Production potential of growing Lavender on the southern slopes of Kashmir valley

Saima Farooq
(2017-FOR-69-M)

Faculty of Forestry

Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir

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Is there anything I can say,
anything I can give
or do for you….
Because all that I´m
all that I have
I owe to you…..
Affectionately Dedicated

To my

Beloved Parents

Who sacrificed their present

to make my future better

Sher-e-Kashmir
University of Agricultural Sciences and Technology of Kashmir
Faculty of Forestry, Benhama, Ganderbal

Certificate – I

This is to certify that the thesis entitled, **"Production potential of growing Lavender on the southern slopes of Kashmir valley"** submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science in Forestry**, to the **Faculty of Forestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir** is a record of bonafide research work carried out by **Ms. Saima Farooq (Regd. No. 2017-FOR-69-M)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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Dr. S. A. Gangoo
Chairman
Advisory Committee

Endorsed

Dean,
Faculty of Forestry

Sher-e-Kashmir
University of Agricultural Sciences and Technology of Kashmir
Faculty of Forestry, Benhama, Ganderbal

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We, the members of the Advisory Committee of **Ms. Saima Farooq (Regd. No. 2017-FOR-69-M),** a candidate for the degree of **Master of Science in Forestry** have gone through the manuscript of the thesis entitled, **"Production potential of growing Lavender on the southern slopes of Kashmir valley"** and recommend that it may be submitted by the student in partial fulfilment of the requirements for the award of the degree.

Advisory Committee

Chairman

Dr. S. A. Gangoo
Professor & Head, Department of Forest Products and Utilization, Faculty of Forestry, SKUAST-K, Benhama, Ganderbal

Members

Dr. M. A. Islam
Professor, Faculty of Forestry,
SKUAST-K, Benhama, Ganderbal

Dr. Amarjeet Singh,
Assistant Professor, Faculty of Forestry,
SKUAST-K, Ganderbal

Dr. Bilal Ahmed Bhat,
Associate Professor, Faculty of Fisheries,
SKUAST-Kashmir

Dean's Nominee

Dr. K.N. Qaiser,
Professor and Head, Department of Natural Resource Management, Faculty of Forestry,
SKUAST-K, Ganderbal

Sher-e-Kashmir
University of Agricultural Sciences and Technology of Kashmir
Faculty of Forestry, Benhama, Ganderbal

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This is to certify that the thesis entitled, **"Production potential of growing Lavender on the southern slopes of Kashmir valley"** submitted by **Ms. Saima Farooq (Regd. No. 2017-FOR-69-M)** to the **Faculty of Forestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir** in partial fulfilment of the requirements for the award of the degree of **Master of Science in Forestry** was examined and approved by the Advisory Committee and External Examiner on …………….. .

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Advisory Committee

External Examiner

Dean
Faculty of Forestry

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Faculty of Forestry, Benhama, Ganderbal

Name of the student	:	**Saima Farooq**
Registration No.	:	2017-FOR-69-M
Major Subject	:	**Forestry**
Minor Subject	:	Silviculture and Plantation Technology/ Agroforestry and watershed management
Major Advisor	:	**Dr. S. A. Gangoo** Professor & Head Department of Forest Products and Utilization, Faculty of Forestry, SKUAST-K, Benhama, Ganderbal
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ABSTRACT

Lavandula angustifolia, popularly known as true lavender are plants grown commercially for the extraction of essential oil and also employed as ornamentals and for honey production. Lavender has a wide adaptation in diverse climatic and soil conditions, being found in several countries in Europe, the Middle East, Asia and North Africa where it is used as source of raw material in the pharmaceutical, food, cosmetics, aromas and agro-industry. The present investigation entitled "Production potential of growing lavender on the southern slopes of Kashmir valley" was carried out at Faculty of Forestry, Benhama, Ganderbal, Jammu and Kashmir. Under the present study, Terminal cuttings (8-10 cm) of lavender with intact vegetative tops were subjected to different IBA concentrations. The first experiment was conducted to ascertain the role of IBA in initiating and accelerating the root development of Lavender cuttings. The cuttings were treated with eleven treatments viz., IBA (200-2000ppm) and Control (no IBA treatment) to study the effect on rooting percentage, number of roots per cutting and length of longest root of *Lavandula angustifolia* cuttings. The results showed that rooting percentage**,** number of roots per cutting and length of roots were significantly influenced when *Lavandula angustifolia* cuttings were treated with different IBA concentrations. Maximum values for rooting percentage, number of primary and secondary roots and length of longest roots were observed in treatment T_{11} with mean values of 91.99 %, 18.75, 76.25 and 24.00cm respectively when Lavender cuttings were treated with IBA@2000ppm. However a significant effect of IBA on before mentioned growth parameters was observed. The second experiment on out planting performance of lavender was carried at three different Spacing's (0.5 m x 0.5 m, 0.5 m x 1 m and 0.5 m x 1.5 m). All the treatments significantly influenced the growth and yield parameters of *Lavandula angustifolia* plants under field conditions. Maximum value for flower buds per plant (265.33) was observed when lavender plants were planted at a spacing of 0.5 m×1.5 m and for fresh and dry herbage yield maximum values (2420.95±11.08 and 1818.91±11.54 respectively) were observed when *Lavender* plants were planted at a spacing of 0.5 m x 0.5 m. Experiment on estimation of oil from the flower spikes of the lavender plants reveal that flowers being economically important part yielded maximum essential oil of 11.75 ml from 80.79 grams of flower spikes when lavender plants were planted at a spacing of 0.5 m x 0.5 m. Similarly maximum essential oil yield (117.50 L/ha) was also observed in treatment T1 in Lavender plants when planted at a spacing of 0.5 m x 0.5 m, followed by T2 (97.50 L/ha) at a spacing of 0.5 m ×1 m and T3 (77.00 L/ha) at a spacing of 0.5 m×1.5 m. The results reveal that spacing had a significant effect on the growth of *Lavandula angustifolia* plants and yield of essential oil.

Keywords: *Lavandula angustifolia,* Essential Oil, IBA, Cuttings, Spacing, oil, ppm.

Signature of Student
Dated____________

Signature of Major Advisor
Dated _________________

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Place: Benhama, Ganderbal
Dated: ________________

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Chapter-1

INTRODUCTION

Man has forever sought the use of flavours and fragrances for a variety of purposes. Higher plants have provided the basic raw material for such fragrances and flavours. Archeological excavations in Mohan-Je-Daro and Harappa reveal that the art of distillation of essential oils in the form of scented waters was developed during the Indus valley civilization, more than 5000 years ago. The technology was later refined and developed in the Middle East. Narrated 'Aisha: I used to perfume Prophet Mohammad (S.A.W) with the best scent available till I saw the shine of the scent on his head and shine beard. (Sahih Bukhari, Hadees No. 5923). India has been one of the major centres of production of perfumes and cosmetics for more than 2000 years. The essential oil industry has grown considerably during the last 60 years. Essential oils are odiferous, volatile constituents of aromatic plants obtained by hydro/steam distillation or super critical carbon dioxide extraction. They form the backbone of perfumery, flavour and cosmetic industry. Currently they have a substantial use in aromatherapy and other traditional system of medicines. The important use to which they are put are as ingredients in the manufacture of soaps, cosmetics, perfumes, skin care and hair care products, anti wrinkling agents, anti age creams, pharmaceuticals, textiles, leather and confectionary. In view of the resurgence in the use of natural flavours, essential oils and aroma chemicals derived thereof and because of the fact of toxicity of synthetic flavours and perfumes, they have become major sectors of trade. Jammu and Kashmir state is very rich in essential oil bearing plants. In India Kashmir valley represents the temperate region besides upper reaches of Himachal Pradesh and Uttranchal. The valley has a great potential of establishing an essential oil industry by cultivating and processing high value essential oil bearing plants of temperate region, which have both domestic consumption and export potential. Indian Institute of Integrated Medicine at Srinagar and its associated Field Station at Bonera (Pulwama) has developed agro and processing technology of several important essential oil bearing plants along with quality profiles based on international standards. The institute has involved farmers for extraction of these high value crops by providing quality planting material and technical know. (Shawl and Qazi, 2008).

Most of us have grown up with the scent of lavender in our homes and this essential oil continues to be as popular today as it has been down the centuries past. Documented evidence for the use of lavender as a therapeutic agent can be traced back to the ancient Romans and Greeks and the continuing popularity and commercial value of lavender was confirmed when it was named 'Herb of the year 1999' by the Herb Growing and Marketing Network in the United States of America (Evelegh, 1996; Anonymous, 1999). *Lavandula* (common name lavender) is a genus of 39 species and 17 hybrids of flowering plants in the mint family Lamiaceae. In addition there are nearly 400 cultivars and field varieties reported from the genus (Upson and Andrews, 2004). Lavenders fall into four main categories: *Lavandula latifolia*, a Mediterranean grass-like lavender; *Lavandula angustifolia*, a stockier plant with a fuller flower, commonly known as English lavender (formerly known as *L. vera* or *L. officinalis*); *Lavandula stoechas*, which has butterfly-like bracts on top of the flowers and is sometimes known as French lavender; and *Lavandula x intermedia*, which is a sterile cross between *L. latifolia* and *L. angustifolia*. The various lavenders have similar ethnobotanical properties and major chemical constituents, however, there are some differences in the reported therapeutic uses for different species. For example most lavenders are believed to have carminative actions but *L. stoechas* is traditionally used for headache, *L. latifolia* as an abortifacient and *L. angustifolia* as a diuretic (Agricultural Research Service, 2000). True lavender (*Lavandula angustifolia*) is the most valued of all lavender species both for its high quality oil and as garden plant. It is a perennial bushy shrub 50-80 cm tall with attractive flowers borne in short compact to long interrupted spikes on a distinct and unbranched peduncle. The flowers are usually of violet-blue to purple shade. While each individual flower is relatively small when grouped together in each spike and open in succession over a period of weeks. The leaves are narrowly linear as compared to broader leaves in lavandin. Bracts ovate to broadly ovate, bracteoles are minute. The plant has an economic plantation life of 15-20 years. Gestation period is two years for attaining economic production level. The site for lavender plantation should be sunny facing south, sloppy, well drained and free from perennial weeds. Plant produces flowers once in a year for 30-40 days during June and July. The plant is cultivated in France, U. K, Bulgaria, New Zealand, Hungary, Australia, China, Russia, Moldova, Ukraine, former Yugoslavia, Morocco, India and to a limited extent in U.S.A for oil and agritourism as lavender tours and festivals conducted in lavender parks are becoming more popular. Indian Institute of Integrative Medicine Srinagar (Erstwhile Regional Research Laboratory) has developed a cultivar through selection which is highly suitable for temperate conditions of Kashmir, hilly areas of Himachal Pradesh, Uttrakhand and Kodikanal areas of South India (Shawl and Kumar, 2000).

The taxonomical hierarchy of *Lavendula* has been shown in Table-1 below.

Table 1: Taxonomical hierarchy of Lavendula

Taxonomy	
Kingdom	Plantae – Plants
Clade	Angiosperms
Order	Lamiales
Family	Lamiaceae – Mint family
Sub family	Nepetoideae
Tribe	Ocimeae
Genus	*Lavendula*

Lavenders have everything for the modern garden as an amenity plant. They are evergreen, fast growing, compact and fragrant. There are numerous references to other qualities of lavender in Roman times – such as cure for mild epilepsy and as a laxative. The production of lavender for aromatherapy, perfumery and alternative medical purposes is now well developed in countries where various species of lavender are found naturally i.e. from the Mediterranean to the Middle East, India, North Africa and Asia. True Lavender (*Lavendula officinalis)* is one of the important plant now-a-days. Lavender essential oil is produced, usually by steam distillation, from both the flower heads and foliage, but the chemical composition differs greatly, with the sweeter and most aromatic oil being derived from the flowers (McGimpsey and Porter, 1999). The essential oil is exquisitely scented and has a very wide range of applications, both in the home and commercially. The oil is used for perfumery, cosmetics, flavouring food and pharmaceutical applications. In recent years it has become an ornamental plant of gardening too. Lavender oil has the biological activities of carminative, antispasmodic, expectorant, stimulant, antibacterial and antiseptic. Thus, it also acts as a powerful antidote to snake venoms. An Australian study provided evidence of the sedative effects of the essential oil of lavender after inhalation (Buchbauer *et al*., 1991).

In food industry, lavender oil is employed in flavouring beverages, ice creams, candy, baked food items and chewing gum. Leaves, petals and flowering tips as raw are used as a condiment in salads, soups, etc. the fresh or dried flowers are also used as a tea. The warm, sweet aroma of lavender, along with its many uses, makes this oil a favourite for Aromatherapy. Lavender oil is considered excellent multi-purpose oil for use in acne, burns, dandruff, dermatitis, eczema, headaches, inflammations, insect bites, sunburn, wounds, stress, insect repellent, anti-lice, skin and hair conditioner. Recent studies have found that essential oils from this extra-ordinary species can replace chemical methods currently in use to suppress sprouting in potato tubers for storage (Vokou *et al*., 1993). In bioactivity studies *Lavendula spp*. has been proven to show its potent activity against insect-pests in India (Sharma *et al*., 1992).

Lavender (*Lavendula angustifolia*) is used in aromatherapy as a relaxant. Its sedative nature, on inhalation, has been shown in both animal and human studies (Buchbauer *et al*., 1991; Diego *et al*., 1998; Lis-Balchin and Hart, 1999). It has a wide range of clinical applications and has been shown to be effective for the use of depression and anxiety in cancer patients (Kite *et al*., 1998). Other value added products like lavender absolute, lavender water and dried flowers have an ever growing demand. The lavender variety developed by RRL contains more than 1.4% of the oil and main constituents of lavender oil are linalool (26%), linalyl acetate (44.5%), α-terpineol (1.49%). Lavendulol (1.41%), lavendulyl acetate (3.4%) and β-caryophyllene (2.8%). It is well known that linalool and linalyl acetate content of lavender oil is mostly used as the criterian of quality. Kashmir lavender oil having linalool > 26% and linalyl acetate > 44%, is of international standards. Lavender oil produced from Kashmir is being sold both in the domestic and international market (Shawl and Kumar, 2000, 2003; Shawl *et al*., 2005).

Lavandula is a small genus of perennial aromatic herbs, sub-shrubs or shrubs confined to the North temperate and tropical regions of the world. In a country of growing and alarming population and low per capita income, one of the major tasks of the planners and the farm scientists is to increase the production per unit area per unit time to feed the growing population (Singh and Chand, 1980). Globalization of market and open economy now provides unlimited export opportunities to agriculture-based countries like India, which are gifted with the varying soil and climatic conditions, having vast natural resources.

World production of various lavender oils, *Lavendula officinalis, Lavendula latifolia, Lavendula hybrid* is nearly 1500 tonns per annum of which 75% is lavandin, 20% lavender and 5% spike lavender oil. Till date domestic demand of lavender oil in India is met through imports and the requirement varies from 25 to 50 tonns per annum (Mehta *et al*., 2000). During British period an abortive attempt was made for commercial cultivation of lavender in India followed by another failure by Sir Col. R. N. Chopra in 1957. During early 80's Central Institute of Medicinal and Aromatic Plants (CIMAP), Lucknow has introduced this plant in Kashmir. However, no commercial cultivation could be established due to changing political scenario in Jammu and Kashmir. During 2000, Institute of Himalayan Bioresource Technology, Palampur has successfully introduced this plant on a semi- commercial scale in District Chamba of Himachal Pradesh, which was assessed to be an alternate location for its cultivation in India. (Singh *et al*., 2007).

Cultivation on an experimental scale has been undertaken at several places in Kashmir at altitudes of 1500 m and the results are promising. There are at present 8 acres under this crop in some parts of Nilgiris and 100ha of land in Kashmir. The oil produced is of as good quality as that of European countries (Sharma *et al*., 1983;Tajuddin *et al*., 1983; Dhar *et al*., 1982; Hussain, 1989; Mallavarapu *et al*., 2000). Lavender oil produced from Kashmir is being sold both in the domestic and international market. Given proper conditions Kashmir valley can become the major centre of production of lavender oil to the world market (Shawl and Kumar 2000, 2003; Shawl *et al*., 2005; Shawl and Qazi, 2008).

Lavender oil is a colourless to pale yellow mobile liquid with a characteristic odour described as being sweet, fresh, floral-herbaceous with a slight balsamic-woody undertone. Lavandin oil is a colourless to pale yellow mobile liquid with a clean, herbaceous, slightly medicinal top-note with a woody-herbaceous undertone. It should be almost free of camphoraceous notes. Spike lavender oil is a colourless to pale yellow mobile liquid with a camphoraceous-herbaceous top-note with a dry, woody, faintly musty undernote (Arctander, 1960; Boelens, 1995). The production statistics for lavender oil and French lavandin oil over the years according to Vinot and Bouscary (1979), Peyron (1983), Basset

(1988), Garnon (1993), Troadec *et al*. (1997), Anon. (2000a), and Moutet *pers. comm*., can be seen in Table 2.

Table 2: Production statistics of lavender oil and lavandin oil (metric tons)

Year	Lavender oil	Lavandin oil
1920	75	-
1923	100[a]	-
1924	110	2
1930	130	50
1940	125	120
1950	75	200
1954	90	260
1956	80[b]	600
1960	130	850
1970	100	900
1980	90	1200
1982	80	950
1986	50	940
1990	35	935
1992	40	1000
1998	55	1100
2001	63	1305
2002	60	1290

a= 90% wild, 10% cultivated

b= 90% cultivated, 10% wild

Lavender a small, non-hardy perennial evergreen shrub is propagated through seeds and cuttings. Multiplication through seeds results in genetic variation which is not economical. The seeds have a poor germination percentage (Takano *et al*., 1990). Vegetative propagation through cuttings is the economical method (Shawl and Kumar, 2000; Singh *et al.,* 1986). The purpose for which the lavender is being raised heavily influences cultivar choice. Most growers favor deep blue flowers, lush growth, and hardiness. Furthermore, seed propagated lavender crops lack plant stand uniformity, complicating cultural practices and failing to deliver the species´ worldwide demanded superior quality essential oil. On the other hand, asexually propagated *Lavandula* species, especially the *angustifolia*, present poor rooting (Tyub *et al*., 2007; Moon *et al*., 2006; Sudria *et al*., 2001)

Rooting of stem cutting is an important horticultural tool for the propagation of ornamental, medicinal and aromatic plants. Factors affecting the rooting of cuttings include application of auxins, seasonal timing at which cuttings are collected, type of cuttings, wounding, physiological and histological factors as well as an imbalance of endogenous phytohormones. Synthetic auxins are known to stimulate adventitious root formation on cuttings, but the world was going to reduce the use of synthetic chemical compounds as a result for its risks to the environment. Indole butyric acid is the most widely used among the root promoting auxinic compounds because it is non-toxic and effective over a wide range of species (Couvillon, 1988). The objective of this experiment was to test different concentrations of IBA on rooting of *Lavandula angustifolia* to establish a commercial propagation protocol for this plant. And in view of its therapeutic properties and a front line essential oil crop in aromatherapy there has been increasing demand for production of lavender oil. The southern slopes in Kashmir valley are the warmer slopes which are mostly calcareous and devoid of vegetation. These are the areas which can be used for cultivation of lavender and thus unproductive land can be brought to valuable production. Hence keeping in view the above facts, present investigation was carried out with the following objectives:

1. Production of rooted cuttings of true lavender for commercial propagation
2. To study lavender flower production on southern slopes at different spacing.
3. Extraction of oil content from flower spikes.

