

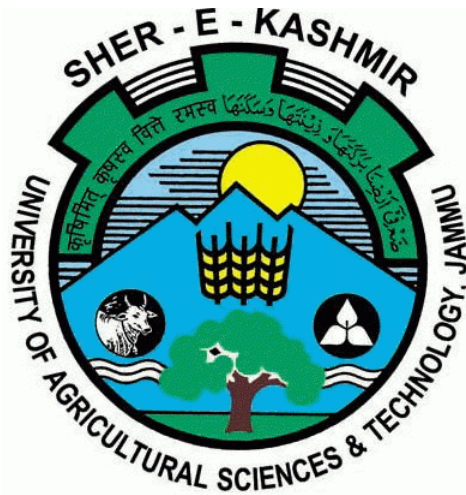
STANDARDIZATION OF PROPAGATION TECHNIQUES IN *Murraya koenigii* Spreng.

By

RAHUL SHARMA
(J-18-M-562)

**Thesis submitted to Faculty of Post Graduate Studies in partial
fulfillment of the requirements for the degree of**

**MASTER OF SCIENCE
IN
FORESTRY**



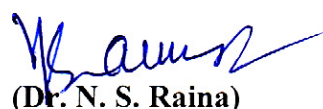
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2021

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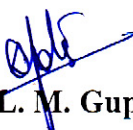
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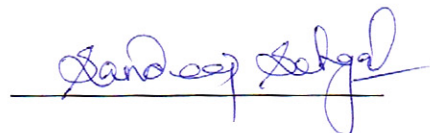
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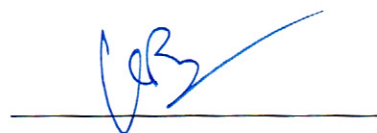


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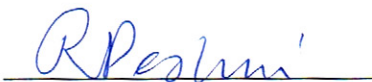


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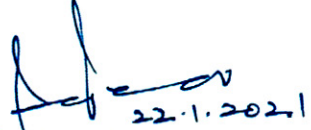
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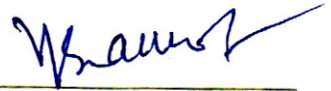


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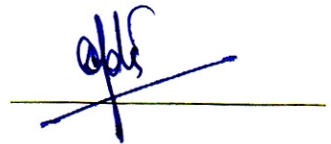
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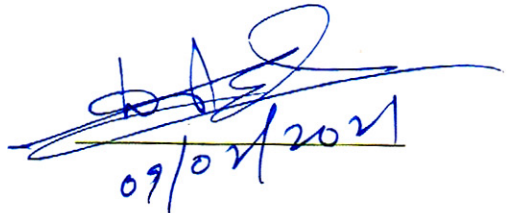
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ACKNOWLEDGEMENT

Acknowledgement in its true essence gives us an opportunity to remember and express our feelings and respect for those whom we absolutely admire and revere the most.

*With limitless humility, I am really grateful to “God”- the almighty who has enabled me to undertake higher studies and who has enabled me to continue doing the efforts for successful completion of present study, even during this pandemic situation. I am grateful to God for bestowing me with such affectionate parents **Sh. Hukam Chand Sharma and Smt. Poonam Sharma** whose love, guidance, inspiration and support encouraged me to choose the route of higher studies for myself. Their sacrifices, heartfelt blessings and firm faith in me has spelled the success of the present study.*

*I am beyond privileged to express the deep sense of gratitude to the most respectful and revered professor, **Dr. Narinder Singh Raina, Professor and Chairperson of Advisory Committee (Division of Agroforestry)** for his valuable, thorough and painstaking guidance, concrete suggestions and constructive criticism with his scientific acumen and proficiency during the course of present investigation.*

*I would like to extend my heartfelt thanks to other members of advisory committee **Dr. Sandeep Sehgal, Associate Professor (Division of Agroforestry), Dr. K. R. Sharma, Professor (Division of Soil Science and Agriculture Chemistry) and Dr. Rajinder Peshin, Professor (Division of Agricultural Extension Education)** for their valuable assistance and guidance during the course of study.*

*I also take this opportunity to express a deep sense of gratitude to **Dr. L. M. Gupta, Professor and Head (Division of Agroforestry)** for his able guidance throughout this period.*

I would like to express my heartiest thanks to the faculty members of Division of Agroforestry Dr. Sushil Kumar Gupta (Professor), Dr. K. K. Sood (Professor) and Dr. Meenakshi Gupta (Assistant Professor) for their voluntary help, suggestions and encouragement during the degree programme.

All the above mentioned, most respected names are highly acknowledged for their efforts, able guidance and support especially during these trying times, amid pandemic.

I humbly express my loyal and heartiest thanks to Mr. Sumir Raina (Stenographer), Mr. R. K. Dhar (FCLA), Mr. Pushap and Mr. Janak (Worker) for their kind help during entire course of study.

Help received from the friends and colleagues is heartily acknowledged. People who deserve the special mentions are Mr. Aatish, Miss Rafia, Mr. Manjot, Mr. Varun, Mr. Javeed, Mr. Joshi, Mr. Akshay, Mr. Jitender, Mr. Suresh, Mr. Jamwal, Mr. Anmol and Miss Amisha.

I would remiss, if I do not articulate my cordial feeling of thanks to my affectionate juniors Mr. Akram, Mr. Yaseer, Mr. Sourav Mr. Kunal and Mr. Tanuj who are ready to help me at any cost.

Last but not the least, I owe a lot to the dedicated effort of Global Village, Jammu for their careful typesetting and giving final shape to my thesis. Any omission in this brief acknowledgement does not mean lack of gratitude.

All are not mentioned, but none is forgotten.

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ABSTRACT

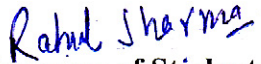
Title of Thesis : “Standardization of propagation techniques in *Murraya koenigii* Spreng.”
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Degree to be awarded : M.Sc. Forestry
Year of award of Degree : 2021
Nam of the University : Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu

Abstract

Murraya koenigii (curry leaf) belonging to family Rutaceae is one of the important medicinal cum aromatic plant which is grown throughout the world. Curry leaf has been used for years in Unani and Ayurvedic prescriptions due to its antibacterial and antifungal properties. In spite of having lots of medicinal values and good revenue, this plant has got least attention by scientists and researchers. Not much work has been done on the propagation of this species. A study entitled, “Standardization of propagation techniques in *Murraya koenigii* Spreng.” was carried out in the Division of Agroforestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha, during the year 2019-2020 to identify the better hormonal concentration for rooting of stem cuttings and suitable potting mixture for seed germination and growth. Two experiments were laid out in CRD (Complete Randomization Design) to study the seed and vegetative propagation protocol. In the first experiment, there were thirteen treatments with three replications each. The results revealed that cuttings treated with IBA 2000 ppm significantly recorded maximum sprouting percentage, rooting percentage, number of lateral roots, shoot length, root length, number of leaves, fresh root biomass and dry root biomass. In the second experiment, efforts were made to select the best potting mixture for seed germination. The results indicated that out of the four different potting mixtures, the seeds sown in soil: sand: vermicompost, (1:1:1) showed significantly higher germination percentage, germinative energy, survival percentage, collar diameter, number of leaves, length of primary root, fresh shoot weight, fresh root weight, dry weight, root:shoot ratio and seedling quality index. Further studies need to be carried out to study the overall success of the seedlings/cuttings raised by using these potting mixtures and hormonal concentrations.

Keywords: *Murraya koenigii*, potting mixtures, hormonal concentrations, propagation, seeds and stem cuttings


Signature of Major Advisor


Signature of Student

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ABBREVIATIONS

@	=	At the rate of
&	=	And
°C	=	Degree Celsius
Fig.	=	Figure
FYM	=	Farm Yard Manure
VC	=	Vermicompost
N	=	Nitrogen
P	=	Phosphorus
K	=	Potassium
g	=	Gram
cm	=	Centimeter
L ⁻¹	=	Per litre
C.D.	=	Critical difference
SE _{m±}	=	Standard error of mean
m	=	Meter
mg	=	Milligram
No.	=	Number
NS	=	Non Significant
ANNOVA	=	Annalysis of variance
%	=	Percent
PP	=	Page
ppm	=	Parts per million
Temp.	=	Temperature
viz.,	=	Vide licet
IBA	=	Indole-3- butyric acid
NAA	=	Napthalene acetic acid
IAA	=	Indole-3- acetic acid
T	=	Treatment
µg	=	Microgram
>	=	Greater than
<	=	Less than
ml	=	Milliletre
J&K	=	Jammu and Kashmir
<i>et al.</i>	=	et alia (Co-workers)

Chapter-1

Introduction

INTRODUCTION

Forests form one of the most important self-perpetuating and intricate terrestrial ecosystem providing magnificent eco-services. Forests in general, provide almost everything- from basic amenities to raw materials for expensive products. Forests are known for their productive functions. These serve as the source of sustenance for various products like food, fuel and timber. Not only this but forests also provide important non-timber forest products especially sugars, starches, spices and condiments, beverages, fumitories, masticatories and narcotics, medicines, essential oils, fatty oils and vegetable fats, waxes, soap substitutes, vegetable ivory, fodder, bioenergy or biofuel, fertilizers, fiber, pulp and paper, tannins, dyes, rubber and other latex products, gums and resins. Apart from their productive functions, these are considered pioneer in restoring, reclaiming and rejuvenating denuded and disturbed soils. Also forests are bestowed with rich and efficacious medicinal and aromatic plants (Seth, 2004).

Human beings have been utilizing plants for basic preventive and curative health care since time immemorial. Recent estimates suggest that over 9,000 plants have known medicinal applications in various cultures and countries (Gopal *et al.*, 2014). The medicinal and aromatic crops are now occupying a significant position on the scene in Indian agriculture. Three different perspectives attributed to that are: Firstly, the traditional health system under Ayurveda, Siddha and Unani takes into account holistic treatment and low cost of treatment with minimum side effects. This is the main reason for the hike in demand for medicinal herbs and aromatic plants. Secondly, these herbs are unrestrictedly collected from the wild sources without any scientific approach. Consequently, density of medicinal and aromatic plants in their natural habitat have started declining rapidly. This unrestricted approach calls for the need of cultivation of these species under field conditions. Lastly, in terms of economy, medicinal and aromatic crops have better scope as compared to other conventional/traditional field crops. These potentially yields higher returns and prices to the cultivators and collectors which is also the result of increasing demand of these crops in the world trade (Deshpande *et al.*, 2006). All these have led to the emergence of

medicinal and aromatic crops as alternatives to some of the traditional uneconomic crops, in a few regions of India (Mohapatra *et al.*, 2018). *Murraya koenigii* Spreng. is one such plant that has gained immense attention.

Murraya koenigii, commonly known as curry leaf or kari patta in Indian dialects, belongs to family Rutaceae which represent more than 150 genera and 1600 species. *Murraya koenigii* is a highly valuable plant which is known for its characteristic aroma and medicinal value (Jagadeeshkanth *et al.*, 2017). It is an important export commodity from India as it fetches good foreign revenue. Most part of this plant is covered with leaves and has a strong peculiar smell. It is more or less deciduous shrub or tree up to 6 m in height and 15-40 cm in diameter with short trunk, thin smooth grey or brown bark and dense shady crown (Kumar *et al.*, 2013). The plant produces small white flowers which can self-pollinate to produce small shiny-black drupes containing a single, large viable seeds. The berry pulp is edible, with a sweet flavour. It grows best in well-drained soils in areas with full sun or partial shade, preferably away from the wind. Growth is more robust when temperatures are at least 18°C (Parmar and Kaushal, 2019).

Murraya koenigii is well distributed in tropical and subtropical areas of Sri Lanka, Malaysia, Indonesia, Southern China and India (Dahlia *et al.*, 2017). In India, it is found in outer Himalayas, from the Ravi eastwards, ascending to 5000 ft. in Assam, Chittagong, Upper and Lower Burma. It is also found in evergreen and deciduous forests of Peninsular India, often as underwood (Singh *et al.*, 2014). The plant also found in the Tarai region of Uttar Pradesh and it is also widely found in the hills of Uttarkhand, Sikkim, Bengal, Central India, Western Ghats, TamilNadu, Maharastra, Karnataka and Kerala (Kumar *et al.*, 2013). This plant adorns every house yard of Southern India.

