three auxins used for pre-treatment, IBA showed more positive response on rooting as compared to IAA and NAA. In winter season no rooting and sprout were observed in any treated cuttings.

Hossain *et al.* (2011) carried out a low-cost propagation trial to explore the clonal propagation techniques for the species with two types of small branch cuttings - nodal leafy cuttings and tip cuttings. The cuttings were treated with 0%, 0.1%, 0.4% and 0.8% IBA solutions and kept in non-mist propagator for letting them root with the objective of assessing the rooting ability. The cuttings were rooted in four weeks and were allowed to grow in the polybags for ten months under nursery condition to assess their steckling capacity. The study revealed that both types of branch cuttings are able to develop roots, shoots, to survive and to form rhizome in the nursery condition. Rooting ability of the cuttings was significantly enhanced by the application of rooting hormone - IBA. The highest rooting percentage in nodal leafy cuttings and the tip cuttings (56.67 and 51.0, respectively) were observed in 0.8% IBA treatment followed by 0.4% IBA and the lowest (34.3 and 30.0 respectively) was in control. The highest number of root developed per cutting (9.77 and 8.33 in nodal leafy cuttings and the tip cuttings, respectively) was also obtained from the cuttings treated with 0.8% IBA solution followed 0.4% IBA treatment and the lowest (3.1 and 2.1 respectively) was in the cuttings without treatment. However, the length of the longest root varied significantly neither with the cutting types nor the concentrations of IBA solution. Survival percentage of the stecklings in nursery condition was significantly enhanced by IBA.

Joshi *et al.* (2012) conducted a study to investigate the effect of age (one and two year old), growing condition (intermittent misting and no misting) and season (summer, monsoon, autumn and spring) on rooting behaviour of culm cuttings of *Bambusa balcooa*. The findings indicated that two year old culm cuttings in the intermittent misting condition gave best response. The findings also indicated that rooting and sprouting percent of culm cuttings planted in different season showed response as spring (March) > summer (June) > monsoon (August) > Autumn (October).

2.2 Effect of Auxins on Acacias

Khosla *et al.* (1982) recorded maximum callus formation in *Acacia catechu* during monsoon period when cuttings were treated with IBA @ 500 ppm.

Rooting trials were carried out using branch cuttings obtained from seven year old plants of *Acacia nilotica* with four different Auxins in three different concentrations and replicated under different shade house environment, open condition and polytunnel. IBA @ 200 ppm was found to be most effective with 40 per cent rooting in cuttings made in the month of September (Gurumurti *et al.* 1994).

Kumar (2000) developed a vegetative propagation protocol to multiply *Acacia mangium* through rooting of cutting, using four concentrations of IBA and IAA. He found 2000 ppm IBA to be the most promising dose with a rooting success of 76.00%.

2.3 Effect of Auxins on Teak

Bhatnagar and Joshi (1978) tested the effects of 50 and 100 µg/l concentrations of IAA and IBA or IPA (Indole Propionic Acid) on rooting of teak cuttings. All the treatments generally promoted rooting and callus formation. However, IBA @ 100µg/l induced maximum rooting in cuttings.

Nautiyal *et al.* (1991) studied the influence of season and growth hormones in the rooting response of *Tectona grandis* branch cuttings. They reported that the best rooting response was observed in May-planted cuttings and the maximum (60.00 %) rooting occurred under NAA 100 and NAA 200 + IBA 200 ppm treatments in the cuttings collected from seedling-raised plants. While in the cuttings from mature trees, the maximum root length of *Tectona grandis* was found under NAA 200 + IBA 100 ppm (cuttings were dipped for 24 hours).

2.4 Effect of auxins on Dalbergia

Rana *et al.* (1987) applied IBA and NAA at 100 and 500 ppm concentrations on stem cuttings and observed 40.00 % rooting at 500 ppm IBA followed by 25.00 % rooting at 100 ppm IAA over control in September planted set.

Gupta *et al.* (1993) reported that the cuttings taken from four years old plants rooted better when planted in the month of-August in comparison to other months. A substantial increase in the percentage (90.00) of rooting occurred when treated with IBA 100 ppm followed by 200 ppm over control. The cuttings from younger plants rooted readily and rooting percentage fell appreciably in the old tree (30 years).

Kulkarni and Takawale (1999) studied the rooting response of juvenile single node cuttings of *Dalbergia sissoo*. The combination of IBA 2500 ppm + Kinetin 1250 ppm gave highest rooting percentage (61.66 %). While, highest value for average number of roots (6.07) and average length of longest root (8.45 cm) were recorded in IBA 2500 ppm treated roots.

Sharma and Pandey (1999) examined the effect of 2000, 5000 and 8000 μg/l IBA on rooting of shoot cuttings of *Dalbergia latifolia* and *Dalbergia sissoo*. IBA @ 5000μg/l was found to be an effective treatment in promoting rooting and also significantly influenced on all other rooting parameters.

Bakshi (2008) worked on single nodal softwood cutting of *Dalbergia sissoo* obtained from vegetative multiplication garden (VMG) with 100%, 50% and 0% leaf area representing full leaf, half leaf and leafless cuttings were propagated under mist chamber following treatment with Indole Butyric Acid (IBA) 2000 ppm. After six weeks of planting, data on rooting, sprouting and allied parameters were noted. The best rooting and sprouting was observed in 100.00 % (Full) leaf area in almost all clones followed by 50.00 % (Half) leaf area. Cuttings without leaf showed poor response in some clones and died in others.

Singh and Bhatt (2009) stated that the branch cutting of *Dalbergia sissoo* collected from higher elevation populations exhibited higher percent of rooting as well as other growth parameters as compare to those from lower elevation. On an average there was 25.00 % rooting with maximum (45.00 %) rooting recorded in the cuttings from Lacchiwala and Fatehpur source. The rooting and growth behavior were significantly ($p<0.05$) positively correlated with source of cutting.

2.5 Effect of Auxins on other species

Surendran (1990) studied the effect of 100 and 1000 ppm IBA concentrations on brown-wood and greenwood cuttings collected from a three years old *Gmelina arborea* tree. He reported that application of IBA 100 ppm gave rooting response up to 73.30% and 1000 ppm up to 60.00 % in brown-wood cuttings over control (26.70 %).

Singh and Dhuria (1992) treated the cuttings of *Gmelina arborea* with 250, 500, 1000, 2000, 4000, 6000, 8000 and 10,000 ppm of IBA. They found better influence of IBA on rooting of branch cuttings as compared to control. IBA 8000 ppm produced maximum percentage of rooted cuttings (83.30 %), average number of roots (12.70) and average number of shoots (23.60) as compared to control (50.00 %) under mist condition during the rainy season (June-September).

Singh *et al.* (2003) studied the effect of two categories of branch cuttings of *Commiphora wightii* when treated with different concentrations of IBA 4000 and 5000 ppm and commercial grade rootex. The maximum rooting percentage (56.94 %) was recorded in medium sized cuttings (length 15-20 cm and width 5-7 mm) when treated with 5000 ppm of IBA. Whereas, minimum (12.28 %) rooting was observed in cuttings treated with commercial grade rootex.

Singh *et al.* (2006) studied the effect of cuttings of approximately 20 cm length and 1.0 cm diameter treated with equimolar (2Mm) dose of IBA, sodium acetate, ascorbic acid and thiamine for 24 hours by basal dipping. After planting, observations were recorded for sprouting per cent, root number, root length and root sprout ratio. Cuttings treated with IBA @ 500 ppm significantly induced adventitious rooting (up to 67 %) in *Grewia optiva.*

Aslam *et al.* (2007) stated that IBA @ 500 ppm performed best over all the treatments regarding rooting behavior *viz*; callusing percentage, rooting percentage, number of roots and length of roots per cutting of *Taxus baccata.*

Madhwal *et al.* (2008) observed *Terminalia chebula* cuttings treated with IBA 4000 ppm having maximum rooting (55.00 ± 10.00 %) while maximum root length was given by cuttings treated with IBA 1000 ppm (8.22 ± 1.37 cm).

Lemay and McCoy (2009) studied the effect of Auxin treatments in the rooting of cuttings of *Cloezia buxifolia* and *Cloezia aquarum*. IBA 10g kg^{-1} was found to be the best for *Cloezia buxifolia* and 20g kg^{-1} IBA was found to enhance quantitatively and qualitatively rooting of both tip and stem cuttings.

MATERIALS

AND

METHODS

III. MATERIALS AND METHODS

The details of the materials used and experimental methods followed during the course of the present investigation are narrated briefly in this chapter.

3.1 General

3.1.1 Experimental site

The present investigation entitled "Efficiency of rooting hormones on propagation of different bamboo species (*Dendrocalamus strictus* and *Bambusa vulgaris*)" was conducted during March - 2012 to November - 2012, at the Green House Complex, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, which is situated at an altitude of about 12 meters above mean sea level, 20^0–58' North latitude and 72^0–54' East longitude. The site experiences typical tropical climate characterized by hot summer, moderately cold winter and humid warm monsoon. Most of the precipitation is received from South West monsoon, concentrated during the months of June, July and August. The temperature during experiment varied from 18.3^0 to 40.0^0. The average figures of the meteorological observations recorded during the course of investigation, are presented in Appendix -I.

3.2 Experimental details

In this experiment, the effect of two forms of Auxins (NAA and IBA) and combination of both on the performance of culm cuttings of *Dendrocalamus strictus* and *Bambusa vulgaris* were studied.

3.2.1 Layout of the experiment

The design of the layout was Randomized Block Design (RBD) with three replications. Nine cuttings of each treatment under each replication were planted. The planting media was sand, soil and vermicompost in 2:1:1 ratio. The details of the treatment are given below.

3.2.2 Details of treatments

3.2.2.1 Treatments

	PGR	Concentration in ppm
T_0	Control	Distilled Water
T_1	NAA	25
T_2	NAA	50
T_3	NAA	75
T_4	NAA	100
T_5	IBA	25
T_6	IBA	50
T_7	IBA	75

T_8	IBA	100
T_9	NAA + IBA	25 + 25
T_{10}	NAA + IBA	25 + 50
T_{11}	NAA + IBA	25 + 75
T_{12}	NAA + IBA	25 + 100
T_{13}	NAA + IBA	50 + 25
T_{14}	NAA + IBA	50 + 50
T_{15}	NAA + IBA	50 + 75
T_{16}	NAA + IBA	50 + 100
T_{17}	NAA + IBA	75 + 25
T_{18}	NAA + IBA	75 + 50
T_{19}	NAA + IBA	75 + 75
T_{20}	NAA + IBA	75 + 100

3.2.2.2 Total number of treatments : 21

3.2.2.3 Number of replication : 3

3.2.2.4 Number of species : 2

i. *Dendrocalamus strictus*

ii. *Bambusa vulgaris*

3.2.2.5 Date of planting of cuttings:

The cuttings were planted in ~~bed during~~ the spring season on 20th March, 2012; water was applied with the help of watering-can on the day of planting and also applied regularly as when required.

