

**STUDIES ON SEED GERMINATION
AND SEED RATE OF SOME
AROMATIC PLANTS**

THESIS

by

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*Submitted in partial fulfilment of the requirements
for the degree of*

MASTER OF SCIENCE

in

**FORESTRY
(FOREST PRODUCTS)**



COLLEGE OF FORESTRY

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2000



FRONTISPIECE



Salvia sclarea L.



Rosmarinus officinalis L.



Matricaria chamomilla L.

Dedicated
to
Everlasting Memories
of my
Revered Father

Acknowledgements

With limitless modesty, I would like to praise and thank GOD – the Almighty, the merciful, the compassionate who bestowed me with good health and divine power to overcome various odds of my life and successful completion of my study.

I deem it an unique opportunity and proud privilege to express my profound sense of gratitude and indebtedness to my esteemed teacher and Chairperson of my Advisory Committee, Dr. Meenu Sood, Asstt. Scientist, Department of Forest Products, for her scholastic guidance, constant supervision, sustained interest and patient counsel throughout the period of investigations and preparation of this manuscript.

I genuinely owe my sincere thanks and obligations towards the members of my Advisory Committee, Dr. L.J. Srivastava, Dr. R.C. Rana, Dr. D. Tripathi, Dr. S.K. Sharma and Dr. J.M. Singh Rastogi for their prudent suggestions, timely help and critical discussions during the course of investigations.

I express my sincere thanks to Dr. Anil Sood for his guidance and timely help as and when needed.

I also wish to extend my thanks to Dr. N.S. Chauhan, Dr. A.N. Kaushal, Dr. K.R. Sharma, Dr. R. Raina, Dr. Y.P. Sharma, Dr. B. Dutt for their noble suggestions and timely help extended to me.

Thanks are due to the technical and field staff who never failed to lend a helping hand.

I shall always remember the amiable and jovial company of all my friends and undoubtedly thanks to Mr(s) Ranjeet, Sachil, Banyal, Guleria, Dinesh, Rajeev, Vipin(s), Anirudh, Mehra, Anand, Naveen, Avtar, Rajnish, Puneet, Arun, Subhash, Yogi, Ashwani, Vivek(s), Raju, Bhupi, Ashish, Rakesh(s), Ajay, Promod, Kalra, Punnu, Saroj, Chandresh, Anita, Manisha, Sonia, Anjana, Seema, Suman, Bharati, Shilpa, Aditi, Deepa and Chandelekhia ji.

I am thankful to my seniors especially Mr. Narender, Umesh, Vikas, Lalit Mohan, Amol Vashishth, Rajesh Kaushal, Rajesh Chauhan, Jagdish Gautam and Dr. R. Banyal for their kind help and cooperation.

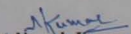
Language seems to be too inadequate media to express my heartfelt gratitude for the eternal affection, lively sentiments and constant encouragements from my brothers – Er. S.K. Bhardwaj, Vimal and cousins – Er. R.S. Gautam, Anil Bhardwaj, Rama, Raju, Dinesh, Paul, Satish and Arvind Gautam. Besides I am highly thankful to all the family members and relatives for their affection from time to time. Above all, I find no appropriate set of words for the kind blessing, persistent prayers and sacrifices made by my mother.

I thank to all the staff of DPT Computers, Nauni for their untiring efforts, while typing this manuscript.

Needless to say, errors and omissions are mine.

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CERTIFICATE-I

This is to certify that the thesis entitled "**Studies on seed germination and seed rate of some aromatic plants**", submitted in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE in FORESTRY (FOREST PRODUCTS)** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan (H.P.) is a bonafide research work carried out by **Mr. NARESH KUMAR (F-98-07-M)** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

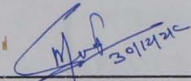
The assistance and help received during the course of investigations have been fully acknowledged.

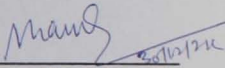
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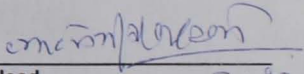

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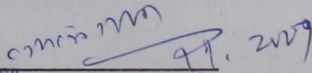
CERTIFICATE-II

This is to certify that the thesis entitled "**Studies on seed germination and seed rate of some aromatic plants**", submitted by **Mr. NARESH KUMAR (F-98-07-M)** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan (H.P.), in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE in FORESTRY (FOREST PRODUCTS)** has been approved by the Student's Advisory Committee after an oral examination of the same in collaboration with the external examiner.


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Chapter I

INTRODUCTION

INTRODUCTION

Chapter 1

INTRODUCTION

Essential oils of aromatic plants have been used in India since the last thousands of years as perfumery material. Frequent mention about the use of essences, perfumes, scented waters, sandal, camphor and saffron for religious functions and marriage ceremonies are found in 'Vedas'. Aromatic plants were featured in personal adornment and beautification of home. At one time perfumes were considered as sign of luxury and were used by urban rich. It is not true now a days because of our day to day requirements like soaps, cosmetics, tooth pastes, mouth washes, shampoos, detergents, household sprays, confectioneries, pharmaceuticals, agarbatties, etc. include the use of suitable essential oils due to fragrance.

The growth of essential oil industry would also be marked by the consumers under the sway of western trends, rapid globalization of fragrances and constant upgradation of technology. India is seventh largest and second most populous country in the world. Despite the low level of per capita income in India, there exists a large class of consumers for packed and branded consumer goods.

The world trade in essential oil is vast. The estimated world production of perfume oils is about 2,50,000 tonnes and the worldwide sale of material is about \$ 5000 million. The annual turnover of all perfumes in India is about Rs. 300 crores, while the market size of Indian cosmetics is estimated at Rs. 4500 crores. The world demand for plant based raw material of essential oils and pharmaceuticals is increasing rapidly (Bhattacharjee, 2000).

In spite of India being predominantly agricultural country with varied climatic conditions suitable for large scale cultivation of variety of essential oil bearing plants, has very less share (0.2%) of export in the world trade (Sunderesh, 1982). The production of essential oil bearing plants in India is limited to sandalwood, lemon grass, geranium, mint and few others, while the rest being still imported. Hence, there is an

urgent need for pursuing all possible efforts to augment cultivation, production and scientific processing of commercially important aromatic plants. It will not only provide assured supply of raw material to the user industries but also reduce the import of these plants.