Chapter-2

REVIEW OF LITERATURE

The present work on "Production potential of growing lavender on the southern slopes of Kashmir valley" is based on number of experiments conducted: for studying the effect of IBA concentrations on different rooting parameters in cuttings of *Lavandula angustifolia* and effect of spacing on yield parameters in *Lavandula angustifolia* plants. The research trials were carried out in the experimental fields and in the laboratory conditions. Little or no work has been conducted for studying the effect of spacing on flower and oil yield in Kashmir valley in general and the country in particular. Hence the published literature of closely related aromatic and medicinal crops has been reviewed in this chapter under the following sub heads:

2.1 Rooting of lavender cuttings

2.2 Cultivation of lavender in field

2.3 Essential oil content in lavender and its chemical composition.

2.1 Rooting of lavender cuttings

Zigene *et al*. (2018) reported that the highest root number/seedling, root weight/seedling, and root length/seedling were obtained for top cuttings and at 7 cm and 9 cm cutting size for root number and root length/seedling, respectively and at 9 cm for root weight/seedling. Generally top cutting with 9cm cutting size demonstrated better nursery establishment of lavender.

Kasem and Abd-El-Baset (2014) conducted an experiment to compare the ability of two bacteria strains from *Agrobacterium rhizogenes* (DSM30200 and A4), yeast extract 0.5, 1 and 2 g/L) and indole butyric acid (IBA)(50, 100, and 150 mg/L) on rooting of the terminal cuttings of *Lavandula angustifolia* L plant. Terminal cuttings of *L. angustifolia* "Munstead" (English lavender) (15 cm long) were obtained from the Experimental Station of Ornamental Plants, Faculty of

Agriculture, Mansoura University, Egypt in January. Two strains of virulent *A. rhizogenes* (DSM30200 and A4) were obtained from Cairo Mircen Laboratory, Egypt. *A. rhizogenes* strains were more effective than most of the other treatments in increasing rooting percentage, roots number and increase of cuttings length except using IBA at 100 and 150 mg/L, as no significant differences were found between them. In contrast, the controls cuttings and cuttings treated with yeast at higher concentrations produced the lowest rooting percentage. Same trend treatments which showed higher rooting characteristics also recorded higher percentage of total carbohydrates, phenol and N percentage. On commercial scale use of two examined strains of *A. rhizogenes* for rooting of terminal cuttings of *L. angustifolia* can reduce the use of synthetic auxins.

Bona *et al.* (2012) conducted an experiment to test different concentrations of indole-3-butyric acid (IBA) on rooting of eight (G1-G8) *L. angustifolia* genotypes from different provenances such as Brazil, France and Germany were cultivated in a greenhouse pertaining to the Plant Sciences Department in the Agrarian Sciences Sector of the Federal University of Parana (UFPR), in Curitiba, Parana, Brazil. After forty days, rooting percentage (RP), root number (RN), length of the longest root (RL) were evaluated. The different accessions presented very diverse response to IBA application. The presence of auxin did not influence rooting on G1. Rooting percentage was considered good, ranging from 80 to 100%, with 20 roots, 10 to 12 cm-long per cutting, in average. Auxin did not influence rooting on G2 either, which presented approximately 50% rooting with five roots, 6-7 cm-long per cutting, in average. There was no statistical difference among treatments for G3, however, 700 mg L^{-1} IBA promoted 91.7% rooting, more than the control, which was 70.8%. Rooting decreased with the greater doses (1500 and 2000 mg L^{-1}) to 70.8% and 58.3%, respectively. Root number on the other hand was greater with the two higher doses, while length of roots followed the behavior of the root percentage variable. For G4, greater percentage of roots was obtained with 2000 mg L^{-1} of IBA but did not differ statistically from the 1500 mg L^{-1} dose, which induced formation of more roots. Auxin seemed to be detrimental to G5, but not statistically different from the other treatments. The control was superior for all the variables tested. The 1500 mg L^{-1} of IBA treatments induced greater percentage, number and length of roots for G6, but it was not statistically superior to other treatments. Rooting of G7 was not influenced by auxin application. For G8, the control was statistically superior to the 1500 mg L^{-1} treatment but did not differ from the 700 mg L^{-1} treatment.

Chandramouli (2001) working under Bangalore condition found that the highest rooting percentage (84.66%), maximum number of roots per cutting (27.83) and length of the longest root (10.70 cm) in hardwood cuttings of Indian lavender when treated with 250ppm IBA for 18 hours followed by 250ppm NAA over control.

Ayanoglu *et al*. (2000) conducted an experiment to study the effect of different locations and hormone doses on the rooting of cuttings of Karabas Lavender (*Lavandula stoechas* L.). The intensive growing areas of Karabas lavender were determined in the province of Hatay, Turkey. The rooting capabilities of cuttings, gathered from different locations (Isikli and Narlica), were investigated. The cuttings were treated with IBA at 0, 1000, 2000, and 4000ppm. Percentage rooting of the cuttings gathered from Isikli were higher than those gathered from Narlica. The hormone doses positively affected the rooting (percentage rooting, number of roots and root length) of cuttings. The highest percentage rooting (70%) was obtained from cuttings gathered from Isikli, treated with 4000ppm IBA.

Kumar and Sreeja (1996) while studying the influence of Indole-butyric acid (IBA) on different types of cuttings in lavender (*Lavandula angustifolia*) showed that basal stem cuttings treated with 2000ppm of IBA showed the highest percentage of rooting (72%) and more number of roots.

Thimmappa and Bhattacharjee (1990) studied the effect of IAA, IBA and NAA at 1000, 2000, 3000ppm on adventitious root formation in stem cuttings of scented geranium (*Pelargonium graveolensis*). They reported that among growth regulators, IBA application was better for rooting over other chemicals and IBA treatment at 2000ppm proved to be the best.

Zlatev *et al*. (1990) studied the effect of IBA, NAA and 2, 4, 5-T on cuttings from 1- year old shoots of 3 lavender (*Lavandula*) cultivars. The cuttings were soaked for 16 hrs in 100 or 150 mg/litre IBA, 50 mg/litre NAA or 2.5 mg/litre 2, 4, 5-T solutions before planting. The control cuttings were soaked in water (wet control) or were not soaked (dry control). IBA was generally the most effective compound and Druzhba was the most responsive cultivar. IBA at 100 mg/litre improved rooting in Druzhba by up to 92.3% compared with the dry control, and at 150 mg/litre it improved rooting by 107.2%. Cultivars Karlovo and Khemus showed markedly poorer responses to treatments.

Somappa (1979) working under Dharwad conditions, observed that Indian lavender (*Bursera delpechiana*) cuttings treated with IBA, 1500ppm produced maximum rooting percentage (53.33%). Also the root characters like number of primary roots per rooted cuttings (4.33%) and length of longest primary root (7.70 cm) was obtained in the cuttings treated with IBA, 1500ppm

2.2 Cultivation of lavender in field

Abbaszadeh *et al*. (2016) conducted an experiment in the Research Institute of Forest and Rangelands, Karaj, Iran, in 2013-14 to study the effect of organic fertilizer on shoot yield and essential oil content of lavender. The treatment groups consisted of vermicompost (0, 5, 10 and 15 tons/ha) and cow manure (0, 10, 20 and 30 tons/ha). The experimental design was a factorial experiment based on randomized complete block design (RCBD) with three replications. The study revealed that the interaction effect of treatments was significant for total shoot and leaf yield ($P \leq 0.05$). The highest sub stem number

(24 N/P) was obtained in 30 tons/ha manure treatment. While, the highest leaf yield (2206.4 kg/ha), annual stem yield (7133.2 kg/ha), annual branches yield (1655.5 kg/ha), total biological yield (1333.6 kg/ha) and essential oil yield (82.67 kg/ha) were determined at 15 tons/ha treatment.

Seidler-Lozykowska *et al*. (2014) conducted an experiment to study yield and quality of lavender flowers. The experiment was established in four different locations (Jary, Paszkow, Plewiska and Slonsk) in Poland. The average yield of fresh lavender flowers varied from 27.67 gm^{-2} (Paszkow control) to 102.00 gm^{-2} (Slonsk) and similar average yield of dried flowers was from 7.83 gm^{-2} (Paszkow control) to 38.00 gm^{-2} (Slonsk) and both yields were significantly different). In both locations (Plewiska and Paszkow) the yield of organic fresh and dried lavender flower yield from organic experiments was higher compared with the yield from conventional cultivation.

Kara and Baydar (2013) analyzed that the Significant differences depending on years and cultivars in the fresh stem, dry stem flower and dry stemless flower yields of lavender and lavandin were found. The highest fresh stem and dry stem flower yields were determined in Dutch cultivar (5647 and 8204, 2885 and 4604 kg ha^{-1}, respectively), the lowest fresh stem and dry stem flower yields were obtained in Giant Hidcote cultivar (2905 and 3999 kg ha-1, 1451 and 1955 kg ha^{-1}, respectively) in both years. Among the lavender and lavandin cultivars, the highest dried stemless flower yield was obtained from Super A (1083 and 1463 kg ha-1, respectively), the lowest dry stemless flower yield was determined from Giant Hidcote (459 and 705 kg ha^{-1}, respectively) for both years.

Hassanpouraghdam *et al*. (2011) conducted a greenhouse pot experiment to evaluate the effects of GA3 foliar application based on RCBD with four replications on growth characteristics and yield of French lavender (*Lavandula officinalis* Chaix.). The treatments included control (foliar spray with distilled water), GA3 foliar application at 100 mgl^{-1}, 200 mgl^{-1} and 300 mgl^{-1} and foliar spray with formulated GA3 tablet prepared at 100 mgl^{-1}concentration.Each experimental unit consisted of three pots each containing one rooted cutting. Pots were spaced 20 cm, 40 cm and 70 cm between pots, within block and between blocks respectively. Leaf fresh and dry weight attained their greatest quantities (146.58 g and 54.50 g) under 300 mgl^{-1} GA3 applications as well as fresh and dry weight of inflorescence (5.33 g and 2.60 g) which showed significant differences between treatments. Further in this study it was estimated that the essential oil content in the inflorescences and leaves of lavender (*Lavandula officinalis* L.) cultivated in Northwest Iran. Air-dried powdered plant materials (50 g) were separately subjected to hydro-distillation by an all-glass Clevenger-type extraction apparatus for 3 hours. Essential oil contents ml/100 g was evaluated based on the dry weight of plant material. The essential oil content was found to be6.25% and 0.64% in the inflorescences and leaves respectively. The oil was analyzed by Gas chromatography (GC) / Mass spectrometry (MS). Thirty seven and thirty four components were identified, comprising 97.0% and 96.5% of inflorescence and leaf total oil respectively.

Baydar (2007) reported that the real lavender has developed very well in dry and calcareous soils with a pH of 5.8-8.5. It produces less volatile oil in soils that are extremely humid, have high base water and a high proportion of organic matter. It is originated from the Mediterranean and is very resistant to stasis and temperature. However, the resistance to cold is not as high as the resistance to stasis. Cold weather can sometimes be seen in regions where winter is very hard. The southern-facing, dominant winds are less cold-covered in sloping areas. However, in sloping areas, the direction of planting is planned to be steep

Shawl *et al.* (2005) raised *Lavendula officinalis* L. from cuttings and studied its chemical composition in Kashmir valley. Lavender cuttings were obtained from 3 year old plants and planted in nursery beds with river sand and well rotten FYM. Beds were covered with coloured polythene sheets (100 microns) and sides were covered with soil for compactness. Also the cuttings were planted in holes made at 4 cm × 5 cm spacing. Furthermore, the rooting was established within a year and the plants were transplanted in February-March at a spacing of 75 cm × 75 cm with a density of 18, 000 plants. The essential oil obtained by steam distillation of flowering spikes of lavender was analyzed by GC and GC-MS. The chemical constituents obtained were linalool (25.57%), linalyl actetate (44.98%), terpineol (1.49%), borneol (2.7%), camphor (1.07%), lavandulyl acetate (3.44%) β- caryophyllene (1.85%), and caryophyllene oxide (2.08%) respectively. The study further reported that Kashmir lavender oil with linalool > 25% and linalyl acetate > 44% is of international standards.

Hoeberechts *et al*. (2004) cultivated lavender (*Lavandula officinalis*) in a profitable way in the Sacra Valley (northwestern Italy) to control weeds by mulching. Four mulch treatments were used *viz*., control (undisturbed soil), polythene mulch, transpiring mulch and draining type mulch respectively. The experiment in the field started on 31 May 2001, transplanting plants arranged in a grid spaced 0.6 m x 0.6 m in a loamy soil, provided with an overhead irrigation system of sprinklers. Periodical measurements of canopy height and diameter, and flowered branch counting were taken to study plant growth. In the control plot, lavender suffered weed invasion. Plants grown with polyethylene and transpiring mulch increased canopy height and width more than plants grown with the other treatments. Thus results indicated that the best mulches to cultivate lavender were polyethylene and transpiring types.

Dixit and Keskar (1994) conducted an experiment to study the effect of plant densities and planting time on growth, yield and flowering of lavender and white types of *Aster amellus* planted on 20 Mar., 20 June or 20 Sep. 1990 at spacing's of 40 × 30, 30 × 30, 30 ×20 or 20 × 20 cm. spacing at 30 × 20 or 30 × 30 cm and planting in March gave the highest yields and flower quality.

2.3 Essential oil content and chemical composition in lavender

Marin *et al*. (2016) conducted a study to determine the chemical composition of the essential oil of *Lavandula officinalis* L. widely cultivated in Spain from organic growth. Essential oil (EO) was extracted from lavender flowers by hydro-distillation. The essential oil was analyzed by (GC)/MS) technique. Furthermore, the study revealed an extraction yield of 3.45 ml/100 g dry weight of lavender. Also, a total of 36 compounds were identified in Spanish organic lavender EO. Major components were linalool (34.44%) followed by linalyl acetate (34.19%) accounting up to 69% of the total composition. Other relevant components were trans-β-o-cymene (5.05%), lavandulyl acetate (4.08%), β-cariophyllene (3.83%), trans-linalool-oxide (3.44%), and β-farnesene (3.08%).

Sasaki *et al*. (2015) conducted an experiment to test the essential oil-emitted flavor (volatile) of lavender by bacteria killing potency using *Escherichia coli*, methicillin-resistant *Staphylococcus aureus* (MRSA), *enterohemorrhagic E. coli* 0157: H7, *Pseudomonas aeruginosa* and *Candida albicans*. Lavender flowers collected in Aomori, Japan were hydro-distilled as a standard extraction method. Citronellal, component of *Rosa rugose*, was used as a reference to compare with that of lavender extract. The result showed that lavender and citronellal flavor (volatile) or oil respectively demonstrated bacteria killing effect in both analytical manners. However, *P. aeruginosa* resisted bacteria killing potency of lavender (citronellal) oil or oil-emitted flavor. It could be concluded that both lavender oil-emitted flavor and oil showed bacteria killing potency.

Nadalin *et al*. (2014) studied essential oil in *Lavandula officinalis* L. extracted from flowers and leaves by hydro-distillation. Lavender was collected in full flowering in July 2011 from cultivated plants at the Institute of Field and Vegetable Crops Novi Sad, Department of Organic Production and Biodiversity-BackiPetrovac (Serbia). Qualitative and quantitative analysis of the obtained essential oil and supercritical extracts (SFE) was carried out using gas chromatography in combination with mass spectrometry (GC/MS) and gas chromatography with flame ionisation detector (GC/FID).The main components of the analysed samples were linalool, linalool acetate, lavandulol, caryophyllene oxide, lavandulyl acetate, terpinen-4-ol and others.

Zheljazkov *et al.* (2013) evaluated the effect of the length of the distillation time (DT) on lavender essential oil yield and composition when extracted from dried flowers. Bulk certified dried flowers of *Lavandula angustifolia* Mill. were purchased from Starwest Botanicals (Rancho Cordova, CA). The distillation study experiment was conducted at the University of Wyoming Sheridan Research and Extension Center in 2012, using 250 g of dried lavender flowers. The essential oil was extracted via the steam distillation method in 2-L steam distillation units. The distillation times (DT) tested in this experiment were:1.5 min, 3 min, 3.75 min, 7.5 min, 15 min, 30 min, 60 min, 90 min, 120 min, 150 min, 180 min, and 240 min. The essential oil yield (range 0.5-6.8%) reached a maximum at 60 min DT. The concentrations of cineole (range 6.4-35%) and fenchol (range 1.7-2.9%) were highest at the 1.5 min DT and decreased with increasing length of the DT. The concentration of camphor (range 6.6-9.2%) reached a maximum at 7.5-15 min DT, while the concentration of linalool acetate (range 15-38%) reached a maximum at 30 min DT. Results suggest that lavender essential oil yield may not increase after 60 min DT.

Verma *et al.* (2010) studied the chemical composition of *Lavandula angustifolia* Mill. cultivated in the mid hills of Uttrakhand, India. The essential oil content in the inflorence of lavender was found to be 2.8% based on the fresh weight. The oil analysed by capillary GC and GC-MS. Thirty seven constituents, representing 97.81% of the oil were identified. The major components of the oil were linalyl acetate (47.56%), linalool (28.06%), lavandulyl acetate (4.34%) and α-terpineol (3.75%).

Baydar (2009) analysed that the Essential oil content of lavandin varies between 1.0-1.5 % in fresh stem flowers and between 5.0-6.0% in dry stemless flowers. Quality and marketable value of lavender essential oil is measured according to essential oil composition. Generally, high quality lavender essential oil contains high levels of linalool and linalyl acetate, but the scent of essential oil deteriorates as the camphor content increases (Adam, 2006).

Biasi and Deschamps (2009) reported that the Lavender has a wide adaptation in diverse climatic and soil conditions, being found in several countries in Europe, the Middle East, Asia and North Africa where it is used as source of raw material in the pharmaceutical, food, cosmetics, aromas and agro industry.

Adams and Yanke (2007) analyzed the composition of two new Kashmir lavender oils and compared with nine commercial lavender oils using GC/MS, GC-FID and chiral GC. Linalool ranged from 27.3-42.2% and linalyl acetate from 27.2-46.5%. Eight of the eleven oils met the European Pharmacopoeia 5.0 (EP5) standard. All of the oils contained 1.1-2.9% (+) - (S) – linalool, well below the EP 5 12.0% maximum. The oils, except for the Hungarian oil, contained from trace to 0.7% (+) – (S) – linalyl acetate, which is below the EP 5 maximum of <=1.0%. The oil from Hungary contained 12.9% of (+) – (S) – linalyl acetate, exceeding the EP 5 standard. The Kashmir lavender oils (‘Karlovo’ and ‘B-18’) were found to be comparable to other commercial oils. The Kashmir grown ‘Karlovo’ oil appeared to be a little better than the ‘B-18’ oil.

Ihsan (2007) extracted essential oils isolated by steam distillation from the fresh and dry flowers of *Lavandula officinalis* L. The flowers were collected at morning from plants that were grown in Medicinal and Aromatic plants field of Ajloun University College North of Jordan at the full flowering stage on 1st July 2004. 50 g of (fresh / dried) flowers were placed in a 1000 ml round bottom flask with 500 ml distilled deionized water and the oils were isolated over 3 h period using a modified Clevenger apparatus. The oil yields from fresh and dried flowers were 1.35% and 3.8% respectively. Also, among 26 compounds identified, the major components were 1, 8 – cineole (18.9%, 20.3%), linalool (34.2%, 33.0%) and borneol (12.1%, 11.0%), respectively.