3.3 Preparation of cuttings

i. Segments are selected from the lower to mid zone of the two year old culm. The upper part and the lateral branches of the upper culm are discarded.

ii. The branches on the selected part of the culm are cut and care being taken not to injure existing buds (Plate - I).

iii. A segment is cut with a sharp knife or saw. Avoid splitting at the cut (Plate - I) especially in thin walled species. Keep 5-10 cm on either side of the node.

iv. Immediately after cutting, wax the cut ends to minimise water loss from cut ends.

3.4 Preparation of growth substance solution

The 1000 ml solutions of 25, 50, 75 and 100 ppm of NAA and IBA were prepared by dissolving 25, 50, 75 and 100 mg of NAA, respectively with addition of small quantity of NaOH solution. This solution was then diluted with double distilled water to make 1000 ml. Separately, 1000 ml of each

Plate-I : Preparation of culm cuttings

solution of NAA and IBA was taken and they were mixed in all possible ways to make their combinations.

3.5 Application of treatments to cuttings and planting

3.5.1 Application of treatments to cuttings

Culm cuttings having 3 nodes were selected and 2 holes each of 5 mm diameter are drilled in the centre of the internode. A rooting hormone solution is poured into the segment cavity and the holes are closed by wrapping and tying a polythene strip.

3.5.2 Planting of cuttings and after care

Culm cuttings are placed horizontally in the bed, spaced 15-30 cm apart from those of another cutting (Plate - II). The cuttings are placed in the top fine sand layer about 3-5 cm above the coarse sand and covered by 3-6 cm of the fine sand. Watering was regularly done using watering-can.

3.6 Observations to be recorded

The cuttings were uprooted carefully after 90 days of planting without damaging the roots. The roots were then washed thoroughly with the help of water to remove the soil stick on them for further observations, which are as follows:

3.6.1 Percentage of cutting sprouted (%)

The percentage of sprouted culm cuttings were calculated by dividing the number of sprouted culm cuttings

Plate-II : Planting of culm cuttings

Plate-III : General view of experimental area

A. *Dendrocalamus strictus*

B. *Bambusa vulgaris*

with the total number of culm cuttings planted and multiplied with hundred.

3.6.2 Percentage of cutting rooted (%)

The percentage of cuttings rooted were calculated by dividing the number of culm cuttings rooted with the total number of culm cuttings planted and multiplied with hundred.

3.6.3 Number of leaves per plant

The total number of leaves per plant in all the culm cuttings under each treatment was recorded and average number of leaves per culm cutting was worked out.

3.6.4 Number of roots at the end of experiment (cm)

Total number of roots in all the culm cuttings under each treatment was recorded and mean number of roots per rooted cuttings was worked out.

3.6.5 Length of roots (cm)

Length of roots of culm cuttings was measured to the nearest centimeter with the help of wooden measuring scale.

3.6.6 Days taken for initiation of first sprouting

The number of days required to sprout of cuttings was recorded from each treatment of all three replications and average was worked out.

3.6.7 Length of sprout at the end of experiment (cm)

Length of spout at the end of experiment was measured to the nearest centimeter with the help of wooden measuring scale.

3.6.8 Collar diameter of sprout (mm)

Collar diameter of the sprout was measured from the ground level up to nearest mm with the help of digital caliper.

3.7 Statistical analysis and interpretation of data

The experimental data of all the characters studied were subjected to the statistical analysis for proper interpretation. A standard method of "Analysis of Variance" was used for analyzing the data appropriate to this design of the experiment. Test of significance suggested by Panse and Sukhatme (1967) was used.

Critical difference (C.D) was calculated for comparison in the case where "F" test was significant. Suitable graphical illustration of the data is presented at appropriate places.

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

"Efficiency of rooting hormones on propagation of different bamboo species (*Dendrocalamus strictus* and *Bambusa vulgaris*)" was studied in the Greenhouse complex, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari. The salient results are furnished below:-

4.1 Percentage of cuttings sprouted (%)

The data related to percentage of cuttings sprouted in bamboo are presented in Table - 4.1 and depicted in Fig.1. The data reveals that on an average various levels of auxins had a pronounced effect on cuttings sprouted.

It is evident from data presented in Table – 4.1 that NAA was found to be more effective than IBA and combination of NAA + IBA in different concentration in both the species of bamboo. The treatment T_4 (NAA 100 ppm) recorded significantly maximum percentage of cuttings sprouted (80.77 and 88.11, respectively for *Dendrocalamus strictus* and *Bambusa vulgaris*) which was followed by treatment T_{20}: NAA 75 ppm + IBA 100 ppm (74.11 and 73.55, respectively for *Dendrocalamus strictus* and *Bambusa vulgaris*).

Table - 4.1: Percentage of cuttings sprouted in bamboos as influenced by various auxins

Treatments	Percentage of cuttings sprouted (%)	
	Dendrocalamus strictus	*Bambusa vulgaris*
T_0 Control	22.44	20.63
T_1 NAA 25 ppm	47.33	50.33
T_2 NAA 50 ppm	67.22	64.44
T_3 NAA 75 ppm	73.44	65.44
T_4 NAA 100 ppm	80.77	88.11
T_5 IBA 25 ppm	34.77	44.00
T_6 IBA 50 ppm	56.11	62.44
T_7 IBA 75 ppm	57.77	64.55
T_8 IBA 100 ppm	61.77	65.88
T_9 NAA 25ppm + IBA 25ppm	33.11	34.55
T_{10} NAA 25ppm + IBA 50ppm	36.00	38.33
T_{11} NAA 25ppm + IBA 75ppm	36.11	45.77
T_{12} NAA 25ppm + IBA 100ppm	64.44	53.66
T_{13} NAA 50ppm + IBA 25ppm	33.44	36.22
T_{14} NAA 50ppm + IBA 50ppm	37.44	47.44
T_{15} NAA 50ppm + IBA 75ppm	48.77	50.22
T_{16} NAA 50ppm + IBA 100ppm	66.44	66.66
T_{17} NAA 75ppm +IBA 25ppm	41.44	49.77
T_{18} NAA 75ppm + IBA 50ppm	52.55	52.99
T_{19} NAA 75ppm + IBA 75ppm	55.11	64.33
T_{20} NAA 75ppm + IBA 100ppm	74.11	73.55
S. Em. ±	2.227	2.577
C. D. at 5%	6.36	7.36
C. V. %	7.50	8.23

Fig.- 1: Percentage of cuttings sprouted in bamboos as influenced by various auxinsns

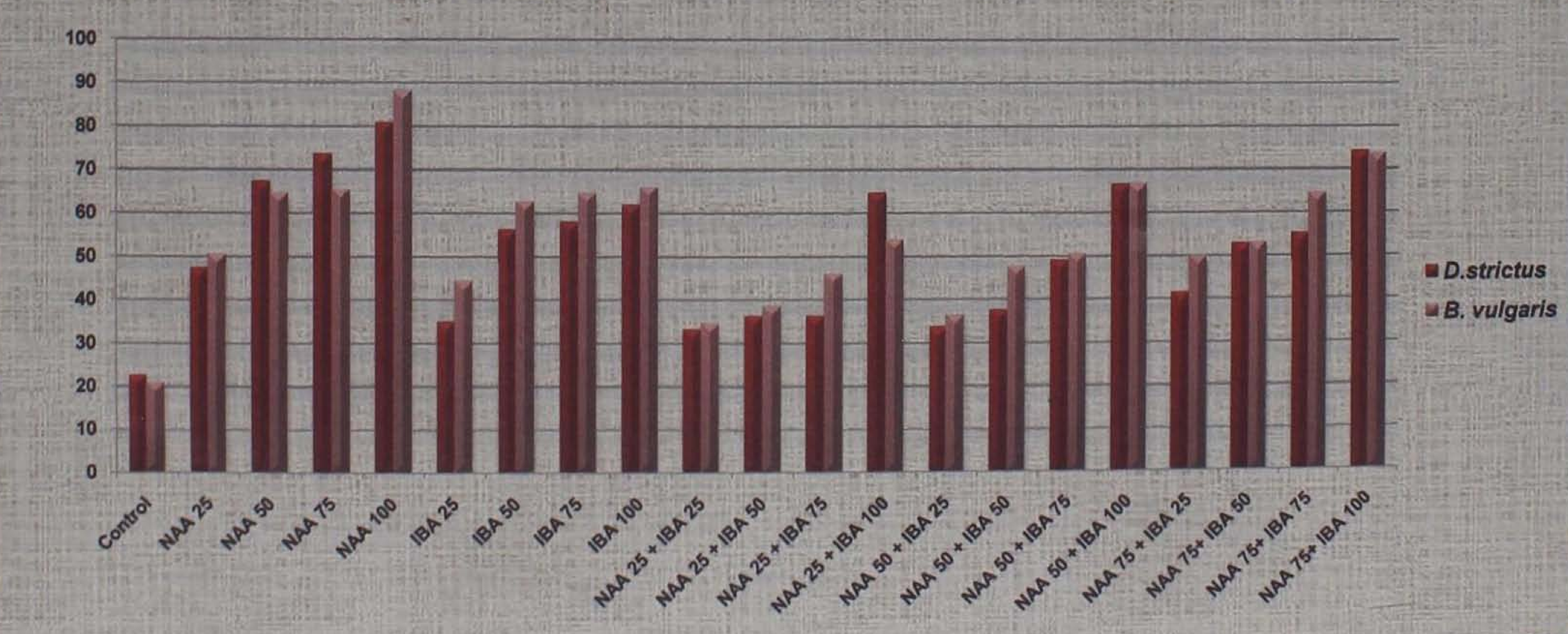


Plate-IV : Sprouting of bamboo culm cuttings as affected by NAA 100 ppm

A. *Dendrocalamus strictus*

B. Bambusa vulgaris

4.2 Percentage of cuttings rooted (%)

The data regarding percentage of cuttings rooted in bamboo are presented in Table – 4.2 and depicted in Fig.2. It is seen from the data presented in Table – 4.2 that NAA had more pronounced effect than IBA and combination of NAA + IBA in different concentration.