The wide range of edaphic and climatic conditions of Himachal Pradesh offer an ample scope for introduction and cultivation of large number of aromatic plants of interest to the perfumery and flavouring industry. Since no work has been done on these aspects in Himachal Pradesh, hence, the present investigations on seed germination and seed rate were undertaken on the following plants :

a) *Salvia sclarea* L. var. Bissar

Clary sage (*Salvia sclarea*; Family : Lamiaceae) has been introduced at Solan (H.P.) from Bulgaria through NBPGR, New Delhi. It is a medium sized (60-90 cm), perennial, cold and drought resistant plant. Oil of Clary sage is a valuable perfumery raw material. It is used in flavouring of non-alcoholic and alcoholic beverages, ice creams, candy and baked goods (Husain *et al.*, 1988). The oil also exhibited analgesic action, antiinflammatory activity (Moretti *et al.*, 1997) and cytotoxic activity (Foray *et al.*, 1999).

b) *Matricaria chamomilla* L. var. Soraksar-60

German chamomile (*Matricaria chamomilla*; Family : Asteraceae) was introduced at Solan (H.P.) from Hungary through NBPGR, New Delhi. It is a medium sized (60-90 cm) annual herb. The flower yield sweet smelling essential oil - the "blue oil" which find a variety of uses in pharmaceutical and perfumery industries. The chamomile extracts are used mainly because of their antiphlogistic properties of chamazulene and (-) alpha-bisabolol (Singh, 1977). It is also used as antiinflammatory, antioxidative, ulcer protective, spasmolytic and tumour protective (Ammon and Kaul, 1992). The mild infusion and herbal tea prepared from *M. chamomilla* have been used in Europe for centuries as a popular remedy against fever, stomach trouble, indigestion,

intestinal pains and as a mild tonic, which is helpful in stimulating the liver regeneration etc.

c) *Rosmarinus officinalis* L.

Rosemary (*Rosmarinus officinalis*; Family : Lamiaceae) is indigenous to South Europe, Asia minor and North America. It was also introduced at Solan from Hungary through NBPGR, New Delhi. It is a dense evergreen shrub, upto one meter in height with a characteristic aromatic smell. Leaves yield 1-2 per cent volatile oil (Husain *et al.*, 1988). Rosemary oil is known to have antioxidative (Svoboda and Deans, 1992), antifungal (Perrucci *et al.*, 1994), antimalarial (Milhau *et al.*, 1997) and antimicrobial activity against certain gram +ve and gram -ve bacteria (Rao and Nigam, 1970). The volatile oil of *R. officinalis* has vascular smooth muscle relaxant effect (Aqel, 1992). Rosemary oil is also used in perfumery for the scenting of toilet water, soaps and for flavouring of food products.

Keeping in view the multifarious uses of these plants in pharmaceutical and perfumery industries, the present investigations were undertaken on seed germination and seed rate of these aromatic plants with the following objectives:

- i) To standardize pre-sowing seed treatments for getting maximum seed germination.
- ii) To study the effect of storage period and storage containers on seed germination.
- iii) To study the effect of depth of sowing and different mulching materials on seed germination.
- iv) To find out optimum seed rate for getting maximum yield.

Chapter 2

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Chapter 2

REVIEW OF LITERATURE

The literature pertaining to the present investigations entitled, "Studies on seed germination and seed rate of some aromatic plants" is reviewed in this chapter. Meagre information is available on these aspects on aromatic plants. Hence, in the present studies the literature available on the related and other plant species has been reviewed aspect wise as under :

- 2.1 Effect of pre-sowing seed treatments on seed germination
- 2.2 Studies on the effect of storage period on seed germination
- 2.3 Studies on the effect of storage containers on seed germination
- 2.4 Effect of depth of sowing on seed germination
- 2.5 Effect of different mulching materials on seed germination
- 2.6 Studies on the effect of seed rates on growth and yield

2.1 EFFECT OF PRE-SOWING SEED TREATMENTS ON SEED GERMINATION

Donnelly (1970) reported that beside environmental factors, the genetic component of species causes dormancy. Seeds of many species fail to germinate inspite of the presence of favourable environmental conditions. Janick (1974) termed this stage as seed dormancy.

Beside the long duration stratification processes, several time efficient pre-sowing treatments envisaging the soaking of seeds for few minutes or hours in chemical solutions or water have been tried to break the dormancy.

The soaking of seeds in water before sowing is known to hydrate the seed tissues, thereby activating them, leading to germination. Also, it softens the seed coat in

numerous species and is, therefore, widely practiced by agriculturists, horticulturists and foresters.

Matias *et al.* (1973) found that soaking of *Pinus caribea* seeds in water at room temperature gave more uniform germination than untreated seeds. Vaenica (1973) reported that the seeds of *Albizia falcata* gave optimum germination when soaked in water at 38°C for 20-30 minutes before sowing.

Some seeds, which had little resistance to germination may respond well to soaking for 24 hours in water at ambient temperature (Kemp, 1975). Danthu *et al.* (1992) also reported better germination of *Acacia senegal* seeds when soaked in water for 12-24 hours. Rudre Gowda *et al.* (1993) also observed that soaking of *Eucalyptus citridora* seeds in distilled water for 18 hours gave 38 per cent germination.

Water treated seeds showed 49 per cent germination in *Hibiscus sabdariffa* L. (Ynove *et al.*, 1996). Kundu *et al.* (1997) reported that soaking of *Alstonia scholaris* seeds in distilled water for 24 hours gave 40.4 per cent germination.

Shyalaja *et al.* (1997) observed maximum germination percentage (56.95%) when seeds of *Catharanthus roseus* L. were soaked in cold water for 20 minutes.

Seeds whose coats are impermeable to moisture and gases must be treated so that permeability is increased without injury to the embryo. Hot water dip and acid scarification is most favoured where seed dormancy is brought about by hard seed coat. According to Hartmann and Kester (1976) the purpose of soaking of seeds in water is to modify hard seed coat, remove inhibitors, soften seeds and reduce the time of germination.