Bousmaha *et al*. (2005) analyzed the composition and the relative proportion of the individual components constituting the essential oils are not constant, may vary according to the harvest times, the development stage of the plant and the different part of the plant.

Flores *et al.* (2005) analyzed that the medicinal and olfactory properties of lavender oil are mainly attributed to monoterpenes, a class of volatile organic compounds that constitute lavender essential oil and give lavender its characteristic aroma. Forty to fifty different monoterpenes can generally be identified in lavender essential oil, with linalool, linalool acetate, 1, 8-cineol, ß-ocimene (usually both *cis*- and *trans*-), terpinene-4-ol and camphor as the major constituents.

Pavlov *et al*. 2005 reported that the *L. angustifolia*, the English lavender, formerly classified as *Lavandula vera* or *Lavandula officinallis*, is considered an excellent rosmarinic acid producer and the best quality lavender species because of its great quality essential oil, which is the most valued in the whole *Lavandula* genus due to its high linalyl-acetate and linalool contents and freeness of camphor, present in other *Lavandula* species and hybrids.

Shawl and Qazi (2004) conducted a study to determine the chemical composition of the essential oil of *Lavendula angustifolia* in Kashmir. The oil was extracted from flower spikes of lavender by steam distillation technique. Two forms of oil, lavender flower oil (colourless, insoluble in water, having of density of 0.885 g/ml) and lavender spike oil (having a density of 0.905 g/ml) were obtained. The major chemical constituent obtained was linalool by GC and GC-MS technique.

Chatterjee (2002) analyzed that the pure oil can be used without base oil. It can be blended with bergamot, clarysage, jasmine, lemon and rose oil to prepare many formulations for different ailments. It has a remarkable effect on the emotional and mental balance of human being. In addition, it is used in soap making, high-quality perfumes, candles, incense sachets, as a detergent and cleaning agent, as an insect repellent, and also used in bath products such as soap, shampoo, bath oil, lotion, bath salt, repel mice. Its powerful antiseptic properties are able to kill many of the frequent bacteria such as typhoid, diphtheria, streptococcus and pneumococcus, as well as being a powerful antidote to some snake venoms. It is very useful in the treatment of burns, sunburn, scalds and bites.

Lis-Balchin (2002) analyzed that the lavender essential oil is higher quality than that produced by lavandin because lavender essential oil has lower camphor content than lavandin cultivars. Therefore, lavender essential oils are used in perfumes and aromatherapy, and lavandin essential oils are used in soap, detergents and cosmetics products. However, lavandin essential oil yield is higher than that from lavenders (Beetham and Entwistle, 1982).

Mallavarapu *et al*. (2000) analyzed the composition of essential oils of lavender (*Lavandula angustifolia*) produced in two different hill stations in Kashmir in western Himalayas and Kodaikanal southern hills, Tamil nadu by GC analysis. 44 constituents representing 97.7% of the oil from Kashmir and 37 constituents accounting for 98.2% of the oil from Kodaikanal were identified. The composition of the oils from these two locations are similar. The major constituents of the oil from Kashmir were linalool (28.2%), alpha-terpineol (2.0%), linalyl acetate (50.6%) and caryophyllene oxide (2.2%) whereas the oil from Kodaikanal contained linalool (28.7%), alpha-terpineol (4.9%) and linalyl acetate (43.1%). The composition of the oils from these two locations is comparable to French lavender oil.

Shawl and Kumar (2000) propagated *Lavendula officinalis* chaix from cuttings in Kashmir. Also, five Karlovo and three Kazanlik clones were obtained from Bulgaria. Rooted cuttings were planted in the field at a distance of 40 cm × 50 cm in rows 1 m apart. The study revealed that vegetative propagation by cuttings is the chief and successful method of raising lavender in temperate climate of Kashmir. Furthermore, two methods, active distillation and hydro-distillation were employed for extraction of essential oil. The oil recovered by hydro-distillation was of higher content as well as higher quality with lesser ester content. Gas chromatography (GC) analysis revealed two major peaks of linalyl actetate (33%) and linalool (28%) in addition to other peaks. The GLC data revealed that oil produced in Kashmir valley is very similar to that produced in Bulgaria.

Venskutonis *et al*. (1997) studied the chemical composition of lavender from Lithuania. The essential oil, hydrodistilled from flowering parts and stems of *L. angustifolia* (collected from plants growing in the experimental garden of the Lithuanian Institute of Horticulture, Babtai), were analysed by capillary GC and GC-MS. Sixty-six constituents were identified. The main essential oil constituents of flowering parts were linalool (20.68%; 5372.4 mg/kg) and linalyl acetate (26.54%; 5121.7 mg/kg). The essential oil content of stems was >30-times lower than that of flowering parts. The main essential oil constituents were linalool (26.45%; 217.4 mg/kg), 1, 8-cineole [eucalyptus] (9.31%; 56.8mg/kg) and linalyl acetate (7.07%; 44.1 mg/kg).

Tajuddin *et al*. (1995) conducted an experiment to study the effect of spacing on the growth and performance of 2 *Lavandula officinalis* [*L. angustifolia*] clones (B-18 and AM3) in Kashmir during 1989-90, and compared with that of the cultivar Karlovo. All clones grew best and had the highest essential oil yield at a spacing of 70 × 40 cm. the spike yield (q/ha), essential oil content (%) and essential oil yield of B-18 was better than that of Karlovo. The oil yield of B-18 increased from 14 kg/ha in 1989 to 189.2 kg/ha in 1991. The oil yield of Karlovo increased from 5 kg/ha in 1989 to 118 kg/ha in 1991. The quality of the essential oil of B-18 was similar with that of Karlovo.

Beetham and Entwistle (1982) analyzed that the Lavender essential oil has more than 100 components with linalool, linalyl acetate, 1, 8-cineol and camphor as the major constituents. Linalyl acetate in lavender essential oil and linalool in lavandin essential oil are higher.

Chapter-3

MATERIAL AND METHODS

An experiment entitled, **"Production potential of growing lavender on the southern slopes of Kashmir valley"** was carried out in Division of Forest Products and Utilization, Faculty of Forestry SKUAST-K during 2017-2019. The details of the material used and the methods employed have been presented in this chapter:

3.1 Experimental site

3.1.1 Location

The present investigation was carried out at Centre for Medicinal plants and Lavender park, Faculty of Forestry Sher-e-Kashmir University of Agricultural Sciences and Technology, Benhama-Watlar, Ganderbal, Kashmir, which are located within the Faculty of Forestry campus at an altitude of 1783.08 m above mean sea level, between $34^0 16'$ N latitude and $74^0 46'$ E longitude.

3.1.2 Climate

The experimental site falls in a mid to high altitude characterized by mild summers and severe winters. The average rainfall at the site is 820 mm per annum most of which is received during rainy and winter season. The site also experiences an average snowfall of about 2-3 feet during winter. The mean meterological data for the experimentation period (2017-19) obtained from the metrological observatory Ganderbal. The experimental site receives a maximum sunshine hours of 12.30 per day. The mean maximum and minimum temperature per annum is19.6°C and 6.8^0 C respectively and mean maximum relative humidity is 82.45% and mean minimum relative humidity is 54.49 % per annum.

3.2 Experiment No. 1:

Production of rooted cuttings of True lavender for commercial propagation. The terminal cuttings (8-10 cm) of lavender with intact vegetative tops were treated with different IBA (11) treatments.

3.2.1 Experimental details

The experiment was laid out in Completely Randomized Design with four replications, each consisting of 11 treatments. The details of the treatments are given below.

1. Control
2. IBA @ 200ppm
3. IBA @ 400ppm
4. IBA @ 600ppm
5. IBA @800ppm
6. IBA @1000ppm
7. IBA @1200ppm
8. IBA @1400ppm
9. IBA @1600ppm
10. IBA @1800ppm
11. IBA @2000ppm

No. of treatments	=	11
No. of replications	=	4
No. of cuttings per replication	=	12

Experimental design: Completely Randomized Design (CRD)

3.2.2 Layout

The experiment consists of 4 sets of root trainers of 11 root trainers each. The treatments were allocated replication wise to the individual root trainer using random number table. The arrangement of root trainers receiving various treatments has been shown in Plate.1 and 2.

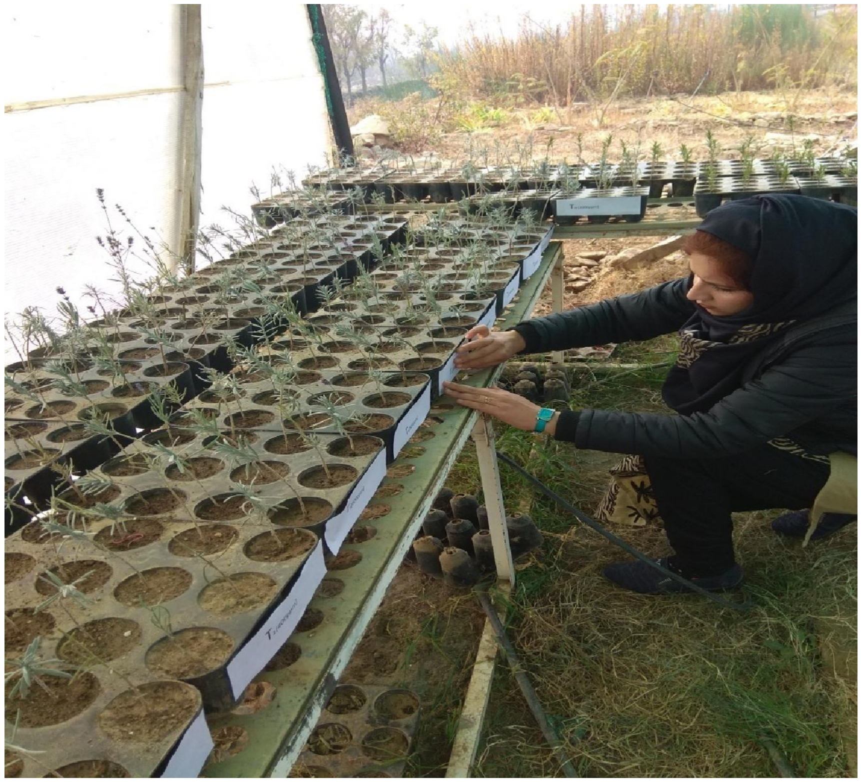


Plate 1: Production of rooted cuttings of lavender in Hiko-trays

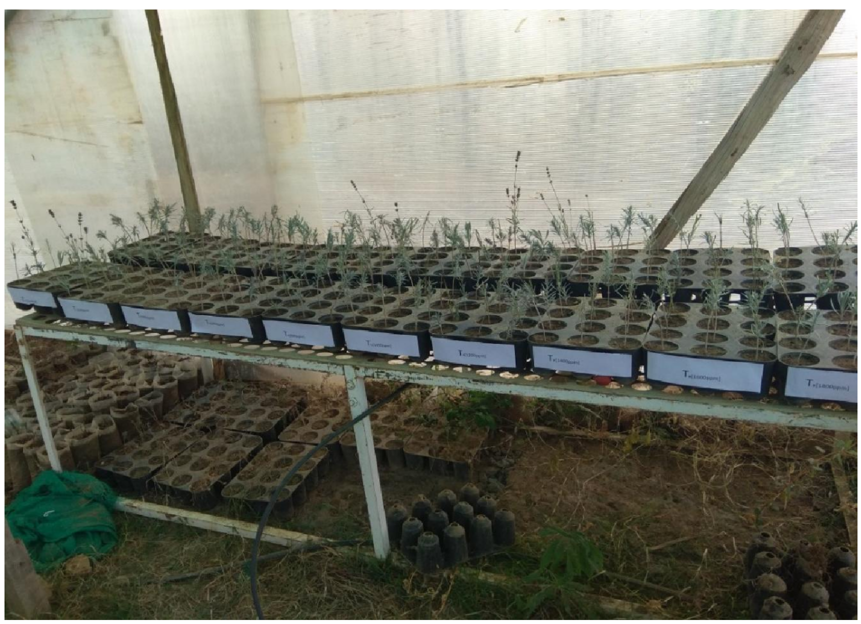


Plate 2: After 5 months the rooted cuttings are ready for plantation

3.2.3 Observations to be recorded:

After 5 months

a. Rooting Percentage (%).

The rooting percentage was calculated using the formula

$$\text{Rooting percentage} = \frac{\textit{Number of Cuttings rooted}}{\textit{Total Number of Cuttings planted}} \times 100$$

b. Number of Roots per Cutting.

The cuttings were uprooted and all the primary and secondary roots developed were counted and their mean was expressed as the number of roots per cutting.

c. Length of Roots (cm)

Length of roots was recorded in centimetres using measuring scale. It is measured from the junction of the root to the root tip of the longest root.

3.3 Experiment No. 2:

To study lavender flower production on southern slopes at different spacing.

3.3.1 Experimental details

The experiment was laid out in Randomized Block Design with 3 treatments (Spacing's) and 6 replications. The lavender plants were planted in 3 contours having 1m vertical distance at following spacing's (treatments).

1. 0.5 m × 0.5 m
2. 0.5 m × 1 m
3. 0.5 m × 1.5 m

A basal dose of 20 kg N, 40 kg P_2O_5 and 40 kg k_2O was applied per hectare basis along with 1 kg of FYM per pit before planting as standardized by

IIIM Srinagar. While 80 kg of N/ ha was also applied in four split doses during the year.

Experimental design	=	Randomized Block Design (RBD)
No. Of treatments	=	3
No. of replications	=	6

Plot size:

Length	=	60 m
Breadth	=	17.33 m
Total area of plot	=	1040 m^2 (approx)

3.3.2 Cultural operations

a. Field preparation:

The experimental field was prepared with the help of spade. The layout and lavelling of the individual contour was carried out by using 'A' frame.

b. Planting material:

True lavender or English lavender (*Lavandula angustifolia* was used for commercial oil production. *Lavandula angustifolia* is considered the best quality lavender species because of its great quality essential oil, which is the most valued in the whole *Lavandula* genus due to its high linalyl-acetate and linalool contents and freeness of camphor, present in other *Lavandula* species and hybrids. *Lavandula angustifolia* can grow upto 50 – 80 cm in height with plantation life upto 15 years.

c. Transplanting:

The clean healthy plants of lavender were transplanted in pits of size 30 cm × 30 cm × 30 cm (0.027 m^3) keeping a row-to-row distance of 0.5 m × 0.5 m, 0.5 m × 1.0 m and 0.5 m × 1.5 m and then covered with soil properly. The

Plate 3: Laying out contours in the field by using ‘A’ frame

experiment was replicated six times in three contours with a vertical distance of 1m.

d. Fertilizer application

The experimental plots received FYM = 1 kg /pit and DAP =100 g/pit which was applied at the time of transplanting. A basal dose of 20 kg N, 40 kg P_2O_5 and 40 kg k_2O was applied per hectare basis before planting as standardized by IIIM Srinagar. While 80 kg of N/ ha was also applied in four split doses during the year.

e. Post Planting Operations

In order to check the weeds three hand-weedings were done per year after planting of the crop of lavender.

f. Water management

The plants received irrigation twice a month after transplanting until flower bud formation and during flowering (1-2 times per week).

g. Harvesting

The flower spikes were harvested with the help of sickles when the flowers start to open. They were harvested in the mornings after the dew has evaporated and before the heat sets in. Then the oil was extracted from fresh spikes after weighing.

3.3.3 Dates of different operations

Operation	Date
Field preparation	17-11-2017
Layout	29-12-2017
Preparation of cuttings	23-2-2018
Plantation of lavender	15-1-2018

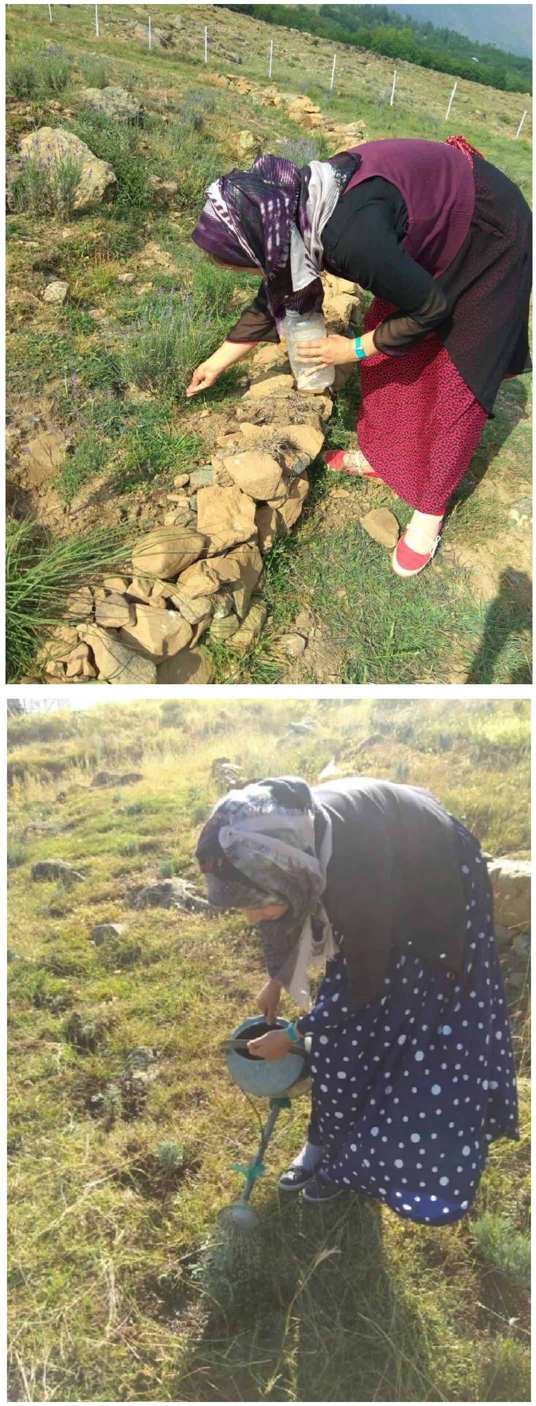


Plate 4: Application of fertilizer and irrigation at experimental site

Fertilizer application

- 1st dose 15-1-2018
- 2nd dose 16-4-2018
- 3rd dose 13-7-2018
- 4rth dose 11-10-2018

Weeding and hoeing

- 1st weeding 5-4-2018
- 2nd weeding 7-6-2018
- 3rd weeding 26-10-2018

Harvesting 3-7-2019

3.3.4 Details of observations recorded:

The various observations recorded in the experiment and the procedure followed are presented in this section.

a. No. of flower buds/plant.

Number of flower buds per plant were recorded by counting the number of flower buds on flower spikes of 60 randomly selected plants per treatment (10 plants per replication) and the mean number of flower buds per plant was worked out.

b. Herbage yield/ha.

After cutting, the above ground portion of plant was removed by clipping herbage from the ground leaving 1/3rd of plant for natural regeneration and the fresh weight of herbage was recorded in grams using electronic balance and reported as mean.

c. Dry weight of herbage/ha.

The herbage were subjected to drying in drying chamber for a week for complete drying after that the herbage were weighed in grams using the same electronic balance and reported as mean.