In *Dendrocalamus strictus*, significantly highest percentage of cuttings rooted (77.44 %) was noted in T_4 (NAA 100 ppm) which was statistically at par with T_{20}: NAA 75 ppm + IBA 100 ppm (72.11 %). Similar trends of results were found in *Bambusa vulgaris*.

4.3 Number of leaves per plant

The data on number of leaves produced by culm cuttings are depicted in Table - 4.3 and illustrated in Fig.3.

Significantly maximum number of leaves per plant in *Dendrocalamus strictus* (89.33) were found in T_4 (NAA 100 ppm), which was followed by T_8 (IBA 100 ppm). Whereas, minimum number of leaves per plant (24.36) were observed in T_0 (control).

In case of *Bambusa vulgaris*, number of leaves per plant (80.67) were registered significantly higher in T_4 (NAA

Table - 4.2: Percentage of cuttings rooted in bamboos as influenced by various auxins

Treatments	Percentage of cuttings rooted (%)	
	Dendrocalamus strictus	*Bambusa vulgaris*
T_0 Control	26.44	27.33
T_1 NAA 25 ppm	47.44	43.22
T_2 NAA 50 ppm	65.11	54.11
T_3 NAA 75 ppm	69.11	67.22
T_4 NAA 100 ppm	77.44	83.11
T_5 IBA 25 ppm	36.77	38.66
T_6 IBA 50 ppm	55.11	53.00
T_7 IBA 75 ppm	65.22	54.55
T_8 IBA 100 ppm	69.44	64.55
T_9 NAA 25ppm + IBA 25ppm	36.44	38.77
T_{10} NAA 25ppm + IBA 50ppm	40.11	41.44
T_{11} NAA 25ppm + IBA 75ppm	41.44	44.44
T_{12} NAA 25ppm + IBA 100ppm	47.44	48.44
T_{13} NAA 50ppm + IBA 25ppm	37.00	44.77
T_{14} NAA 50ppm + IBA 50ppm	45.77	51.88
T_{15} NAA 50ppm + IBA 75ppm	63.44	52.55
T_{16} NAA 50ppm + IBA 100ppm	65.22	65.22
T_{17} NAA 75ppm +IBA 25ppm	59.22	51.44
T_{18} NAA 75ppm + IBA 50ppm	61.11	58.44
T_{19} NAA 75ppm + IBA 75ppm	63.55	64.55
T_{20} NAA 75ppm + IBA 100ppm	72.11	66.66
S. Em. ±	2.784	2.853
C. D. at 5%	7.96	8.15
C. V. %	8.85	9.31

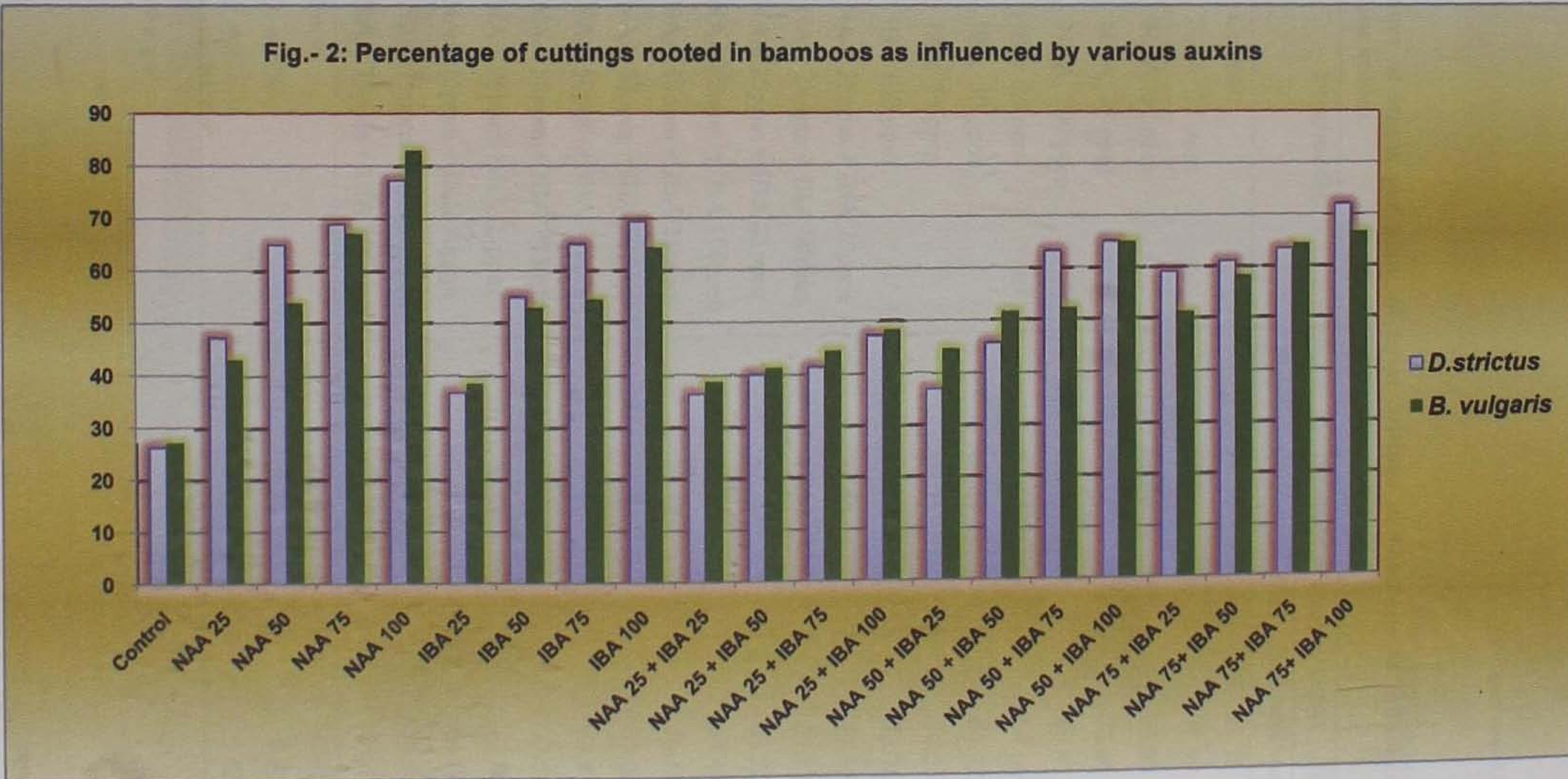


Fig.- 2: Percentage of cuttings rooted in bamboos as influenced by various auxins
90
80
70
60
50
40
30
20
10
0
Control
NAA 25
NAA 50
NAA 75
NAA 100
IBA 25
IBA 50
IBA 75
IBA 100
NAA 25 + IBA 25
NAA 25 + IBA 50
NAA 25 + IBA 75
NAA 25 + IBA 100
NAA 50 + IBA 25
NAA 50 + IBA 50
NAA 50 + IBA 75
NAA 50 + IBA 100
NAA 75 + IBA 25
NAA 75+ IBA 50
NAA 75+ IBA 75
NAA 75+ IBA 100
D.strictus
B. vulgaris

4.3: Number of leaves per plant of culm cuttings in bamboos as influenced by various auxins

Treatments	Number of leaves / plant	
	Dendrocalamus strictus	***Bambusa vulgaris***
T_0 Control	24.36	21.55
T_1 NAA 25 ppm	55.98	71.89
T_2 NAA 50 ppm	66.56	73.89
T_3 NAA 75 ppm	73.11	75.66
T_4 NAA 100 ppm	89.33	80.67
T_5 IBA 25 ppm	65.44	64.66
T_6 IBA 50 ppm	66.89	67.22
T_7 IBA 75 ppm	69.55	70.55
T_8 IBA 100 ppm	80.55	72.78
T_9 NAA 25ppm + IBA 25ppm	35.55	55.55
T_{10} NAA 25ppm + IBA 50ppm	47.00	57.22
T_{11} NAA 25ppm + IBA 75ppm	47.33	61.55
T_{12} NAA 25ppm + IBA 100ppm	51.55	69.44
T_{13} NAA 50ppm + IBA 25ppm	43.11	56.55
T_{14} NAA 50ppm + IBA 50ppm	48.33	60.00
T_{15} NAA 50ppm + IBA 75ppm	50.66	64.89
T_{16} NAA 50ppm + IBA 100ppm	57.88	73.55
T_{17} NAA 75ppm +IBA 25ppm	48.00	63.00
T_{18} NAA 75ppm + IBA 50ppm	49.89	64.00
T_{19} NAA 75ppm + IBA 75ppm	56.11	71.11
T_{20} NAA 75ppm + IBA 100ppm	65.78	78.44
S. Em. ±	2.989	1.902
C. D. at 5%	8.54	5.43
C. V. %	9.11	5.03