Sheikh (1980) studied the effect of boiling water on germination of *Cassia fistula* seeds and observed 67.5 per cent germination after 24 days. Bowen and Eusibio (1981) found that germination in *Acacia mangium* seeds increased significantly when treated with hot water.

Haq and Mina (1988) observed that when the seeds of *Hyoscyamus niger* L. were exposed to light, temperature, chilling, chemical treatment and boiling water treatment, all the treatments showed positive effect on germination except boiling water treatment which decreased the germination.

Kundu *et al.* (1997) reported that soaking of *Alstonia scholaris* seeds in hot water at 50°C for 30 minutes gave 42.4 per cent germination.

A wide range of chemicals have been tested experimentally so as to overcome internal dormancy. They include gibberellic acid, citric acid, hydrogen peroxide and a number of other compounds.

Bachelard (1967) observed the increase in germination percentage of *Eucalyptus* with acid treatment. Singh and Srivastava (1990) reported that soaking of Lavender and Rosemary seeds in one per cent HCl for 12 hours gave 40 and 10 per cent germination, respectively. They further reported that soaking of Lavender seeds in one per cent HCl for 12 hours in case of pre-soaked seeds in water followed by sowing or for 24 hours in case of dry seeds then washing in running water followed by soaking in water for 24 hours and then sowing gave reasonably good germination.

Gentiana wutaiensis and *G. cruciata* seed treated with GA_3 and GA_4 promoted germination and untreated seeds showed complete or partial failure to germination (Thompson, 1969). Dahab *et al.* (1979) reported that GA_3 treatment at 0, 100, 150 ppm for 24 hours increased the germination percentage in *Pistacia khinjuk*.

Carpenter and Smith (1981) observed that the seeds of *Paulownia tomentosa* treated with GA_3 germinated sooner and reached 98 per cent germination in 10 days. Similarly, Pital *et al.* (1984) found that GA_3 improved the germination of intact seeds of *Ostrya virginiana* and resulted in 70-80 per cent germination.

Nargaraja and Farooqi (1989) observed highest germination (72.0%) in *Bursera penicillata* when treated with BA^* at 150 ppm followed by GA_3 at 100 ppm (69.33%).

Kundu *et al.* (1997) reported that GA₃ treatment at 200 ppm for 24 hours gave highest germination in *Alstonia scholaris*. Seed germination was effectively promoted in *Gentiana lutea* seeds soaked overnight in aqueous solution of 50 ppm GA₃ (Yoneda *et al.*, 1992).

In *Salvia columbariae*, gibberellin treatment greatly improved germination from an average of 30.6 to 82.4 per cent for fresh seeds and from an average of 61.8 to 94.9 per cent for stored seeds (Hashemi and Estilai, 1994). Bisht and Kediya (1995) studied the effect of growth regulators/vitamins on the seed germination of *Atropa belladonna* and reported that GA₃ and IBA at 30 ppm gave the best germination.

According to Kretschmer and Franz (1997) *Gentiana scabra* seeds were treated with 300 ppm GA₃ and *G. lutea* seeds with 500 ppm GA₃ gave 75 to 81 per cent germination.

2.2 STUDIES ON THE EFFECT OF STORAGE PERIOD ON SEED GERMINATION

Storage may be defined as the preservation of viable seeds from the time of collection, until they are required for sowing. Storage of seed is necessary to conserve gene resources for breeders and gene-banks.

Longevity is determined by a complex of physiological and environmental factors. A seed contains an embryonic plant in a resting condition and germination is its resumption of the growth. Throughout this resting stage, life processes can not cease entirely (Barton, 1953).

Nutile (1964) reported ^{that} germinability of celery (*Apium graveolens* L. 'Dulce') ^{decreased} reduced as the moisture content during storage period declined from 4.0 per cent to 1.0 per cent. Similarly, the germinability of *Salvia splendens* seeds rapidly declined when moisture content was less than 4.0 per cent (Touzard, 1975).

According to Koopmann (1967) nine per cent moisture content is sufficient for seed storage of sage plant (*Salvia officinalis* L.).

Harington (1970) and Stein *et al.* (1974) observed that fully ripened seeds retain viability for longer period than the immature seeds. Harington (1972) showed the two most important environmental factors viz. relative humidity of the air and temperature, influenced the speed of aging.

Germination requirements of a particular species are the result of interaction between the genetic make up and environmental complex (Willington, 1973). The loss of seed viability is largely governed by the rate of catabolism (Anderson, 1973). Harington (1973) stated that moisture stresses occurring during excessive seed drying cause accelerated aging by compounding the degeneration of cellular membrane and formation of microscopic cracks in seed coats.

Sharma (1980) reported that the seeds of *Moringa oleifera* sown after one month storage gave highest germination percentage. He further reported that the germination percentage goes on decreasing with progressive increase in storage period.

Woodstock *et al.* (1984) observed that respiration rate increases with increased moisture content and temperature and the rate of seed exhaustion is largely determined by these factors. Bewley and Black (1985) reported that respiration resulting in energy release and production of CO₂ and water. Continuing respiration results a decrease in dry matter content and gradual exhaustion of reserve materials. The seeds of sage can be stored for six years or more at 5°C (Kretschmer, 1989).

Kozlowski and Szczyglewska (1995) reported that seeds of *Verbascum phlomides* and *V. thapsiforme* showed about 80 per cent germination during the first year of storage. The seeds kept for five years maintain high germination rate, however in seeds of nine years storage germination rate decreased.

2.3 STUDIES ON THE EFFECT OF STORAGE CONTAINERS ON SEED GERMINATION

Tang and Tamari (1973) reported that seeds of *Hopea helferi* stored at 15°C, with high moisture content in unsealed polythene bags retained 98 per cent of viability

after 37 days and 80 per cent after 60 days. According to Sasaki (1980) *Shorea talura* retained over 50 per cent germination after storage in a closed bag at 4°C for five months and at 21°C for nearly 10 months.

