Studies on induction of rooting in some hard to root mulberry genotypes (*Morus* sp.)

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(2012-S-25-M)

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Thesis

Submitted to

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in partial fulfilment of requirement for the award of the degree of

Master of Science in Sericulture

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Dedicated to my Late Beloved

Mother

Whose Blessings have Encouraged me
to Complete this Research Programme.
To Day
I Thank God as I Fulfilled her Dream

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
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Certificate – I

This is to certify that the thesis entitled **"Studies on induction of rooting in some hard to root mulberry genotypes (*Morus* sp.)"** submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science in Sericulture**, to the Faculty of Postgraduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, is a record of bonafide research work carried out by **Mr. Gh. Mohammad Mir (Regd. No. 2012-S-25-M)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that any help or information received during the course of investigation have duly been acknowledged.

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Certificate – II

We, the members of the Advisory committee of **Mr. Gh. Mohammad Mir (Regd. No. 2012-S-25-M)**, a candidate for the degree of **Master of Science in Sericulture**, have gone through the manuscript of the thesis entitled, **"Studies on induction of rooting in some hard to root mulberry genotypes (*Morus* sp.)"** and recommend that it may be submitted by the student in partial fulfilment of the requirements for the award of degree.

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This is to certify that the thesis, **“Studies on induction of rooting in some hard to root mulberry genotypes (*Morus* sp.)”** submitted by **Mr. Gh. Mohammad Mir (Regd. No. 2012-S-25-M)** to the Faculty of Postgraduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, in partial fulfilment of the requirements for the award of the degree of **Master of Science in Sericulture** was examined and approved by his Advisory Committee and external examiner on ………………..

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ABSTRACT

Physiological requirements for root formation in cuttings have been studied by many workers and the importance of growth substances has well been recognized. In plant species rooting is the soul of survival which supports the plant in uptake of nutrients needed for growth and yield parameters. The proposed investigation entitled "Studies on induction of rooting in some hard to root mulberry genotypes (*Morus* spp.)" was carried out at Temperate Sericulture Research Institute, Mirgund which is located at 34^{o}17′ N latitude and 75^{o}17′ E longitude at an elevation of 1587 m above mean sea level. The cuttings were planted during the last week of March 2013 and maintained in the polyhouse. Sand, clay and farmyard manure (FYM) in the ratio of 6:3:1 formed the rooting medium. Aqueous extract of willow was prepared on the basis of weight/volume. Two concentrations of willow extract (100 and 50 percent) and three concentrations of IBA (1000, 500 and 100 ppm) were used to test their influence on the rooting parameters of three promising genotypes (Goshoerami, Ichinose and SKM-33). From 20th days after planting observations on sprouting were recorded at weekly intervals till the genotype registered consistent readings. Highest sprouting percentage was recorded on 55th days after planting (DAP) and survival of sprouted cuttings declined from 62nd DAP and got stabilised from 83rd DAP. Other parameters were recorded only after the establishment of rooting. 100

percent willow extract recorded highest values for rooting, Number of roots/sapling, length of longest root (cm), root biomass (g), shoot biomass (g) and root volume (cm^3) with values of 83.33, 9.525, 16.233, 3.065, 4.653 and 2.669, respectively. Highest root shoot ratio of 0.693 was recorded through use of 1000 ppm IBA. Goshoerami excelled in almost all the parameters under influence of growth regulators recording highest values of 100 per cent, 65 per cent, 7.800, 13.887 cm, 2.139 g and 1.973 cm^3 for sprouting, rooting, number of roots/sapling, length of longest root, root biomass and root volume respectively. Ichinose recorded highest root shoot ratio of 0.642 while as SKM-33 recorded highest shoot biomass of 3.668 g. Further investigations on the subject can throw more information about the use of willow extract in rooting of mulberry. This would be in a long run helpful for the increased multiplication of mulberry in shortest possible time for the sustenance of sericulture and is predicted to totally revolutionize the nursery industry especially in view of its being economic and eco-friendly.

Key words: Mulberry, willow extract, growth regulators, Rhizocalline, polyhouse.

Signature of Student

Dated : ___________

Signature of Major Advisor

Dated: ________________

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Dated :

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Chapter – 1

INTRODUCTION

The practice of silkworm (*Bombyx mori* L.) rearing for the purpose of cocoon production continues to be one of the most important avocations which provide employment to people from rural areas both directly as well as indirectly. The sericulture industry which is mainly concerned with mulberry cultivation and finally silk cocoon raising does not involve any tedious technique, instead assures income to farmers in quickest possible time. Mulberry sericulture generates remunerative employment to 12-13 persons through out the year (Jolly, 1987) with competitive low investment and short gestation period.

China is the largest silk producing country with production of 1,26,000 metric tons of raw silk (Anonymous, 2013a) followed by India with a production of 23,600 metric tons of raw silk (Anonymous, 2013b). In Jammu and Kashmir 28000 rearers are engaged with silkworm rearing with cocoon crop production of 9.01 lakh MT generating revenue of 1192.67 Lakh rupees (Anonymous, 2013c). The quality of mulberry leaves is considered as a prime factor governing production of good cocoon crop (Kumar, 1988).

In order to fulfill the gap between production and consumption, more and more efforts need to be put in all the sectors of sericulture and one such sector is mulberry cultivation. Since, mulberry constitutes only food for silkworm rearing as such it needs to be propagated on large scale.

Propagation by root grafting takes four to five years to raise plants in the field. In addition it involves high cost of labour and being a skillful process slight error might result in complete failure of graft, besides compatibility of stock and scion is a vital factor (Nanda and Kochar, 1985). The rate of survival in root grafting practiced in Kashmir for propagation of mulberry genotypes of temperate origin is only 20-30 per cent (Bakash and Khan, 2001).

Popular varieties of mulberry available in the valley do not root easily through cuttings, thus coming in the way of progressive development of industry. This not only creates scarcity of mulberry leaf in the area but at the same time reduces the magnitude of silkworm rearing which eventuates in lesser cocoon production and low income generation.

The literature reveals that willow (*Salix* sp.) are fast growing deciduous trees that are found mainly in the north hemisphere in cold arctic and north temperate zones. They root very well irrespective of medium they are grown in and it is said that willow cuttings can even be grown if put upside down. This property of willows is due to the naturally occurring plant rooting hormones which they contain. Willow extract has been successfully used in inducing rooting in rose cuttings. We can take the advantage of this naturally occurring hormone and make extracts (willow water extract) that can be used to induce rooting in cuttings of mulberry plants. Willow extract can be made from cuttings of any tree or shrubs of the willow family.

Popular mulberry varieties viz. Goshoerami, Ichinose, SKM-33 (newly evolved) although good in various quality and quantity traits are shy rooters. Though literature is available on rooting of mulberry through different techniques, yet it is always demanding to have an alternative method/technique which could be put in place for easy and more economic propagation method/technique and one such method could be use of willow extract which has been found effective in enhancing rooting in other plants. So it was felt to use willow extract for testing its influence on rooting in mulberry.

Sericulture is a cottage industry, which generates ample work for the rural agrarian population in general and women folk in particular in food plant cultivation, silkworm rearing and reeling, while men remain also engaged in silk weaving besides attending the work in agriculture fields.

In India, sericulture is practiced as a continuous land based activity throughout the year, yielding a series of about 4-6 cocoon crops in tropical climate (Benchamin, 1994) and estimated to provide direct employment to about six hundred thousand people (Subramanian *et al.*, 1995).

Out of 6.29 lakh villages in India, sericulture is practiced in about 52,000 villages. In Kashmir, sericulture is practiced in 760 villages which constitutes 1.46 per cent of the total sericulture villages in India. The mulberry is generally grown as trees; the farmers often face the shortage of leaf during silkworm rearing, which in turn affects the quality, productivity and economics of this activity (Mir *et al.*, 2005).

In order to explore the possibility of increasing/inducing rooting in mulberry cuttings, willow extract has been used under different concentrations with below given objectives:

- Efficacy of willow extract as a root inducer in mulberry.
- Comparative study on influence of IBA and willow extract on rooting of promising mulberry genotypes under polyhouse conditions.