Curry leaf is a popular leaf-spice used in very small quantity for their distinct aroma due to the presence of volatile oil and their ability to improve digestion. Curry leaf is widely used in Indian cookery for flavouring foodstuffs. The leaves have a slightly pungent, bitter and feebly acidic taste, and they retain their flavour and other qualities even after drying. Curry leaf is also used in many of the Indian Ayurvedic and Unani prescriptions (Singh *et al.*, 2014). *Murraya koenigii* has been widely used for centuries and has a versatile role to play in traditional medicine. The plant is credited with tonic and stomachic properties. Bark

and roots are used as stimulant and externally to cure eruptions and bites of poisonous animals. Green leaves are eaten raw to cure dysentery and for checking vomiting. Leaves and roots are also used traditionally as bitter, analgesic, curing piles, inflammation, itching and are useful in leucoderma and blood disorders (Jain *et al.*, 2012).

The two improved varieties of curry leaf - DWD 1 and DWD 2 released by University of Agricultural Science, Dharwad have a good aroma. They are mainly cultivated in Karnataka. The variety DWD 1 is a clone of single plant root suckers, sensitive to low temperature, shiny and highly aromatic. The leaves have oil content of 5.22 per cent and can be dehydrated at 50°C without loss of quality and made into powder, whereas DWD 2 is a seedling progeny of unknown source is winter insensitive. Its leaves are slightly pale green and less aromatic and gives higher yield than DWD 1 (Madalageri *et al.*, 1994).

Murraya koenigii is normally propagated by seeds. The freshly harvested seeds give maximum germination but, they lose their viability very quickly in storage under open conditions (Thapparangana *et al.*, 2001). Raising of plants through cuttings is considered to be the easiest and most reliable method to obtain true to type plants (Thapparangana *et al.*, 2002). Information available on vegetative propagation methods and potting mixtures used for seed germination in *Murraya koenigii* is scanty. Therefore, the aim of present work was “Standardization of Propagation Techniques in *Murraya koenigii* Spreng.” which has been undertaken with following objectives:

Objectives:

1. To standardize the hormonal concentration for better rooting of stem cuttings
2. To investigate the effect of potting mixture on seed germination and seedling growth

Chapter-2

Review of Literature

REVIEW OF LITERATURE

The relevant literature on the present study entitled “Standardization of Propagation Techniques in *Murraya koenigii* Spreng.” has been reviewed here in this chapter and presented in following sections:

- 2.1 Standardize the hormonal concentration for better rooting of stem cuttings.
- 2.2 Effect of potting mixture on seed germination and seedling growth.

2.1 Standardize the hormonal concentration for better rooting of stem cuttings

Plant cuttings exhibit wide variability in their ease to rooting, some showing a fast response, while others posing difficulties in rooting. The endogenous auxin, indole acetic acid (IAA) and a number of synthetic auxins like indole butyric acid (IBA), naphthalene acetic acid (NAA). have been used by many researchers as root promoting substances in various forest tree species.

Sunderan *et al.* (1983) observed about 80 per cent rooting in *Bambusa arundinaceae* cuttings when treated with 200ppm NAA solution. Singh *et al.* (1986) studied that 1000ppm IBA proved most effective for promoting better growth and development of shoots and roots namely sprouting (63.33%), shoot number (4.75), shoot length (22.08cm), root number (39.1), length of root (19.36cm), dry weight (58.14mg) of roots and establishment (94.73%) in *Lagerstroemia indica*.

Aminah *et al.* (1995) investigated the application of auxin (indole butyric acid, IBA) significantly increased the rate of root emergence in single node leafy stem cuttings of *Shoreu leprosulu* taken from 10-month-old potted seedlings at Institute of Ecology and Resource Management, University of Edinburgh, Edinburgh, UK. IBA 20 µg per cutting was found to be the best with 70% of cuttings rooted within 12 weeks. IBA application also enhanced the number of roots developed on each cutting.

Husen and Mishra (2001) while working with *Cordia alliodora* and *Vitex negundo* reported an increased effectiveness of IBA with increasing concentration, both on rooting percentage and their growth.

Swamy *et al.* (2002) studied the effect of auxins (IBA and NAA) and season on rooting of juvenile and mature hardwood cuttings of *Robinia pseudoacacia* and *Grewia optiva* at Department of Forestry, Indira Gandhi Agricultural University, Raipur, India. Juvenile (2 year old trees) and mature hardwood (15 year old trees) cuttings of *Robinia pseudoacacia* and *Grewia optiva* were tested for their capacity to form roots. The highest rooting in juvenile (83.3%) and mature (66.6%) cuttings was observed with the NAA (500 mg/L) treatment in *Robinia pseudoacacia* during the spring season. In *Grewia optiva*, IBA (250 mg/L) in the monsoon season was most effective and yielding a maximum of 80% and 70% rooting in juvenile and mature cuttings, respectively. Auxin treatments also significantly enhanced the number of roots, root length, leaf number and leaf area.

Thapparangana *et al.* (2002) conducted a research trail at Horticulture Research Station, GKVK, Bangalore. One year old healthy shoots were selected from 10 year old curry leaf trees and were grouped as hard-wood, semi-hardwood and soft wood and these cuttings were treated with 500ppm, 1000ppm, 1500ppm and 2000ppm of IBA solution and 0.1N potassium hydroxide. The result showed that plants obtained from hardwood cuttings treated with 2000ppm of IBA solution showed maximum survival percentage (91.67) and rooting response (37.50).

Khali and Sharma (2003) reported that amongst all the phytohormones tried, IBA was the most effective hormone at concentration of 10000ppm for the induction of higher percentage of rooting in the juvenile cuttings of *Taxus baccata*.

Aslam *et al.* (2007) while working with *Taxus baccata* revealed that IBA 500ppm (out of the three auxins IAA, IBA and NAA) performed best regarding rooting of cuttings (76.666), while control resulted in minimum rooting of 8 percent only.

Kesari *et al.* (2009) examines the amenability of vegetative propagation and effect of maturation in candidate plus tree *Pongimmia pinnata* through rooting of stem cuttings treated with varying concentrations and combinations of auxins. IBA at 4.92 mM was

found to be most effective where rooting percentage and number of roots were significantly higher ($P < 0.01$) than in control. However higher concentrations of auxins above 7 mM in general inhibited the rooting of cuttings. The effectiveness was in the order of IBA > NAA > IAA when applied singly.

Rana *et al.* (2012) performed an experimental trial on branch cuttings of *Ficus roxburghii* which were treated with different hormones in two different seasons: rainy-July and spring-March at Division of Agroforestry, SKUAST-J, Chatha, Jammu. (J&K). Large sized (1.25-2.5 cm diameter) cuttings resulted in statistically higher growth of all the studied parameters than that of small sized (< 1.25 cm diameter) cuttings in both seasons (rainy and spring). The interaction large size x IBA 100 ppm resulted in significantly better growth of the studied parameters in both seasons except for the number of lateral roots, number of shoots, shoot length and number of leaves in rainy season. Therefore, for the successful propagation of *Ficus roxburghii*, large sized cuttings are to be treated with IBA 100 ppm and be planted in spring.

Abidin and Metali (2013) conducted an experiment on effects of different types and concentrations of auxins on juvenile stem cuttings for propagation of potential medicinal *Dillenia suffruticosa* (griff. ex hook. f. and thomson) martelli shrub at Environmental and Life Sciences Group, Faculty of Science, University Brunei Darussalam, Jalan Tungku Link, Brunei Darussalam. This study demonstrates that treatments with 0.10-0.20% NAA and 0.10% IAA and not ABA resulted in the development roots and shoots from leafy stem cuttings and can be used for the mass production of *Dillenia suffruticosa* plantlets, which will prevent the over exploitation of wild stocks.

Memon *et al.* (2013) conducted an experiment to assess the effect of various concentrations of Naphthalene acetic acid (NAA) on sprouting and rooting potential of Bougainvillea stem cuttings at Department of Horticulture, Sindh Agriculture University, Tandojam, Sindh, Pakistan. The results revealed that all the traits related with sprouting and rooting potential of stem cuttings of Bougainvillea were significantly influenced by various NAA concentrations, while varieties did not influence these characters significantly with the exception of number of sprouts per cutting, sprouting and rooting percentage. The best results obtained from the treatment where NAA was applied at the

concentration of 6000 mg L⁻¹ with 3.133 sprouts per cutting, 78.33 % sprouting percentage, 0.680 cm length of sprouts, 75.00 % rooting percentage, 13.862 cm length of roots, 27.833 roots per cutting, 28.20 leaves per cutting and 6.007 cm length of the leaves. Correlation matrix exhibited positive association between sprouting and rooting related parameters of *Bougainvillea* stem cuttings except length of the sprouts.

Bhol and Parida (2015) conducted an experiment at College of Forestry Orissa University of Agriculture and Technology, Bhubaneswar to find out the effect of three growth regulators such as IAA, IBA and NAA each at six different concentrations viz. 50, 100, 150, 200, 250 and 300 ppm along with control on propagation of culm cuttings as well as branch cuttings of *Bambusa vulgaris*. No growth regulator treatment could exert significant influence on the culm cuttings with regard to propagation. There is no need of treating the cuttings of *Bambusa vulgaris* with growth regulators for successful propagation. Soaking the culm cuttings with normal water for 24 hours is suitable method for large scale propagation. However, IAA 100ppm treatment was found effective for propagation of culm–branch cuttings.

Usman and Akinyele (2015) investigated the effect of growth media and hormonal concentration on the sprouting and rooting of *Massularia acuminata* stem cuttings using Indole Butyric Acid (IBA), Naphathelene Acetic Acid (NAA) and Coconut water at four levels (0, 500/25ppm, 1000/50ppm and 1500/100ppm %) at Department of Forest Production and Products, University of Agriculture, Makurdi, Benue. The results showed that growth media and hormonal concentration significantly affect percentage sprouting, shoot length, callusing, number of leaves, rooting, number of roots and length of root per cutting. Highest percentage sprouting (66.67%) and callusing (0.19) was recorded in riversand. Percentage sprouting (71.30%) and callusing (0.23) was greatly affected by coconut water. Highest number of roots (2.67), rooting (0.59cm), shoot length (1.11cm) and root length (0.59cm) were significantly affected by Level 2 (500ppm/25%). The untreated cuttings did better in terms of rooted cutting (0.71) and number of leaves (5.32). The highest number of roots (3.18) and root length (3.66cm) was recorded under NAA (1500ppm). IBA at 1000ppm had the highest shoot length (1.63cm).

Topacoglu *et al.* (2016) conducted an experiment to determine the best hormone doses and ideal rooting medium on *Ficus benjamina* L. stem cuttings. The highest rooting ratio were obtained for 10 ppm of NAA (94.43%) and 100 ppm of IBA (93.9%) in liquid media. Moreover, the highest root length and the average root length were quite low in liquid media.

Matali *et al.* (2017) conducted an experiment to investigate the plant hormones that can be used to propagate stem cuttings of *Dillenia suffruticosa*. Stem cuttings of *Dillenia suffruticosa* were treated using three single auxin hormone: 0.1% Indole Acetic Acid (IAA), 0.1% Indole Butyric Acid (IBA) and 0.2% Naphthalene Acetic Acid (NAA) and 5 commercially available rooting hormones viz; Yates, Clonex and Seradix 1, 2 and 3 and planted in a medium containing a mixture of equal parts black soil and perlite. Results indicated that the cuttings treated with single auxin treatments (mainly 0.2% NAA and 0.1% IAA) had higher survival and rooting percentages, longer roots, and larger leaf surface areas and produced more leaves than those cuttings treated with commercial rooting hormones. It is concluded that compared to commercial rooting hormones, 0.2% NAA and 0.1% IAA were the most effective auxin hormones in promoting survival and growth of *Dillenia suffruticosa* cuttings.

Yan *et al.* (2017) an experiment was made to study the effect of auxins and associated metabolic changes on cuttings of hybrid aspen at Department of Genetics, College of Life Science, Northeast Forestry University, Harbin, China. Hybrid aspen (*Populus tremula* L. × *Populus tremuloides* Michx.) with different concentrations of Indole-3-acetic acid (IAA), Indole-3-Butyric acid (IBA) and 1-Naphthylacetic acid (NAA). Among the three auxins used, 0.54 mM NAA showed more effective induction on rooting as compared to IAA and IBA at the whole level.

Bayraktar *et al.* (2018) investigated the effects of different greenhouse media, rooting media and hormones on propagation by cutting of European yew. The results showed that the highest rooting percentage was 80% in IBA 5000 ppm treatment in perlite rooting media of Greenhouse-2 media. It can be suggested that the rooting table temperature should be 5°C higher than the air temperature, perlite rooting media and 5000 ppm dosage of IBA hormone should be used for high rooting success.

Phuyal *et al.* (2018) studied the effect of different growth hormones, their concentrations and different rooting media on the rooting and sprouting of *Zanthoxylum armatum* at Dabur Nepal Private Limited Nursery, Banepa, Kavre District. The results shows that the hormonal concentrations and growth media significantly affected the rooting and shooting ability of *Zanthoxylum armatum* stem cuttings. IBA was found to be more effective than NAA. Neopeat medium was better than sand and mix media. The highest number of roots (6.5) and root length (11.6 cm) were recorded under IBA 5000 ppm in neopeat medium.