Tylkowski (1984) while studying the effect of storing silver mapple (samaras) on the germinative capacity of seeds and seedling growth observed that germinative capacity of seed is normally lost rapidly but can be maintained almost unchanged for 18 months by packing samaras in sealed bottles at an initial moisture content of 50 per cent and storing at -10°C.

According to Tompsett (1985) storage at 40 per cent moisture content in ventilated containers at 16°C enabled survival of *Shorea roxburghii* seed for nine months with over 50 per cent viability. Chaisurisri *et al.* (1986) obtained success in storing *Azadirachta indica* seeds in a cotton bag at 15°C. Seeds were dried to a moisture content of 46.18 per cent before storing. Under these conditions seeds retained viability for more than 4 months.

Maithani *et al.* (1987) recorded a steep fall in the germination per cent and germination value of *Holoptelia integrifolia* seeds with in two months of storage in open container at room temperature. In seeds taken from sealed polybags at room temperature germination capacity remained high (85%) for 15 months.

Karivaratharaju *et al.* (1989) reported that of ^{the} three storage containes, viz. cloth bags, polythene bags and covered mud pots, the seeds of *Lablab purpureus* (L.) taken from polythene bags showed maximum germination after storage period of 18 months.

Maithani *et al.* (1989) stored *Azadirachta indica* seeds at room temperature and at 15°C or 5°C in sealed and perforated polythene bags, perforated cardboard boxes and over silica gel in desiccators. Both sealed containers and low temperature (5°C) caused rapid deterioration of seeds (complete loss of germination capacity in 1-4 months). While the use of aerated containers at room temperature or 15°C inhibited deterioration and some of the seeds germinated even after six months storage.

Nautiyal and Thapliyal (1993) reported that the seeds of *Toona ciliata* can be stored at 5-8°C in polythene bags for one year with 90 per cent germination.

2.4 EFFECT OF DEPTH OF SOWING ON SEED GERMINATION

Singh *et al.* (1973) reported higher percentage of germination in *Pinus wallichiana* seeds at 15 mm soil depth. Sharma (1980) found maximum germination (66.65%) at 10 mm depth and minimum germination (21.20%) at 5 mm depth of sowing in *Moringa oleifera*.

Hildebrandt and Schulz (1987) conducted studies on sowing trials of some selected herbaceous plants. They concluded that on an average, more herbs emerged from soil covered seeds than from surface-sown seeds but the species with low thousand seed weight (*Achillea millefolium*, *Companula glomerata*) did better with surface sowing.

Fonseca *et al.* (1994) reported that *Dipteryx alata* Vog. seeds should be sown at a depth of 1-3 cm and for *Hancornia speciosa* ^{recommended surface sowing for} surface sowing was recommended so as to get optimum germination. Letchamo and Gosselin (1996) advocated that if faster, uniform emergence and plant establishment is desired, dandelion (*Taraxacum officinale*) seeds should not be sown more than 1.0 cm deep.

2.5 EFFECT OF DIFFERENT MULCHING MATERIALS ON SEED GERMINATION

A usual effect of mulching is to increase soil temperature during winter and lower it during summer (McCalla and Dulley, 1946).

Rowe-Dutton (1957) has defined the mulching as application of covering layer of material to soil surface. In other way mulch is a layer of organic material which is placed on the soil in order to conserve moisture, to hold down weeds and to maintain the temperature of soil and eventually to improve the soil structure and fertility.

Mulches change the soil radiation and water balance to different extent depending upon their characteristics and accordingly may have a favourable or

unfavourable effect on plant growth (Van Wijk *et al.*, 1959; Miller, 1968; Van Bavel and Hillel, 1975). Organic mulches also affect the physical and chemical properties of soil (Chowdhary and Chatterjee, 1967; Black, 1973).

Hussain *et al.* (1969) reported that mulching with sugarcane trash significantly increased germination rate, plant height and rhizome yield of turmeric whereas, Mohanty *et al.* (1990) recorded highest turmeric yield by mulching with forest dry leaves though there was no significant difference in yield among different treatments. They also reported that 80 per cent germination was significantly earlier under different mulching treatments with leaves and straw.

Attia (1970) reported that the mulching treatment helped the winter varieties of wheat to perform better than no mulch under late sown conditions. Prihar *et al.* (1979) advocated ~~that~~ ^{as} application of mulch ^{is} one of the important ways for soil moisture conservation in the upper soil layer, ^{which} ~~thereby~~ ^{es} increasing the minimum and decreasing ^{es} the maximum soil temperature.

Othieno (1980) compared grass mulch and black polythene mulch with no mulch and reported that during prolonged droughts, soil moisture content was generally higher under grass and black polythene mulch, but any type of mulch was better than no mulch in conserving moisture upto 90 cm depth.

In addition to conserving soil moisture by reducing evaporation losses, mulches also improve the soil moisture regime by maintaining higher infiltration rate and reducing surface run-off (Manipura, 1972; Fairbourn and Gardner, 1979).

Berdun *et al.* (1988) observed that plastic mulching decreased the mean number of days from sowing to emergence and also increased the seed yield of maize. Similarly, Choi *et al.* (1990) reported that polythene film mulching reduced time to seedling emergence, flowering and maturity and also increase the crop density of buck-wheat.

Maeda (1991) reported that soil temperature in the upper 0-5 cm layer was on an average 5°C higher under plastic mulch than under unmulched soil. Ricotta and

Masiunas (1991) noticed black plastic mulch greatly increased fresh weight and dry weight-yield of *Ocimum basilium* and *Rosmarinus officinalis*.

Galambosi and Szebeni (1992) reported that black plastic mulch increased soil temperature by 0.2 to 0.6°C and increased the yield of *Origanum* sp., *Thymus* sp., *Salvia officinalis*, *Melissa officinalis*, *Agastachi foeniculum* and *Dracocephalum moldarica* by 20-40 per cent, though in years of extreme heat or cold, yields were reduced especially for *Origanum* sp., *Salvia officinalis* and *Melissa officinalis*.

Rey (1995) conducted studies on the comparison of direct sowing and planting of *Salvia officinalis* and reported that mulched plants produced higher yield than unmulched plants.