Chapter – 2

REVIEW OF LITERATURE

Propagation of mulberry on a large scale is one of the important prerequisite for the development of sericulture industry. For easy and rapid propagation rooting ability of any genotype is of paramount importance. In case of mulberry the propagation through stem cuttings is the easiest, cheapest and quickest method as compared to other methods including grafting for which several studies have been carried out in India particularly in tropical regions to find out rooting potential of mulberry genotypes (Rao and Khan, 1963).

In India the most common method of propagation of mulberry is through stem cuttings which results in preserving prototype plant character (Krishnaswamy, 1994) while in Kashmir valley propagation of mulberry is through root grafting as propagation through stem cutting is not satisfactory (Bindroo and Dhar, 2000; Baksh and Khan, 2001).

Pridham (1942) while studying the factors influencing the rooting of cuttings and growth of young plants observed that rooting of cuttings and subsequent growth of young plants depend primarily upon the maturity and treatment of the stock plant.

While studying the influence of mineral nutrition on production, rooting and survival of cuttings of Azaleas, it was observed that nutritional status of the cuttings and different stages of maturity of cuttings had influence on the rooting of the cuttings (Preston *et al.*, 1953).

The clonal difference in mulberry for root growth parameters clearly indicated that the clones differed significantly for shoot and root length, number of roots/sapling and volume of roots/sapling (Bhat and Hattalmani, 1992).

Studies conducted to determine the relationship between carbohydrates and nitrogen level on the rooting of pear cuttings revealed that appropriate levels of carbohydrates are essential to supply energy for differentiation and root development in the cuttings and it was concluded that the total reserves of carbohydrates coupled with low levels of nitrogen and total number of competing metabolic sites on the cuttings determine the amount of root formation (Ali and Westwood, 1966).

Kasiviswanthan and Iyenger (1967) conducted an experiment to find out the suitable position upto which the cuttings can be prepared for planting and observed that there was a gradual reduction in the mean weight of cuttings from basal to apical end and cuttings obtained from the bottom position of the plant were superior to the cuttings obtained from top position.

The advantage of rooted plants over seedling stock include their faster growth rate (Ooyama and Toyoshima, 1965) greater stock/scion uniformity, better site matching, true to type character and also greater wood volume production (Fielding, 1969).

Comprehensive studies on various aspects of mulberry cuttings have revealed that rooting is an genetic character, which is highly influenced by climatic conditions like soil moisture and temperature (Honda, 1970).

In temperate countries most of the mulberry varieties do not respond to clonal propagation due to poor rooting ability and without pre-treatment (Bindroo *et al.*, 1988 and 2000; Baksh and Khan, 2001).

Hartmann *et al.* (1997) have reported root initiation and rooting ability as the fundamental consideration in vegetatively cultivated crops.

Fotedar *et al.* (1990) while assessing the rooting of Chinese White and five other Japanese varieties under temperate condition obtained satisfactory results in case of Chinese White.

Mala *et al.* (1992) have carried out several studies to find out rooting ability of various mulberry genotypes and have found propagation through stem cuttings as best method in comparison to graft especially in tropical regions of India.

Baksh *et al.* (2000) while assessing the performance of ten genotypes under temperate conditions of Kashmir reporting least rooting ability of 5.56 per cent in Goshoerami and maximum of 60.77 per cent in case of Chinese White.

Baqual *et al.* (2004) have reported improved rooting ability of Goshoerami cuttings upto an extent of 60 per cent in an easy and cost effective way through polyhouse.

Since survival and growth of the plants are important pre-requisite for a genotype to establish in a particular environment, selection of genotypes is done giving due weightage for both the parameters and successful establishment of mulberry plant is achieved if a variety possesses high rooting ability (Fotedar *et al.*, 2006).

Mir *et al.* (2011) while studying the performance of six indigenous mulberry genotypes in Kashmir valley in open and polyhouse condition observed a significant increase in rooting and sprouting percentage under polyhouse conditions.

2.1 Effect of growth regulators on rooting

Propagation by root grafting takes in all, four to five years to raise plants in the field. In addition it involves high cost of labour and being a skilful process, slight error might result in complete failure of grafts. Besides in compatibility of stock and scion is a vital factor (Nanda and Kochhar, 1985).

Baghel *et al.* (1993) reported that ringing of hardwood cuttings of seedless lemon (*Citrus lemon* Burm) recorded maximum rooting percentage, number of leaves per shoot, number of shoots per cutting, length of shoot and dry matter percentage of leaves as compared to etiolation, girdling and control.

Among the plant growth regulators auxins have the greatest effect on rooting of cuttings (Hartmann *et al.*, 1997) and have been found to be very much effective in inducing root formation, increasing the root number and length in many mulberry varieties difficult to be propagated vegetatively (Biswas and Sengupta, 1993).

In an experimental trial conducted from 1960-1963 on the induction of rooting in Japanese mulberry varieties Kosen and Goshoerami by the use of growth regulators, it was observed that all the growth regulators were effective in inducing root formation but the Seradix powder 'Peobder' compound proved to be the best (Rao and Khan, 1963).

While studying the effect of growth regulating substances viz. Seradix B, IAA, IBA and NAA on the rooting of cuttings of a Japanese variety Kosen, Mukharjee and Sharma (1971) observed that rooting and growth was optimum under the influence of IAA at 500 $\mu g\ ml^{-1}$ followed by Seradix B. While least response was obtained in NAA. They further observed that an increase in concentration of IAA from 100-500 $\mu g\ ml^{-1}$ induced better rooting and growth while in case of IBA and NAA a reverse sequence was observed.

Honda (1972) made comprehensive studies on the effect of growth regulators on root initiation of softwood and hardwood cuttings of twenty popular cultivars of mulberry in Japan and observed that NAA is the most effective in inducing root in soft wood cuttings and both NAA and IBA are equally effective for root initiation of hardwood cuttings.

Konarli *et al.* (1977) observed that cuttings of local cv. Sari Asi and Japanese Ichinose dipped to a depth of 2.5 cm in 200 $\mu g\ ml^{-1}$ IBA produced more roots than those dipped in 2-3 mm depth.

While studying the propagation of mulberry through stem cuttings in Kashmir, it was observed that 200 $\mu g\ ml^{-1}$ Gibberellic acid recorded highest percentage of survivability in the cuttings of Goshoerami and Rokokyaso followed by IBA and NAA (Anonymous, 1978).

Shanmugavelu (1975) while working on induction of rooting in mulberry reported that basal cuttings recorded maximum number of roots and larger root length in comparison to middle and terminal cuttings.

Mala and Basavaiah (1991) while studying the effect of IAA and IBA with three concentrations each on the rooting of cuttings of variety S-36 observed maximum survivability with IAA as compared to IBA and 50 µg ml^{-1} IAA was superior than all other concentrations and control.

Experiments conducted on the induction of rooting in hardwood cutting of some temperate mulberry cultivars by use of growth regulators revealed that 100 µg ml^{-1} IBA improved rooting in Goshoerami, Rokokayaso, KNG, Ichinose and Kokso-27 whereas 50 µg ml^{-1} IAA proved effective in Chinese White and NAA was found least effective (Fotedar, 1989 and Fotedar *et al.*, 1990).

While studying the propagation of *Termanalia arjuna* through stem cutting with the help of growth regulators, it was observed that cuttings treated with IBA at 1000 µg ml^{-1} showed better rooting, maximum number of primary roots and higher survival rate after transplanting (Isa *et al.*, 1993).

A nursery trial conducted on the use of NAA and 2,4-D to promote rooting and survival of stem cutting of mulberry variety S-36 revealed that 25 and 50 µg ml^{-1} of IBA gave highest rooting percentage followed by 50 and 75 µg ml^{-1} NAA (Chandrasheker *et al.*, 1996).

While working on rooting of two exotic mulberry cuttings with various growth regulators, Kamili and Shah (1996) observed that efficacy of growth regulators varies from species to species and from variety to variety. They further observed that Goshoerami variety responded well to IAA treatment whereas Kakso-27 showed successful rooting with NAA at 500 µg ml^{-1} concentration. Similar results were observed by Bindroo and Dhar (2000).

Planting of mulberry cuttings in late March is favourable period for higher percentage of sprouting and survival (Anonymous, 1978).