Amiri *et al.* (2019) studied the influence of hormones of IAA, IBA, and NAA on improvement of rooting and early growth of *Tilia rubra* subsp. (rupr.) at Forestry Department, Natural Resources and Marine Science, Tabrait Modares University, Noor, Iran. Based on the findings, compared to control, rooting percentage was enhanced about 37.5% in cuttings imbibed with 100mg/L IBA. Root number and root length respectively showed an increase of 28.6% and 22.3% in cuttings imbibed with 200mg/L IAA. The greatest root mass was perceived in IBA 200mg/L, which was about 2.5 times larger than that in control. In IBA 200mg/L, the increase in leaf mass and total plant mass was 51.4% and 36.2 % respectively. The hormone of 100 mg/L IBA performed an advancement of 37.5% in rooting, 42% in shoot length and 37.5% in seedling survival. As conclusion, it can be accepted that 100mg/l IBA can be favored as a superior choice for seedling production of this species. However, hormones promoted rooting as well as early growth of seedling in *Tilia rubra*.

Nhung *et al.* (2019) conducted an experiment to identify the efficacy of rooting hormones (IAA, IBA and NAA at 0.5, 1.0, 1.5 and 2.0 g L⁻¹), in *Dalbergia tonkinensis* at Department of Training and International Cooperation, Vietnamese Academy of Forest Sciences, District-Hanoi, Vietnam. Cuttings treated with IBA at a concentration of 1.5 g L⁻¹ had the highest rooting percentage and number of roots, attaining 92.2% and 12.3 roots cutting⁻¹ after 45 days respectively.

2.2. Effect of potting mixture on seed germination and seedling growth

Suitable growing medium provides sufficient anchorage or supports the plant, serves as a reservoir for nutrients and water; allows oxygen diffusion to the roots and gaseous exchange between the roots and atmosphere outside the root substrate.

Quisar *et al.* (2005) carried a study on the effect of potting media i.e. peat moss: vermiculite (1:1), Dal weed: sand (1:1), Cupressus leaf litter: sand (1:1), peat moss: sand (1:1) and soil: sand: FYM (1:1:1) on the growth of *Abies pindrow* (Silver Fir) at SKUAST-K. The result of this study showed maximum seedling survival (100%), height (10.20cm), collar diameter (3.71mm) shoot fresh weight (3.79g), root fresh weight (4.22g) and mean height increment (3.92cm) was obtained in potting medium of peat moss: vermiculite (1:1).

Satish *et al.* (2007) conducted an experiment to study the effect of different potting media i.e. red soil: sand: FYM in the ratio of 1:1:1 and 2:1:1, ash: sand: FYM in the ratio of 1:1:1 and paddy husk: sand: FYM in the ratio of 1:1:1 on the seedling growth of *Pongamia pinnata*. The highest germination percentage, height and collar diameter was found in the potting medium of red soil: sand: FYM in the ratio of 2:1:1.

Lokesh *et al.* (2009) conducted an experiment to study the effect of potting media- red soil: sand: Farm Yard Manure (FYM): vermicompost (2:1:0.5:0.5) along with 20g of poultry manure and red soil: sand: Farm Yard Manure (FYM): vermicompost (2:1:0.5:0) along with 20 g of fish manure on growth of *Terminalia chebula* seedlings under nursery. The higher plant height (21.55cm), collar diameter (6.65mm), number of leaves (18.67), root length (51.25cm) and dry weight (46.42g) was obtained in red soil: sand: Farm Yard Manure: vermicompost (2:1:0.5:0.5) along with 20g of poultry manure than red soil: sand: Farm Yard Manure: vermicompost (2:1:0.5:0) along with 20g of fish manure.

Abirami *et al.* (2010) conducted a research trial on the seed germination, seedling growth and vigour of nutmeg (*Myristica fragrans*) at Indian Institute of Spices Research, Calicut, Kerala, India. This experiment revealed that there were significant differences in germination and seedling growth behaviour of nutmeg seeds sown in twenty one different combination of growth media. The results showed germination characters like early germination, germination percentage, germination index and earliness index were

maximum in the treatment T₁₆ containing soil: coir dust: sand: vermicompost in 1:1:1:1: as the media followed by T₁₃ soil: coir dust: sand: FYM 1:1:1:1. Similarly the seedling growth characters like seedling height, girth, number of leaves, shoot length, root length and plant biomass were highest in the treatment media of T₁₆ (soil: coir dust: sand: vermicompost 1:1:1:1) which reflected on higher vigour index in the same treatment.

Bali *et al.* (2013) conducted a study at Department of Forestry and Natural Resources, HNB Garhwal University, Srinagar, Garhwal, Uttarakhand, India to determine the optimum conditions for germination and seedling growth of *Terminalia bellirica* by using four different manures mixed with soil viz. celrich (bio-organic soil enricher), farmyard manure (FYM), goat and poultry manures. Experiments revealed maximum seed germination percent in the FYM and minimum in the poultry manure treatment.

Bala and Laura (2015) conducted an experiment to elucidate the effect of different soil mediums in various ratios on seed germination efficiency and growth of seedling of *Simmondsia chinensis* under in vivo conditions. The highest germination (94%) was recorded for seeds cultivated in S₁ medium containing desert soil and Farm Yard Manure (FYM) (2:1) followed by S₄ medium (90%) having desert soil, clay, FYM (1:1:2), S₃ medium (76%) in 2:1:1 composition and then to S₂ medium (65%) germination in (1:2:1) ratio. Although, *Simmondsia chinensis* display better growth in desert soil, clay and FYM (1:1:2) yet in vivo (nursery) conditions they could raise potentially into healthy plantlets for successful establishment in the field.

Kumar *et al.* (2015) investigated the effect of growing medium and seed size on germination and seedling growth of the *Pinus gerardiana* at Dr. Y. S. Parmer, University of Horticulture & Forestry, Nauni, Solan, Himachal Pradesh, India. The seeds were categorized into two sizes, viz, small (<2.35 cm) and large (>2.35 cm) and five growing medium treatments were used, viz, Soil: Sand: FYM, Soil: Sand: Moss: FYM, Soil: Moss: Vermicompost, Soil: Sand: Vermicompost, and Soil: Sand: Moss: Vermicompost, for assessing their impact on germination and seedling growth. It was observed that, among different growing medium treatments, higher germination and seedling growth parameters were recorded, when Soil: Sand: Moss: Vermicompost was used for the study. Between

different seed sizes, higher germination and seedling growth were recorded when seed size was large.

Dharmveer *et al.* (2016) conducted an experiment on effect of different growing media on seed germination and growth parameters of *Angelica glauca* edgew at Department of Forestry and NR HNB, Garhwal University, Srinagar, Garhwal, Uttarakhand. The present study was conducted to examine the effect different growing media on seed germination and effect of different growing media on growth parameters (shoot and root length and weight). All experiments were arranged, in completely randomized design (CRD) in open and under shade net house conditions with 9 treatments were applied with 3 replications in each treatment. The results showed that the Sand + Soil + Cocopeat + Vermicompost (1:1:1:1) showed significant positive effect on seed germination and seedling development and can be treated as best suited growing media.

Rana *et al.* (2017) conducted a study to determine the effect of different ratio of soil, sand and FYM on *Parkia roxburgii* seeds viz; M₁ (Soil: Sand: FYM 1:1:1) M₂ (Soil: Sand: FYM 1:2:2) M₃ (Soil: Sand: FYM 1:2:3) and M₄ (Soil: Sand: FYM 1:2:4) at Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan. The results of the study showed that potting mixture of soil, sand and FYM in ratio 1:2:4. (M₄) produced significantly highest root length (16.57 cm), shoot length (18.02 cm), seedling length (34.59 cm) and collar diameter (4.70 mm).

Sondarva *et al.* (2017) conducted a study to evaluate organic based potting mixtures for early growth and biomass in *Khaya senegalensis* at College of Forestry, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat, India. Total ten potting mixture combinations were prepared using different organic materials such as Coco peat, Rice husk, Perlite, Vermiculite, FYM, Castor Cake, Neem Cake, Sugarcane press mud and Vermicompost with Red Soil. Among 10 treatments, T₉ i.e., potting mixture composition of vermicompost and red soil in the ratio of 1:1, resulted in maximum seedling growth in terms of height, collar diameter, root length, number of leaves and seedling biomass at 120 days after sowing, followed by T₅ (Sand: Red soil: FYM of 1:1:1) and T₇ (Neem cake: Red soil of 1:1 ratio) in *Khaya senegalensis*. Therefore,

treatment T₉ is suggested to use in the nursery for raising large scale seedling production of *Khaya senegalensis*.

Ahmed *et al.* (2018) conducted an experiment to study the effect of containers (root trainer 250 cc, root trainer 300 cc, polybags 16 × 24 cm-1500cc and polybag 23 × 28 cm-4200cc) and potting media (soil: sand: FYM-1:1:1 and soil: sand: vermicompost-1:1:1) on the growth of *Terminalia bellirica* at Sher-e-Kashmir University of Agricultural Sciences and Technology Jammu, Chatha, Jammu (India). Among the different container sizes and media, the polybag of 23 × 28 cm size and soil: sand: vermicompost (1:1:1) growing media resulted in significantly higher seedling height, collar diameter, number of leaves, length of primary root, fresh shoot and root weight, total seedling fresh weight, dry shoot and root weight, total seedling dry weight, root: shoot ratio and seedling quality. The interaction polybags (23 × 28 cm) × medium (soil: sand: vermicompost-1:1:1) resulted insignificantly higher values for the most of the studied growth parameters than the remaining interactions. The large sized containers (polybag of 23 × 28 cm) in combination with soil: sand: vermicompost (1:1:1) media resulted in better growth of *Terminalia bellirica* seedlings.

Kumar *et al.* (2018) studied the effect of nine growing media viz., T₁: soil, T₂: soil + sand (2:1), T₃: soil + perlite (2:1), T₄: soil + Farm Yard Manure (FYM) (2:1), T₅: soil + vermicompost (2:1), T₆: soil + sand + FYM (1:1:1), T₇: soil + sand + vermicompost (1:1:1), T₈: soil + perlite+ FYM (1:1:1) and T₉: soil + perlite + vermicompost (1:1:1) for their effect on seedling growth of *Albizia lebbek*. Among these media, maximum values of shoot length (23.82 cm), root length (21.14 cm), collar diameter (3.59 mm) and seedling quality index (0.350) were observed in T₇.

Khot *et al.* (2019) conducted an experiment on the effect of different potting media on seed germination and survival of Bullock's heart (*Annona reticulata* L.) at Department of Horticulture, College of Agriculture, Dapoli, Maharashtra, India. The highest germination percentage (70.66 %) was recorded in Soil + FYM (2:1) whereas, the lowest germination percentage (33.33 %) was observed in Soil + FYM (1:2). All the potting media treatments had non-significant effect on survival percentage. In most of the treatments survival percentage was 100 %. It can be concluded that the success of Bullock's heart seedlings was best in Soil +FYM (2:1). However, performance was also better in soil +

vermicompost (1:1), soil + FYM + cocopeat (1:1:1) and FYM + vermicompost + cocopeat (1:1:1). Moreover, FYM + vermicompost + cocopeat (1:1:1) is soilless medium under study that also showed better results. With view to reduce weight of potting media or use of soilless media for easy transportation especially by air or sea, these potting medium have future prospects.

Chapter-3

Materials and Methods

MATERIALS AND METHODS

The study was conducted in Division of Agroforestry, Sher-e-Kashmir University of Agriculture Sciences and Technology of Jammu (SKUAST-J) 2019-20. The details of the experiment site, experimental materials used and the methodology followed during the course of investigation are given here under the following headings:

- 3.1 Experimental site
- 3.2 Experimental details
- 3.3 Statistical analysis

3.1 Experimental site

3.1.1 Location

The experimental site is located in subtropical, Jammu region of Jammu and Kashmir Union Territory which is located at an altitude of 332m above msl at 32⁰ 40' N latitude and 74⁰ 58' E longitude.