2.6 STUDIES ON THE EFFECT OF SEED RATES ON GROWTH AND YIELD

Husain *et al.* (1988) reported that about 1.0 kg seeds of *M. chamomilla* provided sufficient seedlings to cover one hectare of land. While, Singh (1977) reported that 0.5 to 0.8 kg of very clean seeds of *M. chamomilla* with high germination per cent was enough to provide seedlings for stocking one hectare of land.

Massey (1971) reported that spacing did not effect ^athe plant height, but wider spacing increased the stem diameter. Similar findings were also reported by Vijayalakshmi *et al.* (1975) and Ungaro *et al.* (1983). *Effect of spacing on plant height?*

The findings reported by Robinson *et al.* (1980), Khalifa (1984) and Schmidt and Silva (1986) indicated that the plant height increased with the increase in plant population. Thompson (1982) reported that total dry matter accumulation increased significantly with the increase in population of sunflower. *Effect of population on plant height?*

Bhati (1992) stated that the seed rate had significant influence on secondary branches per plant and seed yield in cumint. He reported that seed rate of 14 kg/ha gave the maximum seed yield (5.18 q/ha). However, secondary branches per plant were recorded higher at low seed rate of 8-10 kg/ha. Steer *et al.* (1986) reported that in sunflower shoot dry matter increased with decreased plant density. Singh *et al.* (1989) reported that growth decreased with increase in plant densities, except plant height where a reverse trend was found.

Chapter 3

MATERIALS AND METHODS

The present investigation was carried out in the Department of Chemistry, University of Alberta, Edmonton, Alberta, Canada. The author wishes to express his appreciation to the Department of Natural Sciences and Engineering Research Council of Canada for the financial support of this work.

2. EXPERIMENTAL

2.1 Location

The present investigation was carried out in the Department of Chemistry, University of Alberta, Edmonton, Alberta, Canada.

MATERIALS & METHODS

Reagents and materials were of the highest quality available.

2.2.1. Chemicals

Chemicals used in this work were of the highest quality available. The reagents were used without further purification. The solvents were distilled under reduced pressure and stored over calcium hydride. The water was distilled and stored over calcium hydride. The acids were distilled and stored over calcium hydride. The bases were distilled and stored over calcium hydride. The salts were distilled and stored over calcium hydride. The gases were distilled and stored over calcium hydride. The liquids were distilled and stored over calcium hydride. The solids were distilled and stored over calcium hydride. The reagents were used without further purification. The solvents were distilled under reduced pressure and stored over calcium hydride. The water was distilled and stored over calcium hydride. The acids were distilled and stored over calcium hydride. The bases were distilled and stored over calcium hydride. The salts were distilled and stored over calcium hydride. The gases were distilled and stored over calcium hydride. The liquids were distilled and stored over calcium hydride. The solids were distilled and stored over calcium hydride.

Chapter 3

MATERIALS AND METHODS

The present investigations entitled, "Studies on seed germination and seed rate of some aromatic plants" were conducted in the laboratory and experimental area of the Department of Forest Products at Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh during the years 1998-1999 and 1999-2000.

3.1 EXPERIMENTAL SITE

3.1.1 Location

The present studies were undertaken in the mid hill zone of Himachal Pradesh. The geographic location of the site is as under:

Altitude	:	1200 m
Latitude	:	30°52'N
Longitude	:	70°11'E

3.1.2 Climate

Climate during summer is hot with maximum temperature sometimes rising upto 34°C. On the other hand winters are very cold accompanied by frosts for a few weeks but snowfall is rare phenomenon. This area gets on an average 1000-1300 mm rainfall, most of which is received during monsoon season commencing from June and extending upto September. In general May and June are hottest months and December and January, the coldest. The meteorological data for the experimental area during the year 1998-1999 and 1999-2000 is given in Appendix-I.

3.2 EXPERIMENTAL METHODOLOGY

3.2.1 Experiment-I : Effect of pre-sowing seed treatments on seed germination

Healthy and uniform sized seeds of *S. sclarea*, *M. chamomilla* and *R. officinalis* were used for seed germination studies consisted of 100 seeds for each treatment per replication.

The experiment was laid out in the laboratory in Completely Randomized Design (CRD) with three replications each.

Treatment numbers	Pre-sowing seed treatments
T ₁	Control
T ₂	Immersion in cold water for 24 hrs
T ₃	Immersion in cold water for 48 hrs
T ₄	Immersion in boiling water for 5 minutes
T ₅	Immersion in boiling water for 10 minutes
T ₆	Immersion in 0.5% HCl for 10 minutes and washed the seeds thoroughly with tap water in order to make them free from acid.
T ₇	Immersion in 1.0% HCl for 10 minutes and washed the seeds thoroughly with tap water
T ₈	Immersion in 1.5% HCl for 10 minutes and washed the seeds thoroughly with tap water
T ₉	Immersion in 2.0% HCl for 10 minutes and washed the seeds thoroughly with tap water
T ₁₀	Soaking in gibberellic acid 100 mg/l for two hrs
T ₁₁	Soaking in gibberellic acid 200 mg/l for two hrs

3.2.2 Experiment-II : Studies on the effect of storage period on seed germination

After proper drying, the seeds of *S. sclarea*, *M. chamomilla* and *R. officinalis* were stored at room temperature in the closed containers. After storage, a sample of seeds from each lot was taken and germination studies were undertaken for two years at an interval of three months in the seed-germinator. Daily count of germinated seeds was taken as criteria for germination.

The outline of treatments on seed germination studies at different storage periods are as under :

Treatment numbers	Storage periods
T ₀	Immediately after harvesting
T ₁	3 months
T ₂	6 months
T ₃	9 months
T ₄	12 months
T ₅	15 months
T ₆	18 months
T ₇	21 months
T ₈	24 months

The experiment was laid out in the laboratory in Completely Randomized Design (CRD) with three replications each.

3.2.3 Experiment-III: Studies on the effect of storage containers on seed germination

After proper drying, the seeds of *S. sclarea*, *M. chamomilla* and *R. officinalis* were stored in six different containers upto the time of sowing. The treatments were as under :

Treatment numbers	Storage containers
T ₁	Open tray
T ₂	Gunny bag
T ₃	Plastic jar
T ₄	Paper bag
T ₅	Cloth bag
T ₆	Polythene bag

The experiment was conducted in the nursery under Randomized Block Design (RBD) with six treatments having four replications each.