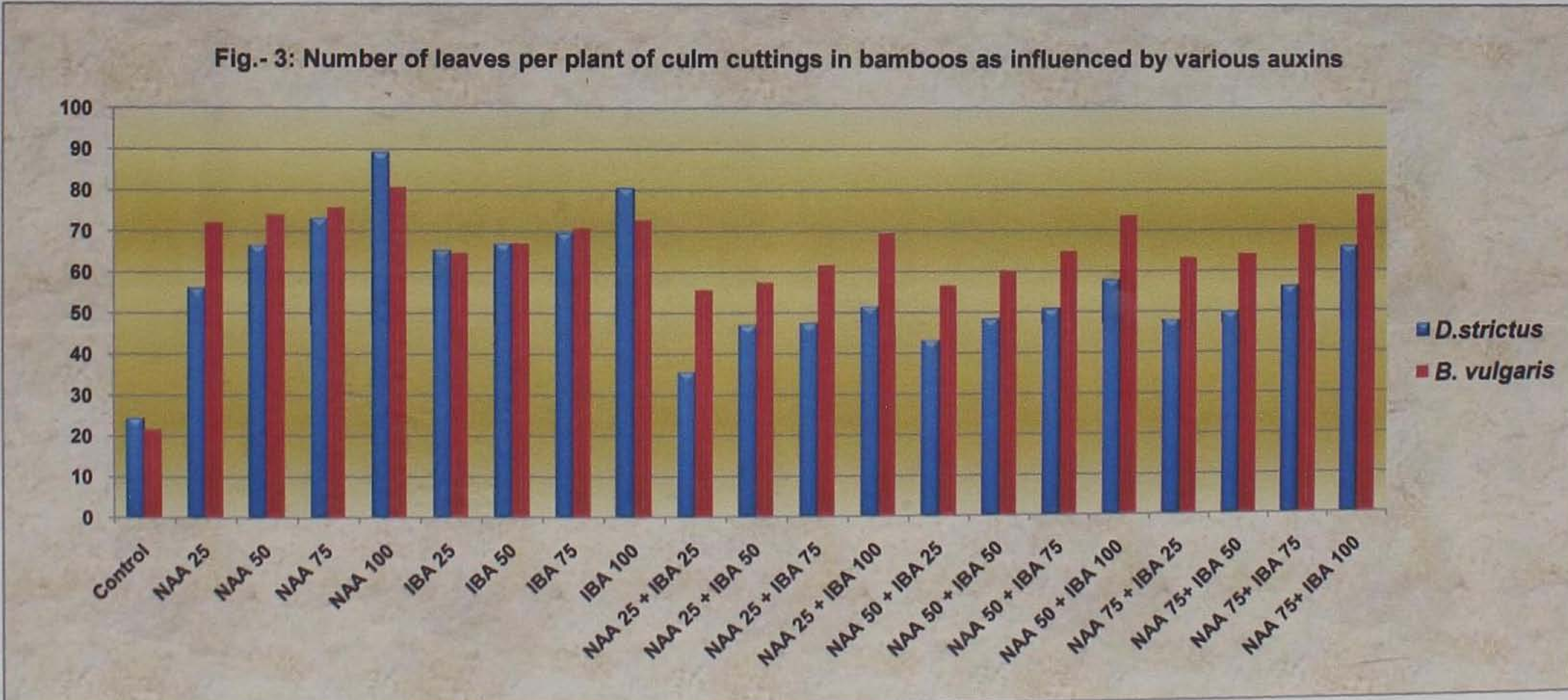
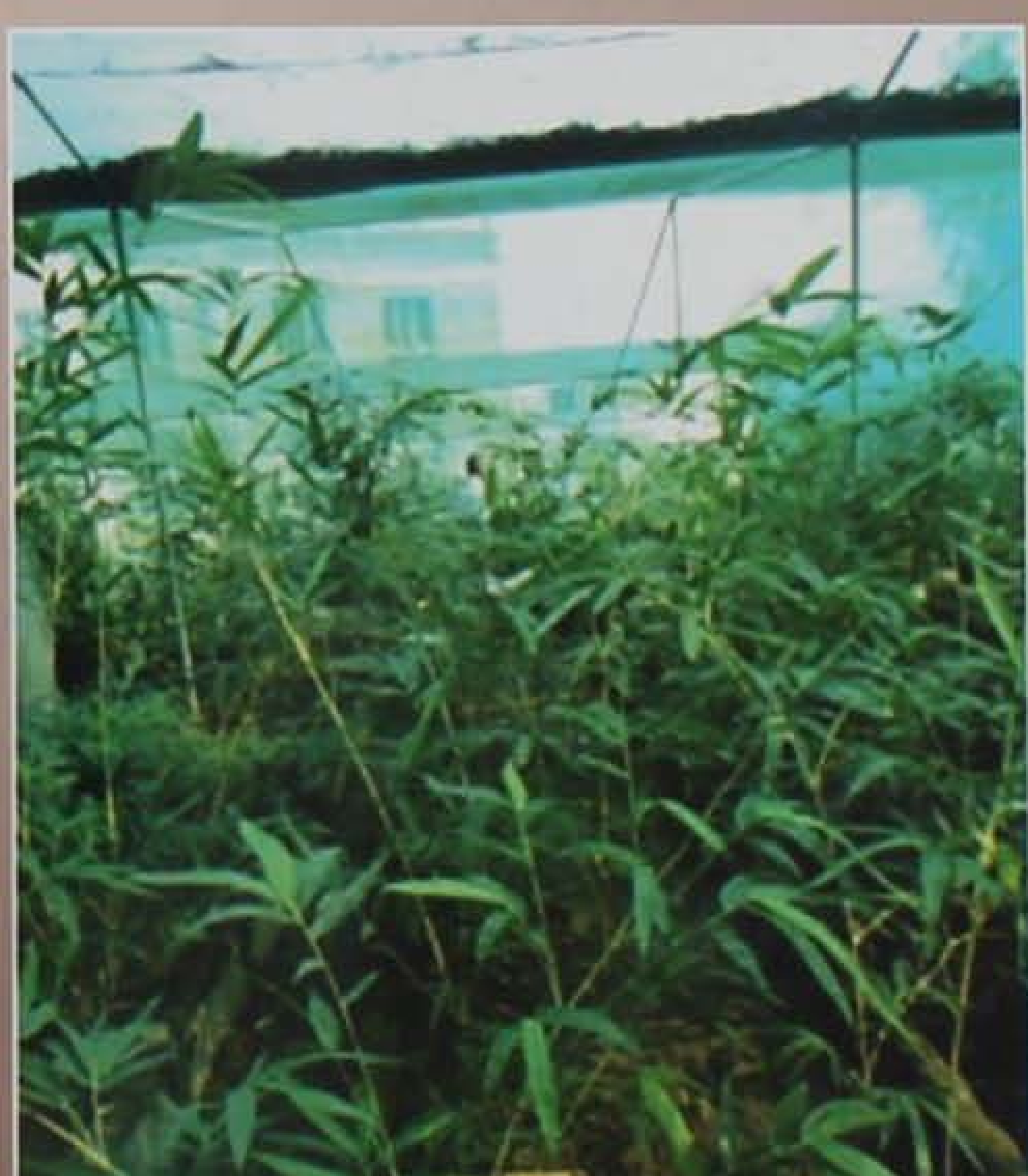


Fig.- 3: Number of leaves per plant of culm cuttings in bamboos as influenced by various auxins
100
90
80
70
60
50
40
30
20
10
0
Control
NAA 25
NAA 50
NAA 75
NAA 100
IBA 25
IBA 50
IBA 75
IBA 100
NAA 25 + IBA 25
NAA 25 + IBA 50
NAA 25 + IBA 75
NAA 25 + IBA 100
NAA 50 + IBA 25
NAA 50 + IBA 50
NAA 50 + IBA 75
NAA 50 + IBA 100
NAA 75 + IBA 25
NAA 75+ IBA 50
NAA 75+ IBA 75
NAA 75+ IBA 100
D.strictus
B. vulgaris

Plate-V : Growth of bamboo culm cuttings as affected by NAA 100 ppm

A. *Dendrocalamus strictus*



B. *Bambusa vulgaris*

100 ppm) which was on same bar with T_{20}: NAA 75 ppm + IBA 100 ppm (78.44 %) and T_3: NAA 75 ppm (75.66).

4.4 Number of roots at the end of experiment

The data with respect to number of roots at the end of experiment of culm cuttings in bamboo species are presented in Table - 4.4 and graphically depicted Fig.4.

It is observed from the data presented in Table – 4.4 that significantly maximum number of roots at the end of experiment (19.66) in *Dendrocalamus strictus* was recorded in NAA 100 ppm (T_4), which was statistically at par with T_8: IBA 100 ppm (18.11), T_{19}: NAA 75 ppm + IBA 75 ppm (17.33) and T_{20}: NAA 75 ppm + IBA 100 ppm (18.33). The least number of primary roots per plant was recorded under T_0: control (6.55).

While in case of *Bambusa vulgaris*, T_4: NAA 100 ppm recorded significantly maximum number of roots at the end of experiment (13.88) which was followed by T_{20}: NAA 75 ppm + IBA 100 ppm (11.33).

4.5 Length of root (cm)

The data regarding length of root are furnished in Table - 4.5 and graphically depicted in Fig.5.

It can be seen from the data presented in Table-4.5 that the culm of cuttings of *Dendrocalamus strictus* treated with

4.4: Number of roots at the end of experiment in bamboos as influenced by various auxins

Treatments	Number of roots/plant	
	Dendrocalamus strictus	*Bambusa vulgaris*
T_0 Control	6.55	7.11
T_1 NAA 25 ppm	14.88	10.22
T_2 NAA 50 ppm	16.00	10.33
T_3 NAA 75 ppm	16.66	11.11
T_4 NAA 100 ppm	19.66	13.88
T_5 IBA 25 ppm	12.00	7.22
T_6 IBA 50 ppm	14.94	7.88
T_7 IBA 75 ppm	11.66	7.89
T_8 IBA 100 ppm	18.11	9.33
T_9 NAA 25ppm + IBA 25ppm	9.55	7.33
T_{10} NAA 25ppm + IBA 50ppm	12.00	7.66
T_{11} NAA 25ppm + IBA 75ppm	14.00	8.88
T_{12} NAA 25ppm + IBA 100ppm	15.11	10.11
T_{13} NAA 50ppm + IBA 25ppm	9.89	7.33
T_{14} NAA 50ppm + IBA 50ppm	12.77	8.33
T_{15} NAA 50ppm + IBA 75ppm	15.00	9.33
T_{16} NAA 50ppm + IBA 100ppm	16.33	10.22
T_{17} NAA 75ppm +IBA 25ppm	14.33	7.66
T_{18} NAA 75ppm + IBA 50ppm	16.00	9.22
T_{19} NAA 75ppm + IBA 75ppm	17.33	11.11
T_{20} NAA 75ppm + IBA 100ppm	18.33	11.33
S. Em. ±	0.828	0.434
C. D. at 5%	2.37	1.24
C. V. %	10.01	8.16

Plate-VI : Rooting of bamboo culm cuttings as affected by NAA 100 ppm

A. *Dendrocalamus strictus*

B. *Bambusa vulgaris*

NAA 100 ppm (T_4) produced longest root length (21.57 cm) which was at par with treatments T_{20} (NAA 75 ppm + IBA 100 ppm), T_{16} (NAA 50 ppm + IBA 100 ppm), T_8 (IBA 100 ppm) and T_{19} (NAA 75 ppm + IBA 75 ppm) i.e. 18.14, 18.11, 18.09 and 18.02 cm, respectively. Whereas, the minimum length of root (11.55 cm) was recorded in control (T_0).

In case of *Bambusa vulgaris* significantly maximum length of root was found in T_4 : NAA 100 ppm (15.44 cm) which was on same bar with T_{20} : NAA 75 ppm + IBA 100 ppm (15.41 cm)

4.6 Days taken for initiation of first sprouting

The data on the days to sprout of culm cuttings are presented in Table - 4.6 and depicted in Fig. 6. It is seen that on an average the different concentrations of auxins had a pronounced effect on days to sprout of culm cuttings in both the species of bamboo.