3.4 Extraction of oil content from flower spikes

The plants were harvested when they were in full bloom. All the spikes from the plants were harvested with the help of sickle and then the oil was extracted by hydro-distillation process in a Clevenger apparatus and the parameters which were recorded are.

3.4.1 Oil content from flower spikes at different spacing

The oil was extracted from the freshly cut spikes of lavender by hydro-distillation using Clevenger apparatus and recorded as oil content on weight basis.

3.4.2 Oil yield (L ha-^{1}).

This was calculated by converting the oil yield (ml) obtained from each treatment to litres and find out the oil yield from one hectare.

3.5 Statistical analysis

In both the experiments, the statistical analysis for each character was carried out on mean values. The data obtained/collected were subjected to statistical analysis of randomized block design and control randomized design. The analysis of data was performed through O. P. Stat statistical software.

Chapter-4

EXPERIMENTAL FINDINGS

An experiment entitled, "Production potential of growing lavender on the southern slopes of Kashmir valley" was carried out in Division of Forest Products and Utilization, Faculty of Forestry, SKUAST-K during 2017-2019. The results obtained from the study have been presented in this chapter. The effect of various IBA treatments on growth parameters of roots and the effect of different spacing between plants on yield and yield attributes of lavender have been described in detail with the help of data tables and depicted through suitable diagrams.

4.1 Lavender (*Lavandula angustifolia*) root growth studies

4.1.1 Production of rooted cuttings of true lavender for commercial propagation

Terminal cuttings of 8-10 cm of *Lavandula angustifolia* were collected from actively growing plants in herbal garden, Faculty of Forestry, SKUAST-K and after removing the bottom 3-5 sets of leaves from the stem, these were dipped 3-4 cm in 10 different IBA treatments with concentrations starting from 200ppm to 2000ppm. 12 cuttings were treated in each treatment and were replicated 4 times with total number of 48 cuttings in each treatment. After 5 months these terminal cuttings were evaluated through the measurements of 3 physical root parameters including rooting percentage, average root number and length of roots.

4.1.2 Rooting percentage of lavender (*Lavandula angustifolia)* under different IBA Treatments

After 5 months the cuttings were uprooted for evaluation of rooting percentage. Table 3 shows the results of different IBA treatments on rooting percentage. Response of rooting percentage of cuttings was different with different IBA treatments. This table reveals that rooting percentage was significantly influenced when *Lavandula angustifolia* cuttings were treated with different IBA concentrations. Analysis of data reveals that maximum percentage of rooting (91.66%) was recorded when *Lavandula angustifolia* cuttings were treated with IBA @ 2000ppm. Control with no IBA treatment recorded the lowest rooting percentage of 33.33.

Thus a significant effect of IBA concentrations was found on rooting percentage of *Lavandula angustifolia* cuttings.

Table 3: Effect of IBA concentrations on rooting percentage of *Lavandula angustifolia* cuttings

Treatment	Mean	S.E.
T_1(control)	33.33	0.01
T_2 (200ppm)	41.66	0.01
T_3 (400ppm)	47.92	2.09
T_4 (600ppm)	54.17	2.41
T_5 (800ppm)	66.66	0.01
T_6 (1000ppm)	70.83	2.41
T_7 (1200ppm)	75.00	3.40
T_8 (1400ppm)	79.17	2.41
T_9 (1600ppm)	83.33	0.01
T_{10} (1800ppm)	87.50	2.41
T_{11} (2000ppm)	91.66	0.01
C.D.($p<0.05$)	5.45	
SE(m)	1.89	
SE(d)	2.67	
C.V.	5.67	

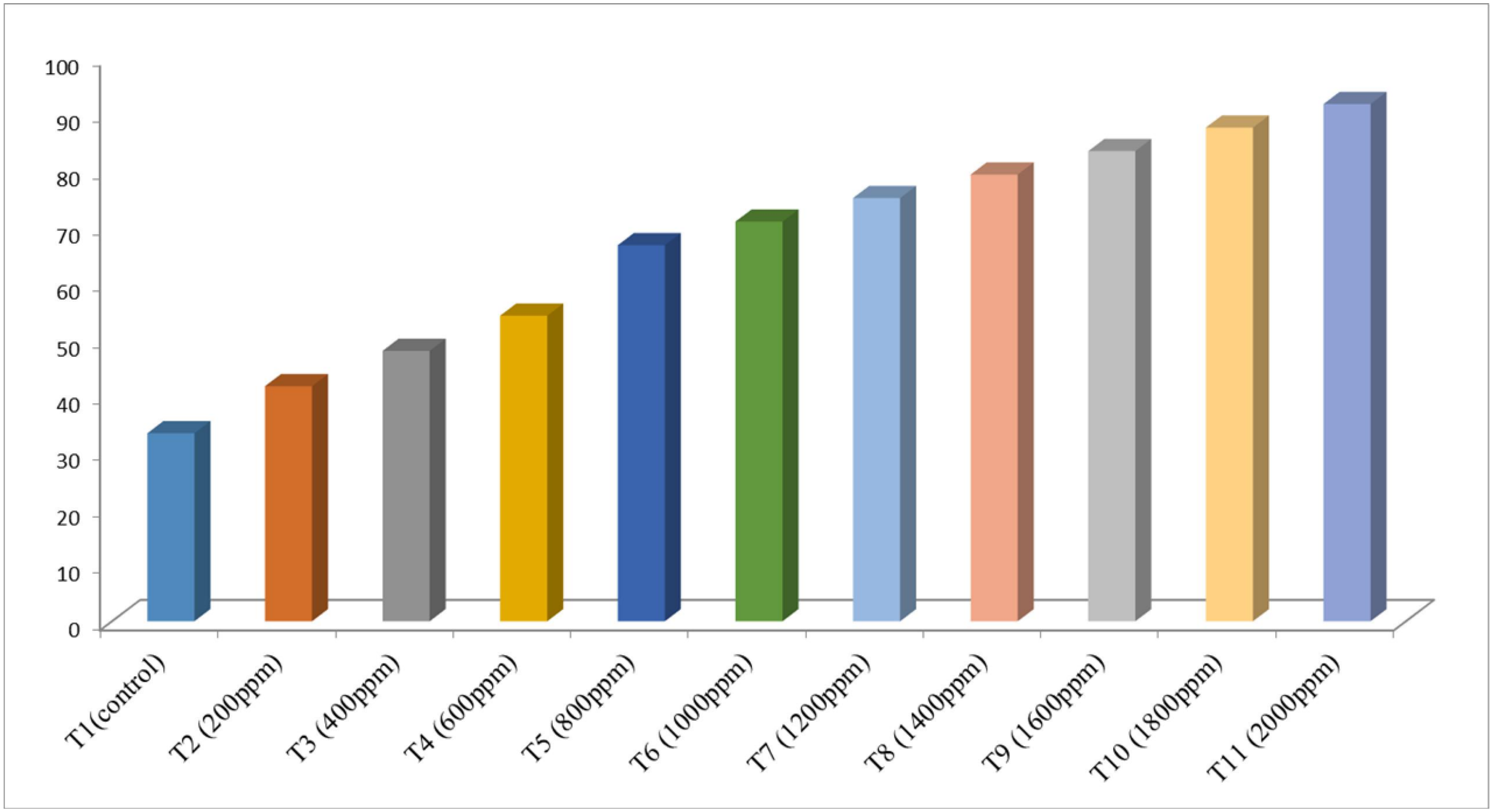


Fig. 1: Effect of IBA concentrations on rooting percentage of *Lavandulaangustifolia* cuttings

Preparation of different IBA concentrations

Plantation of rooted cuttings in Hiko-trays

Plate 5: Cuttings of *Lavandula angustifolia* under different IBA treatments

4.1.3 Number of roots per cutting of Lavender (*Lavandula angustifolia)* under different IBA treatments

After five months of planting the cuttings were uprooted and all the primary and secondary roots developed were counted. Roots up to 1 mm were counted. Data presented in Table 4 indicates that number of primary roots per Cutting was significantly influenced by different IBA concentrations. Perusal of data reveals that maximum number of primary roots per cutting (8.50) was recorded in cuttings treated with IBA@2000ppm and minimum was recorded in control (1.00).

Table 4: Effect of IBA concentrations on number of primary roots in *Lavandula angustifolia* cuttings

Treatment	Mean (No.)	S.E.
T_1(control)	1.00	0.01
T_2 (200ppm)	1.50	0.29
T_3 (400ppm)	2.25	0.25
T_4 (600ppm)	3.00	0.41
T_5 (800ppm)	3.75	0.25
T_6 (1000ppm)	4.25	0.25
T_7 (1200ppm)	5.00	0.01
T_8 (1400ppm)	5.75	0.25
T_9 (1600ppm)	6.50	0.29
T_{10} (1800ppm)	7.25	0.25
T_{11} (2000ppm)	8.50	0.29
C.D.($p<0.05$)	0.74	
SE(m)	0.26	
SE(d)	0.36	
C.V.	11.62	

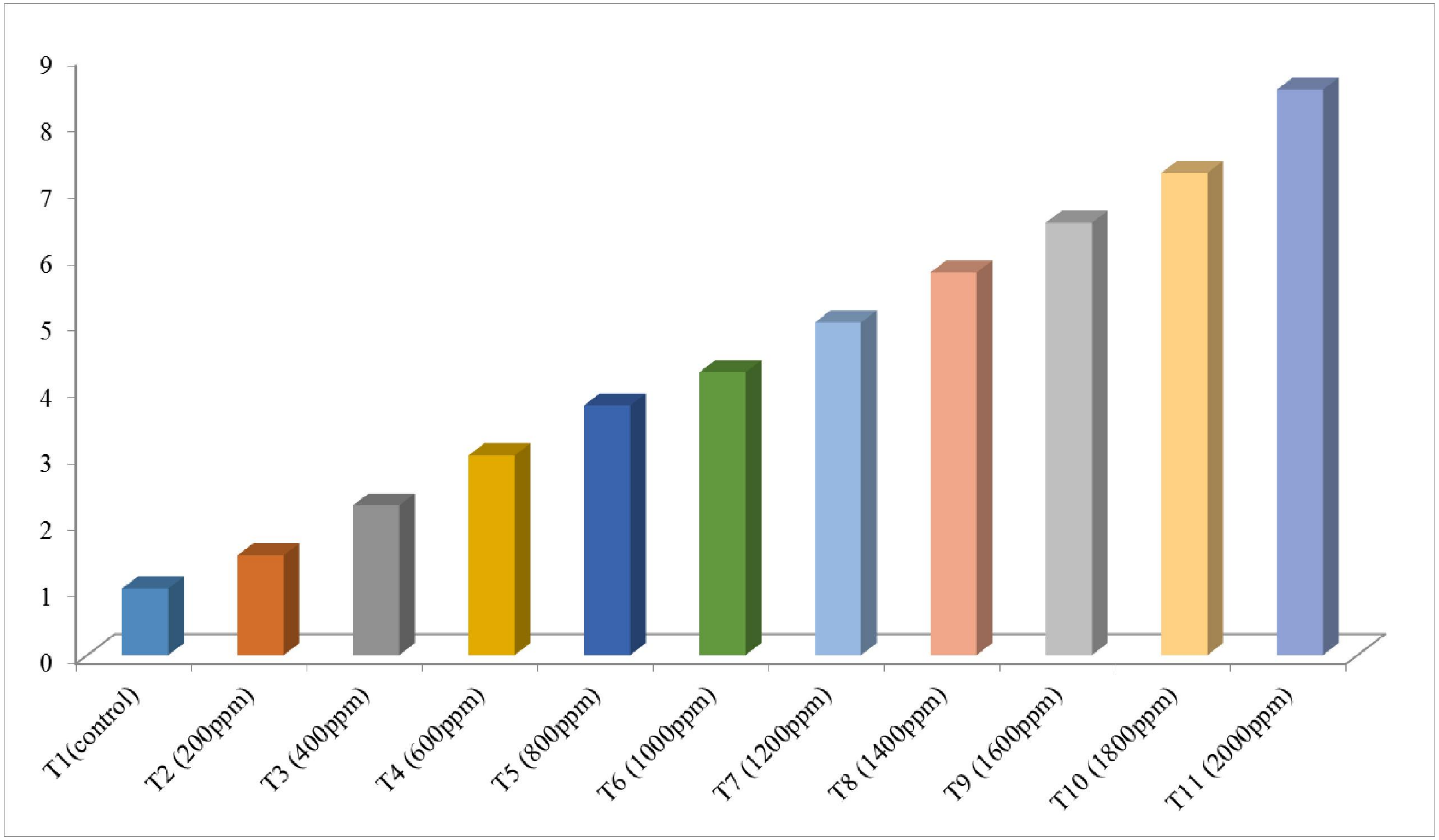


Fig. 2: Effect of IBA concentrations on number of primary roots in *Lavandula angustifolia* cuttings

Table 5 shows the effect of different IBA treatments on number of secondary roots per cutting. The data reveals that maximum number of secondary roots per cutting (76.25) was recorded also with IBA@2000ppm and minimum was recorded in control (19.75).

Thus a significant effect of IBA concentrations was found on number of primary roots and secondary roots per cutting.

Table 5: Effect of IBA concentrations on number of secondary roots in *Lavandula angustifolia* cuttings

Treatment	Mean	S.E.
T_1(control)	19.75	0.85
T_2 (200ppm)	24.25	0.62
T_3 (400ppm)	29.00	0.70
T_4 (600ppm)	32.50	0.86
T_5 (800ppm)	36.25	0.94
T_6 (1000ppm)	46.00	0.40
T_7 (1200ppm)	50.00	0.40
T_8 (1400ppm)	56.50	1.32
T_9 (1600ppm)	62.50	1.70
T_{10} (1800ppm)	69.25	1.03
T_{11} (2000ppm)	76.25	2.09
C.D.($p<0.05$)	3.22	
SE(m)	1.11	
SE(d)	1.58	
C.V.	4.89	

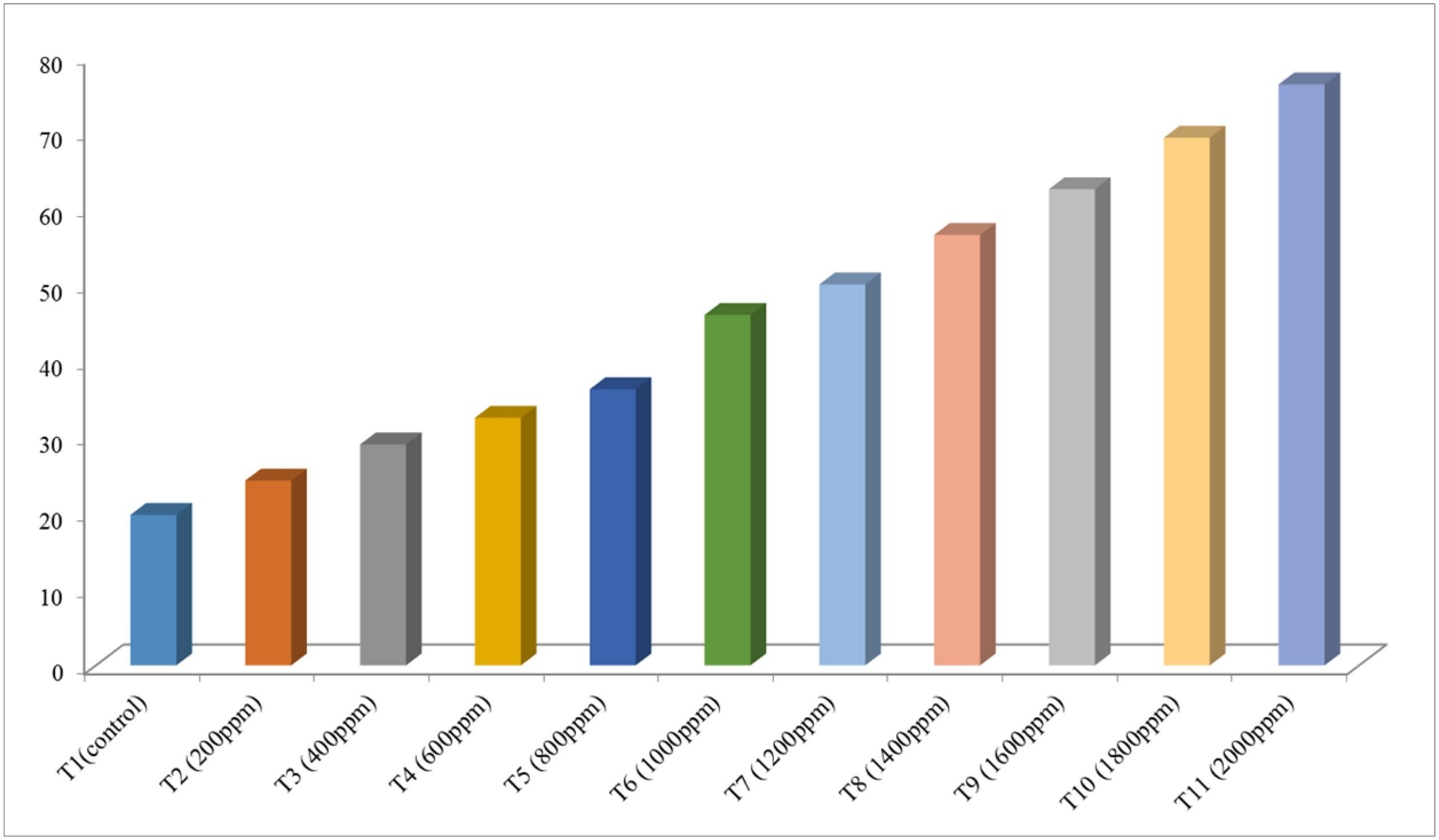


Fig.3: Effect of IBA concentrations on number of secondary roots in *Lavandula angustifolia* cuttings

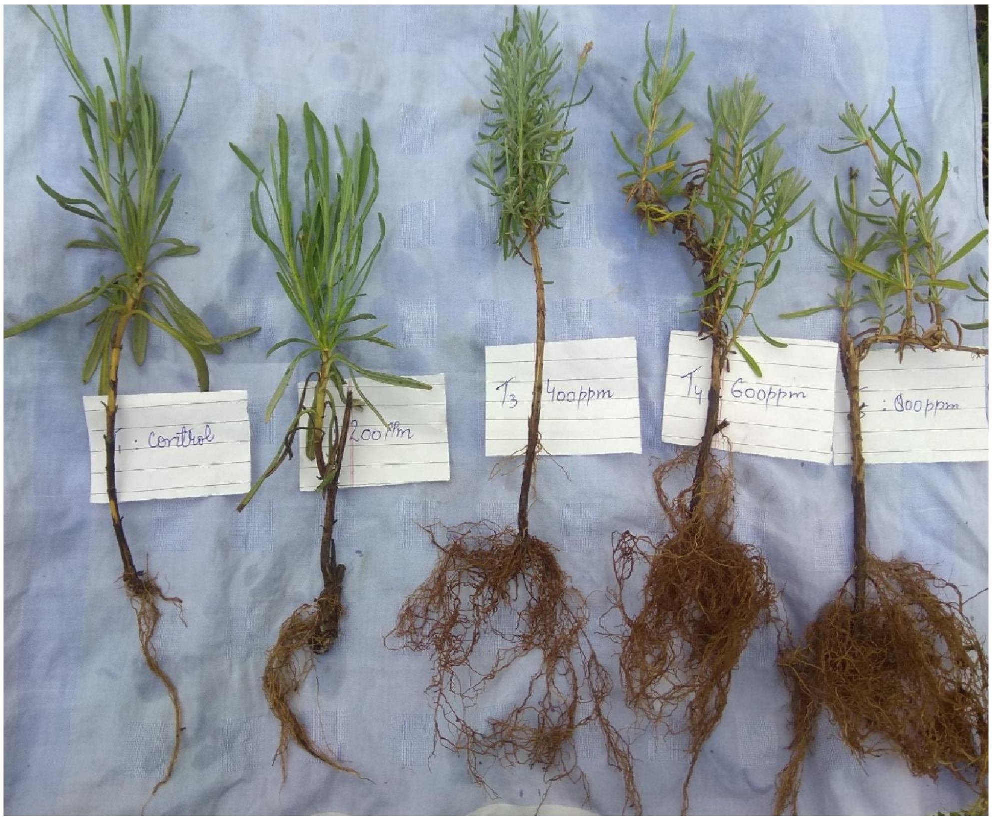


Plate 6: Fibrous root system developed in Hikotrays in all the treatments

4.1.3 Length of roots of lavender (*Lavandula angustifolia)* under different IBA treatments

A perusal of data presented in Table 6 reveals that different IBA treatments had a significant influence on length of roots of *Lavandula angustifolia* cuttings. Observations from Table 6 reveals that maximum length of roots (24.00 cm) was recorded when *Lavandula angustifolia* cuttings were treated with IBA@2000ppm followed by IBA treatment @ 1800ppm. Control with no IBA treatment recorded the minimum length of roots (6.00 cm).