3.2.4 Experiment-IV: Effect of depth of sowing on seed germination

The seeds were sown in the nursery beds at different depths mentioned below :

Treatment numbers	Sowing depths
T ₀	Surface sowing
T ₁	0.5 cm
T ₂	1.0 cm
T ₃	1.5 cm
T ₄	2.0 cm
T ₅	2.5 cm
T ₆	3.0 cm

This experiment was laid out in the nursery in Randomized Block Design (RBD) with four replications each.

3.2.5 Experiment-V: Studies on the effect of different mulching materials on seed germination

During the present studies the following mulches were used:

Treatment numbers	Mulching materials
T ₀	Control (no mulch)
T ₁	Dry grass
T ₂	Black polythene sheet
T ₃	Farm Yard Manure
T ₄	Pine needles
T ₅	Wheat straw

This experiment was laid out in the field in Randomized Block Design (RBD) replicated four times. The above mentioned mulches were spread over the nursery beds.

3.2.6 Experiment-VI: Studies on the effect of seed rates on growth and yield

The experiment was laid out in Randomized Block Design (RBD) replicated thrice with eight treatments of seed rate. The details of treatments given were as under:

Treatment numbers	Seed rates (kg/ha)
T ₁	0.5
T ₂	1.0
T ₃	1.5
T ₄	2.0
T ₅	2.5
T ₆	3.0
T ₇	3.5
T ₈	4.0

3.3 OBSERVATIONS RECORDED

During the present investigations, the observations were recorded on the following parameters :

- i) Germination per cent
- ii) Mean daily germination
- iii) Peak value
- iv) Germination value
- v) Germination energy index

The observations on these parameters were recorded in the laboratory for Experiments I and II, whereas for Experiments III, IV and V in addition to these parameters, the observations were also recorded for the following parameters in the nursery:

- i) Shoot length (cm)
- ii) Root length (cm)
- iii) Survival per cent

In Experiment-VI, observations were recorded on the following parameters :

- i) Plant height (cm)
- ii) Number of branches/ plant
- iii) Flowering shoot/ flower/ leaf yield (q/ha)
- iv) Oil content (%)
- v) Oil yield (kg/ha)

Germination per cent

The total number of seeds germinated were counted and germination per cent was worked out on the basis of total number of seeds sown.

Mean daily germination (MDG)

Mean daily germination was calculated as the cumulative percentage of full seed germination at the end of the test divided by the number of days from sowing to the end of the test or the total per cent germination divided by total days in the test gives the final mean daily germination.

Peak value (PV)

Peak value was calculated as the maximum mean daily germination at any time during the period of test (Czabator, 1962).

Germination value (GV)

Germination value is an index combining speed and completeness of seed germination. Daily germination counts were recorded and GV was calculated as per the method of Czabator (1962).

$$GV = PV \times MDG$$

where,

PV = Peak value of germination

MDG = Mean daily germination or final mean daily germination

Germination energy index (GEI)

Germination energy index was calculated as :

$$GEI = \frac{A_1 + A_2 + A_3 + A_4 + \dots + A_n}{N + n} \times 100$$

where,

$A_1 + A_2 + A_3 + A_4 + \dots + A_n$ are the seed germinated upto n^{th} days

N = Total number of seeds taken

n = Number of days upto which seed germinated.

Shoot length (cm)

The seedling height was recorded in centimeters from the base of the seedling to the tip of the shoot and was reported as mean.

Root length (cm)

The length of the root was measured from collar to the lower most tip of the primary root and was reported as mean.

Survival percentage

Survival percentage was calculated as :

$$\frac{\text{Plant per cent in the bed}}{\text{Number of seeds germinated}} \times 100$$

Plant height (cm)

The plant height was recorded in centimeters from the base of the plant to the tip of the shoot and was reported as mean.

Number of branches/plant

The number of branches/ plant were counted and were reported as mean.

Flowering shoot/flower/leaf yield (q/ha)

Flowering shoot/ flower/ leaf yield was measured in quintals per hectare (q/ha).

Oil content (%)

The oil content was recorded in per cent.

Method of oil extraction
↓
P
↓

Oil yield (kg/ha)

The oil yield was recorded in kilograms per hectare (kg/ha).

3.4 STATISTICAL ANALYSIS

The data recorded was subjected to statistical analysis under completely randomized design and randomized block design as described by Gomez and Gomez (1984).

EXPERIMENTAL RESULTS

EXPERIMENTAL RESULTS

Chapter 4

EXPERIMENTAL RESULTS

The results obtained during the present investigations entitled, "Studies on seed germination and seed rate of some aromatic plants" are presented in this chapter under the following headings:

- 4.1 Effect of pre-sowing seed treatments on seed germination
- 4.2 Studies on the effect of storage period on seed germination
- 4.3 Studies on the effect of storage containers on seed germination
- 4.4 Effect of depth of sowing on seed germination
- 4.5 Studies on the effect of different mulching materials on seed germination
- 4.6 Studies on the effect of seed rates on growth and yield

4.1 EFFECT OF PRE-SOWING SEED TREATMENTS ON SEED GERMINATION

The pre-sowing treatments were evaluated based upon their comparative effect on seed germination under laboratory conditions. The results thus obtained are presented under the following headings:

4.1.1 *Salvia sclarea* L.

4.1.1.1 Germination per cent

The perusal of data in Table 1 showed that the highest seed germination was recorded when seeds of *S. sclarea* were soaked in gibberellic acid 200 mg/l for 2 hours (80.00%). It was followed by T_{10} (76.67%), T_1 (75.00%), T_4 (73.33%) and T_8 (73.33%) and these values were statistically at par with each other. However, the lowest germination was observed when seeds were immersed in boiling water for 10 minutes (51.67%).

Table 1. Effect of pre-sowing seed treatments on seed germination of *Salvia sclarea* L.