3.1.2 Climate and weather conditions

Jammu being a subtropical region has a climate with hot dry summer season and humid rainy season. The annual rainfall ranges from 1000 mm to 1200 mm. The weather data recorded at meteorological observatory of SKUAST-J, Chatha, during studied period (July 2019- January2020) is given in Figure 3.1

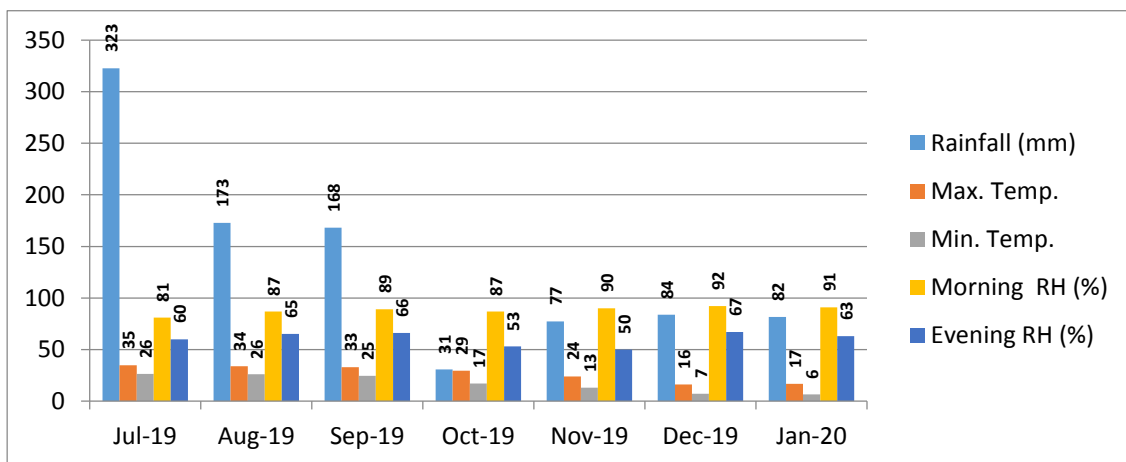


Figure 3.1: Weather data during the course of investigation trial

3.2 Experimental Details

3.2.1 Effect of hormonal concentration for better rooting of stem cuttings

3.2.1.1 Treatment details:

The treatments of the experiment comprised of three hormones i.e. IBA (indole-butyric acid), IAA (Indole- acetic acid) and NAA (Naphthalene- acetic acid) at four different concentrations of 500ppm, 1000ppm, 1500ppm and 2000ppm, respectively were used. The details are shown in Table 3.1.

Table 3.1 Detail of different hormones at different concentrations used for the study

Treatment	Hormones	Concentrations (ppm)
T ₁	IBA	500
T ₂		1000
T ₃		1500
T ₄		2000
T ₅	NAA	500
T ₆		1000
T ₇		1500
T ₈		2000
T ₉	IAA	500
T ₁₀		1000
T ₁₁		1500
T ₁₂		2000
T ₁₃	Control	No Treatment

3.2.1.2 Design of Experiment

The experiment was laid out in CRD (Completely Randomized Design) having one factor i.e. different hormonal concentrations. In the experiment there were thirteen treatments combination with three replications each. There were 15 cuttings in a single

treatment and observations were recorded on six cuttings randomly (two per replication). The details of experimental and statistical design are as under:

- **Design** : CRD (Completely Randomized Design)
- **Number of treatments** : 13
- **Number of replications** : 03
- **Planting Material** : Cuttings
- **Time of Planting Cuttings** : First week of August 2019

3.2.1.3 Cutting collection and preparation

The cuttings of *Murraya koenigii* were collected from shrubs growing in the Sidhra area of Jammu (J&K). For this, vigorously growing and disease free plants were selected and marked after an initial survey. The 12-15 cm long pencil sized diameter cuttings with at least 3-4 nodes were collected from the marked donors. The cuttings were then wrapped in moist sphagnum moss to avoid desiccation during transportation from collection site to the experimental nursery of the Division of Agroforestry. Each cutting was given slanting cut at the top and horizontal cut with a sharp razor blade. The fresh cuttings were then used for treatment and planting in the polythene bags.

3.2.1.4 Preparation of rooting powder formulations

The required amount of IBA (Indole- butyric acid), IAA (Indole- acetic acid) and NAA (Naphthalene- acetic acid) was taken respectively in a 250 ml beaker and dissolved thoroughly in approximately 10-15 ml of absolute alcohol (95% ethanol). Then, a desired amount of talcum powder was taken and added into the beaker containing dissolved auxin. The mixture was continuously stirred with a glass rod to form homogenous slurry. The powdered formulation was then transferred to volumetric flask of 100 ml to make a true solution and stored in a cool dry place away from sunlight to avoid auxin degradation.

3.2.1.5 Application of rooting hormones

The cuttings were treated with the given rooting powder formulation just before planting for 5-10 seconds. The basal end of each cutting was dipped in the prepared rooting hormones to ensure uniform application of rooting hormones to each cutting. After that

each cutting was immediately planted in polybags to prevent the drying of hormones in sunlight.

3.2.1.6 Planting of cuttings

The treated cuttings were planted 7-8 cm deep holes made in the centre of the poly bags after treatment. The soil around the cutting was slightly pressed to hold the cutting firmly, but not compacted, to ensure adequate aeration of the rooting zone. Irrigation was carried out manually, daily in the morning and the evening for the first one month of planting. Thereafter, Weeding was also done in the bags as and when necessary. To avoid desiccation, paraffin wax was applied at the tip of each cutting at the time of planting of cuttings.

3.2.1.7 Observations recorded

As per the experiment, the following observations were recorded:

- i. Sprouting percentage
- ii. Rooting percentage
- iii. Number of shoots
- iv. Number of lateral roots
- v. Root length (cm)
- vi. Fresh root biomass (g)
- vii. Dry root biomass (g)
- viii. Average shoot length/Plant height (cm)
- ix. Number of leaves per plant

3.2.1.7.1 Sprouting percentage

The total number of cuttings that sprouted after 45 days under each treatment was counted and expressed as sprouting per cent.

$$\text{Sprouting percentage} = \frac{\text{number of sprouted cuttings}}{\text{total number of cuttings}} \times 100$$

3.2.1.7.2 Rooting percentage

The total number of cuttings that rooted after 90 days under each treatment was counted and expressed as rooting per cent.

$$\text{Rooting percentage} = \frac{\text{number of rooted cuttings}}{\text{total number of cuttings}} \times 100$$

3.2.1.7.3 Number of shoots

The rooted cuttings were made free of the growing medium in polybags by thorough washing in water. Then, the total number of the shoots per cutting were counted and averaged to find the mean value of each treatment. A maximum upto four cuttings per replication were taken for observations.

3.2.1.7.4 Number of lateral roots

The rooted cuttings were made free of the growing medium in poly bags by thorough washing in water. Then, the total number of the roots per cutting were counted and averaged to find the mean value of each treatment. A maximum upto four cuttings per replication were taken for observations.

3.2.1.7.5 Root length (cm)

The length of the primary roots in every rooted cutting was measured to find the mean root length per treatment. A maximum upto four cuttings per replication were taken for observations.

3.2.1.7.6 Fresh root biomass (g)

The fresh weight of the roots was recorded using digital electronic balance for individual rooted cuttings and then mean value calculated for each treatment.

3.2.1.7.7 Dry root biomass (g)

The dry weight of the roots was recorded using digital electronic balance for individual rooted cuttings after keeping them in the oven at 60°C for 48 hours and then mean value calculated for each treatment.

3.2.1.7.8 Average shoot length/plant height (cm)

Shoot length/Plant height of each cutting was measured by using graduated scale. The scale was kept close to the cutting to record the length of the shoot in centimeters. The average shoot corresponds to the plant height which was recorded at 90 days of growth.

3.2.1.7.9 Number of leaves per plant

The number of leaves of each selected seedling was counted and averaged to find the mean value of each treatment.

3.2.2 Effect of potting mixture on seed germination and seedling growth

3.2.2.1 Potting media

For this experiment, soil was collected from the forest nursery of Division of Agroforestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu. The soil was cleaned thoroughly by removing unwanted materials like plant parts, stones and weeds. Soil of the farm is sandy loam (Rana and Sood, 2012). Media for the experiment was prepared by using soil, sand, well decomposed farm yard manure (FYM) and vermicompost (VC). These ingredients were mixed in proper proportions to get the requisite media. The potting media comprised of 4 treatments namely soil only, soil: sand (1:1), soil: sand: FYM (1:1:1) and soil: sand: vermicompost (1: 1: 1) (Table 3.2)

Table 3.2: Details of potting mixtures, ingredients and their proportions used for the study

Treatments	Details	Proportion
T ₁	Soil only	1
T ₂	Soil : Sand	1:1
T ₃	Soil : Sand : FYM	1:1:1
T ₄	Soil : Sand : Vermicompost	1:1:1

3.2.2.2 Design of experiment:

The experiment was laid out in CRD (Completely Randomized Design) having one factor i.e. potting mixtures. In the experiment there were four treatments combination with five replications each. There were 50 plants in a single treatment and observations were recorded on fifteen plants per treatment randomly (three per replication). The details of experimental and statistical design is as under:

- **Design** : CRD (Completely Randomized Design)
- **Number of treatments** : 04
- **Number of replications** : 05
- **Planting material** : Seeds
- **Date of sowing** : 19th July 2019

3.2.2.3 Seed collection, extraction and sowing

Fully ripen fruits of curry leaf were collected in July 2019. The berries were brought to the laboratory and the extraction of seeds were done manually by removing the mucilaginous substance by squeezing in water and then they were washed three to four times. Small and under sized seeds were not used for the experimentation.

For each treatment 200-300g seeds were used. The specified number of seeds (2-3 seeds) were sown uniformly to a depth of one cm in polybags containing different potting mixtures i.e. soil, sand, FYM, and VC in specified proportions (Table- 3.2). The polybags were watered every day regularly with the help of water can with rose haed.

3.2.2.4 Observations recorded

As per the experiment, the following observations were recorded:

- i. Number of days taken for germination
- ii. Germination percentage
- iii. Survival percentage
- iv. Germinative energy

- v. Number of leaves
- vi. Average shoot length (cm)
- vii. Collar diameter (mm)
- viii. Primary root length(cm)
- ix. Total seedling fresh weight (g)
- x. Fresh shoot weight (g)
- xi. Dry shoot weight (g)
- xii. Fresh root weight (g)
- xiii. Dry root weight (g)
- xiv. Root: shoot ratio (dry weight)
- xv. Sturdiness quotient
- xvi. Seedling quality index

3.2.2.4.1 Number of days taken for germination

The number of days taken for initiation of emergence of seedling was recorded in each treatment.

3.2.2.4.2 Germination percentage

Germination percentage was calculated by dividing the total number of seeds germinated by total number of seeds sown and multiply by 100.

$$\text{Germination percentage} = \frac{\text{number od seed germinated}}{\text{total number of seed sown}} \times 100.$$

3.2.2.4.3 Survival percentage

The survival percentage of each treatment was recorded at 90 days after seed sowing. The survival percentage was calculated by using formuala as given below:

$$\text{Survival percentage} = \frac{\text{number of survived sseedlings}}{\text{total number of seedlings}} \times 100.$$

3.2.2.4.4 Germinative energy

Germinative energy (GE) was calculated on the basis of the percentage of the total number of seeds that had germinated when the germination reached its peak.

$$\text{GE (\%)} = \frac{\text{number of seeds germinated upto a peak germination}}{\text{Total no of seed sown}} \times 100.$$

3.2.2.4.5 Number of leaves

The number of leaves of each selected seedling of *Murraya koenigii* was counted before the harvest.

3.2.2.4.6 Average shoot length (cm)

Shoot length of each seedling was measured by using graduated scale. The scale was kept close to the seedling and reading from the collar level to top was recorded at length of the shoot in centimeters.

3.2.2.4.7 Collar diameter (mm)

The collar diameter of seedlings was measured with the help of digital calliper. The collar diameter was expressed in millimeters (mm).

3.2.2.4.8 Primary root length (cm)

Length of primary roots was recorded after uprooting. The selected seedlings was uprooted carefully without causing damage to root system. The root was washed in water. The length of Primary root was measured with the help of a centimeter scale.

3.2.2.4.9 Total seedling fresh weight (g)

The fresh shoot and root weight of each selected seedling was measured with the electronic balance to determine the total fresh weight which was expressed in grams.

3.2.2.4.10 Fresh shoot weight (g)

Each selected seedling was cut at collar level, shoot and root portion were separated. Then fresh shoot weight was recorded using digital electronic balance. The fresh shoot weight has been expressed in grams.

3.2.2.4.11 Dry shoot weight (g)

The shoot was dried in hot air oven at 65⁰ C for 48 hours. After drying, the shoot weight was recorded using digital electronic balance.

3.2.2.4.12 Fresh root weight (g)

The fresh root weight was recorded using digital electronic balance. The fresh root weight has been expressed in grams.

3.2.2.4.13 Dry root weight (g)

The root were dried in hot air oven at 65⁰ C in the paper bag for 48 hours. After drying, the root weight was recorded using digital electronic balance.