Thus a significant effect of different IBA concentrations was also recorded on length of roots.

Table 6: Effect of IBA concentrations on root length (cm) of *Lavandula angustifolia* cuttings

Treatment	Mean	S.E.
T_1(control)	6.00	0.35
T_2 (200ppm)	8.00	0.35
T_3 (400ppm)	9.00	0.20
T_4 (600ppm)	10.00	0.20
T_5 (800ppm)	14.00	0.35
T_6 (1000ppm)	16.00	0.20
T_7 (1200ppm)	18.50	0.35
T_8 (1400ppm)	21.13	0.32
T_9 (1600ppm)	22.00	0.41
T_{10} (1800ppm)	23.00	0.35
T_{11} (2000ppm)	24.00	0.35
C.D. ($p<0.05$)	0.93	
SE(m)	0.32	
SE(d)	0.46	
C.V.	4.13	

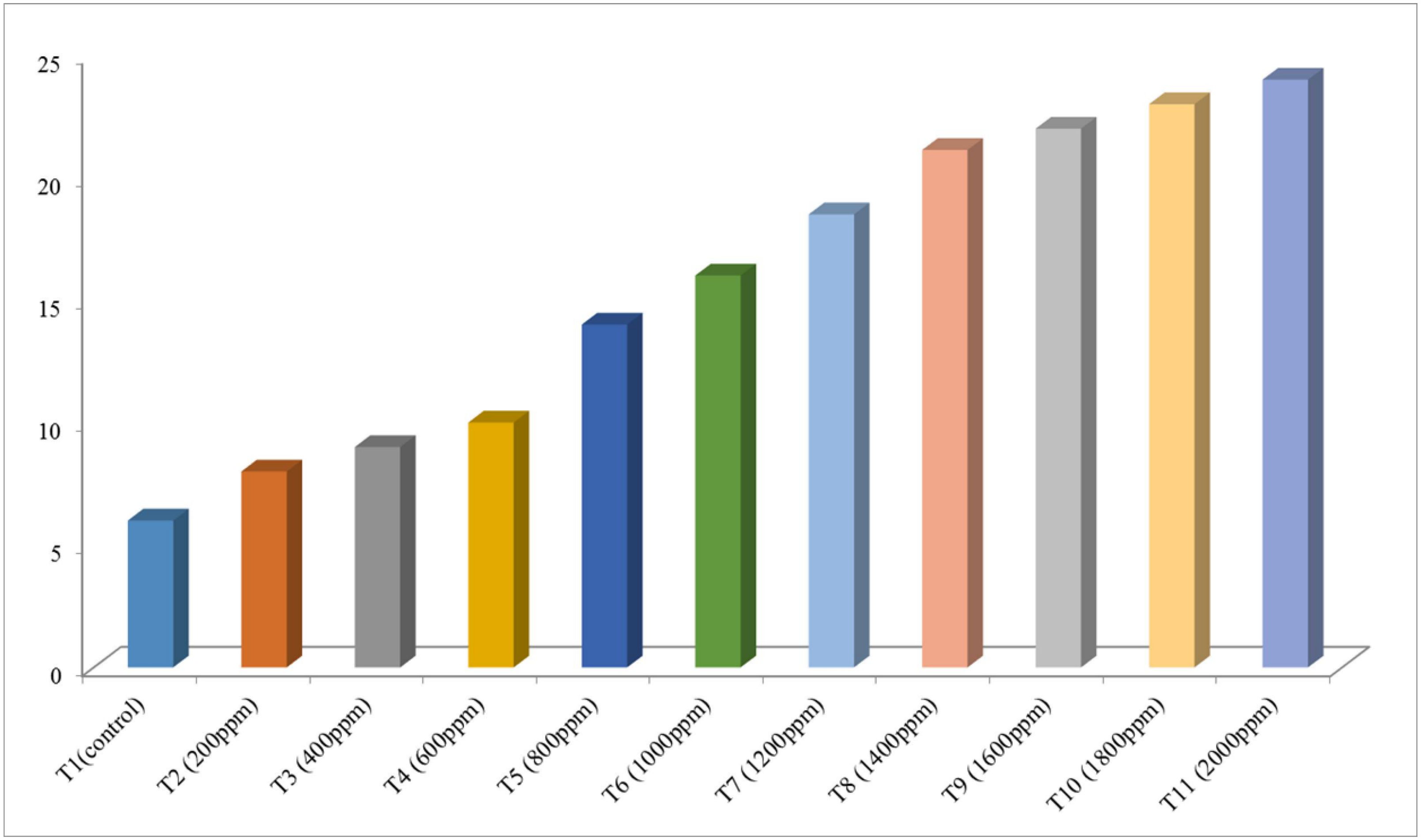


Fig. 4: Effect of IBA concentrations on root length (cm) of *Lavandula angustifolia* cuttings

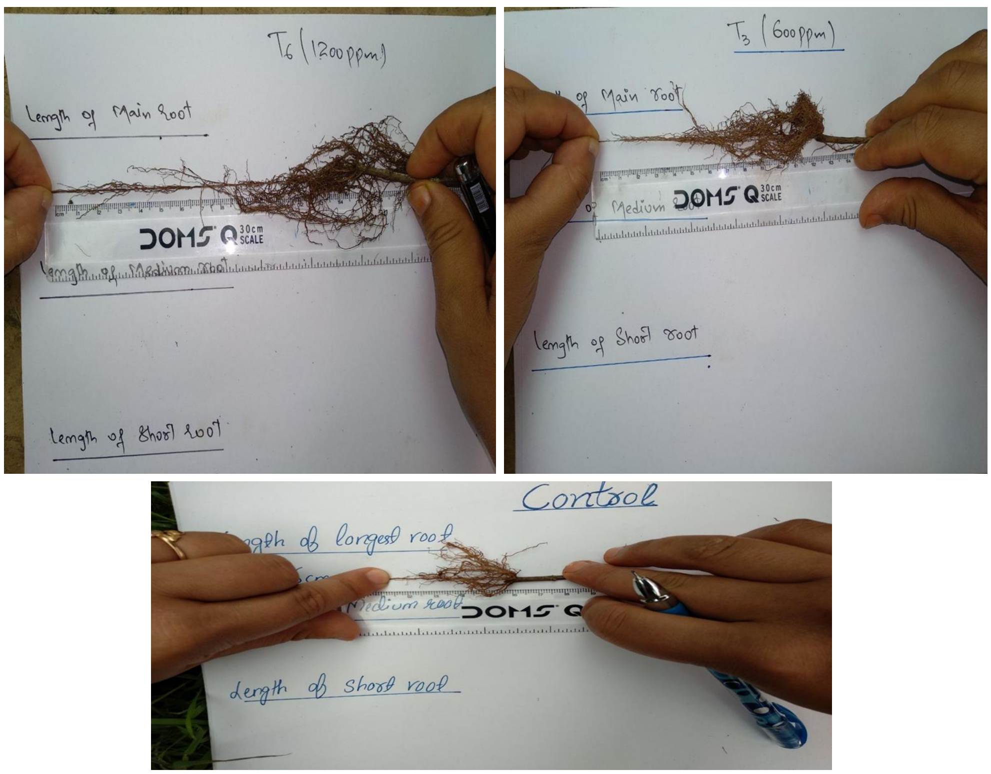


Plate 7: Measuring the length of longest root with the help of measuring scale

4.2 Study Lavender *(Lavandula angustifolia)* flower production on southern slopes

The lavender plants were planted in 3 contours with a vertical distance of 1m at three different spacing between plants (1) 0.5m×0.5m 2) 0.5m×1.0m 3) 0.5m×1.5m). After one growing season the below parameters were recorded.

4.2.1 Number of flowers buds per plant

An examination of data presented in Table 7 reveals that a significant effect of spacing on number of flower buds per plant. The data from Table 7 reveals that maximum number of flower buds per plant (265.33) was observed when lavender plants were planted at a spacing of 0.5m×1.5m where as the minimum number of flower buds per plant (210.00) were observed at a spacing of 0.5m×0.5m.

Thus a significant effect of different spacing was recorded on number of flower buds per plant.

Table 7: Effect of different spacing on No. of flower buds per plant

Treatment	Mean	S.E.
T_1(0.5m × 0.5m)	240.00	3.72
T_2(0.5m × 1.0m)	251.83	3.31
T_3(0.5m × 1.5m)	265.33	4.20
C.D.(p<0.05)	11.45	
SE(m)	3.76	
SE(d)	5.32	
C.V.	3.65	

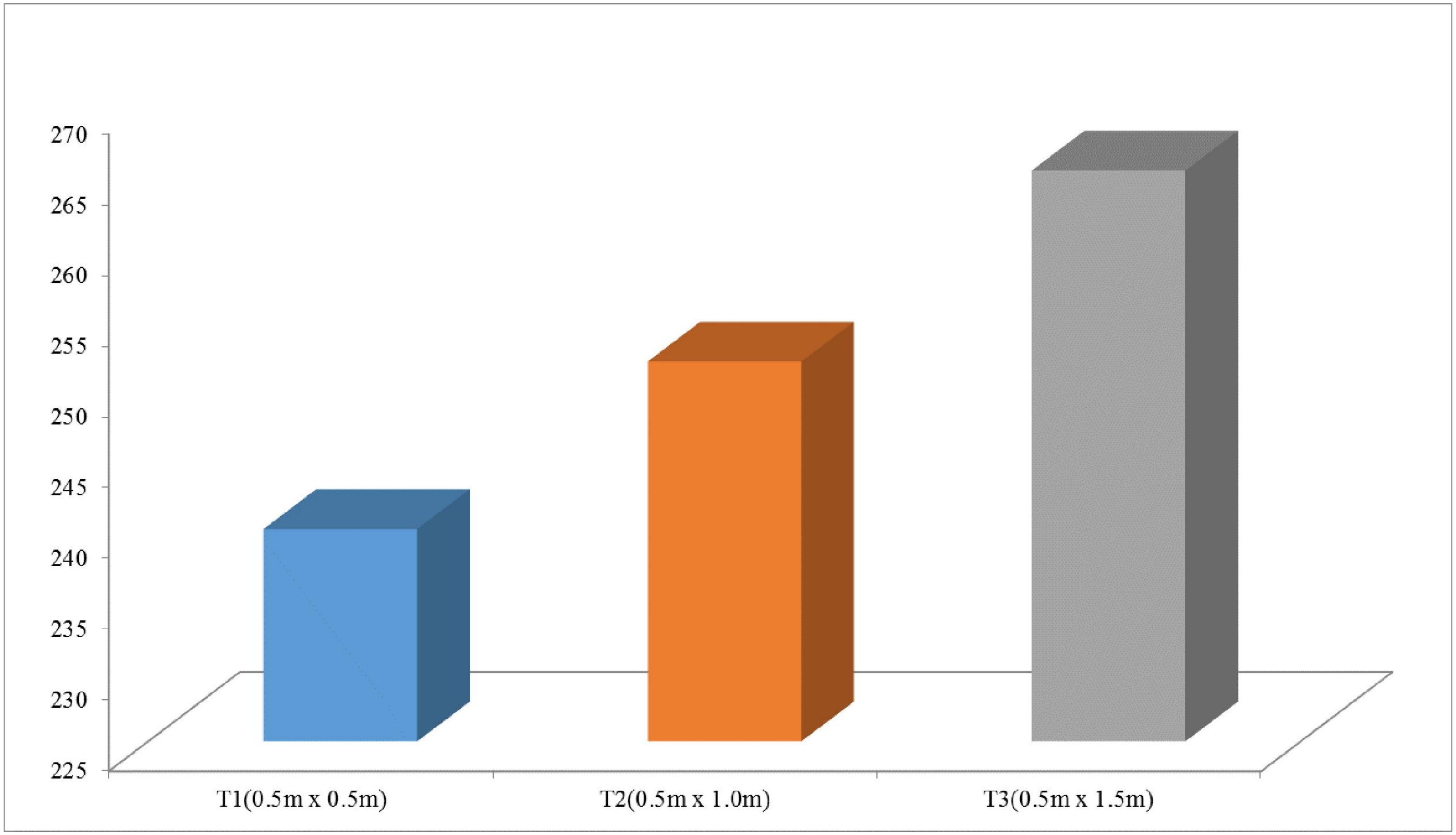


Fig. 5: Effect of different spacing on No. of flower buds per plant

Plate 8: ***Lavandula angustifolia*** **in full bloom at the experimental site**

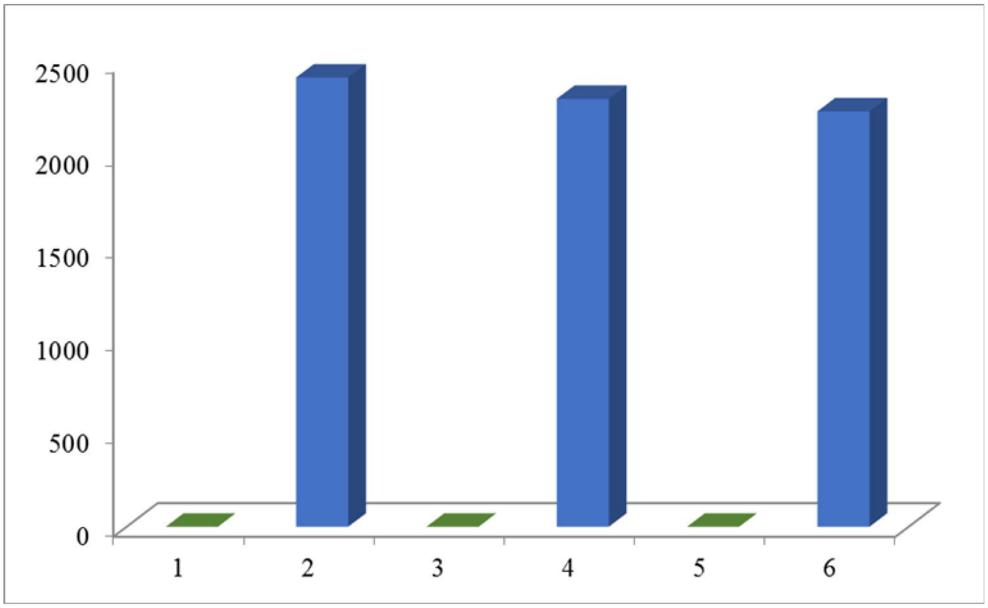
4.2.2 Fresh Herbage yield/ha and dry weight of herbage/ha.

The lavender plants were planted in the field under different spacing. A statistically significant effect of spacing on above ground biomass was recorded. The interpretation of data from Table 8 indicates that spacing had a significant effect on the fresh weight, dry weight and moisture percentage of herbage. It was found that maximum fresh weight of 2420.95±11kg/ha and dry weight of 1818.91±11kg/ha were observed when lavender plants were planted at a spacing of 0.5m x 0.5m whereas the minimum values for fresh weight (2238.80±16kg/ha) and dry weight (1630.50±14kg/ha) were observed at 0.5m x 1.5m spacing.

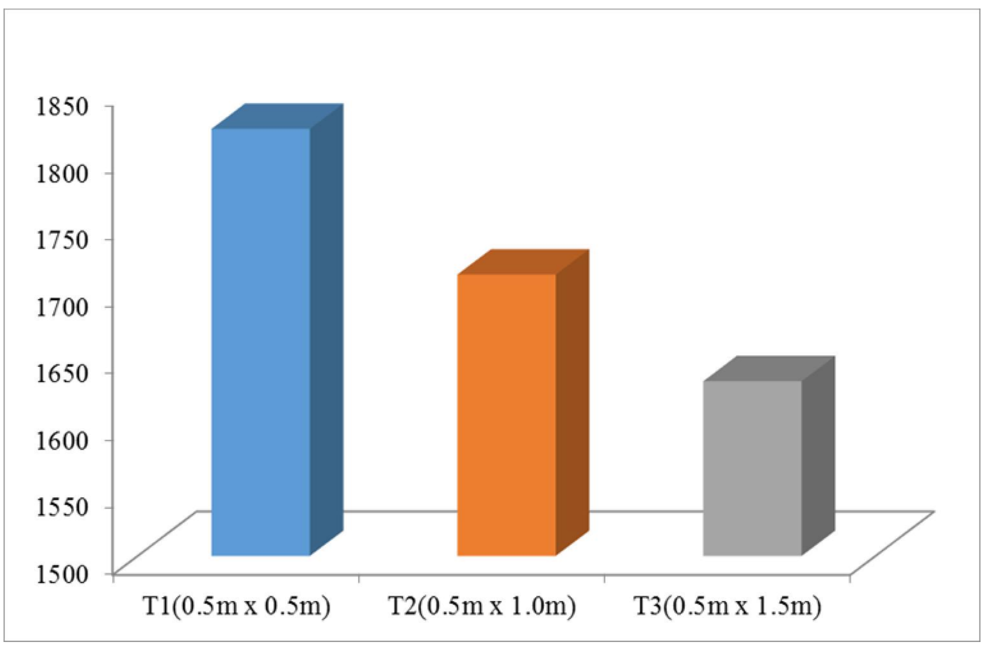
Analysis of data showed a significant effect of spacing on herbage fresh weight, dry weight and moisture percentage.

Table 8: Effect of different spacing on fresh and dry weight of herbage yield (Kg/ha)

Treatment	Fresh weight Herbage yield (Kg/ha) Mean	Dry weight Herbage yield (Kg/ha) Mean	Moisture %age
T_1(0.5m × 0.5m)	2420.95±11.08	1818.91±11.54	24.86±0.13
T_2(0.5m × 1.0m)	2305.96±4.07	1710.11±4.97	25.66±0.20
T_3(0.5m × 1.5m)	2238.80±16.04	1630.50±14.93	27.17±0.16
C.D. (p<0.05)	34.97	34.27	0.52
SE(m)	11.49	11.26	0.17
SE(d)	16.26	15.93	0.24
C.V.	1.21	1.60	1.62



Fresh weight Herbage yield (Kg/ha)



Dry weight Herbage yield (Kg/ha

Fig. 6: **Effect of different spacing on fresh and dry weight of herbage yield (Kg/ha)**

Fresh weight of herbage (grams)

Dry weight of herbage (grams)

Plate 9: Weighing of herbage yield in the laboratory of Faculty of Forestry, SKUAST-K

4.3 Extraction of oil content from flower spikes

The plants were harvested when they were in full bloom. The whole plant leaving the basal one-third of the plant for natural regeneration was harvested and the fresh herbage was used for extraction of oil by steam distillation process in a Clevenger apparatus.