While studying the minimum number of buds required in shoot portion of stem cuttings for obtaining maximum survival, it was observed that basal portion of the cutting with 3-4 buds recorded higher survival percentage as compared to middle portion (Anonymous, 1980).

Murakamin (1980) observed that quantum of roots and shoots of cuttings differs according to the parts of shoot from which cuttings were made. Basal portion of the shoot produce larger amount of the roots and shoots than that of younger ones.

Tiku and Bindroo (1989) reported that plantation from April to 1st week of August are most favourable periods for propagation of hardwood cuttings of easy rooting cultivars of mulberry.

Nautiyal *et al.* (1991) while studying the rooting response of branch cuttings of teak (*Tectona grandis*) as influenced by season and growth hormones have concluded that the correlation of the rooting of the cuttings is significant at 0.1 per cent level of probability with season and at 1 per cent level with the hormone treatments.

Haines *et al.* (1992) while studying the prospects for the mass production of superior selection age phenotypes of *Acacia* sp. have demonstrated that variation in rooting ability within genotypes on the same locations are due to genetic variation.

In India, the most common method of vegetative propagation and popular isolation of high yielding mulberry varieties is through stem cuttings as it is easy, cheap and the most convenient method (Sujathama and Dandin, 1998).

Palanisamy and Bisen (2001) while investigating on vegetative propagation techniques for *Dendrocalamus asper* reported that the cuttings when treated with 200 ppm of IAA followed by subsequent provision of mist chamber having temperature of 30±2^{o}C with 70 to 80 per cent RH gave satisfactory results.

Peer (2002) while studying the propagation of some cultivars of mulberry (*Morus* spp) through stem cuttings under Kashmir conditions have concluded that by maintaining proper environment under polyhouse (optimum temperature and high relative humidity), rooting can be induced in mulberry stem cuttings which are otherwise difficult to root.

The studies on rooting behaviour of some temperate varieties of mulberry revealed that varieties differed significantly in their rooting behaviour. Highest rooting percentage viz. 55 per cent was recorded in Goshoerami and minimum 16.6 per cent in Ichinose (Munshi *et al.*, 2003).

Mala and Basavaiah (1991) observed that cuttings taken from plants that have made vigorous growth and hence have carbohydrate accumulation in excess of inorganic nitrogen rooted properly and this accumulation increases with age, thus increasing the rooting capacity.

Kumar and Syamal (2005) while studying the effect of etiolation and plant growth substances on rooting and survival of air layers of guava have observed that etiolation and application of different concentrations of auxins greatly influence the number of secondary roots per primary root.

Bhargava *et al.* (2006) while experimenting with propagation of *Capparis decidus* through cuttings have concluded that semi-hard wood cuttings gave superior results over softwood and hardwood in terms of sprouting and rooting percentage as sprouting and rooting of softwood and hardwood cuttings may be attributed to the immaturity and very hard tissue respectively at the base of cuttings. Similar results have also been presented in earlier studies of Vashishtha (1987) who reported that in *Capparis deciduas*, semi-hardwood cuttings gave better response.

Mukherjee and Sikdar (1977) while studying the rooting of matured cuttings of S.146 mulberry variety found the highest root number, root length with NAA and IBA treatment.

2.2 Effect of willow extract on rooting of some plant species

While working on the rooting experiment on rose cuttings, Kawse (1964) observed that willow extract has the ability to stimulate rooting unmatched by any previously known rooting substances, including plant hormones.

In a comparative study on the rooting activity of water extracts of chestnut and willow by bean root test, Gesto *et al.* (1977) found that willow extract increased rooting and showed a rhythm in the content of endogenous growth substances.

While working on the ability of willow extract to assist in rooting. Kawase (1970) reported that all plants contain rhizocaline and other factors in greater or lesser amounts, and it is also seasonally variable, with the highest concentrations observed in the early spring.

The separation of a cutting-from a plant causes IAA to move polarly and accumulate at the base of the cutting stem. This “auxin gradient” then causes the hypothetical rhizocaline to follow suit. Rhizocaline then assists the IAA to form roots. This substance is actually three or four different unknown elements or compounds and has been suggested by researchers to be either vitamin B, vitamin H, Boron, sugar, various Nitrogen compounds, or something else. Further chemical research is continuing to identify rhizocaline with certainty.

Willow is perhaps the easiest to root of all woods, and thus contains more rhizocaline than hard-to-root plants. As rhizocaline is perfectly water soluble, it is available to plants, and as it is natural in all vegetable matter, it is non-polluting in large concentrations (Kawase, 1970)

The extract from willow indicated three major root -promoting fractions at Rf 0-0.1, 0.7-0.8, and 0.3-0.4 in a decreasing order of their activities when paper chromatographed with isopropanol: ammonia: water 8:1:1 v/v. The Rf 0-0.1 fraction consisted of at least four fractions and the strongest one did not move from the starting line on the chromatogram. This starting line fraction was extremely strong in rooting activity and its highest concentration resulted in 8.7 times as many roots as controls Gesto *et al.* (1977).

Chapter – 3

MATERIALS AND METHODS

The proposed investigation on the rooting ability of mulberry genotypes (*Morus* spp) was carried out at Temperate Sericulture Research Institute, Mirgund under polyhouse conditions during 2013. The cuttings were planted during the last week of March and maintained in the polyhouse, sand, clay and farmyard manure (FYM) in the ratio of 6:3:1 formed the rooting medium. Aqueous extract of willow was prepared on the basis of weight/volume. Observations on weekly intervals were recorded on the sprouting till the genotype registered consistent readings. This was taken as the rooting of genotype. The varieties of mulberry used for the study are given as under :

i. Goshoerami (*M. latifolia*)

ii. Ichinose (*M. alba* Linn)

iii. SK.M-33 (M.SK.M.33 cv)

3.1 Geographical features of the experimental site

The Temperate Sericulture Research Institute, Mirgund is located at $34^{o}17'$ N latitude and $75^{o}17'$ E longitude at an elevation of 1587 m above mean sea level. The Institute is 18 km from Srinagar on Srinagar-Uri National Highway No. 1-A in Baramulla district and spread over an area of 20 hectares, where various research programmes, trials, covering all the activities pertaining to sericulture are being conducted.

3.2 Climate

The climate is Temperate-cum-Mediterranean and of continental type characterized with marked seasonality. The region falls into mid to high altitude temperate zones which are characterized by a sub-microthermic regime where winter is severe extending from 15^{th} December up to mid of March. During winter

Plate-1 :   View of polyhouse where experiment was conducted

Plate-2 : **Preparation of cutting under progress**

Plate-3 : Filling of polybags with rooting medium

the valley remains almost covered with snow and temperature often goes below the freezing point.

3.3 Observation recorded

3.3.1 Experimental details

Design	:	CRD
Genotypes	:	03 (Goshoerami, Ichinose, SKM-33)
Treatments	:	06 (root promoters 05, control 01)

I	=	Willow extract 100%
II	=	Willow extract 50%
III	=	IBA 1000 ppm
IV	=	IBA 500 ppm
V	=	IBA 100 ppm
VI	=	Distilled water (control)

No. of replications	:	04
No. of cuttings/treatment/replication	:	10
Treatment combinations	:	18

3.3.2 Methodology of willow extract

Aqueous extract of willow was prepared by dipping 1 to 1.5 inch long horizontally cut pieces of willow branches about 9 months old into the boiling water immediately after removing from the flame. The lid of container containing boiling water was closed keeping the willow pieces immersed for 24 hours allowing them to steep (Kawase, 1964). The extract thus obtained was then filtered to prepare concentrations i.e. (100 and 50%).

Chopped pieces of willow cuttings for preparation of extract

Filtering willow extract

Plate-4 : Willow extract preparation

3.3.3 Preparation of hormone

IBA 100, 500 and 1000 ppm was prepared by dissolving 0.1, 0.5 and 1 g of hormone respectively in 10 ml of 100 per cent ethanol then made the volume to 1 litre in distill water.

3.3.4 Rooting medium

Sand, clay and well decomposed farmyard manure was thoroughly mixed in the ratio of 6:3:1 and put in polybags having the size of 4.5 x 11 inch with 3-4 pores at the bottom to avoid water logging conditions in the polythene bags rotting of cuttings (Baqual *et al.*, 2004).