Further perusal of data on the influence of different concentrations of auxins on days to sprout of cuttings indicated that the effect of auxins was found significant. However, in *Dendrocalamus strictus*, earlier sprouting (7.11) was recorded in T_4: NAA 100 ppm which was statistically at par with T_1 (8.89), T_2 (8.11), T_3 (7.33), T_4 (7.11), T_7 (7.33), T_8 (7.22), T_{11} (7.78), T_{12} (7.67), T_{14} (8.11), T_{15} (7.66), T_{16} (7.44), T_{18} (8.00), T_{19} (7.44) and

: - 4.5: Length of root (cm) of culm cuttings in bamboos as influenced by various auxins

Treatments	Length of root (cm)	
	Dendrocalamus strictus	*Bambusa vulgaris*
T_0 Control	11.55	6.61
T_1 NAA 25 ppm	14.85	7.47
T_2 NAA 50 ppm	14.93	8.53
T_3 NAA 75 ppm	16.23	10.77
T_4 NAA 100 ppm	21.57	15.44
T_5 IBA 25 ppm	12.43	7.05
T_6 IBA 50 ppm	14.27	8.38
T_7 IBA 75 ppm	14.84	9.10
T_8 IBA 100 ppm	18.09	11.00
T_9 NAA 25ppm + IBA 25ppm	15.02	7.35
T_{10} NAA 25ppm + IBA 50ppm	15.93	7.74
T_{11} NAA 25ppm + IBA 75ppm	17.14	8.73
T_{12} NAA 25ppm + IBA 100ppm	17.26	10.33
T_{13} NAA 50ppm + IBA 25ppm	15.51	7.52
T_{14} NAA 50ppm + IBA 50ppm	16.95	8.28
T_{15} NAA 50ppm + IBA 75ppm	17.18	8.94
T_{16} NAA 50ppm + IBA 100ppm	18.11	13.32
T_{17} NAA 75ppm +IBA 25ppm	15.95	8.70
T_{18} NAA 75ppm + IBA 50ppm	17.63	9.16
T_{19} NAA 75ppm + IBA 75ppm	18.02	9.46
T_{20} NAA 75ppm + IBA 100ppm	18.14	15.41
S. Em. ±	1.35	0.416
C. D. at 5%	3.86	1.19
C. V. %	14.40	7.84

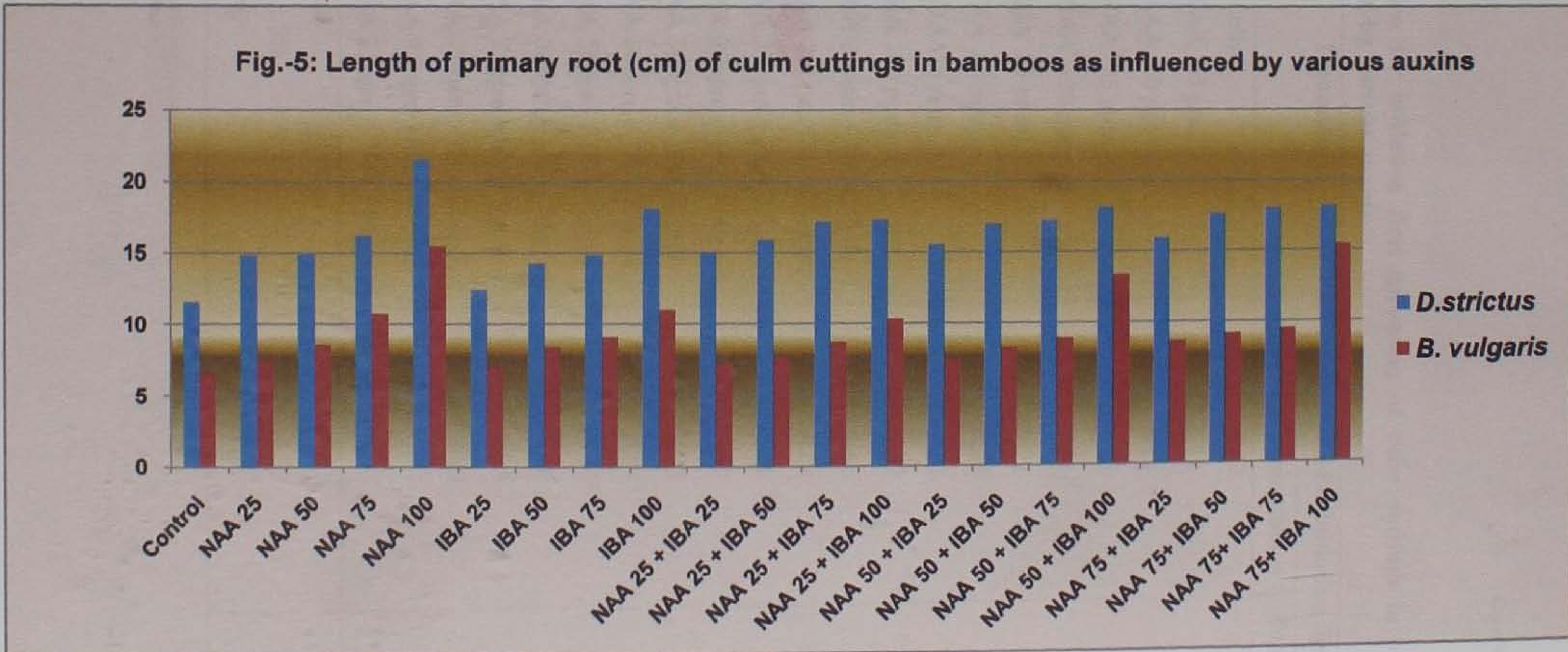
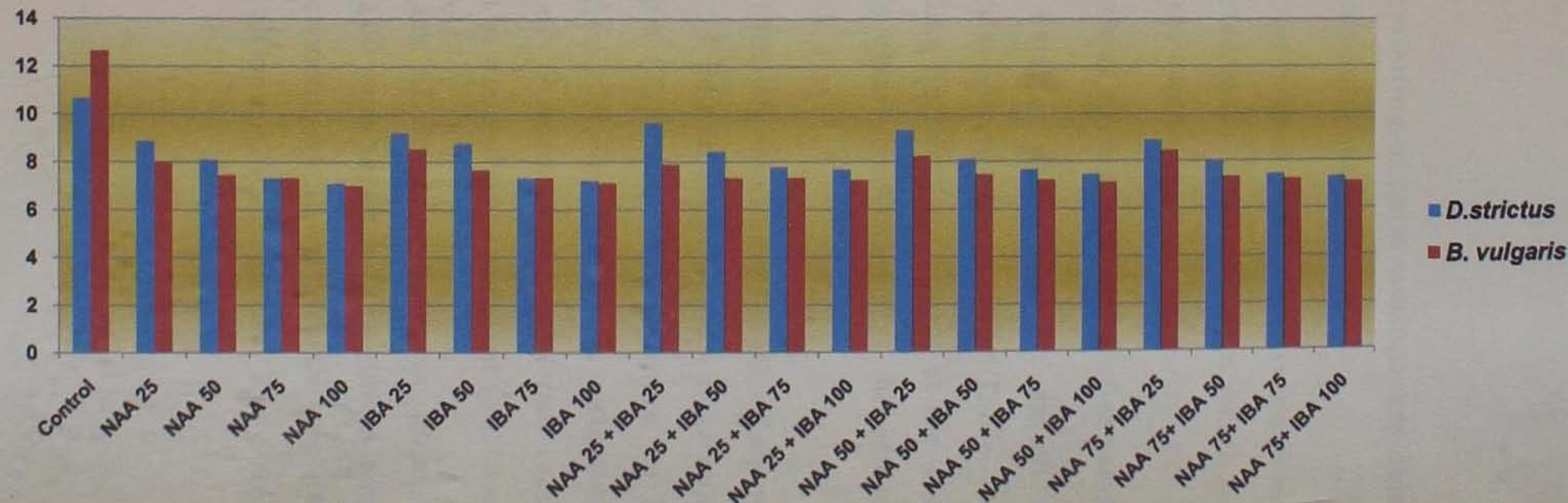


Fig.-5: Length of primary root (cm) of culm cuttings in bamboos as influenced by various auxins
25
20
15
10
5
0
Control
NAA 25
NAA 50
NAA 75
NAA 100
IBA 25
IBA 50
IBA 75
IBA 100
NAA 25 + IBA 25
NAA 25 + IBA 50
NAA 25 + IBA 75
NAA 25 + IBA 100
NAA 50 + IBA 25
NAA 50 + IBA 50
NAA 50 + IBA 75
NAA 50 + IBA 100
NAA 75 + IBA 25
NAA 75+ IBA 50
NAA 75+ IBA 75
NAA 75+ IBA 100
D.strictus
B. vulgaris

- 4.6: Days taken for initiation first sprouting of culm cuttings in bamboos as influenced by various auxins

Treatments	Days taken for initiation first sprouting	
	Dendrocalamus strictus	*Bambusa vulgaris*
T_0 Control	10.67	12.66
T_1 NAA 25 ppm	8.89	8.00
T_2 NAA 50 ppm	8.11	7.44
T_3 NAA 75 ppm	7.33	7.33
T_4 NAA 100 ppm	7.11	7.00
T_5 IBA 25 ppm	9.22	8.55
T_6 IBA 50 ppm	8.78	7.66
T_7 IBA 75 ppm	7.33	7.33
T_8 IBA 100 ppm	7.22	7.11
T_9 NAA 25ppm + IBA 25ppm	9.66	7.89
T_{10} NAA 25ppm + IBA 50ppm	8.44	7.33
T_{11} NAA 25ppm + IBA 75ppm	7.78	7.33
T_{12} NAA 25ppm + IBA 100ppm	7.67	7.22
T_{13} NAA 50ppm + IBA 25ppm	9.33	8.22
T_{14} NAA 50ppm + IBA 50ppm	8.11	7.44
T_{15} NAA 50ppm + IBA 75ppm	7.66	7.22
T_{16} NAA 50ppm + IBA 100ppm	7.44	7.11
T_{17} NAA 75ppm +IBA 25ppm	8.89	8.44
T_{18} NAA 75ppm + IBA 50ppm	8.00	7.33
T_{19} NAA 75ppm + IBA 75ppm	7.44	7.22
T_{20} NAA 75ppm + IBA 100ppm	7.33	7.11
S. Em.±	0.53	0.63
C. D. at 5%	1.51	1.81
C. V. %	11.17	14.10

Fig.- 6: Days taken for initiation first sprouting of culm cuttings in bamboos as influenced by various auxins



T_{20} (7.33). The sprouting of culm cuttings was delayed (10.67) in untreated (control) culm cuttings.