4.3.1 Oil content (ml) from flower spikes at different spacing

Flower spikes were collected from plants when they were in full bloom. At this stage the plant has the maximum number of flower buds which have attained maximum dimensions. The collected flower spikes were subjected to hydro-distillation process in a Clevenger apparatus for estimation of essential oil.

Table 9 shows that a significant effect of spacing was found on oil content of flowers at different spacing with maximum oil yield of 11.75 ml obtained from 80.79 grams of flower spikes was observed at a spacing of 0.5m x 0.5m and minimum oil yield of 7.70 ml obtained from 74.63 grams of flower spikes was observed at 0.5m x 1.5m spacing, suggesting a significant effect of different spacing on oil content.

Table 9: Oil content from flowers at different spacing (ml)

Treatment	Mean	S.E.
T_1(0.5m × 0.5m)	11.75	0.07
T_2(0.5m × 1.0m)	9.75	0.07
T_3(0.5m × 1.5m)	7.70	0.03
C.D.(p<0.05)	0.54	
SE(m)	0.17	
SE(d)	0.25	
C.V.	4.49	

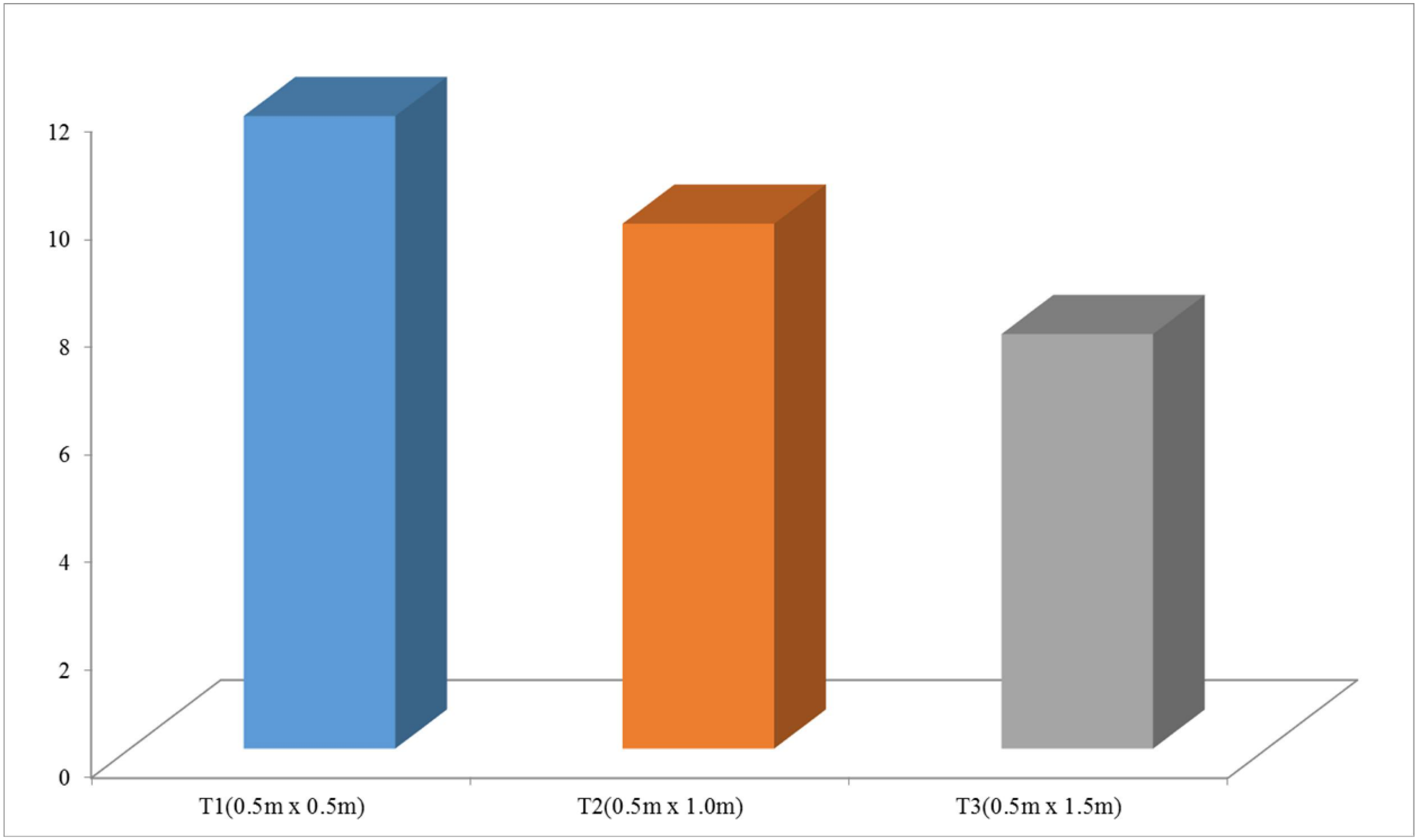


Fig. 7: Oil content from flower spikes of *Lavendula angustifolia* at different spacing (ml)

Plate 10: Flower spikes of *Lavandula angustifolia* for extraction of oil

4.3.2 Yield of lavender oil at different spacing (L/ha)

Critical analysis of data from Table 10 reveals a significant effect of spacing was found on yield of oil per hactare. Maximum oil yield of 117.5 L/ha was observed when lavender plants were planted at a spacing of 0.5m x 0.5m whereas the minimum values for oil yield of 77.00 L/ha was observed when plants were planted at 0.5m x 1.5m spacing.

Thus spacing had a significant effect on oil yield from flower spikes of lavender plants.

Table 10: Yield of Lavender oil at different spacing L/ha

Treatment	Mean	S.E
T_1(0.5m × 0.5m)	117.50	0.76
T_2(0.5m × 1.0m)	97.50	0.76
T_3(0.5m × 1.5m)	77.00	2.89
C.D. (p<0.05)	5.43	
SE(m)	1.78	
SE(d)	2.52	
C.V.	4.49	

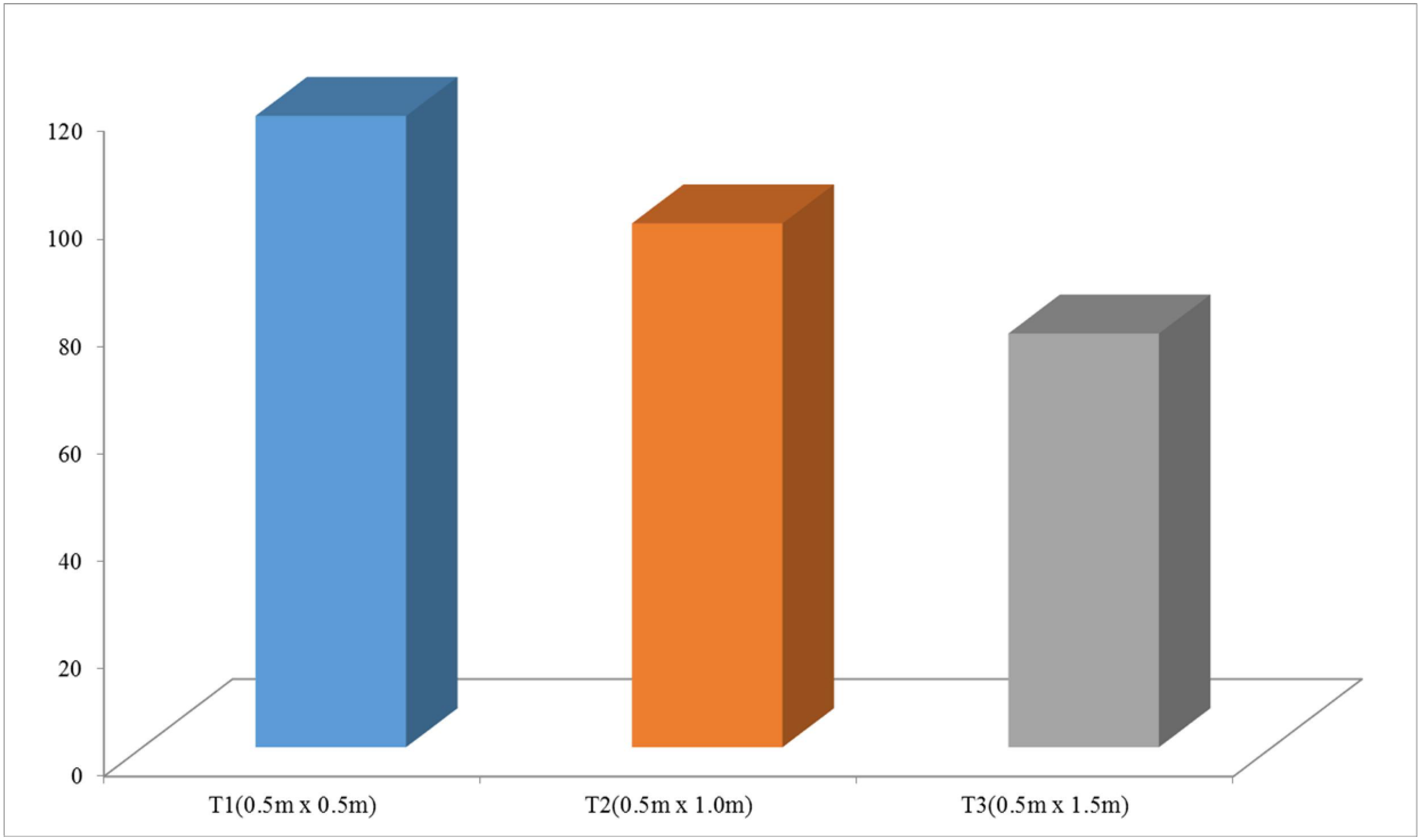


Fig. 8: Yield of Lavender oil at different spacing L/ha

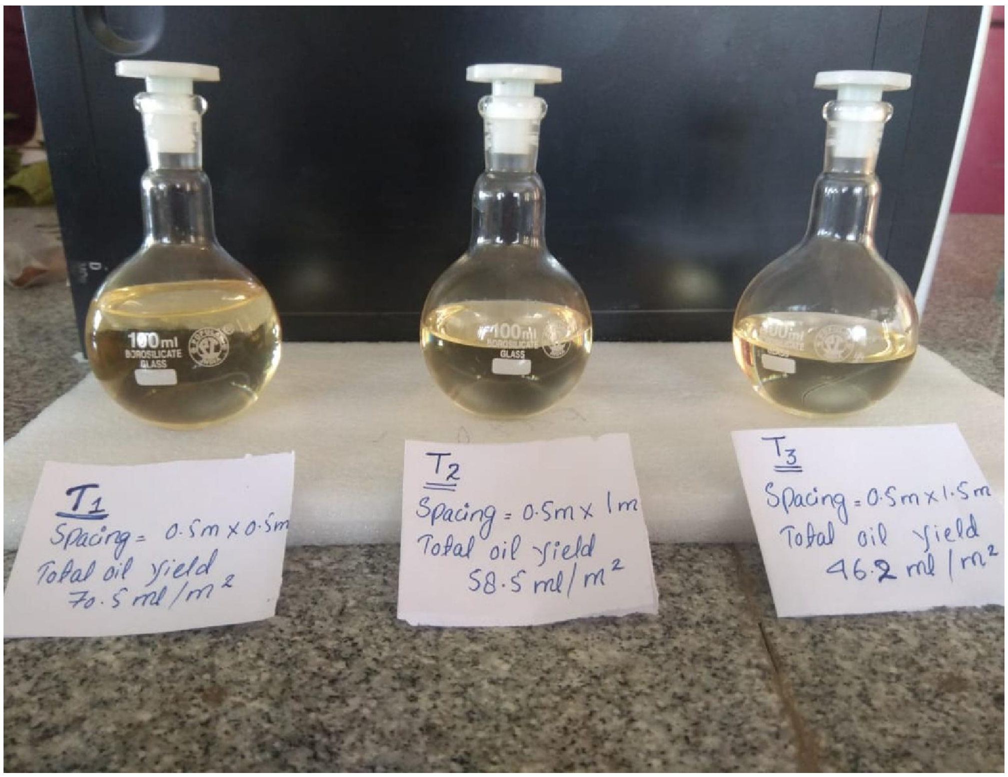


Plate 11: **Extraction of oil content from flower spikes of *Lavandula angustifolia* using Clevenger apparatus**

Chapter-5

DISCUSSION

The experimental results presented in the preceding chapter gives an account of the effect of different IBA concentrations on root growth parameters and effect of different spacing on number of flower buds, herbage yield and oil content of lavender by growing on southern slopes of Kashmir valley. An attempt, however, has been made in this chapter to interpret the important findings of the present study to establish the 'cause' and 'effect' relationship in light of available evidences as far as possible.

5.1 Production of rooted cuttings of *Lavendula angustifolia* for commercial propagation

5.1.1 Effect of different IBA treatments on the growth parameters of *Lavendula angustifolia.*

The objective of this experiment was to test different concentrations of indol-3-butyric acid (IBA) on rooting of lavender cuttings. Cuttings of lavender were collected in the last week of February 2018 and were treated with different doses (200 – 2000ppm) of IBA. The hormone (IBA) used in this study has been found to be reliable in stimulating the production, elongation and uniformity of adventitious roots from *Lavendula angustifolia* cuttings. Adventitious roots induced on the treated terminal cuttings were evaluated through the measurements of three physical root parameters including rooting percentage (RP), root number (RN), and length of the longest root (RL). Rooting percentage, number of roots per cutting and length of roots were significantly influenced when *Lavendula angustifolia* cuttings were treated with different IBA concentrations. The data (Table 3-6) reveal that maximum percentage of rooting (91.66%), number of primary roots per cutting (8.50), number of secondary roots per cutting (76.25) and length of roots (24 cm) were recorded when *Lavendula angustifolia* cuttings were treated with IBA @ 2000ppm whereas the Control with no IBA treatment recorded the lowest rooting percentage (33.33%), number of primary roots per cutting (1.00), number of secondary roots (19.75) and length of roots (6.00 cm). A similar trend of increase in rooting percentage, root number and length of roots in Indian lavender by growth regulators (IBA and NAA) have also been reported by earlier workers (Somappa, 1979 and Chandramouli, 2001). Similar were the results of increase in rooting percentage (66.66%), number of primary and secondary roots (12.30 and 17.57 respectively) and length of longest primary and secondary roots (25.30 cm and 34.93 cm respectively) were found when IBA was used in concentration of 2000ppm by Swetha (2005). Likewise Ayanoglu *et al.* (2000) reported increasing rooting percentage, number of roots and root length with increase in IBA concentration in lavender cuttings with highest percentage rooting (70%) recorded from cuttings treated with IBA 4000ppm. These results are also supported by the findings of Bona *et al.* (2012), reported an overall increase in rooting percentage, root number and length of roots in eight (G1-G8) *L. angustifolia* genotypes with increase in IBA concentration. Zlatev *et al.* (1990) also observed a similar trend of increase in rooting percentage, number of roots and length of roots in lavender with increase in IBA concentration.

Adventitious root formation is a key step in plant propagation. From a scientific point of view, rooting is a highly interesting developmental pathway. Phytohormones are known to trigger different responses in plants as well to affect other metabolic pathways. Auxins, for instance, can stimulate cell divisions and cell elongation and also controls lateral and adventitious root formation (Mishra *et al.*, 2009), since a link between auxin and the activation of cell divisions in the pericycle is required for lateral root initiation (Francis and Sorrel, 2001). Rooting among the vegetative methods of propagation is undoubtedly the most evolved and expanded method (Awan *et al.*, 2012). Efficient rooting treatment yields a high percentage of rooted shoots and a high-quality root system. IBA is highly effective in stimulating rooting due to its lower mobility and higher chemical stability in the plant tissue (Hartmann *et al.*, 2002), it may speed the root initiation process up, as well as to increase percentage of rooted cuttings and the number of formed roots per cutting. Exogenous application of IBA may induce changes in enzymatic activities (Perioxidase and indole acetic acid (IAA) oxidase) and in their effectors contents (phenolic) allowing the establishment of the favourable endogenous hormone balance. It is well known that applied auxin induce modifications in their own metabolism, mostly by conjugation and in other hormones such as cytokinins (Kasem and Abd-El-Baset, 2014).

The present investigation, IBA at 2000ppm showed better results followed by IBA at 1800ppm and IBA at 1600ppm in the cuttings (Table 3-6). This effect may be due to its slow translocation property or slow destruction by auxin destroying enzyme system (Debnath and Maiti, 1990). The cuttings which received IBA, 2000ppm excelled all other treatments in all the root characters and it was followed by IBA, 1800ppm and IBA, 1600ppm. Regarding number of primary and secondary roots, the cuttings treated with IBA, 2000ppm performed over other treatments in control. This may be due to enhanced hydrolysis of carbohydrates caused by auxin treatment (Rajarama, 1997). Further Krishnamurthy (1981) opined that auxins would bring about various physiological changes, but the mechanism by which these changes are brought about is not fully understood except for the effect of cell elongation. The better response to optimum concentration of IBA may be attributed to increased rate of respiration, accumulation of higher levels of amino acids at their bases, 48 hours after the treatment than untreated cuttings. This pattern is continued with nitrogenous substances accumulating in the basal part of treated cuttings, apparently mobilized in the upper part and translocated as aspargine (Strydom and Hartmann, 1960). As regards to the length of longest roots per cutting, cuttings treated with IBA @ 2000ppm performed better over other treatments. However the length of longest root (24.00cm) was seen in IBA @ 2000ppm. Similar views was held by Somappa (1979) obtained increased root length on IBA treated cuttings in Indian lavender. All IBA treatments were found to increase the length of roots. Similar results were also reported by several earlier workers (Vijaykumar, 1973, Jayashankar *et al*., 1990 and Singh, 2001). It may be attributed to the action of auxin activity which might have caused hydrolysis and translocation of carbohydrates and nitrogenous substances at the base of cuttings and resulted in accelerated cell elongation and cell division in suitable environment (Singh *et al*., 2003). Another possible reason may be due to the early formation of roots and more utilization of reserved food materials of the treated cuttings under mist conditions (Ghatnatti, 1997).

The use of different concentrations of IBA in *Bougainvillea glabra* cuttings had a significant effect on root number, root length, root diameter, root weight compared to control (Niaz and Muhammad, 2002). The number of the induced roots per cutting of rosemary was significantly increased by time of cutting Soaking and concentration of the IBA (Elhaak *et al*., 2015). The increase in root number and length by IBA improves the success and survival of the cuttings after transplanting in the soil. Kumari *et al*. (2010) reported that auxins can control cell enlargement, bud formation and root initiation and also promote the production of other hormones. Rooting ability in *Pongamia pinnata* was linked to auxin application influenced the rooting behaviour in mature stem cuttings of 10 different accessions growing in their natural habitat, may be due to differences in physiological state of the individual during collection and endogenous hormone levels, besides genotype (Kesari *et al*, 2010). Similar results obtained by Blythe *et al*. (2003) on cuttings of *Hedera helix*, although auxin was not essential for rooting, root percentage and length were greater when treated with IBA. Bona *et al*. (2010) observed that percentage of roots of *Lavandula dentata* increased with IBA application and a quadratic regression was obtained for root number, being 2000 mg L^{-1} considered the best IBA concentration.