3.2.2.4.14 Root: shoot ratio (dry weight basis)

The root: shoot ratio (dry weight basis) was obtained by dividing the dry root weight (g) by dry weight shoot (g) of each seedling separately.

3.2.2.4.15 Sturdiness quotient

It is the height of seedling in centimeters divided by the collar diameter in the millimeters. It reflects the stocky or spindly nature of the seedlings. A small quotient indicates a sturdy plant with higher expected chance of survival, especially on windy or dry sites. Sturdiness quotient was calculated by using the formula given by Rollar (1977).

$$\text{Sturdiness quotient} = \frac{\text{height of seedling (cm)}}{\text{collar diameter (mm)}}$$

3.2.2.4.16 Seedling quality index

Seedling quality index assessment was made by using the formula given by Dickson *et al.*, 1960.

$$\text{Seedling Quality Index} = \frac{\text{Total dry weight}}{\frac{\text{Height (cm)}}{\text{Collar diameter (mm)}} + \frac{\text{shoot dry weight (g)}}{\text{root dry weight (g)}}}$$

3.3 Statistical analysis

The statistical analysis for each character was carried out on mean values. The data was analysed using the technique of variance (ANOVA) in accordance with procedure outlined by Gomez and Gomez (1984). The effect of different treatments was tested at 0.05 level of significance.



A: Experimental Field



B: Filling of Polybags



C: Preparation of Hormones



D: Dipping of cuttings



E: Planting of cuttings

Plate 1: An overview of experiment of cuttings along with different operations



A: Experimental Field



B: Preparation of different potting mixtures



C: Filling of Polybags



D: Seeds of *Murrya koenigii*

Plate 2: An overview of seed and seedlings experiment along with different operations

Results

EXPERIMENTAL RESULTS

The experimental results obtained during the course of investigation with respect to different parameters of the study entitled “Standardization of Propagation Techniques in *Murraya koenigii* Spreng.” have been presented under the following headings:

4.1 Effect of hormonal concentration for better rooting of stem cuttings

- 4.1.1 Sprouting percentage
- 4.1.2 Rooting percentage
- 4.1.3 Number of shoots
- 4.1.4 Number of lateral roots
- 4.1.5 Average shoot length/plant height
- 4.1.6 Average root length
- 4.1.7 Number of leaves
- 4.1.8 Fresh root biomass
- 4.1.9 Dry root biomass

4.2 Effect of potting mixture on seed germination and seedling growth

- 4.2.1 Number of days taken for germination
- 4.2.2 Germination percentage
- 4.2.3 Germinative energy
- 4.2.4 Survival percentage
- 4.2.5 Collar diameter
- 4.2.6 Number of leaves
- 4.2.7 Average shoot length
- 4.2.8 Primary root length
- 4.2.9 Fresh shoot weight
- 4.2.10 Fresh root weight
- 4.2.11 Total seedling fresh weight
- 4.2.12 Dry shoot weight
- 4.2.13 Dry root weight
- 4.2.14 Root: shoot ratio (dry weight basis)
- 4.2.15 Sturdiness Quotient
- 4.2.16 Seedling quality index

4.1 Effect of hormonal concentration for better rooting of stem cuttings

4.1.1 Sprouting percentage

The data regarding the effect of hormonal concentration on sprouting percentage (%) are given in Table 4.1

Table 4.1: Effect of hormonal concentration on sprouting of stem cuttings in *Murraya koenigii*

Treatment Code	Treatments	Sprouting (%)
T ₁	IBA @ 500ppm	22.09 (28.02) *
T ₂	IBA @ 1000ppm	38.81 (38.51) *
T ₃	IBA @ 1500 ppm	46.30 (42.86) *
T ₄	IBA @ 2000ppm	56.48 (48.70) *
T ₅	NAA @ 500ppm	20.00 (26.54) *
T ₆	NAA @ 1000ppm	25.56 (30.35) *
T ₇	NAA @ 1500ppm	29.89 (33.12) *
T ₈	NAA @ 2000ppm	33.34 (35.25) *
T ₉	IAA @ 500ppm	19.76 (26.37) *
T ₁₀	IAA @ 1000ppm	24.67 (29.77) *
T ₁₁	IAA @ 1500ppm	28.67 (32.35) *
T ₁₂	IAA @ 2000ppm	32.64 (34.83) *
T ₁₃	Control (No Treatment)	8.78 (17.22) *
	CD_{0.05}	2.11 (1.39) *
	SE_{m±}	0.72 (0.47) *

*Figures in parenthesis are transformed (angular) value

Sprouting percentage of cuttings was significantly affected by different hormonal concentrations. The treatment T₄ (IBA 2000ppm) recorded significantly higher sprouting (56.48%), followed by T₃ (IBA 1500ppm) and T₂ (IBA 1000ppm) having sprouting percentage of 43.60 per cent and 38.8 per cent, respectively and the difference were significant with T₄. The sprouting percentage observed in T₁ (IBA 500 ppm) (22.09%), T₅ (NAA 500ppm) (20.00%) and T₉ (IAA 500 ppm) (19.76%) were statistically at par with each other. Similarly, T₆ (NAA 1000ppm) (25.56%) and T₁₀ IAA (1000 ppm) (24.67%)

were also statistically at par. However, treatment T₁₃ (Control) recorded the lowest sprouting (8.78%) of cuttings.

4.1.2 Rooting percentage (%)

The data which showed the effect of hormonal concentrations on rooting percentage (%) are given in Table 4.2

Table 4.2: Effect of hormonal concentration on rooting of stem cuttings in *Murraya koenigii*

Treatment Code	Treatments	Rooting percentage
T ₁	IBA @ 500ppm	18.78 (25.66)*
T ₂	IBA @ 1000ppm	23.67 (29.10)*
T ₃	IBA @1500 ppm	31.11 (33.89)*
T ₄	IBA @ 2000ppm	41.67 (40.19)*
T ₅	NAA @ 500ppm	7.69 (16.06)*
T ₆	NAA @1000ppm	12.39 (20.59)*
T ₇	NAA @1500ppm	14.80 (22.61)*
T ₈	NAA @2000ppm	16.67 (24.07)*
T ₉	IAA @500ppm	6.97 (15.29)*
T ₁₀	IAA @ 1000ppm	12.11 (20.35)*
T ₁₁	IAA @ 1500ppm	14.39 (22.28)*
T ₁₂	IAA @ 2000ppm	16.34 (23.83)*
T ₁₃	Control (No Treatment)	0.00 (0.00)*
	CD_{0.05}	1.69 (1.38)*
	SE_{m±}	0.58 (0.47)*

*Figures in parenthesis are transformed (angular) value

The data revealed that the critical difference between rooting percentage was significantly influenced by hormonal concentrations. The per cent rooting was recorded maximum (41.67%) in the cutting treated with T₄ (IBA 2000ppm) than all other hormonal concentrations. It was followed by T₃ (IBA 1500ppm) (31.11%), T₂ (IBA 1000ppm) (23.11%) and T₁ (18.78%). The per cent rooting in T₅ (NAA 500) (7.69%) and T₉ (IAA 500ppm) (6.97%) were statistically at par with each other. Similarly, T₈ (NAA 2000ppm)

(33.34%) and T₁₂ (IAA 2000ppm) (32.64%) were also statistically alike. However, T₁₃ (Control) failed to produce any roots.

4.1.3 Number of shoots (per cutting)

The data pertaining to the effect of hormonal concentration on number of shoots (per cutting) are given in Table 4.3

Table 4.3: Effect of hormonal concentration on number of shoots (per cutting) of stem cuttings in *Murraya koenigii*

Treatment Code	Treatments	Number of shoots
T ₁	IBA @ 500ppm	1.600
T ₂	IBA @ 1000ppm	1.967
T ₃	IBA @ 1500 ppm	3.200
T ₄	IBA @ 2000ppm	2.967
T ₅	NAA @ 500ppm	1.667
T ₆	NAA @ 1000ppm	2.273
T ₇	NAA @ 1500ppm	1.527
T ₈	NAA @ 2000ppm	2.010
T ₉	IAA @ 500ppm	1.700
T ₁₀	IAA @ 1000ppm	2.067
T ₁₁	IAA @ 1500ppm	2.097
T ₁₂	IAA @ 2000ppm	1.670
T ₁₃	Control (No Treatment)	0.000
	CD_{0.05}	NS
	SE_{m±}	0.629

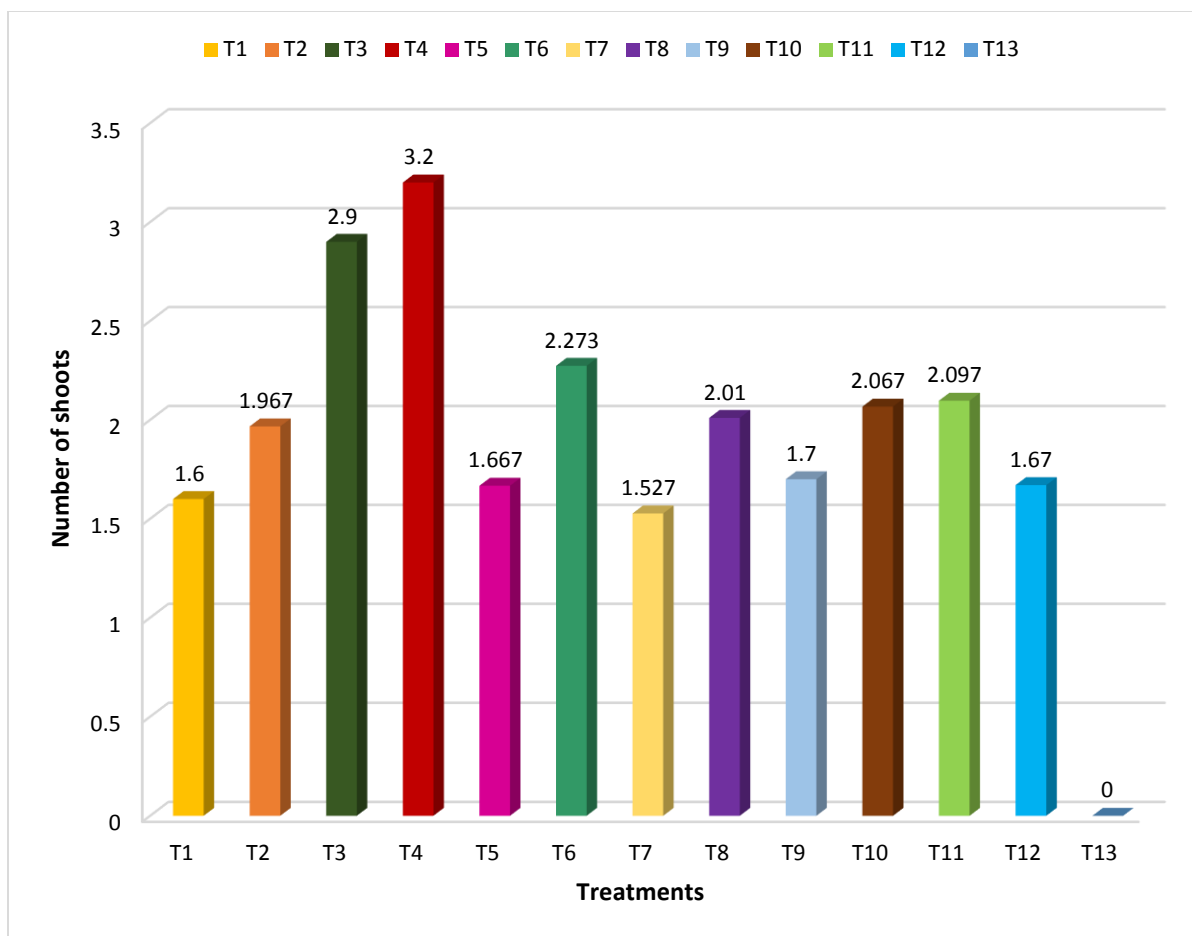


Figure 4.1: Effect of hormonal concentration on number of shoots (per cutting) of stem cuttings in *Murraya koenigii*

The data pertaining the critical difference on account of effect of hormonal concentration on *Murraya koenigii* cuttings were found to be statistically non-significant. However, the maximum number of shoots (per cutting) (3.20) was found in T₄ (IBA 2000) whereas, the minimum number of shoots (per cutting) were observed in T₅ (NAA 500ppm) (1.60). Cuttings maintained as T₁₃ (control) failed to strike shoots.

4.1.4 Number of lateral roots

The data associated to the effect of hormonal concentration on number of lateral roots (per cutting) are shown in Table 4.4.