Treatments	Germination (%)	Mean daily germination (%)	Peak value (%)	Germination value (%)	Germination energy index (%)
T ₁	58.33 (49.82)	4.17	9.25	38.57	59.80
T ₂	63.33 (52.74)	4.52	10.83	48.95	78.18
T ₃	75.00 (60.08)	5.35	15.00	80.25	113.72
T ₄	73.33 (59.06)	5.23	12.22	63.91	89.22
T ₅	51.67 (45.06)	3.69	8.33	30.73	48.59
T ₆	63.33 (52.74)	4.52	16.67	75.35	65.69
T ₇	70.00 (56.84)	5.00	17.08	85.40	90.20
T ₈	71.33 (55.77)	5.13	19.72	101.16	103.92
T ₉	73.33 (59.06)	5.23	21.11	110.41	105.88
T ₁₀	76.67 (61.22)	5.47	17.08	93.43	149.80
T ₁₁	80.00 (63.55)	5.71	17.08	97.53	156.86
CD _{0.05}	(6.21)	0.41	1.92	4.94	12.87

Figures in parenthesis are arcsine transformed values

4.1.1.2 Mean Daily Germination (MDG)

The data presented in Table 1 elucidated that MDG values varied from 3.69 to 5.71 per cent in different treatments. Maximum MDG values were obtained (5.71% and 5.47%) when seeds were soaked in gibberellic acid 200 mg and 100 mg/l for two hours, respectively. It was followed by T_3 (5.35%) when seeds were immersed in cold water for 48 hours. These values were statistically at par with each other. The lowest MDG value was recorded when seeds were immersed in boiling water for 10 minutes (3.69%) which was statistically different from all other treatments.

4.1.1.3 Peak Value (PV)

The appraisal of data in Table 1 depicted that the maximum PV was obtained when seeds were immersed in 2.0 per cent HCl for 10 minutes (21.11%) which was at par with 1.5 per cent HCl treatment (19.72%) for 10 minutes. Although the PV was 17.08 per cent, when seeds were immersed in 1.0 per cent HCl for 10 minutes and GA₃ 100 mg/l and 200 mg/l for 2 hours which was at par with 0.5 per cent HCl treatment for 10 minutes (16.67%). The lowest PV (8.33%) was recorded when seeds of *S. sclarea* were immersed in boiling water for 10 minutes which was statistically different from all other treatments.

4.1.1.4 Germination Value (GV)

A perusal of data in Table 1 revealed that the highest GV (110.41%) was recorded when seeds of *S. sclarea* were immersed in 2.0 per cent HCl for 10 minutes which was significantly different from all other treatments. This was followed by 1.5 per cent HCl treatment (101.16%) and gibberellic acid 200 mg/l treatment for 2 hours (97.53%) and these were statistically at par with each other. The lowest value was observed in T_3 (30.73%) and it was statistically different from all other treatments.

4.1.1.5 Germination Energy Index (GEI)

Data in Table 1 revealed that soaking of seeds in gibberellic acid 200 mg/l for 2 hours gave the highest GEI (156.86%) which was statistically at par when seeds were

soaked in 100 mg/l gibberellic acid for 2 hours (149.80%), but significantly different from all other treatments. Immersion of seeds in boiling water for 10 minutes (T_4) registered the minimum GEI (48.59%) which was at par with control (59.80%) but differed significantly from all other treatments.

4.1.2 *Matricaria chamomilla* L.

4.1.2.1 Germination per cent

A critical look at Table 2 illustrated that the highest germination (73.33%) was recorded when seeds were soaked in gibberellic acid 200 ppm for two hours (T_{11}) which was statistically at par with T_{10} and T_3 (70.33% and 68.33%), when seeds were soaked in 100 mg/l gibberellic acid for 2 hours or immersed in cold water for 48 hours, respectively. Although no germination was registered when seeds were immersed in 1.5 per cent HCl and 2.0 per cent HCl for 10 minutes, respectively. The lowest germination (15.00%) was observed when seeds were soaked in 1.0 per cent HCl for 10 minutes and it was significantly different from all other treatments.

Since no germination was found in *Matricaria chamomilla* seeds when treated with 1.5 per cent and 2.0 per cent HCl for 10 minutes so the germination parameters viz., MDG, PV, GV and GEI ^{were} was not observed.

4.1.2.2. Mean Daily Germination (MDG)

Data in Table 2 elucidated that maximum MDG (5.24%) was obtained when seeds were soaked in 200 mg/l gibberellic acid for 2 hours which was accompanied by 100 mg/l gibberellic acid treatment for 2 hours (5.02). Lowest MDG value (1.07%) was recorded with 1.0 per cent HCl which was significantly different from all other treatments.

4.1.2.3 Peak Value (PV)

The appraisal of data in Table 2 depicted the maximum PV with 200 mg/l gibberellic acid for 2 hours (17.08%) which was at par when seeds were soaked in 100 mg/l gibberellic acid for 2 hours (15.83%) or immersed in cold water for 48 hours

Table 2. Effect of pre-sowing seed treatments on seed germination of *Matricaria chamomilla* L.

Treatments	Germination (%)	Mean daily germination (%)	Peak value (%)	Germination value (%)	Germination energy index (%)
T ₁	60.00 (50.88)	4.29	11.33	48.61	62.76
T ₂	63.33 (52.80)	4.52	14.58	65.90	91.18
T ₃	68.33 (55.77)	4.81	15.83	76.14	105.88
T ₄	36.67 (37.26)	2.62	7.75	20.31	44.11
T ₅	21.67 (27.60)	1.55	4.58	7.10	29.41
T ₆	26.67 (31.00)	1.91	5.91	11.29	38.24
T ₇	15.00 (22.60)	1.07	3.00	3.21	23.53
T ₈	0.00 (0.00)	0.00	0.00	0.00	0.00
T ₉	0.00 (0.00)	0.00	0.00	0.00	0.00
T ₁₀	70.33 (56.82)	5.02	15.83	79.47	117.65
T ₁₁	73.33 (58.93)	5.24	17.08	89.50	126.47
CD _{0.05}	(5.08)	0.43	1.53	5.02	13.04

Figures in parenthesis are arcsine transformed values

(15.83%). The lowest PV (3.00%) was recorded with 1.0 per cent HCl treatment which was statistically different from all other treatments.