In general, IBA @ 2000ppm have been found to induce better root system in *Lavandula angustifolia* cuttings. The basis for this may be enhancement of hydrolysis of nutrient reserves (mainly starch) by auxin treatment. According to Nanda *et al. (*1968) enhanced hydrolysis activity in the presence of exogenously applied hormones was responsible for the increased rooting in auxin treated cuttings. The lowest value of rooting percentage, number of roots per cutting and root length was recorded in control treatment (no IBA application) suggesting that endogenous auxin concentration is not sufficient for inducing rooting in *Lavandula angustifolia*. Similar findings have been reported by Bharathy *et al*. (2004) in case of carnation and by Kazankaya *et al*. (2005) in case of other cultivars of rose.

5.2 Effect of different spacing on the yield parameters of *Lavendula angustifolia*

An examination of data (Table 7) indicated a significant effect of spacing on number of flower buds per plant. Number of flower buds per plant increases with increase in spacing between plants and maximum number of flower buds per plant (265.33) was obtained when lavender plants were planted at a spacing of 0.5m × 1.5m whereas minimum number of flower buds per plant (240.00) was observed when lavender plants were planted at a spacing of 0.5m × 0.5m. Narrow spacing yielded lowest number of flower buds/plant. The reason may be due to that wider spacing promotes branching, because of the exposure of plant to promote branching, furthermore, may be due to that the wider spacing affect hormonal sinking therefore bending of plants may lead to concentrate hormones at nodes and induce branching. The results of the present study for this character is in agreement with the findings of Ravanappa *et al*. (1998) who reported that the lowest plant density treatment obtained from the widest spacing (75 × 60 cm) produced the highest number of branches per plant. This might be due to the fact that the plants in wider spacing could receive more light, nutrients and other resources than the plants of close spacing.

Generally as the spacing gets narrower, the number of branches per plant decreased significantly. The result observed in the current investigation were supported by earlier findings where greater number of branches were recorded due to wider spacing's and lesser plant density (Abebe 2007). Similarly (Damtew *et* *al., 2*011) reported that higher number of branches/plant were observed at lower planting density, while the lowest number of branches/plant at the highest planting density in *A. annua*. Similar results were also been reported by Simon *et al.* (1990). The reduction in number of flower buds per plant with decrease in spacing may be due to greater inter-plant competition for incident light, soil nutrition, soil moisture and mutual shading of each other at high plant density than at low plant density. There was also failure of auxiliary buds to initiate branches or death of branches at higher density due to competition for assimilates between vertical and lateral growth (Sangoil, 2000).

The inverse trend was observed for fresh weight of herbage, dry weight of herbage and moisture percentage of herbage yield. An examination of data (Table 8) indicated a significant effect of spacing on fresh weight of herbage yield and dry weight of herbage yield. Maximum values of fresh weight of herbage yield/ha (2420.95±11kg/ha,) and dry weight of herbage/ha (1818.91±11kg/ha) were observed when lavender plants were planted at a spacing of 0.5m×0.5m whereas the minimum values of fresh weight of herbage yield (2238.80±16 kg/ha) and dry weight of herbage yield (1630.50±14 kg/ha) were observed at a spacing of 0.5m×1.5m. The highest values of these parameters under closer spacing might be due to the fact that the plant density was maximum under narrow spacing as compared to higher spacing. The present investigation are in line with the findings of Zelecki (1972) in *Matricaria chamomilla*; Vadiel *et al*. (1980) in *Mentha citrate*; Randhawa *et al*. (1984b) in *Mentha spicata*; Ramchandra *et a.,* (2002) in *Pogostemon cablin*. Similar results have been reported by Choudhari *et al. (*2013) who recorded highest dry leaf yield of 2.46 tonnes/ha at a spacing of 45 x 60cm for *Artemisia annua*. Abirami *et al*. (2014) also reported that maximum values for yield parameters in *Artemisia annua* were observed at 45 x 45cm spacing however the results were statistically at par with 45 cm x 60 cm spacing. Our results are also in consonance with those of Nigussie *et al. (*2015) who reported higher yield at 40 cm x 60 cm as compared to higher spacing of 60 cm x 80 cm, 80 cm x

100cm and 100 cm x 120 cm in *Artemisia annua*. Dixit and Keskar (1994) also reported that highest values of yield and flower quality in lavender when planted at a close spacing of 30 × 20 cm or 30 × 30 cm. In our study *Lavandula angustifolia* plants raised in the field at a spacing of 0.5m x 0.5m recorded the maximum yield owing to the fact that the plant density at such spacing was more (40, 000 plants per hectare) as compared to higher spacing of 0.5m x 1.0m (20, 000 plants per hectare) and 0.5m x 1.5m (13, 000 plants per hectare). Under conditions of sufficient soil moisture and nutrients, higher population is necessary to utilize all the growth factors efficiently. The present finding is in agreement with the result of Zewdinesh *et al*. (2011) who found higher dry leaf yield at the highest plant density in *Artemisia annua*. Higher dry leaf yield per hactare at higher planting density compared to the lower density was also reported by Diemer and Griffee (2005). Singh and Singh (2002) explained that establishment of optimum population per unit area of the field is essential to get maximum yield. Optimum planting density is required to enable plants to take the best advantages of light, air, water and nutrients, and to prevent them from competition. An increase in biological yield with increasing plant population density was also reported by Nekonam and Razmjoo (2007) and Najafi and Moghadam (2002) in *Plantago ovata*.

Growth and yield of herbal plants are closely connected with meteorological conditions and agrotechnical procedures (Azizi and Kahrizi, 2008; Acimovic, 2013). Although growth, yield and essential oil of medicinal plants are under control of genetic factors; however, these features are affected by the environmental factors too. Zaffaroni and Schneiter (1991) noted that three production variables that a producer can manipulate to influence the production of a given crop are plant population, row arrangement and hybrid selection. There are many factors that influence agronomic characteristics, biomass and essential oil yield of aromatic and medicinal plants. Among these plant spacing deserves special attention (Ramamneh, 2009).

5.3 Extraction of oil from *Lavandula angustifolia*

The oil yield of lavender is a function of spikes per plant, number of flowers, spike length, spike weight and number of plants per unit area which is based on number of shoots per unit area. Thus, any change in these characters directly or indirectly is bound to have its effect on the final spike yield in lavender.

Significant effect of spacing was found on oil content of flowers of *Lavendula angustifolia.* It was found that closer spacing of 0.5m x 0.5m recorded maximum oil content (11.75 ml from 80.79 grams of flower spikes) and oil yield (117.5 L/ha) whereas minimum oil content (7.70 ml from 74.63 grams of flower spikes) and oil yield (77.00 L/ha) was recorded with 0.5m x 1.5m spacing, suggesting a significant effect of different spacing on oil content and yield. Similar views was held by Tajuddin *et al*. (1995) who reported the highest essential oil yield in lavender when planted at a close spacing of 70 × 40 cm. Abirami *et al.* (2014) also reported a maximum oil yield at closer spacing in contrast to higher spacings in *Artemisia annua*. The present findings are also in agreement with the result of (Zewdinesh *et al*., 2011) found higher essential oil yield at the highest plant density in *A. annua.* Likewise, in corn mint, highest biomass and maximum essential oil yield were produced due to the narrow spacing's (Rao, 2002). The increasing essential oil yield at higher densities i.e., at lower spacing may be due to the contribution of higher above ground biomass, fresh flower yield and dry flower yield at higher densities. Mert *et al.* (2002) also reported that the ecotype Samakaya of *Artemisia annua* gave highest oil yield at spacing of 15 plants/ $m^{2.}$ Nigussie *et al.* (2015) noted the effect of plant population density (four intra-rows *viz*. 40, 60, 80, 100 cm and four inter-row plant spacing's of 60, 80, 100, 120 cm) on growth and yield of Artemisia (*Artemisia annua* L.) and found that maximum above ground biomass (72605 kg/ha), leaf fresh weight (9510 kg/ha), leaf dry weight (5392.7 kg/ha) and essential oil yield (23.39 kg/ha) were attained due to spacing combination 40 cm intra-row and 60 cm inter-row spacing.

Chapter-6

SUMMARY AND CONCLUSION

The present work entitled **"Production potential of growing lavender on the Southern slopes of Kashmir valley "** was conducted during 2017-18 and 2018-19 at Centre for Medicinal plants and Lavender park, Faculty of Forestry, **Sher-e-Kashmir University of Agricultural Sciences and Technology.** The experiment was aimed to fulfill the following objectives:

1. Production of rooted cuttings of true lavender for commercial propagation.
2. To study lavender flower production on southern slopes at different spacing's.
3. Extraction of oil content from flower spikes.

The first experiment was conducted under Completely Randomized Design with four replications to ascertain the role of IBA in initiating and accelerating the root development of *Lavandula angustifolia* cuttings. The conventional propagation of *Lavandula angustifolia* by seeds is not recommended for commercial production. Plants grown from seed are variable in growth, color, and essential oil composition. Germination rate of seeds are low and seedlings are slow to grow out to transplanting size. The experiment was conducted with 11 treatments *viz*., control, IBA @ 200ppm, IBA @ 400ppm, IBA @ 600ppm, IBA @ 800ppm, IBA @ 1000ppm, IBA @ 1200ppm, IBA @ 1400ppm, IBA @ 1600ppm, IBA @ 1800ppm and IBA @ 2000ppm to study the effect on rooting percentage, number of roots per cutting and root length of *Lavandula angustifolia* cuttings. The results reveal that rooting percentage, number of roots per cutting and length of roots were significantly influenced when *Lavandula angustifolia* cuttings were treated with different IBA concentrations. Maximum values for rooting percentage (91.66%), number of primary and secondary roots per cuttings (8.50 and 76.25) respectively, and length of longest root (24cm) were observed when *Lavandula angustifolia* cuttings were treated with IBA@2000ppm. Thus a significant effect of IBA on before mentioned growth parameters was observed.

The second experiment on out planting performance of *Lavandula angustifolia* to study flower production at different spacing's was carried under Randomized Block Design with six replications and included three treatments (spacing) *viz*. 0.5m×0.5m, 0.5m×1.0m and 0.5m×1.5m to evaluate their respective effects on Number of flower buds per plant, fresh weight of herbage/ha. and dry weight of herbage/ha. of *Lavendula angustifolia* plants planted in three equal contours. All three treatments significantly influenced the growth and yield parameters of *Lavandula angustifolia* plants under field conditions. For number of flower buds/plant, treatment 3rd (0.5m × 1.5m) was found superior with higher values (265.33) than treatment 1st and treatment 2nd and for fresh and dry herbage yield/ha treatment 1st with 0.5m×0.5m spacing was found superior than treatment 2nd (0.5m×1.0m) and treatment 3rd (0.5m×1.5m). Higher values for fresh herbage yield/ha (2420.95 ± 11 kg/ha) and dry weight of herbage yield/ha (1818.91 ± 11 kg/ha) were recorded in plants planted at a spacing of 0.5m×0.5m. Minimum values for number of flower buds per plant (210.00) was recorded in treatment 1st (0.5m × 0.5m) whereas, the minimum values for fresh weight of herbage yield/ha (2238.80 ± 16.04 kg/ha), and dry weight of herbage yield/ha (1630.50 ± 14.93 kg/ha) were recorded in plants planted at a spacing of 0.5m×1.5m. Thus a significant effect of spacing was found on yield parameters of *Lavandula angustifolia* seedlings.

Experiment on extraction of oil from flower spikes of the *Lavandula angustifolia* plants reveal that lavender plants yielded maximum essential oil of 11.75 ml obtained from 80.79 grams of flower spikes when planted at spacing of 0.5m × 0.5m. Similarly plants planted at a distance of 0.5m×1.5m yielded minimum essential oil content of 7.70 ml obtained from 74.64 grams of flower spikes when lavender plants were planted at spacing of 0.5m×1.5m. Another part of this experiment on estimation of total yield of lavender oil in L/ha at different spacing's reveal that maximum yield of lavender oil *viz*., 117.50 L/ha was found when lavender plants were planted at spacing of 0.5m×0.5m followed by oil yield of 97.50 L/ha when planted at spacing of 0.5m×1.0m and minimum yield of lavender oil (77.00 L/ha) was found when planted at spacing of 0.5m×1.5m. Furthermore, significant effect of different spacing was recorded on yield of lavender oil.

CONCLUSIONS

- Rooting percentage, No. of primary and secondary roots per cutting and Length of roots were recorded maximum in treatment 11 at an IBA concentration of 2000 ppm.
- Number of flower buds per plant was recorded maximum in treatment 3^{rd} with 0.5m × 1.5m spacing.
- Fresh and dry herbage yield were recorded maximum in treatment 1^{st} with 0.5m×0.5m spacing.
- Maximum essential oil content obtained from flower spikes when plants were planted at a spacing of 0.5m×0.5m.
- Maximum oil yield was also recorded in treatment 1^{st} with 0.5m×0.5m spacing
- Gross income through lavander cultivation on southern slopes was highest at the spacing of 0.5m×0.5m which yields 117.5 L/ha of oil, while as the cost of 1 litre lavander oil is Rs 10, 000 (Ten thousand rupees) which costs around 11,75,000 Rs/ha (Eleven lakhs seventy five thousand rupees approx.)

LITERATURE CITED

Abbaszadeh, B., Mavandi, P. and Mirza, M. 2016. Dry matter and essential oil yield changes of *Lavandula officinalis* under cow manure and vermicompost application. *Journal of Medicinal Plants and By-products* **1**: 97-1.

Abebe, T. 2007. Effect of plant spacing on the yield and yield related traits of *Vernonia galamensis.* Agronomy thesis, Alemaya University, Alemaya, Ethiopia pp. 70.

Abirami, K., Vrendra, S. Rana., Baskaran, V. and Satyabrata, M. 2014. Effect of plant spacing on herb, essential oil and artemisinin yields in the antimalarial herb (*Artemisia annua*) *Indian journal of Agronomy* **59**(1): 163-167.

Aćimović, M. G. 2013. The influence of fertilization on field of caraway, anise and coriander in organic agriculture. *Journal of Agricultural Science* **58**(2): 85-94.

Adams, R. P. and Yanke, T. 2007. Kashmir lavender oil: a comparison of new Kashmir lavender oils with commercial lavender oils. *Perfumer and Flavorist* **32**(7): 40-44.

Agricultural Research Service, 2000. Dr Duke's phytochemical and ethnobotanical databases. http://www.ars-grin-gov/duke/.

Al-Ramamneh, E. A. 2009. Plant growth strategies of *Thymus vulgaris* L. in response to population density. *Industrial Crops and Products* **30**: 389-394.

Anon. 2000a. Les huiles essentielles franciases a fin 1999. *Perfum, Cosmet, Actualites* **151**: 15.

Anonymous, 1999. Lavender to be promoted in ’99. Countryside Small Stock J **83**: 102.

Arctander, S. 1960. Perfume and flavour materials of natural origin, S. Arctander, Elizabeth, New Jersey pp. 736.

Awan, A. A. E., Ullah, S. J., Khan, A. O. and Masroor, S. 2012. Growth response of various olive cultivars to different cutting lengths. *Pakistan Journal of Agricultural Science* **49**: 283-287.

Ayanoglu, F., Mert, A. and Kaya, A. 2000. The effects of different locations and hormone doses on the rooting of cuttings of Karabas lavender (*Lavandula stoechas* L.) grown in the flora of Hatay. *Turkish Journal of Agriculture and Forestry* **24**: 607-610.

Azizi, K. and Kahrizi, D. 2008. Effect of nitrogen levels, plant density and climate on yield quantity and quality in cumin (*Cuminum cyminum* L.) under the conditions of Iran. *Asian Journal of Plant Science* **7**(8): 710-716.

Baydar, H. 2007. Medical, aromatic and pleasure crops science and technology, (Extended II edition). Süleyman Demirel University (Faculty of Agriculture) **51**: 205-212.

Baydar, H. 2009. Lavender. Medicinal and Aromatic Plant Science and Technology (3rd press). Suleyman Demirel University Press No. **51**: 274-278.

Beetham, J. and Entwistle, T. 1982. The Cultivated Lavenders. Royal Botanic Gardens, Melbourne.

Bharathy, P. V., Sonawane, P. C. and Sasnu, A. 2004. Effect of plant growth regulators, type of cutting and season on rooting of carnation (*Dianthus caryophyllus* L.) cuttings. *Indian Journal of Horticulture* **61**: 338-341.

Biasi, L. A. and Deschamps, C. 2009. *Plantas aromáticas: do cultivo à produção de oleo essencial*. Curitiba: Layer Studio Gráfico e Editora Ltda. 160.

Blythe, E. K., Sibley, J. L., Tilt, K. M. and Ruter, J. M. 2003. Cutting propagation with auxin applied via a stabilized organic rooting substrate. Combined Proceedings International Plant Propagators Society, Seattle **53**: 275-283.

Boelens, M. H. 1995. Chemical and sensory evaluation of *Lavandula* oils. *Perf, flav* **20**(3): 23-51.

Bona, C. M., Biasi, L. A., Lipski, B., Masetto, M. A. M. and Deschamps, C. 2010. Adventitious rooting of auxin-treated *Lavandula dentata* cuttings. Ciência Rural, Santa Maria **40**(5): 1210-1213.

Bona, C. M., Masetto, M. A., Deschamps, C. and Biasi, L. A. 2012. Rooting induction of different *Lavandula angustifolia* accessions by auxin application. Semina: *Ciências Agrárias, Londrina* **33**(1): 175-182.

Bousmaha, L., Bekkara, F. A., Tomi, F. and Casanova, J. 2005. Advances in the chemical composition of *Lavandula dentata* L. essential oil from Algeria. *Journal of Essential Oil Research* **17**: 292-295.

Buchbauer, G., Jirovetz, L., Jager, W., Dietrich, H. and Plank, C. 1991. Aromatherapy: evidence for sedative effects of the essential oil of lavender after inhalation. *Z Naturforsch C* **46**: 1067-1072.

Chandramouli, 2001. Influence of growth regulators on the rooting of different types of cuttings in *Bursera penicilliata* (DC) Engl. Msc (Agri) thesis, University of Agricultural Sciences, Bangalore. India.

Chatterjee, S. K. 2002. Cultivation of medicinal and aromatic Plants in India-Acommrcial approach. *Actacta Hort. (ISHS)* **576**: 191-202.

Choudhary, R., Pandey, S. T., Roshan, C. and Jat, A. L. 2013. Effect of planting geometry on *Artemisia annua*. *Environment and Ecology* **31**(2A): 701-703.

Couvillon, G. A. 1988. Rooting responses to different treatment. *Acta Horticulturae* **227**: 187-196.

Damtew, Z., Tesfaye, B. and Bisrat, Daniel. 2011. Leaf, Essential oil and Artemisinin yield of Artemesia (*Artemisia annua* L.) As influenced by harvesting age and plant population density. *World Journal of Agricultural Sciences* **7**(4): 404-412.

Debnath, G. C. and Maiti, S. C. 1990. Effect of growth regulators on rooting of softwood cuttings of guava (*Psidium guajava* L.) under mist. *Haryana Journal of Horticultural Sciences* **19**: 79-85.