Whereas in case of *Bambusa vulgaris* earlier sprouting (7.00) was reported in T_4: NAA 100 ppm which was on same bar with all treatments except control (T_0)

4.7 Length of sprout at the end of experiment (cm)

The data on the length of sprout at the end of experiment of culm cuttings are given in Table - 4.7 and depicted in Fig. 7. The data on length of sprout at the end of experiment of culm cuttings clearly indicated that the effect of auxins was found significant.

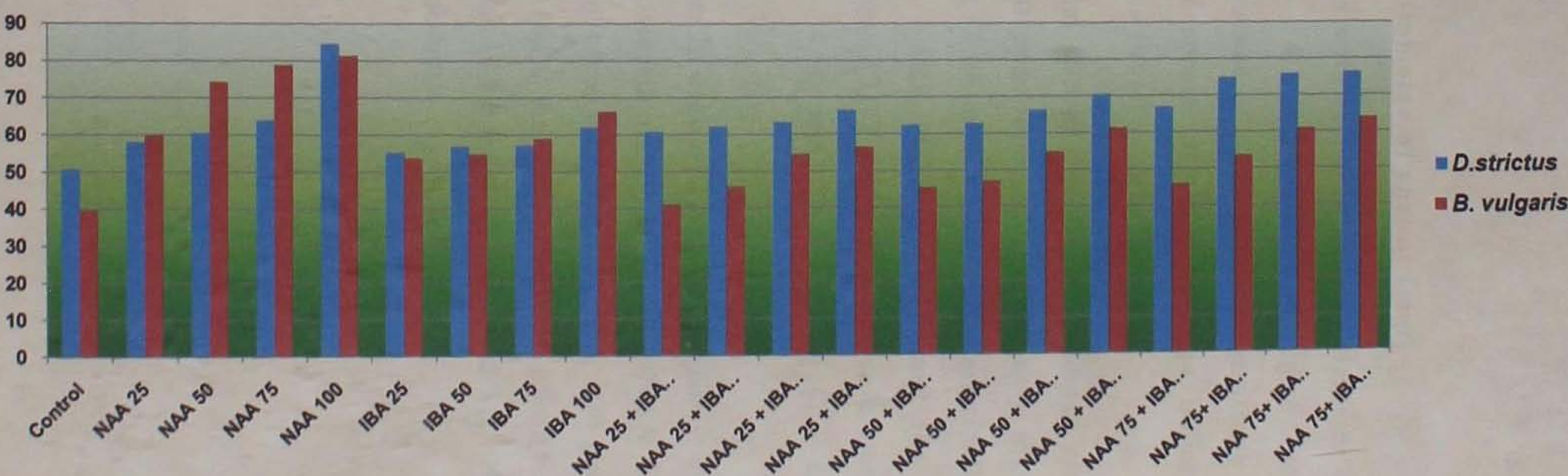
Significantly maximum length of sprout at the end of experiment (84.53 cm) in *Dendrocalamus strictus* was recorded in NAA 100 ppm (T_4) which was followed by NAA 75 ppm + IBA 100 ppm (T_{20}, 76.32 cm). While, untreated culm cuttings (T_0: Control) of *Dendrocalamus strictus* recorded minimum length of sprout at the end of experiment (50.70 cm).

In case of *Bambusa vulgaris*, culm cuttings treated with T_4: NAA 100 ppm registered maximum length of sprout at the end of experiment (81.32 cm) which was statistically at par with T_2: NAA 50 ppm (74.22 cm) and T_3 : NAA 75 ppm (78.83 cm).

4.7: Length of sprout at the end of experiment in bamboos as influenced by various auxins

Treatments	Length of sprout at the end of experiment (cm)	
	Dendrocalamus strictus	*Bambusa vulgaris*
T_0 Control	50.70	39.61
T_1 NAA 25 ppm	57.99	59.89
T_2 NAA 50 ppm	60.48	74.22
T_3 NAA 75 ppm	63.97	78.83
T_4 NAA 100 ppm	84.53	81.32
T_5 IBA 25 ppm	55.22	53.61
T_6 IBA 50 ppm	56.88	54.70
T_7 IBA 75 ppm	57.13	58.83
T_8 IBA 100 ppm	62.03	66.17
T_9 NAA 25ppm + IBA 25ppm	60.81	40.94
T_{10} NAA 25ppm + IBA 50ppm	62.14	45.84
T_{11} NAA 25ppm + IBA 75ppm	63.31	54.55
T_{12} NAA 25ppm + IBA 100ppm	66.59	56.43
T_{13} NAA 50ppm + IBA 25ppm	62.37	45.31
T_{14} NAA 50ppm + IBA 50ppm	62.82	46.95
T_{15} NAA 50ppm + IBA 75ppm	66.31	54.80
T_{16} NAA 50ppm + IBA 100ppm	70.43	61.25
T_{17} NAA 75ppm +IBA 25ppm	66.84	45.75
T_{18} NAA 75ppm + IBA 50ppm	74.92	53.41
T_{19} NAA 75ppm + IBA 75ppm	75.79	60.77
T_{20} NAA 75ppm + IBA 100ppm	76.32	63.77
S. Em. ±	2.58	2.79
C. D. at 5%	7.39	7.99
C. V. %	6.92	8.53

Fig.-7: Length of sprout (cm) at the end of experiment in bamboos as influenced by various auxins



4.8 Collar diameter of sprout (mm)

The data with respect to collar diameter of sprout are presented in Table - 4.8 and depicted in Fig. 8. Further perusal of data on the influence of different concentrations of auxins on collar diameter of sprout of culm cuttings indicated that the effect of auxins was found significant.

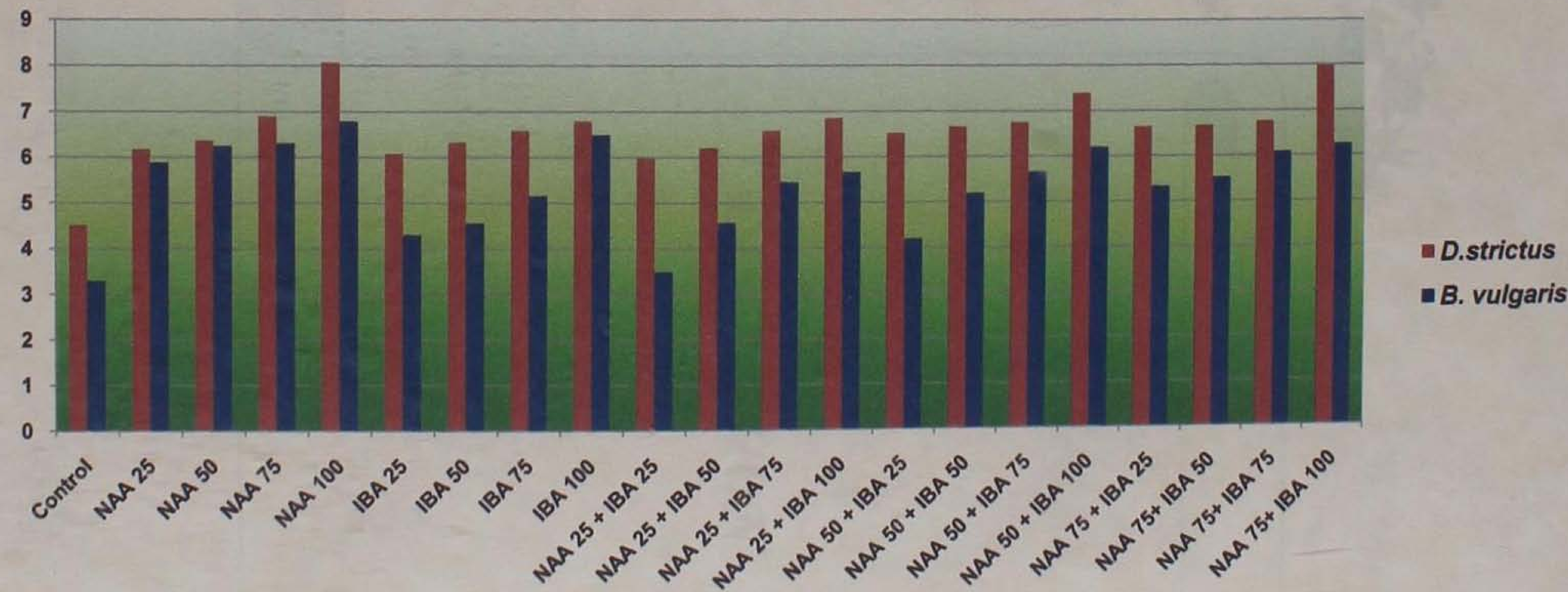
The culm cuttings of *Dendrocalamus strictus* treated with T_4: NAA 100 ppm reported significantly maximum collar diameter of sprout (8.06 mm) which was statistically at par with T_{16}: NAA 50 ppm + IBA 100 ppm (7.38 mm) and T_{20}: NAA 75 ppm + IBA 100 ppm (7.97 mm). The collar diameter of sprout was minimum in (4.50 mm) in untreated (T_0: Control) culm cuttings.

However in case of *Bambusa vulgaris*, collar diameter of sprout was registered maximum in T_4 : NAA 100 ppm (6.78 mm) which was on same bar with T_8 : IBA 100 ppm (6.48 mm), T_3 : NAA 75 ppm (6.30 mm), T_2 : NAA 50 ppm (6.24 mm), T_{20} : NAA 75 ppm + IBA 100 ppm(6.24 mm), and T_{16} : NAA 50 ppm + IBA 100 ppm (6.19 mm).