3.4 Planting and cultural activities

Before planting the cuttings were given fungicide treatment by immersing in 0.1% Mencozeb for 30 minutes and then thoroughly washed with distilled water under shade. After that mulberry cuttings at the time of planting (last week of March) were first immersed in the hormone/willow extract for 30 minutes and then planted in the polybags keeping upper most bud exposed. The rooting media was well moistened through the application of water by plastic cane.

The cuttings were maintained properly by watering in the morning and evening hours with the help of water sprinkler, temperature in the range of 25-30^{o}C and relative humidity in the range of 80-90 per cent in the polyhouse were maintained by sprinkling water with spray pump in mist form. Manual weeding at regular intervals was done to remove weeds from polybags for smooth growth of saplings and uniform light percolation. Further the polythene cover was lifted from sides of polyhouse as per requirement and that was done in order to maintain optimum temperature as far as possible and to ensure proper upkeep of growing saplings.

Plate-5 : Treatment of cuttings with growth regulators

3.4.1 Biometric observations recorded

The biometric observations recorded throughout the experiment are elucidated blow:

3.4.2 Sprouting percentage

Sprouting percentage was recorded at weekly intervals after 20 days of plantation and noted/calculated as :

$$\frac{\text{Number of cuttings sprouted}}{\text{Total cuttings planted}} \text{ x100}$$

3.4.3 Rooting percentage

This was recorded after 75-105 days of planting when no change in the sprouting was registered by the genotypes. At that stage sprouted cuttings were taken out of polybags and rooting percentage was calculated as suggested by Dandin and Jolly (1986) by the following formula :

$$\frac{\text{Number of cuttings rooted}}{\text{Total number of cuttings planted}} \text{ x100}$$

3.4.4 Number of roots/sapling

The saplings were gently pulled out of polybags. Rooted cuttings were drenched with water to loosen soil adhering to them and to facilitate their easy detachment from soil with out damaging their root system. Dried with blotting paper and then counted/calculated.

3.4.5 Length of longest root (cm)

Saplings were gently removed from polybags, washed and dried on a blotting paper and measured with the help of measuring scale.

3.4.6 Root biomass (g)

This was taken by cutting the root mass of sapling with the help of sharp blade, drying it on blotting paper and weighing it on digital balance.

3.4.7 Shoot biomass (g)

The whole shoot biomass was cut off from the sapling and weighed on digital balance for accuracy in weight.

3.4.8 Root shoot ratio

The root and shoot biomass taken above was used to calculate the root shoot ratio.

3.4.9 Root volume (cm^3)

This was taken by washing and cutting the root portion from the saplings. It was then dried on a blotting paper and immersed in a graduated cylinder filled with water up to a particular level. The increase in water level in the cylinder (water displaced by immersed root) gave the root volume.

Plant-6 :   Measuring of root volume

Chapter – 4

EXPERIMENTAL FINDINGS

The experimental findings recorded during the studies entitled "Studies on induction of rooting in some hard to root mulberry genotypes (*Morus* spp.)" conducted under polyhouse conditions at Temperate Sericulture Research Institute, Mirgund during 2013 are reflected under following headings :

4.1 Sprouting percentage

Results regarding spouting percentage and survival after sprouting as influenced by growth regulators, varieties and their interaction are presented in Tables-1 to 4 and Tables-5 to 10, respectively.

4.1.1 Influence of growth regulators

Periodical observation of the sprouting progress indicated that it increased consistently up to the 55th day after planting (DAP) when it reached maximum in all varieties under experiment. Growth promoters exhibited influence on the genotypes with T_1 showing maximum sprouting percentage 93.33 per cent followed by T_2 90.00. Least sprouting of 76.66 per cent was recorded in control. From 62th DAP cuttings started to wither and survival of sprouted cuttings started to decline which continued till 83rd DAP then onwards it remained constant when T_1 recorded highest survival 83.33 per cent followed by T_2 72.50 per cent, T_3 66.66 per cent, least survival was observed in control 44.60 per cent

4.1.2 Influence of Genotypes

Mean values of genotypes with different treatments did not vary significantly through out the sprouting phase till 55th DAP still higher sprouting percentage of 90.00 per cent was recorded in Goshoerami followed by Ichinose and SKM-33 with sprouting percentage of 87.50 and 84.16 respectively. Survival after sprouting also did not exhibit any significant influence between genotypes, however higher survival of 65.00 per cent was recorded in Goshoerami followed by Ichinose and SKM 33 with survival percentage of 63.33 and 60.41respectively.

Table-1 : **Influence of growth regulators on sprouting percentage of mulberry genotypes 34th days after planting (DAP)**

Treatments	Genotypes			Mean
	Gosherami	Ichinose	SKM-33	
T_1 (Willow extract 100%)	40.00	36.00	36.00	**37.33**
T_2 (Willow extract 50%)	40.00	36.00	32.00	**36.00**
T_3 (IBA 1000 ppm)	36.00	36.00	36.00	**36.00**
T_4 (IBA 500 ppm)	32.00	36.00	36.00	**34.66**
T_5 (IBA 100 ppm)	36.00	36.00	32.00	**34.66**
T_6 Distilled water (control)	36.00	36.00	36.00	**36.00**
Mean	**36.66**	**36.00**	**34.66**	

CD$_{(p\leq0.05)}$

Treatment (T) = NS

Genotype (G) = NS

T x G = NS

Table-2 : Influence of growth regulators on sprouting percentage of mulberry genotypes 41st days after planting (DAP)

Treatments	Genotypes			Mean
	Gosherami	Ichinose	SKM-33	
T_1 (Willow extract 100%)	60.00	54.00	54.00	**56.00**
T_2 (Willow extract 50%)	60.00	54.00	48.00	**54.00**
T_3 (IBA 1000 ppm)	54.00	54.00	54.00	**54.00**
T_4 (IBA 500 ppm)	48.00	54.00	54.00	**52.00**
T_5 (IBA 100 ppm)	54.00	54.00	48.00	**52.00**
T_6 Distilled water (control)	54.00	54.00	54.00	**54.00**
Mean	**55.00**	**54.00**	**52.00**	

CD$_{(p\leq0.05)}$

Treatment (T) = NS

Genotype (G) = NS

T x G = NS

Table-3 : **Influence of growth regulators on sprouting percentage of mulberry genotypes 48th days after planting (DAP)**

Treatments	Genotypes			Mean
	Gosherami	Ichinose	SKM-33	
Percentage (Willow extract 100%)	80.00	72.00	72.00	**74.66**
T_2 (Willow extract 50%)	80.00	72.00	72.00	**72.00**
T_3 (IBA 1000 ppm)	725.00	72.00	72.00	**72.00**
T_4 (IBA 500 ppm)	64.00	72.00	72.00	**69.33**
T_5 (IBA 100 ppm)	72.00	72.00	64.00	**69.33**
T_6 Distilled water (control)	72.00	72.00	72.00	**72.00**
Mean	**73.33**	**72.00**	**70.66**	

CD$_{(p\leq0.05)}$

Treatment (T) = NS

Genotype (G) = NS

T x G = NS

Table-4 : **Influence of growth regulators on sprouting percentage of mulberry genotypes 55th days after planting (DAP)**

Treatments	Genotypes			Mean
	Gosherami	Ichinose	SKM-33	
Percentage (Willow extract 100%)	100.00	90.00	90.00	**93.33**
T_2 (Willow extract 50%)	100.00	90.00	80.00	**90.00**
T_3 (IBA 1000 ppm)	90.00	90.00	90.00	**90.00**
T_4 (IBA 500 ppm)	80.00	90.00	90.00	**86.66**
T_5 (IBA 100 ppm)	90.00	90.00	80.00	**86.66**
T_6 Distilled water (control)	80.00	75.00	75.007	**76.66**
Mean	**90.00**	**87.50**	**84.16**	

$CD_{(p \leq 0.05)}$

Treatment (T) = NS

Genotype (G) = NS

T x G = NS

Table-5 : Influence of growth regulators on survival percentage of sprouted mulberry genotypes 62nd days after planting (DAP)