Table 4.4: Effect of hormonal concentration on number of lateral roots (per cutting) of stem cuttings in *Murraya koenigii*

Treatment Code	Treatments	Number of lateral roots
T ₁	IBA @ 500ppm	9.83
T ₂	IBA @ 1000ppm	12.17
T ₃	IBA @ 1500 ppm	15.43
T ₄	IBA @ 2000ppm	18.20
T ₅	NAA @ 500ppm	3.80
T ₆	NAA @ 1000ppm	5.90
T ₇	NAA @ 1500ppm	6.87
T ₈	NAA @ 2000ppm	7.07
T ₉	IAA @ 500ppm	3.73
T ₁₀	IAA @ 1000ppm	5.77
T ₁₁	IAA @ 1500ppm	6.47
T ₁₂	IAA @ 2000ppm	7.00
T ₁₃	Control (No Treatment)	0.00
	CD_{0.05}	1.82
	SE_{m±}	0.62

Different hormonal concentrations exhibited variation in number of lateral roots (per cutting). Maximum number of lateral roots (per cutting) (18.20) was found in T₄ (IBA 2000). It was followed by 15.43 in T₃ (IBA 1500ppm), 12.17 in T₂ (IBA 1000ppm) and 9.83 in T₁ (IBA 500ppm) and the critical difference between T₃ and T₂ with respect to T₄ was significant (Table 4.4). Rest of the treatments were statistically at par with each other. However, Cuttings maintained as T₁₃ (Control) failed to produce lateral roots.

4.1.5 Average shoot length/plant height

The data pertaining to the effect of hormonal concentration on average shoot length/Plant height are presented in Table 4.5.

Table 4.5: Effect of hormonal concentration on average shoot length (cm) of stem cuttings in *Murraya koenigii*

Treatment Code	Treatments	Shoot length/Plant height (cm)
T ₁	IBA @ 500ppm	5.21
T ₂	IBA @ 1000ppm	5.94
T ₃	IBA @ 1500 ppm	6.17
T ₄	IBA @ 2000ppm	7.07
T ₅	NAA @ 500ppm	4.14
T ₆	NAA @ 1000ppm	4.36
T ₇	NAA @ 1500ppm	4.76
T ₈	NAA @ 2000ppm	5.01
T ₉	IAA @ 500ppm	4.10
T ₁₀	IAA @ 1000ppm	4.28
T ₁₁	IAA @ 1500ppm	4.75
T ₁₂	IAA @ 2000ppm	5.05
T ₁₃	Control (No Treatment)	0.00
	CD_{0.05}	0.45
	SE_{m±}	0.15

It is noticeable from the data that the critical difference between different hormonal concentrations bring into play shows a significant influence on average shoot length/plant height of cuttings. Maximum shoot length (7.07 cm) was registered in T₄ (IBA 2000ppm). It was followed by (6.17) in T₃ (IBA 1500ppm). Shoot length in the treatments T₁₂ (IAA 2000ppm), T₈ (NAA 2000ppm), T₇ (NAA 1500ppm) and T₁₁ (IAA 1500) having values 5.05, 5.01, 4.76 and 4.75 were not having statistically significant differences among themselves. Treatment T₁₃ (Control), on the other hand failed to produce any shoots.

4.1.6 Average root length

The data regarding to the effect of hormonal concentration on average root length (cm) are manifest in Table 4.6.

Table 4.6: Effect of hormonal concentration on average root length (cm) of stem cuttings in *Murraya koenigii*

Treatment Code	Treatments	Root length (cm)
T ₁	IBA @ 500ppm	2.95
T ₂	IBA @ 1000ppm	3.50
T ₃	IBA @1500 ppm	3.93
T ₄	IBA @ 2000ppm	4.47
T ₅	NAA @ 500ppm	1.23
T ₆	NAA @1000ppm	1.60
T ₇	NAA @1500ppm	1.94
T ₈	NAA @2000ppm	2.17
T ₉	IAA @500ppm	1.16
T ₁₀	IAA @ 1000ppm	1.58
T ₁₁	IAA @ 1500ppm	1.88
T ₁₂	IAA @ 2000ppm	2.08
T ₁₃	Control (No Treatment)	0.00
	CD_{0.05}	1.04
	SE_{m±}	0.36

The data revealed that the average root length (cm) differences were statistically significant by different hormonal concentrations. Maximum shoot length 4.47 cm was conspicuous in T₄ (IBA 2000) and the differences were statistically at par with T₃ (IBA 1500ppm) and T₂ (IBA 1000ppm) bearing respective values of 3.93 cm and 3.50 cm. Average root length (cm) in T₈ (NAA 2000ppm), T₁₂ (IAA 2000ppm), T₇ (NAA 1500ppm), T₁₁ (IAA 1500ppm), T₆ (NAA 1000ppm), T₁₀ (IAA 1000ppm), T₅ (NAA 500ppm) and T₉ (IAA 500ppm) bearing respective values of 2.17 cm, 2.08 cm, 1.94 cm, 1.88 cm, 1.60 cm, 1.58 cm, 1.23 cm and 1.16 cm were also not having statistically significant differences. However, cuttings maintained in T₁₃ (control) did not strike shoots.

4.1.7 Number of leaves

The data presented in Table 4.7 depicted the effect of hormonal concentration on number of leaves on *Murraya koenigii* cuttings.

Table 4.7: Effect of hormonal concentration on number of leaves of stem cuttings in *Murraya koenigii*

Treatment Code	Treatments	Number of leaves
T ₁	IBA @ 500ppm	6.43
T ₂	IBA @ 1000ppm	8.93
T ₃	IBA @ 1500 ppm	9.30
T ₄	IBA @ 2000ppm	13.33
T ₅	NAA @ 500ppm	5.13
T ₆	NAA @ 1000ppm	5.43
T ₇	NAA @ 1500ppm	5.80
T ₈	NAA @ 2000ppm	6.10
T ₉	IAA @ 500ppm	5.00
T ₁₀	IAA @ 1000ppm	5.53
T ₁₁	IAA @ 1500ppm	5.67
T ₁₂	IAA @ 2000ppm	6.03
T ₁₃	Control (No Treatment)	0.0
	CD_{0.05}	0.87
	SE_{m±}	0.30

The data shows that the critical difference in number of leaves were significantly influenced by different hormonal concentrations. The number of leaves was found maximum 13.33 in T₄ (IBA 2000) followed by 9.30 in T₃ (IBA 1500ppm). Number of leaves in T₈ (NAA 2000ppm) were statistically at par with T₁₂ (IAA 2000ppm) and T₇ (NAA 1500ppm), respectively. However, T₁₃ (control) failed to produce leaves.

4.1.8 Fresh root biomass

The data introduced in Table 4.8 revealed the effect of hormonal concentration on fresh root biomass (g) on *Murraya koenigii* cuttings.

Table 4.8: Effect of hormonal concentration on fresh root biomass (g) of stem cuttings in *Murraya koenigii*

Treatment Code	Treatments	Fresh root biomass (g)
T ₁	IBA @ 500ppm	0.005
T ₂	IBA @ 1000ppm	0.006
T ₃	IBA @ 1500 ppm	0.010
T ₄	IBA @ 2000ppm	0.022
T ₅	NAA @ 500ppm	0.002
T ₆	NAA @ 1000ppm	0.003
T ₇	NAA @ 1500ppm	0.004
T ₈	NAA @ 2000ppm	0.004
T ₉	IAA @ 500ppm	0.002
T ₁₀	IAA @ 1000ppm	0.003
T ₁₁	IAA @ 1500ppm	0.003
T ₁₂	IAA @ 2000ppm	0.004
T ₁₃	Control (No Treatment)	0.000
	CD_{0.05}	0.002
	SE_{m±}	0.001

The data showed maximum fresh root biomass bearing value 0.022 g in T₄ (IBA 2000ppm) followed by 0.010 g in T₃ (IBA 1500). The differences in fresh root biomass in rest of the treatments were statistically at par with each other. On the other hand, T₁₃ (Control) failed to generate roots.

4.1.9 Dry root biomass

The data dispensed in Table 4.9 showed the effect of hormonal concentrations on dry root biomass (g) on *Murraya koenigii* cuttings.

Table 4.9: Effect of hormonal concentration on fresh root biomass (g) of cuttings in *Murraya koenigii*

Treatment Code	Treatments	Dry root biomass (g)
T ₁	IBA @ 500ppm	0.0023
T ₂	IBA @ 1000ppm	0.0031
T ₃	IBA @1500 ppm	0.0050
T ₄	IBA @ 2000ppm	0.0101
T ₅	NAA @ 500ppm	0.0009
T ₆	NAA @1000ppm	0.0017
T ₇	NAA @1500ppm	0.0021
T ₈	NAA @2000ppm	0.0022
T ₉	IAA @500ppm	0.0018
T ₁₀	IAA @ 1000ppm	0.0019
T ₁₁	IAA @ 1500ppm	0.0020
T ₁₂	IAA @ 2000ppm	0.0021
T ₁₃	Control (No Treatment)	0.000
	CD_{0.05}	0.0011
	SE_{m±}	0.0007

The data shows that the critical difference was found statistically significant during the experimental course of study. Maximum dry root biomass bearing value 0.0101 g was observed in T₄ (IBA 2000ppm) followed by 0.0050 g in T₃ (IBA 1500). Dry root biomass (g) recorded in the remaining treatments were not statistically significant with each other. However, T₁₃ (Control) failed to produce any roots.

4.2 Effect of potting mixture on seed germination and seedling growth

4.2.1 Number of days taken for germination

Number of days taken for germination were counted on the daily basis. The observations with regard to this parameter in *Murraya koenigii* are presented in Table 4.10. The number of days taken for seed germination were significantly affected by the different potting mixtures. The maximum (18.40 days) number of days for germination were recorded in T₂: Soil: Sand (1: 1) whereas, the minimum (13.40 days) were recorded in T₄: Soil: Sand: Vermicompost (1: 1: 1). The critical difference was statistically significant between the treatments during the experimental year.

4.2.2 Germination percentage

Germination percentage of the seeds of *Murraya koenigii* was studied by sowing seeds in various potting mixtures. The data on the effect of potting mixtures on germination percentage (%) are given in Table 4.10. The maximum germination (96.00%) was observed in the T₄: Soil: Sand: Vermicompost (1: 1: 1) and the difference was statistically at par with T₃: Soil: Sand: Farm Yard Manure (1: 1: 1) and T₁: (soil only) having values (94.00%) and (90.00%). Although, minimum (78.00%) germination was observed in the T₂: Soil: Sand (1:1).

4.2.3 Germinative energy

Germinative energy was recorded based on the percentage of the total number of seeds that germinated as the germination peaked. Results on this parameter are provided in Table 4.10. Throughout the experimental year the critical differences were statistically significant among the treatments. Maximum germinative energy (52.00%) was observed in the T₄: Soil: Sand: Vermicompost (1: 1: 1) and minimum germinative energy (14.00%) was observed in T₂: Soil: Sand (1: 1) where as T₃ and T₁ were the second and third most effective methods respectively.

4.2.4 Survival percentage

The survival percentage after seed sowing was estimated at 90 days. In *Murraya koenigii*, the data so obtained are listed in Table 4.10. Survival percentage was maximum (98.00%) in T₄: Soil: Sand: Vermicompost (1:1:1) which was higher than that of remaining potting mixture treatments. The minimum survival percentage (79.45 %) was recorded in T₂: Soil: Sand (1: 1). The critical difference was statistically significant between all the treatments during the experimental year.

Table 4.10: Effect of different potting mixture on germination and survival parameters of *Murraya koenigii* seeds.

Treatments	Number of days taken for germination	Germinative energy (%)	Germination Percentage (%)	Survival Percentage (%)
T ₁	16.2	34.00	90.00 (73.54)*	86.68 (68.78)*
T ₂	18.4	14.00	78.00 (64.87)*	79.45 (63.24)*
T ₃	14	46.00	94.00 (78.92)*	95.78 (78.71)*
T ₄	13.4	52.00	96.00 (82.61)*	98.00 (82.41)*
Mean	15.5	36.50	89.50 (72.48)*	89.97 (73.28)*
CD _{0.05}	1.2	10.90	11.31 (9.21)*	7.39 (10.71)*
SE _{m±}	0.4	3.61	3.74 (4.64)*	2.44 (3.54)*

*Figures in parenthesis are transformed (angular) value

T₁: (soil only)

T₂: Soil: Sand (1: 1)

T₃: Soil: Sand: Farm Yard Manure (1: 1: 1)

T₄: Soil: Sand: Vermicompost (1: 1: 1)

4.2.5 Collar diameter

The collar diameter (mm) of the seedlings was recorded in nursery beds. The data regarding this parameter in *Murraya koenigii* are presented in Table 4.11. The analysis of the data revealed that the effect of different potting mixtures applied to the *Murraya koenigii* seeds were recorded statistically significant critical difference during the experimental trial. The T₄: Soil: Sand: Vermicompost (1:1:1) resulted maximum (2.42 mm) collar diameter which showed at par results with T₃: Soil: Sand: Farm Yard Manure (1:1:1). However, T₂: Soil: Sand (1: 1) showed (1.63 mm) least collar diameter in seedlings.