Table - 4.8: Collar diameter (mm) of sprout in bamboos as influenced by various auxins

Treatments	Collar diameter of sprout (mm)	
	Dendrocalamus strictus	*Bambusa vulgaris*
T_0 Control	4.50	3.29
T_1 NAA 25 ppm	6.17	5.88
T_2 NAA 50 ppm	6.36	6.24
T_3 NAA 75 ppm	6.89	6.30
T_4 NAA 100 ppm	8.06	6.78
T_5 IBA 25 ppm	6.07	4.30
T_6 IBA 50 ppm	6.32	4.56
T_7 IBA 75 ppm	6.57	5.15
T_8 IBA 100 ppm	6.78	6.48
T_9 NAA 25ppm + IBA 25ppm	5.97	3.48
T_{10} NAA 25ppm + IBA 50ppm	6.20	4.55
T_{11} NAA 25ppm + IBA 75ppm	6.57	5.44
T_{12} NAA 25ppm + IBA 100ppm	6.84	5.66
T_{13} NAA 50ppm + IBA 25ppm	6.51	4.19
T_{14} NAA 50ppm + IBA 50ppm	6.65	5.19
T_{15} NAA 50ppm + IBA 75ppm	6.74	5.65
T_{16} NAA 50ppm + IBA 100ppm	7.38	6.19
T_{17} NAA 75ppm +IBA 25ppm	6.64	5.32
T_{18} NAA 75ppm + IBA 50ppm	6.66	5.52
T_{19} NAA 75ppm + IBA 75ppm	6.75	6.08
T_{20} NAA 75ppm + IBA 100ppm	7.97	6.24
S. Em. ±	0.40	0.23
C. D. at 5%	1.13	0.67
C. V. %	10.42	7.56

Fig.-8: Collar diameter of sprout (mm) in bamboos as influenced by various auxins



DISCUSSION

V. DISCUSSION

An investigation on "Efficiency of rooting hormones on propagation of different bamboo species (*Dendrocalamus strictus* and *Bambusa vulgaris*)" was carried out at the Greenhouse complex, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari with a view to evaluate best hormone for vegetative propagation. The results obtained during the course of present investigation have been discussed with an aim to establish cause and affect relationship in the light of findings of other workers in this chapter with the following headings.

5.1 Growth parameters

5.2 Root parameters

5.1 Growth parameters

The data presented in Tables – 4.1, 4.3, 4.6, 4.7 and 4.8 clearly revealed that NAA was found to be more effective than IBA and combination of NAA + IBA in different concentration in both the species of bamboo. The treatment T_4 (NAA 100 ppm) recorded significantly maximum percentage of sprouting, number of leaves per plant, sprout length and collar diameter at the end of experiment as well as earlier sprouting in

Dendrocalamus strictus and *Bambusa vulgaris*. The next best treatment in order to response is T_{20} (NAA 75 ppm + IBA 100 ppm) for majority of the parameters. Variable response among various bamboo species generally resulted due to the differences in morphological features and endogenous levels of stored photosynthates and auxillary substances. These results are in close proximity with the earlier findings of Saharia and Sen (1990). The exogenous application of various growth regulators, mostly auxins, has been reported to positively influence on induction and growth in culm cuttings of bamboos (Agnihotri and Ansari, 2000 and Singh *et al.* 2002). Exogenous application of auxins becomes effective if their endogenous level is low for example due to inactive growth phase or less accumulation in distal plant parts. Similar trends of results were earlier reported by Nath *et al.* (1986) in *Bambusa pellida* and *Teinostachym dullooa*.

5.2 Root parameters

It is evident from Tables – 4.2, 4.4 and 4.5 that significantly highest percentage of cuttings rooted, number of roots per plant and length of root in both the species of bamboo was noted in T_4 (NAA 100 ppm) which was on same bar with T_{20} (NAA 75 ppm + IBA 100 ppm) in *Dendrocalamus strictus*. In case of *Bambusa vulgaris* it was followed by for percentage of cuttings rooted and number of roots per plant while length of root was on same bar with NAA 100 ppm. Variable response in percentage of cuttings rooted might be due to different genetic makeup of these two species. Moreover, these variations are also due to varied endogenous natural auxins in different species of bamboo. Similar result was earlier reported by Saharia and Sen (1990). The variation in rooting ability observed due to tried auxins and their combinations may be attributed to species ability of signal reorganization and its amplification which depends on genetic makeup of the species. This results are in close proximity with the earlier findings of Seethalakshmi *et al.* (1983), Nain *et al.* (2007) in *B. tulda* and *B. vulgaris*, Rana *et al.* (1987) in *Dalbergia sissoo* and Nautiyal (1991) in *Tectona grandis*.

SUMMARY

&

CONCLUSION

VI. SUMMARY AND CONCLUSION

The present investigation was carried out on the "Efficiency of rooting hormones on propagation of different bamboo species (*Dendrocalamus strictus* and *Bambusa vulgaris*)" at Greenhouse complex, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari.

The experiment comprised of 4 levels of NAA, IBA and their combinations along with control. This experiment was laid out in Randomized Block Design (RBD) comprising of twenty one treatments and three replications. The observations on various parameters were recorded and the results obtained are summarized here.

6.1. Percentage of cuttings sprouted in both the species of bamboo was recorded significantly maximum in T_4: NAA 100 ppm (80.77 and 88.11, respectively for *Dendrocalamus strictus* and *Bambusa vulgaris*) which was followed by treatment T_{20}: NAA 75 ppm + IBA 100 ppm (74.11 and 73.55, respectively for *Dendrocalamus strictus* and *Bambusa vulgaris*).

6.2. Significantly higher percentage of cuttings rooted (77.44 and 83.11 %, respectively for *Dendrocalamus strictus* and

Bambusa vulgaris) was noted in T_4 (NAA 100 ppm) which was statistically at par with T_{20}: NAA 75 ppm + IBA 100 ppm (72.11 %) in *Dendrocalamus strictus.* While in *Bambusa vulgaris*, it was followed by T_{20} : NAA 75 ppm + IBA 100 ppm (66.66 %).

6.3. In *Dendrocalamus strictus*, significantly maximum number of leaves per plant (89.33) were found in T_4 (NAA 100 ppm), which was followed by T_8 (IBA 100 ppm). While in case of *Bambusa vulgaris,* number of leaves per plant (80.67) were registered significantly higher in T_4 (NAA 100 ppm) which was on same bar with T_{20}: NAA 75 ppm + IBA 100 ppm (78.44 %) and T_3: NAA 75 ppm (75.66).

6.4. The number of roots per plant of *Dendrocalamus strictus* was recorded in NAA 100 ppm (T_4), which was statistically at par with IBA 100 ppm (18.11), NAA 75 ppm + IBA 75 ppm (17.33) and NAA 75 ppm + IBA 100 ppm (18.33). The least number of roots per plant was recorded under T_0: control (6.55). While in case of *Bambusa vulgaris*, NAA 100 ppm recorded significantly maximum number of roots per plant (13.88) which was followed by NAA 75 ppm + IBA 100 ppm (11.33).

6.5. With respect to length of roots, it was found significantly maximum (15.44 cm) in NAA @ 100 ppm (T_4) which was at par with treatment T_9 *i.e.* NAA 25 ppm + IBA 25 ppm

(15.41cm). Whereas, the minimum length of root (6.61cm) was recorded in control (T_0). The similar trend of results was observed for *Bambusa vulgaris*.

6.6 Earlier sprouting (7.11) of *Dendrocalamus strictus* culm cuttings was recorded in T_4: NAA 100 ppm which was statistically at par with T_1 (8.89), T_2 (8.11), T_3 (7.33), T_4 (7.11), T_7 (7.33), T_8 (7.22), T_{11} (7.78), T_{12} (7.67), T_{14} (8.11), T_{15} (7.66), T_{16} (7.44), T_{18} (8.00), T_{19} (7.44) and T_{20} (7.33). The sprouting of culm cuttings was delayed (10.67) in untreated (control) culm cuttings. Whereas in case of *Bambusa vulgaris* earlier sprouting (7.00) was reported in NAA 100 ppm which was on same bar with all treatments except control (T_0)

6.7 The length of sprout at the end of experiment (84.53 cm) in *Dendrocalamus strictus* was recorded significantly higher in NAA 100 ppm (T_4) which was followed by NAA 75 ppm + IBA 100 ppm (T_{20}, 76.32 cm). While, untreated culm cuttings of *Dendrocalamus strictus* recorded minimum length of sprout at the end of experiment (50.70 cm). In case of *Bambusa vulgaris*, culm cuttings treated with T_4: NAA 100 ppm registered maximum length of sprout at the end of experiment (81.32 cm) which was statistically at par with T_2 : NAA 50 ppm (74.22 cm) and T_3 : NAA 75 ppm (78.83 cm).

6.8 The culm cuttings of *Dendrocalamus strictus* treated with NAA 100 ppm reported significantly maximum collar diameter of sprout (8.06 mm) which was statistically at par with NAA 50 ppm + IBA 100 ppm (7.38 mm) and NAA 75 ppm + IBA 100 ppm (7.97 mm). However in case of *Bambusa vulgaris*, collar diameter of sprout was registered maximum in T_4 : NAA 100 ppm (6.78 mm) which was on same bar with T_8 : IBA 100 ppm (6.48 mm), T_3 : NAA 75 ppm (6.30 mm), T_2 : NAA 50 ppm (6.24 mm), T_{20} : NAA 75 ppm + IBA 100 ppm (6.24 mm), and T_{16} : NAA 50 ppm + IBA 100 ppm (6.19 mm).

Conclusion :

From the above findings it is concluded that NAA was found to be more effective than IBA and combination of NAA + IBA in different concentration in both the species of bamboo. In both the species of bamboo in their efficiency for inducing sprouting as well as rooting, NAA 100 ppm recorded significantly maximum percentage of cuttings sprouted, percentage of cuttings rooted, number of leaves per plant, number of roots per plant, length of root at the end of experiment, length of sprout at the end of experiment, collar diameter of sprout at the end of experiment as well as earlier sprouting. In majority of the parameters the treatment T_{20}: NAA

75 ppm + IBA 100 ppm remained on same bar with T_4 (NAA 100 ppm) that indicates that next best treatment in order to response is T_{20}: NAA 75 ppm + IBA 100 ppm.

REFERENCES

REFERENCE

Agnihotri Kiran and Ansari. S. A. (2000). Adventitious rhizogenesis in relation to seasonal variation, size of culm branch cutting and IAA treatment in bamboos. *Indian Forester*, **126** (8): 971-984.

Aslam M.; Syed S. R.; Salathia, H. S. and Seth, C. M. (2007). Auxin induced rooting in *Taxus baccata* Linn. stem cuttings. *Indian J. Forestry,* **30** (2): 221 – 226.

Banik, R. L. (2008). Issues in production of bamboo planting materials-lessons and strategies. *Indian Forester*, **134** (3): 291-304.

Bakshi, M. (2008) Effect of leaf area on rooting and growth of single nodal cuttings of *Dalbergia sissoo* Roxb. (Shisham). *Indian J. Forestry*, **31** (4): 519-523.

Bhatnagar, H. P. and Joshi, D. N. (1978). Rooting response of branch cuttings of Teak (*Tectona grandis* L.). *Indian J. Forestry*, **1** (1): 79 - 83.