Treatments	Genotypes			Mean
	Gosherami	Ichinose	SKM-33	
T_1 (Willow extract 100%)	100.00	90.00	90.00	**93.33**
T_2 (Willow extract 50%)	100.00	80.00	80.00	**86.66**
T_3 (IBA 1000 ppm)	80.00	80.00	70.00	**76.66**
T_4 (IBA 500 ppm)	80.00	80.00	90.00	**83.33**
T_5 (IBA 100 ppm)	80.00	80.00	70.00	**76.66**
T_6 Distilled water (control)	80.00	70.00	70.00	**73.33**
Mean	**86.66**	**80.00**	**78.33**	

CD$_{(p\leq0.05)}$

Treatment (T) = 9.88

Genotype (G) = NS

T x G = 4.03

Table-6 : Influence of growth regulators on survival percentage of sprouted mulberry genotypes 69th days after planting (DAP)

Treatments	Genotypes			Mean
	Gosherami	Ichinose	SKM-33	
T_1 (Willow extract 100%)	95.00	90.00	80.00	**83.33**
T_2 (Willow extract 50%)	100.00	80.00	70.00	**83.33**
T_3 (IBA 1000 ppm)	70.00	70.00	70.00	**70.00**
T_4 (IBA 500 ppm)	70.00	70.00	70.00	**70.00**
T_5 (IBA 100 ppm)	60.00	70.00	60.00	**63.33**
T_6 Distilled water (control)	60.00	60.00	60.00	**60.00**
Mean	**75.83**	**73.33**	**68.33**	

CD$_{(p\leq 0.05)}$

Treatment (T) = 11.02

Genotype (G) = NS

T x G = 4.50

Table-7 : **Influence of growth regulators on survival percentage of sprouted mulberry genotypes 76th days after planting (DAP)**

Treatments	Genotypes			Mean
	Gosherami	**Ichinose**	**SKM-33**	
T_1 (Willow extract 100%)	95.00	90.00	80.00	**88.33**
T_2 (Willow extract 50%)	80.00	80.00	70.00	**76.66**
T_3 (IBA 1000 ppm)	70.00	70.00	70.00	**70.00**
T_4 (IBA 500 ppm)	60.00	70.00	60.00	**63.33**
T_5 (IBA 100 ppm)	50.00	60.00	60.00	**56.66**
T_6 Distilled water (control)	50.00	50.00	50.00	**50.00**
Mean	**67.50**	**70.00**	**65.00**	

$CD_{(p \leq 0.05)}$

Treatment (T) = 8.90

Genotype (G) = NS

T x G = 3.63

Table-8 : Influence of growth regulators on survival percentage of sprouted mulberry genotypes 83rd days after planting (DAP)

Treatments	Genotypes			Mean
	Gosherami	Ichinose	SKM-33	
T_1 (Willow extract 100%)	95.00	80.00	75.00	**83.33**
T_2 (Willow extract 50%)	80.00	70.00	67.50	**72.50**
T_3 (IBA 1000 ppm)	65.00	70.00	65.00	**66.66**
T_4 (IBA 500 ppm)	52.50	61.25	60.00	**57.91**
T_5 (IBA 100 ppm)	50.00	56.25	52.50	**52.91**
T_6 Distilled water (control)	47.50	42.50	42.50	**44.16**
Mean	**65.00**	**63.33**	**60.41**	

$CD_{(p \leq 0.05)}$

Treatment (T) = 5.937

Genotype (G) = NS

T x G = 10.283

Table-9 : Influence of growth regulators on survival percentage of sprouted mulberry genotypes 90th days after planting (DAP)

Treatments	Genotypes			Mean
	Gosherami	Ichinose	SKM-33	
T_1 (Willow extract 100%)	95.00	80.00	75.00	**83.33**
T_2 (Willow extract 50%)	80.00	70.00	67.50	**72.50**
T_3 (IBA 1000 ppm)	65.00	70.00	65.00	**66.66**
T_4 (IBA 500 ppm)	52.50	61.25	60.00	**57.91**
T_5 (IBA 100 ppm)	50.00	56.25	52.50	**52.91**
T_6 Distilled water (control)	47.50	42.50	42.50	**44.16**
Mean	**65.00**	**63.33**	**60.41**	

$CD_{(p \leq 0.05)}$

Treatment (T) = 5.937

Genotype (G) = NS

T x G = 10.283

Table-10 : Influence of growth regulators on survival percentage of sprouted mulberry genotypes 97th days after planting (DAP)

Treatments	Genotypes			Mean
	Gosherami	Ichinose	SKM-33	
T_1 (Willow extract 100%)	95.00	80.00	75.00	**83.33**
T_2 (Willow extract 50%)	80.00	70.00	67.50	**72.50**
T_3 (IBA 1000 ppm)	65.00	70.00	65.00	**66.66**
T_4 (IBA 500 ppm)	52.50	61.25	60.00	**57.91**
T_5 (IBA 100 ppm)	50.00	56.25	52.50	**52.91**
T_6 Distilled water (control)	47.50	42.50	42.50	**44.16**
Mean	**65.00**	**63.33**	**60.41**	

$CD_{(p \leq 0.05)}$

Treatment (T) = 5.937

Genotype (G) = NS

T x G = 10.283

4.1.3 Interaction effect between growth regulators and genotypes

Interaction effect between genotypes and growth regulators remained non significant till 55th DAP while as survival after 62nd DAP showed significant influence with T_1 (100 % willow extract) recording 95 per cent survival in Goshoerami being significantly different from Ichinose and SKM-33 which were in turn at par with each other.

4.2 Rooting percentage

The results regarding rooting percentage as influenced by growth regulators, varieties and their interaction are presented in Table-11.

4.2.1 Influence of growth regulators on rooting

The use of various growth regulators had a significant effect on rooting percentage of cuttings with T_1 (100 % willow extract) being significantly higher over rest of the treatments recording a value of 83.33 per cent. On the other hand T_2 (50% willow extract) and T_3 (1000 ppm, indole butyric acid) were at par with each other with rooting value of 72.50 and 66.66 per cent, but significantly higher than T_4, T_5 and T_6. However least value of rooting percentage viz., 44.16 per cent was recorded in T_6 (control).

4.2.2 Influence of genotypes

Although varietal influence on rooting through use of different growth regulators was non-significant yet, highest value of rooting percentage (65%) was recorded in Gosheoerami followed by Ichinose and SKM-33 recording rooting of 63.33 and 60.41 per cent, respectively.

4.2.3 Interaction effect between growth regulators and genotypes

The interaction effect between varieties and growth regulators recorded significant difference with T_1 (100% willow extract) recording rooting percentage of 95 per cent in Gosherami. However, it was least in T_6 (control) with a value of 47.5 per cent.

Table-11 : Influence of growth regulators on rooting ability (%) of mulberry genotypes

Treatments	Genotypes			Mean
	Gosherami	Ichinose	SKM-33	
T_1 (Willow extract 100%)	95.00	80.00	75.00	**83.33**
T_2 (Willow extract 50%)	80.00	70.00	67.50	**72.50**
T_3 (IBA 1000 ppm)	65.00	70.00	65.00	**66.66**
T_4 (IBA 500 ppm)	52.50	61.25	60.00	**57.91**
T_5 (IBA 100 ppm)	50.00	56.25	52.50	**52.91**
T_6 Distilled water (control)	47.50	42.50	42.50	**44.16**
Mean	**65.00**	**63.33**	**60.41**	

CD$_{(p\leq 0.05)}$

Treatment (T) = 5.937

Genotype (G) = NS

T x G = 10.283

Similar observations were recorded with other test varieties viz., Ichinose and SKM-33 where also rooting was significantly higher in T_1 (100% willow extract) with a value of 80 and 75 per cent, respectively. However in these varieties also least rooting percentage viz., 42.5 per cent recorded in control (T_6).

4.3 Number of roots/sapling

The results regarding number of roots/sapling as influenced by varieties, growth regulators and their interaction are presented in Table-12.

4.3.1 Influence of growth regulators

The various growth regulators indicated significant effect on number of roots/sapling with T_1 (100 % willow extract) recording value of 9.525 per cent which was significantly higher over rest of the treatments but at par with T_3 recording value of 8.725. however, least number of roots/sapling (5.967) was recorded in control (T_6).