4.2.6 Number of leaves

Number of leaves were recorded in nursery beds. The data pertaining to the number of leaves are presented in Table 4.11. Number of leaves was significantly influenced by potting mixtures. The number of leaves in T₄: Soil: Sand: Vermicompost (1:1:1) was recorded maximum (10.6) which was statistically at par with (9.2) in T₃: Soil: Sand:FYM (1:1:1) whereas least number of leaves (6.2) were recorded in T₂: Soil: Sand (1: 1). All the treatment differences were statistically significant during the experimental year.

4.2.7 Average shoot length

Readings for shoot length of the seedlings were recorded in nursery beds. The data so recorded with regard to this parameter in *Murraya koenigii* are presented in Table 4.11. The maximum shoot length (14.05 cm) was observed in T₄: Soil: Sand: Vermicompost (1:1:1) followed by (13.45 cm) in T₃: Soil: Sand:FYM (1:1:1) and (12.46 cm) in T₁: Control (soil only). The minimum shoot length (10.36 cm) was observed in T₂: Soil: Sand (1: 1). All the treatment difference were statistically significant during the experimental year.

4.2.8 Fresh shoot weight

The differing potting mixture significantly influenced the fresh shoot weight (per-seedling). Observations on this parameter are presented in Table 4.11. Maximum shoot weight (2.01 g) was recorded in the potting mixture T₄: Soil: Sand: Vermicompost (1:1:1) which was at par with T₃: Soil: Sand: Farm Yard Manure (1:1:1) whereas the minimum

fresh shoot weight (0.70 g) was recorded in T₂: Soil: Sand (1: 1). All the treatments critical difference were statistically significant during the experimental year.

4.2.9 Dry shoot weight

Dry shoot weight varied significantly with respect to potting mixtures. The observations with regard to this parameter in *Murraya koenigii* are presented in Table 4.11. Maximum dry shoot weight (0.92 g) was observed in T₄: Soil: Sand: Vermicompost (1:1:1) and minimum dry shoot weight (0.36 g) was observed in T₂: Soil: Sand (1: 1). However, T₃: Soil: Sand:FYM (1:1:1) and T₁: Control (soil only) bearing (0.75 g) and (0.55 g) dry shoot weight respectively. The critical difference was statistically significant between the treatments during the experimental year.

Table 4.11: Effect of different potting mixture on above ground parameters of *Murraya koenigii* seedlings.

Treatments	Collar diameter (mm)	Number of leaves plant ⁻¹	Average shoot length (cm)	Fresh shoot weight (g)	Dry shoot weight (g)
T ₁	2.04	8.6	12.46	1.50	0.55
T ₂	1.63	6.2	10.36	0.70	0.36
T ₃	2.29	9.2	13.45	1.91	0.75
T ₄	2.42	10.6	14.05	2.01	0.92
Mean	2.04	8.65	12.58	1.40	0.65
CD _{0.05}	0.24	2.3	1.67	0.31	0.04
SE _{m±}	0.12	0.8	0.55	0.10	0.02

T₁: (soil only)

T₃: Soil: Sand: Farm Yard Manure (1: 1: 1)

T₂: Soil: Sand (1: 1)

T₄: Soil: Sand: Vermicompost (1: 1: 1)

4.2.10 Primary root length

Root length (cm) of each selected seedlings was recorded in nursery beds. The observations with regard to this parameter in *Murraya koenigii* are presented in Table 4.12. All the potting mixtures significantly different from one another with respect to length of primary roots. The maximum primary root length (19.1 cm) was recorded in T₄: Soil: Sand: Vermicompost (1:1:1) followed by (17.3 cm) in T₃: Soil: Sand:FYM (1:1:1) and (15.7 cm) in T₁ (Soil only). The minimum shoot length (10.6 cm) was observed in T₂: Soil: Sand (1: 1).

4.2.11 Fresh root weight

The fresh root weight (per seedling) exhibited significant difference in the different potting mixtures. The observations with regard to this parameter in *Murraya koenigii* are presented in Table 4.12. The data divulged that the effect of potting mixtures on root fresh weight (per seedling) was significant as the critical difference was significant. The maximum fresh root weight (2.70 g) was observed in the potting mixture T₄: Soil: Sand: Vermicompost (1:1:1) which was statistically superior to all the remaining potting mixtures. Minimum fresh root weight (0.50 g) was observed in T₂: Soil: Sand (1: 1).

4.2.12 Dry root weight

Dry root weight (per seedling) varied significantly with respect to different potting mixtures. The observations with regard to this parameter in *Murraya koenigii* are presented in Table 4.12. Maximum dry root weight (1.39 g) was recorded in the potting in T₄: Soil: Sand: Vermicompost (1:1:1). It was followed by (0.82 g) in T₃: Soil: Sand: FYM (1:1:1) . However, least dry root weight (0.26 g) was recorded in T₂: Soil: Sand (1: 1). All the treatments difference showed significant effect during the experimental year.

Table 4.12: Effect of different potting mixture on below ground parameters of *Murraya koenigii* seedlings.

Treatments	Primary root length (cm)	Fresh root weight (g)	Dry root weight (g)
T₁	2.04	8.6	12.46
T₂	1.63	6.2	10.36
T₃	2.29	9.2	13.45
T₄	2.42	10.6	14.05
Mean	2.04	8.65	12.58
CD_{0.05}	0.24	2.3	1.67
SE_{m±}	0.12	0.8	0.55

T₁: (soil only)

T₃: Soil: Sand: Farm Yard Manure (1: 1: 1)

T₂: Soil: Sand (1: 1)

T₄: Soil: Sand: Vermicompost (1: 1: 1)

4.2.13 Total seedling fresh weight

Each potting mixtures significantly differed from one another with respect to the total seedling fresh weight. The observations with regard to this parameter in *Murraya koenigii* are presented in Table 4.13. The total seedling fresh weight (4.71 g) was highest in T₄: Soil: Sand: Vermicompost (1:1:1) which was superior over all other treatments. However, the lowest (1.28 g) fresh seedling weight was recorded in T₂: Soil: Sand (1: 1). The critical difference was statistically significant between the treatments during the experimental year.

4.2.14. Root: shoot ratio (dry weight basis)

The root: shoot ratio (dry weight basis) in each potting mixtures was significantly different from each other during the experimental year. Observations with regard to this parameter in *Murraya koenigii* are presented in Table 4.13. Highest root: shoot ratio (1.51) was recorded in T₄: Soil: Sand: Vermicompost (1:1:1) followed by (1.08) in T₃: Soil: Sand:FYM (1:1:1) . The lowest (0.71) root: shoot ratio was recorded in T₁: (Soil only). The critical difference was statistically significant between the treatments during the experimental year.

4.1.15 Sturdiness quotient

The effect of potting mixtures on sturdiness quotient differences were not statistically significant. The observations with regard to this parameter in *Murraya koenigii* are presented in Table 4.13. The maximum sturdiness quotient was observed (13.88) in T₁: (Soil only) followed by (13.72) in T₄: Soil: Sand: Vermicompost (1:1:1) and (13.58) in T₃: Soil: Sand:FYM (1:1:1) . Even so, least sturdiness quotient was observed (12.94) in T₂: Soil: Sand (1: 1). The Figure (4.2) represents the effect of potting mixtures on sturdiness quotient of *Murraya koenigii* seedlings.

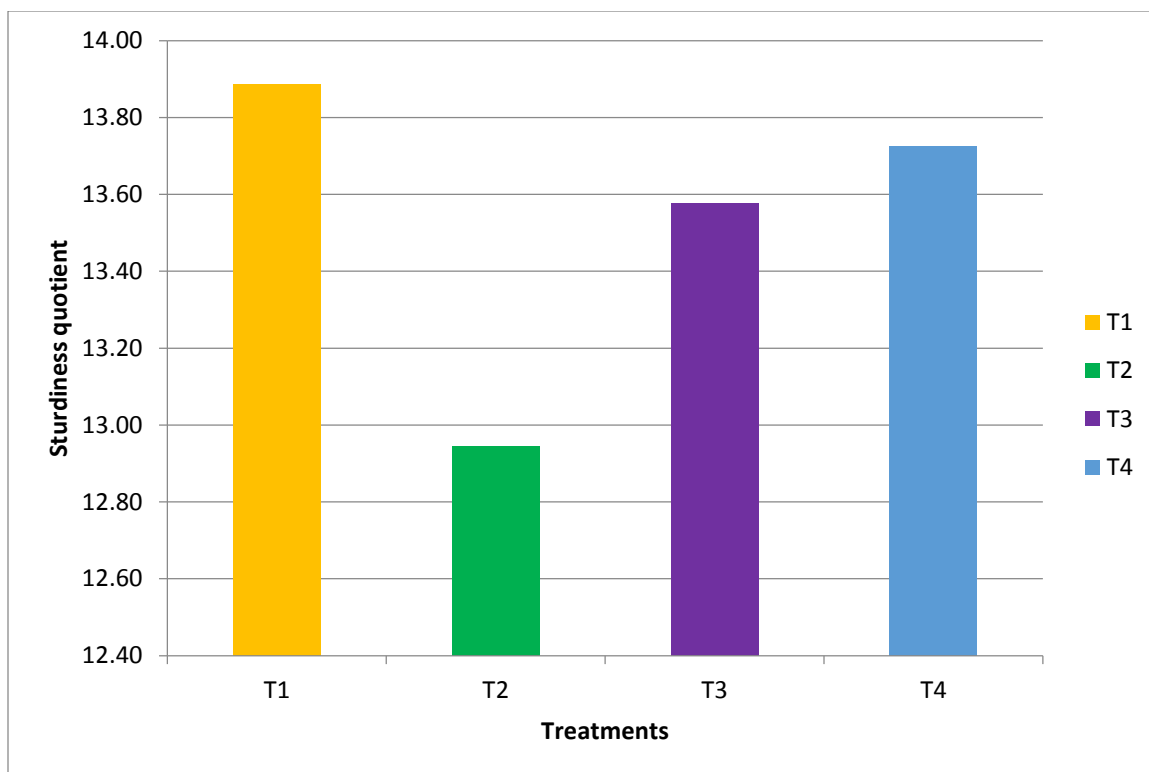


Figure 4.2: Effect of potting mixture on sturdiness quotient of *Murraya koenigii* seedlings

4.2.16 Seedling quality index

The seedling quality index of the different potting mixture was recorded during the current study. The observations with regard to this parameter in *Murraya koenigii* are presented in Table 4.13. The seedling quality index increased from (0.004) in T₂: Soil: Sand (1: 1) to (0.006) in T₁: (Soil only) and reached maximum (0.016) in T₄: Soil: Sand: Vermicompost (1:1:1). The critical difference was statistically significant between the treatments during the experimental year.

Table 4.13: Effect of different potting mixture on seedlings quality parameters of *Murraya koenigii* seedlings.