Dubey, R. M.; Das, P. S. and Choudhury Reeta (2008). An investigation into macro-proliferation of some selected bamboo species of Assam. *Indian Forester*, **134** (3): 367-378.

Gupta, B. B.; Kumar, A. and Negi, D. S. (1993). Vegetatative propagation through branch cuttings in *Dalbergia sissoo* Roxb. *Indian Forester*, **119** (59) : 383 - 387.

Gurumurti, K., Gupta, B. B. and Adarsh Kumar (1994). Hormonal regulation of root formation. In the monal regulation of plant growth and development (Ed. S.S. Purohit). Agrobotanical Publishers (India). pp. 387-400.

Haridasan, K. and Tewari, S. (2008). Bamboo for Pan India programme- preliminary observation from recent trials. *Indian Forester*, **134** (3): 314-324.

Hossain, M. A.; Islam, M. S.; Bhuiyan, M. K.; Hossain, M. M. and Lee Hojoung (2011). Clonal propagation of *Bambusa vulgaris* schrad ex wendl by leaf branch cuttings. *Journal of Forestry Research*, **22** (3): 387-392.

Joshi Reena.; Tewari, S. K.; Kaushal, R. and Tewari, L (2012). Rooting behaviour of *Bambusa balcooa* Roxb. in relation to season, age and growing conditions. *Indian Forester*, **138** (1): 79-83.

Kaushal; R.; Gulabrao, Y. A.; Tewari, S. K.; Chaturvedi Sumit and Banik, R. L (2011). Clonal propagation of important bamboo species through branch cuttings. *Indian J. Forestry*, **34** (1): 29-34.

Khosla, P. K.; Nagpal, R. and Puri, S. (1982). Propagation of some agroforestry species by air-layering. *Indian J. Forestry*, **5** (3) : 171 - 174.

Kulkarni, P. K. and Takawale, P. S. (1999). Studies on rooting in juvenile cutting of *Dalbergia sissoo*. *J. Trop. For.*, **15** (1) : 178 - 181.

Kumar A. (2000). Clone propagation of *Acacia mangium* through rooting of cutting. *Ann. For.*, **8** (2): 250 - 252.

Kumar Adarsh (1991). Mass production of field planting stock of *Dendrocalamus strictus* through macro proliferation- A technology. *Indian Forester*, **117** (12): 1046-1052.

Kumar Adarsh.; Dhawan Meena and Gupta, B. B (1990). Flowering and rooting of *Bambusa tulda* culm cuttings in response to growth regulating substances. *Indian Forester*, **116** (7): 547-553.

Kumar Adarsh.; Gupta, B. B. and Negi, D. S (1991). Vegetative propagation of *Dendrocalamus strictus* through macro-proliferation- II. *Indian Forester*, **117** (8): 621-624.

Kumar Rakesh and Pal Mohinder (2003). Carbohydrate in relation to rooting of culm cuttings of *Dendrocalamus* *strictus* (Roxb.) *Indian Forester*, **129** (11): 1355-1360.

*Lemay; Gateble and McCoy (2009). Vegetative propagation of two endemic species of *Cloezia brongn* and Gris for conservation and mining re-vegetation activities in New Caledonia. *New For.*, **37**: 1 - 8.

Madhwal; Kumar; Nautiyal, S.; Rayal, S. P. and Nautiyal, D. P. (2008). Rooting response of Juvenile shoot cuttings of *Terminalia chebula* Retz. under different hormonal treatments. *Indian Forester*, **134** (2): 270 - 274.

Mandal, A. K. and Subramanian, K. N (1992). On the genetic improvement of bamboos. *Indian Forester*, **118** (1): 55-59.

McClure (1966). Propagation of *Bambusa* and *Dendrocalamus* species by culm cuttings. *Indian Forester*, **116** (10): 780-784.

*Medina, J. C.; Ciaramello, D. and Castro, G. A. de P (1962). Propagacao vegetative bamboo imperial (*Bambusa vulgaris* schrad var. vittata A. et C. Riv). Bragantia *(Boletin Tecnico do Institute Agrenomico de Sao Paulo)*, **21** (370): 653-665 (Portuguese).

Nain, N. P. S.; Meena, S. L.; Kunjam, K. K.; Tripathi, S. P. and Singh Sanjay (2007). Clonal propagation of some bamboo species through adventitious rhizogenesis in culm cuttings. *Indian Forester*, **133** (2): 206-210.

Nath, M.; Phukan, U.; Barua, G.; Devi, M.; Barua, B and Deka, P. C (1986). Propagation of certain bamboo species from chemically treated culm cutting. *Indian J. Forestry*, **9** (2): 151-156.

Nath, S and Das, P. K (1995). Mass production of *Dendrocalamus membranaceus* planting stock through culm cuttings at seedling stage. *Indian Forester*, **121** (8): 743-748.

Nautiyal, S.; Singh, U. and Gurumurti, K. (1991). Rooting response of branch cuttings of Teak (*Tectona grandis*) as influnced by season and growth hormones. *Indian Forester*, **117** (4) : 249 - 255.

Panse, V. G. and Sukhatme, P. V. (1967). Statistical Methods for Agricultural Workers, I.C.A.R., New Delhi.

Rana, U.; Gairola, A. and Nautiyal, A. R. (1987). Seasonal variation in rooting of stem cuttings of *Dalbergia sissoo* and auxin effects on it. *Indian J. Forestry*, **10** (3) : 220 - 222.

Razvi Sajad.; Nautiyal Subhash.; Bakshi Meena.; Bhat Jahangeer A. and Pala Nazir A. (2011). Influence of season and phytohormones on rooting behaviour of green bamboo by cutting. *International J. of Conservation Science*, **2** (3): 199-206.

Saharia, U. K and Sen, S. K (1990). Optimum age of bamboo culms for nodal cuttings. *Indian Forester*, **116** (10): 780-784.

Seethalakshmi, K. K.; Venkatesh, C. S. and Surendran.T (1983). Vegetative propagation of bamboo using growth promoting substances. *Indian J. Forestry*, **6** (2): 98-103.

Sharma, L. K and Pandey, O. N. (1999). Effect of plant growth regultors on rooting behavior of cuttings of *Dalbergia sissoo* Roxb. and *Dalbergia latifolia* Roxb. *Indian Forester*, **125** (4) : 421 - 425.

Sharma, Y. M. L. (1987). Production and utilization of bamboos and related species in the South Asia Region. *Indian Forester*, **114** (10) : 603-609.

Singh Sānjay.; Ansari, S. A. and Kumar Pramod (2002). Clonal Propagation of *Bambusa nutans* through Culm and branch cutting. *Indian Forester*, **128** (1): 35-40.

Singh, B. and Bhatt, B. (2009). Sprouting and rooting response of *Dalbergia sissoo* stem cuttings collected from different altitudes. *Indian Forester*, **145** (3): 342-345.

Singh, B.; Singh, J.; Tiwari, S. K. and Ansari A. A. (2003). Mass multiplication through stem branch cuttings of *Commiphora wightii* an important medicinal plant. *J. Trop. For.*, **19** : 14 – 18.

Singh, S. P.and Dhuria, S. S. (1992). Effect of Indole Butyric Acid on steckling production of *Gmelina arborea* in different season. *J. Trop. For.*, **8** (4) : 343 - 346.

Singh, S.; Meena, S. L. and Ansari, S. A. (2006). Rooting response of semi hardwood shoot cuttings of *Grewia optiva* and *Largerstroemia parviflora. Indian Forester,* **132** (12) : 1661 – 1666.

Somashekar, P. V.; Lakshmikant, R. N.; Rathore, T. S.; Reddy, K. S and Lakshman, A. C (2004). Macro-propagation of *Guadua angustifolia* Kunth- an exotic and fast growing bamboo species. *Indian Forester*, **130** (6): 655-662.

*Stapleton, C. M. A. (1982). Bamboo in east Nepal: preliminary findings (Dec 1981- June 1982). Report from forest survey and research office, department of forest, His majesty's Government of Nepal, Kathmandu.

*Stapleton, C. M. A. (1985a). Bamboos in Jackson, J. K Manual of afforestation techniques for Nepal. Nepal/UK forestry research project, Kathmandu.

*Stapleton, C. M. A. (1985b). Studies on vegetative propagation of *Bambusa* and *Dendrocalamus* species by culm cuttings in Nepal (to be published in) *Proceeding of IDRC bamboo workshop, Hangzhou China 1985.*

Stapleton, C. M. A. and Tamrakar, S. M. (1984). Planting of large bamboo 'Bans' by the traditional method. *Nepal Forestry Technical Bulletin*, **9** : 15-17.

Surendaran, T.; Venkatesh, C. S. and Seethalkashmi, K. K (1983). Vegetative of the thorny bamboo *Bambusa arundinacea* Wild. using some growth regulators. *J. of Tree science*. **2**: 10-15.

Surendran, C. (1990). Vegetative propagation in *Gmelina arborea* Roxb. through single noded cuttings. *Indian J. Forestry*, **13** (2) : 162 - 164.

Tiwari, D. N. (1992). A Monograph on Bamboo. International Book Distributors, Dehra Dun, India. p. 498.

*Tystjarvi, P. K. (1981). Silviculture aspects of community forestry development in the hills of Nepal.

---

* - Originally not seen

APPENDIX

Appendix - I: Mean meteorological data during March – 2012 to November – 2012

Year – 2012								
Month	Temperature (^0C)		RH (%)		Wind Speed (km/hrs)	Sunshine (hr)	Rainfall (inch)	Evaporation (mm/day)
	Max	Min	Max	Min				
March	34.8	16.5	78.7	28.3	3.7	8.5	0.0	6.2
April	35.8	23.0	85.0	41.6	4.9	9.1	0.0	6.8
May	25.0	35.8	84.0	56.9	7.9	9.8	6.0	6.6
June	33.3	27.2	84.4	68.1	9.6	7.8	155.0	5.6
July	30.7	26.3	92.1	83.2	6.6	2.2	271.0	3.6
August	30.0	25.6	92.4	82.5	4.6	2.5	200.0	3.5
September	30.2	24.5	93.0	76.0	2.5	4.1	618.0	2.2
October	34.9	22.1	80.0	46.6	0.7	7.6	12.0	4.2
November	33.2	16.2	72.8	31.5	0.8	8.6	0.0	4.5

CERTIFICATE

This is to certify that I have no objection for supplying to any scientist any copy or any part of this thesis at a time through reprographic process, if necessary for rendering reference services in a library or documentation centre.

Place : Navsari

Date : 20.04.2013

(B. D. Mesariya)