4.3.2 Influence of genotypes

Varietal influence did not indicate any significant difference on number of roots/sapling with the variety of various growth regulators. However number of roots/sapling was in the order of Goshoerani>Ichinose>SKM-33 with the values of 7.800, 7.715 and 7.552, respectively.

4.3.3 Interaction effect between growth regulators and genotypes

The interaction effect was non-significant. However, higher values of number of roots/sapling in respect of all these varieties under study were recorded in T_1 (100 % willow extract) with values of 9.750, 9.400 and 9.425, respectively. Lowest values for number of roots/sapling in respect of Goshoerami, Ichinose and SKM-33 was recorded in T_6, with values of 6.400, 5.850 and 5.650, respectively.

Table-12 : Influence of growth regulators on number of roots/sapling

Treatments	Genotypes			Mean
	Gosherami	Ichinose	SKM-33	
T_1 (Willow extract 100%)	9.750	9.400	9.425	**9.525**
T_2 (Willow extract 50%)	7.200	8.575	8.000	**7.925**
T_3 (IBA 1000 ppm)	9.200	8.600	8.375	**8.725**
T_4 (IBA 500 ppm)	7.250	7.763	7.763	**7.592**
T_5 (IBA 100 ppm)	7.000	6.100	6.100	**6.400**
T_6 Distilled water (control)	6.400	5.850	5.650	**5.967**
Mean	**7.800**	**7.715**	**7.552**	

CD$_{(p\leq0.05)}$

Treatment (T) = 1.1986

Genotype (G) = NS

T x G = NS

4.4 Length of longest root (cm)

The results regarding the influence of various growth regulators varieties and their interaction on root length are presented in Table-13.

4.4.1 Influence of growth regulators

Use of various growth regulators had a significant effect on the length of root/sapling. Highest values for longest root were recorded in T_1 (16.233 cm) which was at par with T_2 (14.917 cm) but significantly different then rest of the treatments. T_4 and T_5 with values of 12.923 and 11.752 were at par with each other. Least value of 9.276 were recorded in T_6.

Impact of willow extract remained highest followed by hormones which in turn were superior over the control.

4.4.2 Influence of genotypes

Varietal influence on length of roots was significant with highest values of 13.887 recorded in Goshoerami which was at par with that of SKM-33 (13.379) but significantly different for that of Ichinose (12.391).

4.4.3 Interaction effect between growth regulators and genotypes

The length of root was not influenced by the use of various growth regulators and did not either indicate any significant interaction effect with various varieties under test.

However, Goshoerami with T_1 (100 % willow extract) recorded highest values of 16.973 and least values with T_6 (9.000). Similarly higher values for Ichinose and SKM-33 were recorded with T_1 (100 % willow extract) recording values of 15.150 and 16.575, respectively. Lowest values in these varieties were recorded in T_6 reflecting values of 9.790 and 9.038, respectively.

Table-13 : Influence of growth regulators on length of longest root (cm)

Treatments	Genotypes			Mean
	Gosherami	Ichinose	SKM-33	
T_1 (Willow extract 100%)	16.973	15.150	16.575	**16.233**
T_2 (Willow extract 50%)	15.800	14.450	14.500	**14.917**
T_3 (IBA 1000 ppm)	14.875	13.375	14.393	**14.214**
T_4 (IBA 500 ppm)	13.675	11.155	13.940	**12.923**
T_5 (IBA 100 ppm)	13.000	10.425	11.830	**11.752**
T_6 Distilled water (control)	9.000	9.790	9.038	**9.276**
Mean	**13.887**	**12.391**	**13.379**	

CD$_{(p\leq0.05)}$

Treatment (T) = 1.6975

Genotype (G) = 1.2003

T x G = NS

4.5 Root biomass (g)

The results regarding root biomass as influenced by various growth regulators and their interaction are presented in Table-14.

4.5.1 Influence of growth regulators

The use of various growth regulators had a significant effect on root biomass of saplings with T_1 (100 % willow extract) recording significantly higher values of 3.065 g on the other hand T_2 and T_3 were at par with each other with root biomass of 2.539 of 2.379g, respectively. However least value of root biomass viz., 1.302 g was recorded in T_6 (control).

4.5.2 Influence of genotypes

Varietal response of root biomass recorded non significant difference with the use of various growth regulators, however Goshoerami recorded highest root biomass of 2.139 g/sapling while as other two test varieties viz., Ichinose and SKM-33 recorded value of 2.056 and 2.106 g respectively.

4.5.3 Interaction effect between growth regulators and genotypes

The interaction effect between varieties and growth regulators remained non significant. T_1 (100 % willow extract) recorded highest root biomass of 3.5 g in Goshoerami, however it was least in T_6 (control) with value of 1.270 g.

Similar observations were also recorded with Ichinose and SKM-33 where also treatment T_1 (100 % willow extract) recorded highest values of 2.435 and 3.260, respectively. Lowest values in respect of these varieties was recorded in T_6 with values of 1.630 and 1.005 respectively.

Table-14 : Influence of growth regulators on root biomass (g)

Treatments	Genotypes			Mean
	Gosherami	Ichinose	SKM-33	
T_1 (Willow extract 100%)	3.500	2.435	3.260	**3.065**
T_2 (Willow extract 50%)	2.450	2.195	2.973	**2.539**
T_3 (IBA 1000 ppm)	2.050	2.310	2.778	**2.379**
T_4 (IBA 500 ppm)	1.880	1.920	1.505	**1.768**
T_5 (IBA 100 ppm)	1.685	1.845	1.120	**1.550**
T_6 Distilled water (control)	1.270	1.630	1.005	**1.302**
Mean	**2.139**	**2.056**	**2.106**	

CD$_{(p\leq0.05)}$

Treatment (T) = 0.54

Genotype (G) = NS

T x G = NS

4.6 Shoot biomass (g)

The results regarding shoot biomass influenced by varieties, growth regulators and their interaction are presented in Table-15.

4.6.1 Influence of growth regulators

The use of various growth regulators had a significant effect on shoot biomass/sapling with T_1 (100% willow extract) being significantly higher over rest of the treatments recording 4.653 g/sapling shoot biomass. On the other hand T_2 (50% willow extract) and T_3 (1000 ppm indole butyric acid) were at par with other with shoot biomass/sapling of 4.008 and 3.443 g, respectively, however least value of shoot biomass viz. 2.502 (g) was recorded in T_6 (control).

4.6.2 Influence of genotypes

Varietal influence on shoot biomass through use of different growth regulators was non-significant with SKM-33 recording shoot biomass of 3.668/sapling which was higher than rest of the two varieties viz. Goshoerami and Ichinose recording shoot biomass of 3.301 and 3.203/sapling respectively.

4.6.3 Interaction effect between growth regulators and genotypes

The interaction effect between varieties and growth regulators recorded non-significant difference. However, T_1 (100% willow extract) recorded higher shoot biomass (5.210 g) with SKM-33. Similarly higher values of 5.00 and 3.750 g were recorded in Goshoerami and Ichinose with T_1 (100 % willow extract) and least values of 2.338, 2.970 and 2.200 were recorded with T_6 in Goshoerami, Ichinose and SKM-33, respectively.

Table-15: Effect of growth regulators on shoot biomass (g) of mulberry genotypes

Treatments	Genotypes			Mean
	Gosherami	Ichinose	SKM-33	
T_1 (Willow extract 100%)	5.00	3.750	5.210	**4.653**
T_2 (Willow extract 50%)	4.035	3.640	4.350	**4.008**
T_3 (IBA 1000 ppm)	3.00	3.155	4.175	**3.443**
T_4 (IBA 500 ppm)	2.658	3.025	3.090	**2.924**
T_5 (IBA 100 ppm)	2.778	2.678	2.988	**2.814**
T_6 Distilled water (control)	2.338	2.970	2.200	**2.502**
Mean	**3.301**	**3.203**	**3.668**	

CD$_{(p \le 0.05)}$

Treatment (T) = 0.66

Genotype (G) = NS

T x G = NS

4.7 Root-shoot ratio

The results regarding root shoot ratio as influenced by varieties, growth regulators and their interaction are presented in Table-16.