Dhar, A. K., Sharma, S. D., Bhat, B. K. and Atal, C. K. 1982. Prospectus of lavender cultivation in Kashmir, *Pafai Journal* **4**(4): 20-22.

Diego, M. A., Jones, N. A., Field, T., Hernandez-Reif, M., Schanberg, S. and Kuhn, C. 1998. Aromatherapy positively affects mood, EEG patterns of alertness and math computations. *International Journal of Neuropsychiatry* **96**: 217-224.

Diemer, P. and Griffee, P. 2005. *Artemisia annua*; the plant, production and processing and medicinal applications pp. 392.

Dixit, S. V. and Keskar, B. G. 1994. Effect of plant densities and planting time on growth, yield and flowering of *Michaelmas daisy*. *Journal of Maharashtra Agricultural Universities* **19**: 349-352.

Elhaak, M. A., Matter, M. Z., Zayed, M. A. and Gad, D. A. 2014. Propagation principles in using indole-3-butyric acid for rooting rosemary stem cuttings. *Journal of Horticulture* **2**: 1.

Evelegh, T. 1996. Lavender. Lorenz Books: Sydney.

Flores, G., Blanch, G. P., Ruiz, D. C., M. L. and Herraiz, M. 2005. Enantiomeric composition studies in *Lavandula* species using supercritical fluids. *Journal of separation Science* **28**: 2333-2338.

Francis, D. and Sorrell, D. A. 2001. The interface between the cell cycle and plant growth regulators: a mini review. *Plant Growth Regulation*, *Dordrescht* **33(1)**: 1-12.

Garnon, M. 1993. Production et marche des essences de lavande et de lavandin (Mai 1992). Rivista I tan. EPPOS **4**: 384-410.

Ghatnatti, S. A. 1997. Studies on propagation of *Duranta plumeri* Jacq. Var. Goldiana by stem cuttings with growth regulators under mist. Msc. (Agri) thesis, University of Agricultural Sciences, Dharwad.

Hartmann, H. T., Kester, D. E., Davies, F. T. and Geneve, R. L. 2002. Plant Propagation: Principles and Practices, Prentice-Hall, New Delhi, India pp. 76.

Hassanpouraghdam, M. B., Hassani, A., Vojodi, L., Asl, B. H. and Rostami, A. 2011. Essential oil constituents of *Lavandula officinalis* Chaix. from Northwest Iran. *Chemija* **22**(3): 167-171.

Hoeberechts, J., Nicola, S. and Fontana, E. 2004. Growth of lavender (*Lavandula officinalis*) and rosemary (*Rosmarinus officinalis*) in response to different mulches. *Acta Horticulturae* **629**: 26.

Husain, A. 1989. Some recent developments in improvement of agrotechnology of essential oils. *In proceedings of 11th International congress of Essential oils, Fragrances and Flavours*. Oxford IBH Publishing Co. Pvt. Ltd. New Delhi **2**: 41-46.

Ihsan, S. A. 2007. Essential oil composition of *Lavandula officinalis* L. grown in Jordan. *Journal of Kerbala University* **5**(1): 18-21.

Jayashankar, S., Chezhin, N., Abdul Khader, M. A. and Nanjan, K. 1990. Studies on the rooting of terminal cuttings of *Ficus infectoria* roxb. *South Indian Horticulture* **38**: 170-172.

Kara, N. and Baydar, H. 2013. Determination of lavender and lavandin cultivars (*Lavandula sp*.) containing high quality essential oil in Isparta, Turkey. *Turkish Journal of Field Crops* **18**(1): 58-60.

Kasem, M. M. and Abd-El-Daset, M. M. 2014. A comparative study to improve rooting of English lavender stems cuttings. *African Journal of Agricultural Research* **9**(50): 3632-3637.

Kazankaya, A., Yoruk, E. and Dogan, A. 2005. Effect of IBA on rooting of *Rosa canina* hardwood cuttings from Lake Van Region, Turkey. *Acta Horticulturae* **690**: 153-158.

Kesari, V., Das, A. and Rangan, L. 2010. Effect of genotype and auxin treatments on rooting response in stem cuttings of CPTs of *Pongamia pinnata*, a potential biodiesel legume crop. *Current Science, Columbus* **98**(9): 1234-1237.

Kite, S. M., Maher, E. J., Anderson, K., Young, T., Young, J., Wood, J., Howells, N. and Bradburn, J. 1998. Development of an aromatherapy service at a Cancer Centre. *Palliat Med* **12**: 171-180.

Krishnamurthy, M. N. 1981. Plant growth substances. TATA McGraw Publishing Company Limited, New Delhi.

Kumar, N. and Sreeja, K. V. 1996. Effect of growth regulators on the rooting ability of lavender (*Lavandula angustifolia* Mill.) *Indian Perfumer* **40**: 93-94.

Kumari, M., Patade, V. Y., Arif, M. and Ahmed, Z. 2010. Effect of IBA on seed germination, sprouting and rooting in cuttings for mass propagation of *Jatropha curcus* L. strain. *Research Journal of Agriculture and Biological Sciences* **6**(6): 691-696.

Lis-Balchin, M. 2002. Lavander. The Genus *Lavandula.* Medicinal and Aromatic Plants-Industrial Profiles **29**: 268.

Lis-Balchin, M. and Hart, S. 1999. Studies on the mode of action of the essential oil of lavender (*Lavandula angustifolia* P. Miller). *Phytother Research* **13**: 540-542.

Mallavarapu, G. R., Mehta, V. K., Sastry, K. P., Krishnan, K. R., Ramesh, S., Kumar, S., Kukreja, A. K., Dwivedi, S. and Singh, A. K. 2000. Composition of lavender oils produced in Kashmir and Kodaikanal. *Journal of Medicinal and Aromatic Plant Sciences* **22**: 768-770.

Marin, I., Sayas-Barbera, E., Viuda-Martos, M., Navarro, C. and Sendra, E. 2016. Chemical composition, antioxidant and antimicrobial activity of essential oils from organic fennel, parsley, and lavender from Spain. *Foods* **5**(18): 1-10.

McGimpsey, J. A. and Porter, N. G. 1990. A Growers Guide for Commercial Production New Zealand Institute for Crop and Research Limited, Christchurch.

Mehta, V. K., Sastry, P., Parmeswaran, J. N. and Padhakrishan, K. 2000. Lavender prospectus in Kashmir valley and Tamil Nadu hills. *Journal of Medicinal and Aromatic Plant Sciences* **22**: 540-543.

Mert, A., K1r1c1, S. and Ayanoglu, F. 2002. The effects of different plant densities on yield, yield components and quality of *Artemisia annua* L. ecotypes. *Journal of Herbs, Spices and Medicinal plants* **9**(4): 413-418.

Mishra, B. S., Singh, M., Aggrawal, P. and Laxmi, A. 2009. Glucose and auxin signaling interaction in controlling *Arabidopsis thaliana* seedlings root growth and development. *PLoS ONE*, *San Francisco* **4**(2): 1-13.

Moon, T., Wilkinson, J, M. and Cavanagh, H. M. A. 2006. Antibacterial activity of essential oils, hydrosols and plant extracts from Australian grown *Lavandula* spp. *The international Journal of Aromatherapy, Oxford* **16**(1): 9-14.

Moutet, L. 1980. Lavandin Abriales, lavandin Grosso: what is their future? *Perf. Flav.* **4**(6): 27-28

Nadalin, V., Lepojevic, Z., Ristic, M., Vladic, J., Nikolovski, B. and Adamovic, D. 2014. Investigation of cultivated lavender (*Lavandula officinalis* L.) extraction and its extracts. *Chemical Industry & Chemical Engineering Quarterly* **20**(1): 71-86.

Najafi, F. and Moghadam, P. R. 2002. Effect of irrigation regimes and plant density on yield and agronomic characteristics of blond psyllium (*Plantago ovata*). *Journal of Agricultural Science and Technology* **16**: 59-65.

Nanda, K. K., Purohit, A. N., Bala, A. and Anand, V. K. 1968. Seasonal rooting response of stem cuttings of some forest tree species to auxins. *Indian Forester* **94**: 154-162.

Nekonam, M. S. and Razamjoo, K. H. 2007. Effect of plant density on yield, Yield components and Effective medicinal ingredients of Blod Psyllium (*Plantago ovata* F.). *Journal of Agricultural Biology* **9**(4): 607-609.

Niaz, A. and Muhammad, I. 2002. Influence of various concentrations of indole byric (IBA) on different types of *Bougainvillea glabra*. *Sarhad Journal of Agriculture* **18**(3): 263-270.

Nigussie, A., Lule, B. and Gebre, A. 2015. Effect of plant population density on growth and yield of Artemisia (*Artemisia annua* L.). *International Journal of Advanced Biological and Biomedical Research* **3**(4): 384-390.

Pavlov, A. L., Georgiev, M. L., Panchev, I. N. and Ilieva, M. P. 2005. Optimization of rosmarinic acid production by *Lavandula vera* MM plant cell suspension in a laboratory bioreactor. *Biotechnology Progress, Pittsburgh* **21**(2): 394-396.

Peyron, L. 1983. Lavandes et lavandins dans le monde. *Perfum, Cosmet, Aromes* **54:** 55-60.

Rajarama, H. A. 1997. Studies on propagation of pomegranate (*Punica granatum* L.) by cuttings. Msc. (Agri) thesis, University of Agricultural Sciences, Dharwad.

Ramachandra, K. M., Vasundhara, M., Farooqi, A. A. and Srinivasappa, K. N. 2002. Evaluation of patchouli (*Pogostemon cablin* Pellet.). varieties in relation to different plant densities. *Indian Perfumer* **46**(1): 7-14.

Randhawa, G. S., Mahey, R. K., Sidhu, B. S and Saini, S. S. 1984. Herb and oil yields of *Mentha spicata* under different row spacings and nitrogen levels in Punjab. *Indian Perfumer* **28**(3-4): 146-149.

Rao, B. R. 2002. Biomass yield, essential oil yield and essential oil composition of rose scented geranium (*Pelargonium* species) as influenced by row spacings and inter cropping with corn mint (*Mentha arvensis* L. f.). *Indian Crop Production* **16**: 133-144.

Ravanappa, U. G., Nalawadi and Sheelavantar, M. N. 1998. Influence of plant density on branching, dry matter, production yield of green chilly varieties, **11**(3): 733-736.

Sangoil, L. 2000. Understanding plant density effects on maize growth and development: An important use to maximize grain yield. *Science Rural* **39**(1): 59-68.

Sasaki, J., Yamanouchi, K., Nagaki, M., Arima, H., Aramachi, N. And Inaba, T. 2015. Antibacterial effect of lavender (*Lavandula*) flavor (volatile). *Journal of Food Science and Engineering* **5**: 95-102.

Seidler-Lozykowska, K., Mordalski, R., Kucharski, W., Kedzia, B. and Bocianowski, J. 2014. Yielding and quality of lavender flowers (*Lavandula angustifolia* Mill.) from organic cultivation. *Acta Scientiarum Polonorum Hortorum Cultus* **13**(6): 173-183.

Sharma, R., Gupta, A., Patwardhan, S., Hebbalkar, D., Tare, V. and Bhonde, S. I. 1992. Bioactivity of Lamiaceae plants against insects. *Indian Journal of Experimental Biology* **30**: 244-246.

Sharma, S. D., Bhan, M. K., Kaul, M. K. and Dhar, P. L. 1983. Morphological and oil content variation in lavender introduced in Kashmir. *Indian Perfumer* **27**(1): 28-31

Shawl, A, S., Nisar, A., Kumar, T., and Qurishi, M, A. 2008. Chemical investigation of essential oil of *Lavendula* × *intermedia*. *Indian Perfumer* **52**(3): 47-49.

Shawl, A. S. and Kumar, T. 2000. Potential of lavender oil industry in Kashmir. *Journal of Medicinal and Aromatic Plant Sciences* **22**: 319-321.

Shawl, A. S. and Kumar, T. 2003. Organic Lavender. Proceedings of National Seminar on organic products and their future prospectus, SKUAST (K), Srinagar pp. 47-52.

Shawl, A. S. and Qazi, G. N. 2004. Production and trade of medicinal plants in India. *SKUAST Journal of Research* **6**: 1-12.

Shawl, A. S. and Qazi, G. N. 2008. Production of high value essential oils in Jammu and Kashmir. *Science for Better Tomorrow* pp. 110-118.

Shawl, A. S., Kumar, T., Shabir, S., Chisti, N. and Kaloo, Z. A. 2005. Lavender-A versatile industrial crop in Kashmir. *Indian Perfumer* **49**(2): 235-238.

Simon, J. E., Charles, D., Cebert, E., Grant, L., Janick, J. and Whipkey, A. 1990. *Artemisia annua* L: a promising aromatic and medicinal. **In**: *Advances in New crops* (Eds. J. Janick and J. E., Simon). Timber press, Portland, Oregon, USA pp. 522-526.

Singh, A. K. 2001. Effect of auxins on rooting and survival of jasmine (*Jasminum sambac* Ait.) stem cuttings. *Progressive Horticulture* **33**: 174-177.

Singh, A. K., Rajesh Singh., Mittal, A. K., Singh, Y. P. and Shiva, J. 2003. Effect of plant growth regulators on survival rooting and growth characters in laung pepper (*Pepper longum* L.). *Progressive Horticulture* **35**: 208-211.

Singh, A., Singh, M. and Singh, D. V. 1986. The successful use of intercropping for weed management in medicinal yam (*Dioscorea floribunda* Mart. Gal.) *Tropical Pest Management* **32**: 105-107.

Singh, C. M. and Chand, P. 1980. Note on economics of grain-legume intercropping and N-fertilization in maize. *Indian Journal of Agricultural Research* **14**: 62-64.

Singh, N. P. and Singh, R. A. 2002. Scientific crop production, X press Graphics, Delhi-28, 1st ed., India pp. 102-109.

Singh, S., Singh, V., Kiran-babu, G. D., Kaul, V. K, and Ahuja, P. S. 2007. Economics of lavender (*Lavandula officinalis* L.) in Himachal Pradesh. *Journal of Non Timber Forest Products* **11(2)**: 97-100.

Somappa, K. 1979. Studies on improvement of propagation of some forest and plantation crop species. M. Sc. (Agri) Thesis, University of Agricultural sciences, Dharwad, India.

Strydom, D. K. and Hartmann, H. T. 1960. Absorption, distribution and destruction of indole-acetic acid in plum cuttings. *Plant Physiology* **35**: 435-442.

Sudria, C., Palazon, J., Cusido, R., Bonfill, M., Pinol, M. T., Morales, C. 2001. Effect of benzyladenine and indolebutyric acid on ultrastructure, glands formation, and essential oil accumulation in *Lavandula dentate* plantlets. *Biologia Plantarum, Praha* **44**(1): 1-6.

Swetha, H. 2005. Propagation of Indian lavender (*Bursera delpechiana* Poiss. ex Engl.) through cuttings under mist. Msc. (Agri) Thesis. University of Agricultural Sciences, Dharwad, India.

Tajuddin, Shawl, A. S., Nigam, M. C. and Hussain, A. 1983. Production of lavender oil in Kashmir Valley, *Indian Perfumer* **27**: 56-59.

Tajuddin., Singh, A. K., Saproo, M. L., Hussain, A. 1995. Performance of lavender clones under different spacings in Kashmir. *Current Research on Medicinal and Aromatic Plants* **17**: 13-16.

Takano, T., Oak, K., Kawabata, M. 1990. Germination characteristics of herb seeds in *Labiatae*. *Journal of Scientific Rep. Fac. Agric. Meijo Univ*. **26**: 17-24.

Thimmappa, D. K. and Bhattacharjee, S. K. 1990. Standardization of propagation of scented geranium from stem cuttings. *Indian Perfumer* **34**: 56-60.

Troadec, Y. 1997. Huile essentielle de lavande de Haute Provence criteres analytiques et lieu au terroir. *Revista Ital*. EPPOS 1997 (Numero Speciale, 15th Journees Internationales Huiles Essentielles) pp. 201-241.

Tyub, S., Kamili, A. N. and Shah, A. M. 2007. Effect of BAP on shoot regeneration in shoot tip cultures of *Lavandula officinalis*. *Journal of Research and Development, Srinagar* **7**: 125-130.

Upson, T. and Andrews, S. 2004. The Genus *Lavendula*: The University of Chicago Press pp. 11-14.

Vadiel, B., Arumugam, R. and Kumar, N. 1980. Influence of row spacing on the yield and oil content of bergamot mint. (*Mentha citrate Ehrh.) Indian Perfumer* **24**(4): 207-209.

Venskutonis, P. R., Depkevicius, A. and Baranouskiene, M. 1997. Composition of the essential oil of lavender (*Lavandula angustifolia* Mill.) from Lithuania. *Journal of Essential oil Research* **9**: 107-110.

Verma, R. S., Rahman, L. U., Chanotiya, C. S., Verma, R. K., Chauhan, A., Yadav, A., Singh, A. and Yadav, A. 2010. Essential oil composition of *Lavandula angustifolia* Mill. cultivated in the mid hills of Uttarakhand, India. *Journal of the Serbian Chemical Society* **75**(3): 343-348.

Vijaykumar, N. 1973. Studies on the propagation of guava (*Psidium guajava* L.) by cuttings. Phd. Thesis, University of Udaipur, Udaipur.

Vinot, M. and Bouscary, A. 1979. Les lavandins. *Perfum, Cosmet, Aromes* **28**: 45-54.

Vokou, D., Vareltizidou, S. And Katinakis, P. 1993. Effects of aromatic plants on potato storage: sprout suppression and antibacterial activity. *Agricultural Ecosystem Environment* **47**: 223-235.

Zalecki, R. 1972. The cultivation and manuring of tetraploid chamomile. Part Ⅱ. Row width and sowing density. *Herba polonica* **18**(1): 70-78.

Zewdinesh, D., Bizuayehu, T. and Daniel. 2011. Leaf, essential oil and Artemisinin yield of Artemisia (*Artemisia annua* L.) as influenced by harvesting age and plant population density. *World Journal of Agricultural Science* **7**(4): 404-412.

Zheljazkov, V. D., Cantrell, C. L., Astatkie, T and Jeliazkova, E. 2013. Distillation time effect on lavender essential oil yield and composition. *Journal of Oleo Science* **62**(4): 195-199.

Zigene, Z. D., Kassahun, B. M. and Degu, B. 2018. Effect of cutting Size and Position on Propagation Ability of Lavender (*Lavandula angustifolia* L.)

the 4rth Biennial *Conference of the Ethiopian Horticultural Science Society (EHSS)*.

Zlatev, S., Iliev, L., Karanov, E., Tsolova, M. and Donchev, T. 1990. Stimulation of root formation in lavender by growth regulators. *Fiziologiya na Rasteniyata* **16**: 63-67.

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Faculty of Forestry, Benhama, Ganderbal
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Certificate

Certified that all the corrections/amendments as suggested by External Examiner Dr. Shakir P. Sultan, Scientist, Plant Biotech. CSIR, IIIM, Sanat Nagar, Srinagar during Viva-Voce examination held on 01-01-2020 have been incorporated in the manuscript entitled **"Production potential of growing Lavender on the southern slopes of Kashmir valley"** submitted by **Ms. Saima Farooq (Regd. No. 2017-FOR-69-M).**

Dr. S. A. Gangoo
Chairman
Advisory Committee