Treatments	Root:shoot ratio (dry weight basis)	Sturdiness quotient	Seedling quality index	Total seedling fresh weight
T₁	0.71	13.88	0.006	2.35
T₂	0.73	12.94	0.004	1.20
T₃	1.08	13.58	0.011	3.26
T₄	1.51	13.72	0.016	4.71
Mean	1.00	13.53	0.009	2.79
CD_{0.05}	0.07	NS	0.002	0.43
SE_{m±}	0.02	0.62	0.001	0.14

T₁: (soil only)

T₃: Soil: Sand: Farm Yard Manure (1: 1: 1)

T₂: Soil: Sand (1: 1)

T₄: Soil: Sand: Vermicompost (1: 1: 1)

NS: Non-significant



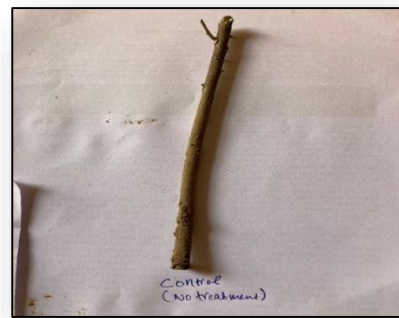
A: IBA @ 500,1000,1500,2000 (ppm)



B: NAA @ 500,1000,1500,2000 (ppm)



C: IAA @ 500,1000,1500,2000 (ppm)



D: Control (No Treatment)



E: IBA @ 2000ppm

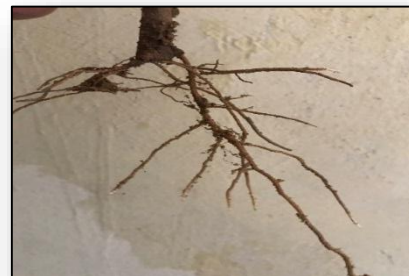
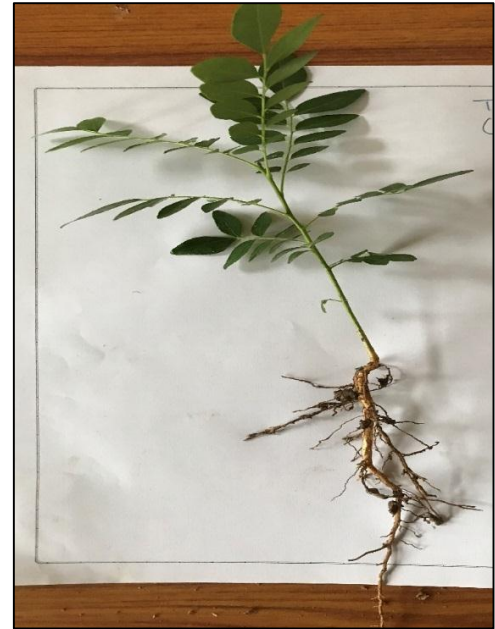


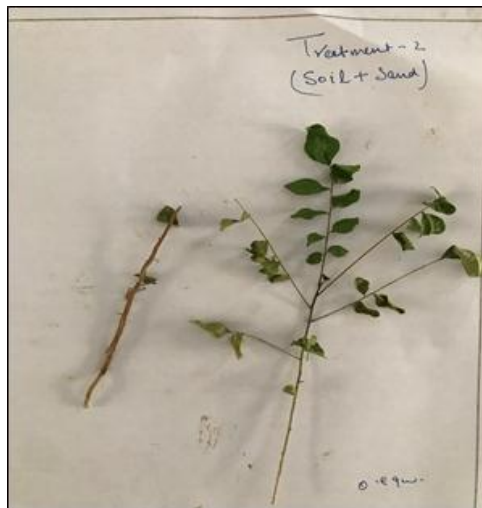
Plate 3: Rooting of stem cuttings treated with different hormonal concentrations



T₂: Soil: Sand (1: 1)



T₄: Soil: Sand: VC (1: 1: 1)



T₂: Soil: Sand (1: 1)



T₄: Soil: Sand: VC (1: 1: 1)

**Plate 4: Plate showing fresh seedlings & dry seedlings grown in T₂:
Soil: Sand (1:1) and T₄: Soil: Sand: VC (1: 1:1)**

Chapter-5

Discussion

DISCUSSION

A comprehensive study on “Standardization of Propagation Techniques in *Murraya koenigii* Spreng.” under nursery conditions was carried out in the Division of Agroforestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu during the year 2019-2020. The results so obtained are discussed in the light of current literature.

5.1 Standardization of the hormonal concentration for better rooting of stem cuttings

For rooting of cuttings, hormonal concentration is important. Different studies have found different effects of hormonal concentration on rooting of cuttings (Hartman *et al.*, 2011). The present experiment investigated the effect of hormonal concentration for better rooting of stem cuttings in *Murraya koenigii*. Twelve different hormonal concentrations along with control were used in the experiment.

Different hormonal concentrations influenced all the parameter tested except the number of shoots. T₄ (IBA 2000ppm) showed the highest sprouting percentage (56.48%), rooting percentage (41.67 %), shoot length/plant height (7.07 cm), number of lateral roots (18.20) and number of leaves (13.33). The enhancement of per cent sprouting of buds in stem cuttings might be due to the stimulation of hydrolysis of nutrient reserves and their mobilization (Babu *et al.*, 2018). Synthetic auxins are most commonly used to promote root development in clonal propagation. Auxin promotes the starch hydrolysis and the mobilization of sugars and nutrients at the base of the cuttings during the regeneration of adventitious roots (Husen and Pal, 2006). These results are consistent and corroborated with the findings of earlier workers, who demonstrated that IBA was most effective auxin in triggering rooting in stem cuttings than IAA and NAA (Babaie *et al.*, 2014). Similar results have also been reported by Thapparangana *et al.* (1996) in hardwood cuttings of curry leaf.

Characters like maximum root length (4.47 cm), fresh root biomass (0.022 g) and dry root biomass (0.0101 g) appeared in T₄ (IBA 2000ppm). This might be due to the maximum root initiation in this treatment. The application of auxins naturally or exogenously applied are required for initiation of adventitious roots on stems. It appears probable that the success of IBA is due to its low auxin activity and its slow degradation by auxin destroying enzyme (Singh *et al.*, 2014). Exogenous application of auxins might have supplemented the endogenous levels of auxins leading to enhanced rooting as a result of increased cell division and cell elongation. The role of IBA in improving both rooting percentage and development of roots have been reported by Hartman *et al.* (2011). Similarly, Dhatu (2009) reported similar findings in IBA treated cuttings of *Murraya koenigii* at higher concentration.

The current study indicates that hormonal concentration plays a significant role in rooting of cuttings in *Murraya koenigii* and cuttings treated with T₄ (IBA 2000 ppm) was found to be better for root enhancement.

5.2 Effect of potting mixture on seed germination and seedling growth

For seedlings germination and growth, the selection of potting media is important. Different studies have found different effects of potting media under nursery conditions on the growth of plant seedlings. The present experiment examined the effect of the potting media on the germination and growth of seedlings of *Murraya koenigii*. Four different potting media (T₁) soil only, (T₂) soil: sand in the ratio 1: 1, (T₃) soil: sand: FYM in the ratio 1:1:1 and (T₄) soil: sand: Vermicompost in the ratio 1: 1: 1 were taken for the study.

Except the sturdiness quotient, the potting media greatly affected all the parameters tested. T₄ (soil: sand: vermicompost, 1: 1: 1) reported the highest percentage of seed germination (96.00%), fresh seedling weight (3.82 g), collar diameter (2.42 g), number of leaves (10.6), root length (19.1 cm), fresh shoot weight (2.01 g), dry shoot weight (0.92), fresh root weight (2.70 g), dry root weight (1.39 g), root: shoot ratio (1.51) and seedling quality index (0.0016). The values of these parameters followed a trend: T₄ (soil: sand: Vermicompost, 1: 1: 1) > T₃ (soil: sand: FYM, 1: 1: 1) > T₁ (soil only) > T₂ (soil: sand, 1:1). The better growth in (T₄) soil: sand: Vermicompost in the ratio 1: 1: 1 could be attributed

because vermicompost is high in organic matter which increases water and nutrient holding capacity of the medium for supply to the plant than that of the remaining media (Kaur, 2017). Similar finding have also been recorded by Amhed (2017) at SKUAST-J, Jammu (J&K) in case of *Terminalia bellirica* seedlings.

The minimum number of days taken for germination (13.40 days), germinative energy (52.00%), and highest survival percentage (98.00%) was observed in T₄ (soil: sand: Vermicompost, 1: 1: 1). It may be due to the organic matter present in the vermicompost that improves the nutrient availability and phosphorus absorption which ultimately increases the speed of emergence (Bharadwaj, 2013). Matching findings have also been reported by Kaur (2017) at Punjab Agricultural University, Regional Research Station, Gurdaspur (Punjab) in Mango seedlings. Shoot length (14.05 cm) was maximum in T₄ (soil: sand: Vermicompost, 1: 1: 1) which could be attributed to better root initiation in this media.

The current study indicates that potting media plays an important role in growth of seedlings of *Murraya koenigii* and that (T₄) Soil: Sand: Vermicompost in the ratio 1: 1: 1 is better than rest of treatments for raising seedlings of *Murraya koenigii*.

Chapter-6

Summary and Conclusion

SUMMARY AND CONCLUSION

The current study on the topic “Standardization of Propagation Techniques in *Murraya koenigii* Spreng.” was conducted in the Division of Agroforestry, Sher-e-Kashmir University of Agricultural Sciences and Technology- Jammu during the year 2019-2020. The objectives of the study were:

- 1) To standardize the hormonal concentration for better rooting of stem cuttings
- 2) To investigate the effect of potting mixture on seed germination and seedling growth

6.1 Response of hormonal concentrations on rooting of stem cuttings

The experiment was laid out in CRD (Complete Randomization Design). The total number of treatments were 13 with three replications. The results obtained from the investigation were subjected to analysis of variance at 0.05 levels of significance. The findings of the present study are summarized below:

The results showed that the response of hormonal concentrations on all the parameters i.e. sprouting percentage, rooting percentage, number of lateral roots, shoot length, root length, number of leaves, fresh root biomass and dry root biomass were significant. However, the response of hormonal concentrations on number of shoots was non-significant. There was a general trend of increase in all the parameters with increase in IBA concentrations and were recorded maximum in T₄ (IBA 2000ppm), whereas untreated cuttings failed to produce roots.

The treatment T₄ (IBA 2000ppm) had significantly recorded the highest sprouting percentage (56.48 %), rooting percentage (41.67 %), number of lateral roots (18.20), shoot length/plant height (7.07 cm) root length (4.47 cm), number of leaves (13.33), fresh root biomass (0.022 g) and dry root biomass (0.0101 g). The response of hormonal concentrations on rooting of stem cuttings are summarized in the Table 6.1.

Table 6.1: Summary of response of hormonal concentrations on stem cuttings

Parameters recorded	Effect
Sprouting percentage	S
Rooting percentage	S
Number of shoots	NS
Number of lateral roots	S
Root length	S
Shoot length/Plant height	S
Number of leaves	S
Fresh root biomass	S
Dry root biomass	S

S- Significant at 0.05 level, NS- Non-significant at 0.05 level

In general there was an increase in all the parameters recorded - sprouting percentage, rooting percentage, number of lateral roots, shoot length, root length, number of leaves, fresh root biomass and dry root biomass with increase in IBA hormonal concentrations which could be attributed by more stable structure of IBA than the IAA and NAA.

6.2 Effect of potting mixture on seed germination and seedlings growth

The experiment was laid out in CRD (Complete Randomization Design). The total number of treatments were four and each treatment had five replications. The results obtained from the investigation were subjected to analysis of variance at 0.05 levels of significance. The findings of the present study are summarized in the Table 6.2.

Table 6.2: Summary of effect of potting mixtures on seed germination and seedlings growth

Parameters recorded	Effect
Germination percentage	S
Number of days taken for germination	S
Germinative energy	S
Survival percentage	S
Collar diameter	S
Number of leaves	S
Primary root length	S
Average shoot length	S
Fresh shoot weight	S
Dry shoot weight	S
Fresh root weight	S
Dry root weight	S
Root: shoot ratio	S
Sturdiness quotient	NS
Seedling quality index	S

S- Significant at 0.05 level, NS- Non-significant at 0.05 level

Out of all the potting mixtures, T₄ (soil: sand: vermicompost (1:1:1)) had significantly recorded maximum germination percentage (96%), minimum number of days taken for germination (13.40 days), germinative energy (52%), survival percentage (98%), collar diameter (2.42 mm), number of leavesplant⁻¹(13.33), shoot length (14.05 cm), primary root length (19.10 cm), fresh shoot weight (2.01 g), dry shoot weight (0.92 g), fresh root weight (2.70 g), dry root weight (1.39 g), root: shoot ratio (1.51) and seedling quality index (0.0016) than the remaining potting mixture. The overall best performance was in potting mixture T₄ (soil: sand: vermicompost (1:1:1)) which could be attributed to higher nutrient content in vermicompost than FYM. On an average the N, P

and K content in vermicompost is 0.5-1.5, 0.1-0.3 and 0.15-0.56% respectively, compared to 0.5, 0.2 and 0.56% in FYM (<http://www.agritech.tanu.ac.in>).

6.3 Recommendations

Based on the present study the following conclusions can be drawn:

- *Murraya koenigii* could be propagated vegetatively by cuttings and rooting could be improved with the application of IBA hormone at 2000 ppm concentration.
- This study also revealed that *Murraya koenigii* can also be successfully propagated by seeds.
- Among the four potting mixtures i.e. soil only, soil: sand (1:1), soil: sand: FYM (1: 1: 1) and soil: sand: vermicompost (1: 1: 1), soil: sand: vermicompost (1: 1: 1) were the most promising one for raising better quality seedlings of *Murraya koenigii*.

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CERTIFICATE-IV

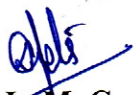
Certified that all the necessary corrections as suggested by the external examiner and the Advisory committee have been duly incorporated in the thesis entitled “Standardization of Propagation Tehniques in *Murraya koenigii* Spreng.” submitted by Mr. Rahul Sharma, Registration No.J-18-M-562.



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