4.7.1 Influence of growth regulators

The use of various growth regulators had significant effect on root shoot ratio of saplings with T_3 (1000ppm IBA) recording highest values of 0.693 per cent being at par with T_1 (100% willow extract) having values of 0.658. Rest of treatments T_2, T_4, T_5 and T_6 with values of 0.631, 0.609, 0.556 and 0.515 were also significantly different from each other.

4.7.2 Influence of genotypes

Highest root shoot ratio of 0.642 was recorded in Ichinose which was in turn par with the Goshoerami (0.641) and significantly different from SKM-33 (0.548).

4.6.3 Interaction effect between growth regulators and genotypes

The interaction effect between varieties and growth regulators recorded significant difference with T_4 recording highest root shoot ratio of 0.707 in Goshoerami. However, it was least in T_6 (control) with a value of 0.543.

Similar observation was recorded with other test varieties viz., SKM-33recording values of 0.683 with T_2 and Ichinose recording values of 0.732 with T_3. However, in these varieties also least value of root shoot ratio of 0.456 and 0.548 was recorded in control (T_6).

Table-16 : Effect of growth regulators on root shoot ratio of mulberry genotypes

Treatments	Genotypes			Mean
	Gosherami	Ichinose	SKM-33	
T_1 (Willow extract 100%)	0.700	0.649	0.625	**0.658**
T_2 (Willow extract 50%)	0.607	0.603	0.683	**0.631**
T_3 (IBA 1000 ppm)	0.683	0.732	0.665	**0.693**
T_4 (IBA 500 ppm)	0.707	0.634	0.487	**0.609**
T_5 (IBA 100 ppm)	0.606	0.688	0.374	**0.556**
T_6 Distilled water (control)	0.543	0.548	0.456	**0.515**
Mean	**0.641**	**0.642**	**0.548**	

$CD_{(p \leq 0.05)}$

Treatment (T) = 0.01474

Genotype (G) = 0.00851

T x G = 0.00602

4.8 Root volume (cm^3)

The results regarding root volume (cm^3) as influenced by varieties growth regulators and their interaction are presented in Table-17.

4.8.1 Influence of growth regulators

The use of various growth regulators had significant effect on root volume of sapling with T_1 (100 % willow extract) recording higher values of 2.669 significantly different than rest of treatments. T_2 with value of 2.185 was at par with T_3 (1.9783). Least value of 1.185 were recorded in control.

4.8.2 Influence of genotypes

Growth regulators did not exhibit any influence on varieties, however Goshoerami recorded highest root volume of 1.973. The other two varieties viz., Ichinose and SKM-33 recorded values of 1.776 and 1.729 respectively.

4.8.3 Interaction effect between growth regulators and genotypes

The interaction effect between varieties and growth regulators remained non-significant. T_1 (100 % willow extract) in respect of Goshoerami recorded highest root volume of 3.175, however it was least in T_6 with a value 1.240 cm^3.

Similarly higher values of T_1 (100 % willow extract) were recorded in Ichinose and SKM-33 with values of 2.170 and 2.663 respectively. Lowest values of 1.313 and 1.003 in these varieties was recorded with T_6.

Table-17 : Effect of growth regulators on root volume (cm^3)

Treatments	Genotypes			Mean
	Gosherami	Ichinose	SKM-33	
T_1 (Willow extract 100%)	3.175	2.170	2.663	**2.669**
T_2 (Willow extract 50%)	2.200	2.010	2.345	**2.185**
T_3 (IBA 1000 ppm)	2.080	2.110	1.745	**1.978**
T_4 (IBA 500 ppm)	1.643	1.553	1.493	**1.563**
T_5 (IBA 100 ppm)	1.500	1.500	1.128	**1.376**
T_6 Distilled water (control)	1.240	1.313	1.003	**1.185**
Mean	**1.973**	**1.776**	**1.729**	

$CD_{(p\leq0.05)}$

Treatment (T) = 0.38

Genotype (G) = NS

T x G = NS

Chapter – 5

DISCUSSION

Vegetative propagation of plants is most common method of perpetuation. It is only short cut method that results in production of true to type plants. Like many other crop varieties mulberry is also grown vegetatively in Kashmir through various methods. Although these methods are result oriented still there is potential for improvement which could be achieved through different means and present study is a step in that direction. The result of present study entitled "Studies on induction of rooting in some hard to root mulberry genotypes (*Morus* spp.)" have thrown open new information which is discussed as under:

5.1 Willow water extract

Kawse (1964) has observed that willow extract contains Rhizocaline in sufficient quantity having ability to stimulate rooting unmatched by any previously known rooting substances, including plant hormones.

The name rhizocaline was first suggested by Bouillenne and Went (1933) for the rooting substances produced by the leaves in the presence of light. This substance not considered a plant nutrient was thermostable, stored in cotyledons and buds with basipetally polar transport.

According to the rhizocaline hypothesis the polar transport of auxin causes it to accumulate at the base of a cutting and the resulting auxin gradient causes a downward movement of Rhizocaline towards the base of the cuttings. Rhizocaline and auxin thus accumulated at the base of the cutting act together in root formation (Kawase, 1964).

The existence of rhizocaline or rhizocaline like substance was amply demonstrated by Hess (1964), but the exact nature of rhizocaline has not been well established.

5.2 Sprouting percentage

Sprouting indicated general increase in all test varieties and all treatments till it reached maximum, followed by steady decline till it recorded a constant value. The initial increase in sprouting could be due to the utilization of the stored food material from the cuttings and decline could be attributed to their non establishment of roots. Higher percentage of sprouting/survivability was recorded in treatments viz., willow extract and IBA depicting decline with the reduction in their concentration which could be attributed to reduction in the concentration of respective growth regulators.

Goshoerami indicated highest percentage in sprouting (95 %) as compared to Ichinose which recorded (80 %) sprouting followed by SKM-33 with 75% only. The variation in sprouting percentage could be attributed to the genetic makeup of the genotypes. Increase in sprouting under polyhouse conditions have been observed by Mir *et al.* (2011).

5.3 Rooting percentage

The application of different growth regulators had a profound influence upon rooting percentage of cuttings in all test varieties. Impact of willow extract remained highest followed by hormones which in turn were superior over the control. Significantly highest rooting viz., 95% was recorded in Goshoerami with T_1 (100% willow extract). However in the same variety rest of the treatments recorded rooting percentage in the order of $T_2>T_3>T_4>T_5>T_6$ respectively.

Similar trend was observed in other test varieties viz . Ichinose and SKM - 33 where also T_1 (100% willow extract) recorded significantly higher rooting percentage viz. 80 and 75 % respectively. The increased percentage of rooting of cuttings with growth regulator treatment might be due to mobilization of nutritional reserves to the region of root formation, thereby enhancing the activity of hydrolysing the enzymes (Nanda and Kochher, 1985). The rest of the treatments in both the varieties travelled behind in decreasing order from T_2 to T_6.

The differential rooting response of mulberry varieties with hormonal treatments has also been reported by Rao and khan (1963), Hartman *et al.* (1997), these findings are also in line with the results of Mukherjee and Sikdar (1977) who indicated the influence of hormones on rooting of different mulberry varieties.

Higher percentage of rooting was recorded in treatments viz., willow extract and IBA depicting decline with the reduction in their concentration. These findings corroborate with the findings of Mukharjee and Sharma (1971) who observed increase in rooting with increase in hormonal concentrations.

5.4 Number of roots/sapling

The varied growth regulator concentrations in different treatments had significantly influenced the root number/sapling with T_1 (100% willow extract) recording value of 9.75 in Goshoerami which was at par with T_3 with a value of 9.2 but both of them were significantly higher over rest of the treatments.

Number of roots/sapling with different treatments also indicated influence in Ichinose where T_1 (100 % willow extract) with values of 9.4 was significantly higher than T_4, T_5 and T_6 but at par with T_2 and T_3 where as in case of SKM-33 again T_1 (100 % willow extract) recorded highest values of 9.425 but this was at par with T_3 with a value of 8.725. The increased root number although a varietal character, yet it must have got influenced by various hormonal concentrations.

The increase in number of roots/cutting as a result of growth regulators might be due to their accumulation at the base of cutting to a suitable level for initiation and development of roots (Hartmann *et al.*, 1997). These results are in conformity with the findings of Shanmugavelu (1975) in Kanva-2, Konarli *et al.* (1977) in Ichinose and Isa *et al.* (1993) in *Termanalia arjuna*. These findings are also in conformity with the results of Shanmugavelue (1975) Isa *et al.* (1993) who also reported that the cutting treated with IBA at 1000 µg ml^{-1} showed better rooting and maximum number of primary roots in *Terminalia arjuna*.

5.5 Length of longest root (cm)

Impact of willow extract remained highest followed by hormones which in turn were superior over the control. The various growth regulators and their concentrations indicated that T_1 (100 % willow extract) had significant impact upon root length in all the test varieties with a value of 16.973 in Goshoerami, 15.150 in Ichinose and 16.575 in respect of SKM-33, however in respect of Goshoerami and Ichinose T_1 (100 and willow extract) was at par with T_2. The increase in length of roots might be due to enhanced hydrolysis of carbohydrates which resulted due to auxin treatment (Nanda and Kochher, 1985). Shanmugavelu (1975) in Kanva-2 and Mukherjee and Sikdar (1977) in S146 also reported increased length of roots with hormonal treatment. The influence of root length is although a varietal feature, yet the hormonal treatment might have resulted in furthering the root length. These findings are in line with the results of Ali and Westwood (1966) who reported that carbohydrate content and other mineral reserves in cuttings coupled with low levels of nitrogen and total no of competing metabolic sites on the cuttings determine the amount of root formation. The results are also in conformity with the findings of Mala and Basavaiah (1991), Mukherjee and Sikdar (1977) who reported highest root length with hormonal treatments.

5.6 Root biomass

Root biomass which determine the robustness of growing plant was also influenced by various hormonal/ growth regulator concentrations.

The various growth regulators and their concentrations indicated that T_1 (100 % willow extract) had significant impact upon root biomass recording values of 3.065 being at par with T_2 (2.539) and significantly different from rest of treatments. Impact of willow extract remained highest followed by hormones which in turn were superior over the control.

The increase in root weight/biomass might be due to higher uptake of nutrients and accumulation of photosynthetase by the roots of treated cuttings

(Baghel *et al.*,1993). These results are in agreement with the findings of Nath and Barooah (1992) in different mulberry varieties.

5.7 Shoot biomass

The various growth regulators and their concentrations indicated that T_1 (100 % willow extract) had significant impact upon shoot biomass recording values of 4.653 being at par with T_2 (4.008) and significantly different from rest of treatments. Impact of willow extract remained highest followed by hormones which in turn were superior over the control.

Variation in shoot biomass through different treatments is attributed to the effect of growth regulators and their concentrations used. The increase in biomass above ground may be due to the maximum rooting observed in growth regulator treated cuttings which might have absorbed more nutrients along with moisture (Sandhu *et al.*, 1991). These findings are in conformity with the results of Honda (1970) who also reported similar response of cuttings of mulberry varieties treated with NAA & IBA. Gesto *et al.* (1977) also found that willow extract increased rooting which in turn is bound to show influence on shoot biomass. In the instant case 100% concentration of willow extract in respect of T_1 (100 % willow extract) might have influenced the shoot biomass.

5.8 Root-shoot ratio

Root shoot ratio is a symbol of plant health and gives the significant idea about the nitrogen assimilation potential of any crop variety (Richard, 1992).

Different treatments have exhibited positive influence in the root shoot ratio of test varieties. Highest root shoot ratio (0.6933) was recorded in T_3 (IBA 1000 ppm) which was significantly different from rest of three treatments followed by T_1 (100 % willow extract) with a value 0.63100. Ichinose exhibited highest root shoot ratio of 0.642. Least root shoot ratio (0.548) was recorded in control. Root shoot ratio is an inherent character of variety and varies from variety to variety.

5.9 Root volume

Among all the test varieties root volume was found to be highest in Goshoerami (1.973) which can be attributed to its inherent character which in turn makes it higher yielder as well. Further the effect of growth regulators coupled with ambient condition of temperature and humidity might have had their influence on their root volume. These findings are in accordance with the results of Bhat and Hartellmeni (1992) who reported varied root formation including root volume in various varieties of mulberry genotypes. Increase in root volume under hormonal treatments can be attributed to higher root biomass. The increase in root weight might be due to higher uptake of nutrients and accumulation of photosynthetase by the roots of NAA & IBA treated cuttings (Baghel *et al.*, 1993). These results are in agreement with the findings of Nath and Barooah (1992) in different mulberry varieties.

Chapter – 6

SUMMARY AND CONCLUSION

The research regarding "Studies on induction of rooting in some hard to root mulberry genotypes (*Morus* spp.)" with stem cuttings under Kashmir climatic conditions has been conducted at Temperate Sericulture Research Institute, Mirgund during spring 2013. The purpose of the study was to find out the efficacy/performance of some growth regulators (freshly extracted willow extract locally available in the Kashmir Valley) for promoting successful rooting in hard to root mulberry cultivars for which experiment was laid under polyhouse conditions.

The main findings of the research programme are given as under:

- Sprouting percentage of different varieties under study indicated highest values on 55^{th} DAP. From 62^{nd} days after planting survival of sprouted cuttings declined becoming stable from 83^{rd} DAP.
- Impact on rooting percentage with willow extract remained highest followed by hormones which in turn were superior over the control. T_1 (100 % willow extract) recorded highest value of 83.33 per cent. On the other hand T_2 (50% willow extract) and T_3 (1000 ppm, indole butyric acid) were at par with each other with rooting value of 72.50 and 66.66 per cent respectively.
- 100 per cent willow extract and 1000 ppm IBA recorded highest values (9.525, 8.725) for number of roots/sapling. Least number of roots/sapling (5.967) were recorded in control (T_6).
- Longest root length (16.233) was recorded in T_1 (100 % willow extract) followed by T_2 (14.917) least root length 9.276 was recorded in T_6 (control).

- Highest root biomass (3.065) was recorded in T_1 (100 % willow extract) followed by T_2 (2.53). Least root biomass of 1.30 was recorded in T_6.
- The use of various growth regulators had a significant effect on shoot biomass/sapling with T_1 (100% willow extract) being significantly higher over rest of the treatments recording 4.653 g/sapling shoot biomass. On the other hand T_2 (50% willow extract) and T_3 (1000 ppm indole butyric acid) were at par with other with shoot biomass/sapling of 4.008 and 3.443 g, respectively,
- T_3 (1000ppm IBA) recorded highest root shoot values of 0.693 per cent followed by T_1 (100% willow extract) recording values of 0.658.
- T_1 (100 % willow extract) recorded highest values of 2.669 for root volume significantly different than rest of treatments. T_2 with values of 2.185 was at par with T_3 (1.9783).

CONCLUSION

- T_1 (100% willow extract) has given promising results in almost all the parameters viz. rooting, number of roots/sapling, length of longest root, root biomass, shoot biomass and root volume in all the varieties under study.
- Impact of willow extract on almost all rooting parameters remained highest followed by hormones which in turn were superior over the control.
- Goshoerami has proved to be the best variety in respect of almost all rooting parameters. Ichinose and SKM-33 too have the potential to be exploited in Silk Industry.

- ➡ Further investigations on the subject can throw more information about the use of willow extract in rooting of mulberry. This would be, in a long run, helpful for the increased multiplication of mulberry in shortest possible time for the sustenance of sericulture industry and is predicted to totally revolutionize the nursery industry especially in view of its being eco friendly and economic.

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***Original not seen**

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CERTIFICATE

Certified that all the corrections/amendments as suggested by External Examiner Dr. Pankaj Tewary, Scientist-D & I/C P-4 BSF, CSB, Ministry of Textiles, Govt. of India Post: Safapora, Manasbal, Ganderbal Kashmir – 193 504 (J&K) during Viva-Voce examination held on December 13th of August, 2014 have been incorporated in the manuscript entitled "**Studies on induction of rooting in some hard to root mulberry genotypes (*Morus* sp.) in Kashmir"** submitted by **Mr. Gh. Mohammad Mir (Regd. No. 2012-S-25-M)**.

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