4.1.2.4 Germination Value (GV)

A perusal of Table 2 revealed that the highest germination value (89.50%) was recorded with 200 mg/l gibberellic acid treatment for 2 hours (T_{11}). This was significantly different from all other treatments. It was followed by T_{10} (79.47%). The lowest value (3.21%) was observed at T_1 , which was statistically at par with T_3 (7.10%).

4.1.2.5 Germination Energy Index (GEI)

Data in Table 2 revealed that 200 mg/l gibberellic acid treatment for 2 hours gave the highest GEI (126.47%) which was at par with 100 mg/l gibberellic acid for 2 hours (117.65%), but significantly different from all other treatments. T_1 registered the minimum GEI (23.53%) which was at par with T_3 (29.41%).

4.1.3 *Rosmarinus officinalis* L.

4.1.3.1 Germination per cent

The perusal of data in Table 3 showed that the highest germination of *R. officinalis* seeds was recorded when immersed in 2.0 per cent HCl for 10 minutes (59.33%) which was at par with 1.5 per cent HCl treatment for 10 minutes (54.91%). The germination of T_2 (21.23%) was statistically at par with T_3 (24.58%). Similarly, when seeds were soaked in 100 mg/l or 200 mg/l gibberellic acid for 2 hours, the germination (45.68% and 47.14%) was found statistically at par with each other. The lowest germination was observed in control (16.81%).

4.1.3.2 Mean Daily Germination (MDG)

The data presented in Table 3 elucidated that MDG value varied from 1.20 to 4.24 per cent in different treatments. Maximum MDG (4.24%) was obtained when seeds were immersed in 2.0 per cent HCl for 10 minutes (T_9) which was statistically at

Table 3.

Effect of pre-sowing seed treatments on seed germination of *Rosmarinus officinalis* L.

Treatments	Germination (%)	Mean daily germination (%)	Peak value (%)	Germination value (%)	Germination energy index (%)
T ₁	16.81 (11.24)	1.20	1.82	2.18	18.46
T ₂	21.23 (17.05)	1.51	3.69	5.57	21.73
T ₃	24.58 (19.36)	1.76	4.46	7.85	26.58
T ₄	35.92 (31.39)	2.57	5.97	15.34	38.81
T ₅	41.64 (34.85)	2.97	7.42	22.04	45.64
T ₆	43.25 (40.18)	3.09	9.14	28.24	57.74
T ₇	47.50 (41.59)	3.39	10.36	35.12	64.13
T ₈	54.91 (49.22)	3.92	12.16	47.67	69.46
T ₉	59.33 (52.42)	4.24	14.83	62.88	83.18
T ₁₀	45.68 (40.07)	3.26	9.64	31.43	114.67
T ₁₁	47.14 (43.74)	3.37	10.37	34.95	128.13
CD _{0.05}	(3.82)	0.34	1.14	4.16	13.06

Figures in parenthesis are arcsine transformed values

par with T_8 (3.92%) in which seeds were immersed in 1.5 per cent for 10 minutes. The MDG in T_4 (2.57%) and T_5 (2.97%) was found to be statistically at par with each other. However, T_5 (2.97%) was also at par with T_6 (3.09%) which was further at par with T_7 (3.39%), T_{10} (3.26%) and T_{11} (3.37%). The lowest MDG was recorded in control (1.20%) and it was statistically different from all other treatments.

4.1.3.3 Peak Value (PV)

A perusal of data presented in Table 3 revealed that the maximum PV (14.83%) was recorded when seeds were immersed in 2.0 per cent HCl for 10 minutes and was statistically different from all other treatments. The PV for T_2 (3.69%) and T_3 (4.46%) were at par with each other. Similarly, the PV for T_6 (9.14%) was at par with T_{10} (9.64%) which was further at par with T_{11} (10.37%) and T_7 (10.36%).

4.1.3.4 Germination Value (GV)

A perusal of data presented in Table 3 revealed that the highest GV (62.88%) was recorded in 2.0 per cent HCl treatment for 10 minutes (T_9) which was statistically different from all other treatment. The GV for T_{10} (31.43%) and T_{11} (34.95%) was at par with each other. The lowest GV (2.18%) was recorded in control (T_1) and it was at par with T_2 (5.57%).

4.1.3.5 Germination Energy Index (GEI)

Data in Table 3 revealed that highest GEI (128.13%) was obtained when seeds were soaked in gibberellic acid 200 mg/l for 2 hours which differed significantly from all other treatments. GEI value for T_6 was (57.74%) which was statistically at par with T_7 (64.13%) and T_8 (69.46%). The lowest GEI (18.46%) was recorded in control (T_1) and it was statistically at par with T_2 (21.73%) and T_3 (26.58%). Further, T_4 (38.81%) and T_5 (45.64%) were also statistically at par with each other.

4.2 STUDIES ON THE EFFECT OF STORAGE PERIOD ON SEED GERMINATION

The seeds after a storage period of 3 months (T_1), 6 months (T_2), 9 months (T_3), 12 months (T_4), 15 months (T_5), 18 months (T_6), 21 months (T_7), 24 months (T_8) and control (T_0) were evaluated based upon their comparative effect on seed germination under laboratory conditions and the results thus obtained are illustrated under the following headings:

4.2.1 *Salvia sclarea* L.

4.2.1.1 Germination per cent

The data presented in Table 4 revealed that the highest germination (68.67%) was recorded in T_0 when seeds were sown immediately after harvesting and it was at par with T_1 (62.66%) when seeds were sown after 3 months of storage, but significantly different from all other treatments. Whereas, no germination was obtained when seeds were stored more than 15 months. T_8 registered lowest germination (13.33%).

Since the *S. sclarea* seeds did not germinate after the storage period of 15 months, so the germination parameters viz., MDG, PV, GV and GEI were not observed after the storage period of 15 months.

4.2.1.2 Mean Daily Germination (MDG)

It is evident from Table 4 that the highest MDG (4.76%) was recorded in T_0 when seeds were sown immediately after harvesting which was statistically different from all other treatments. This was followed by T_1 (4.48%) and T_2 (4.17%). The lowest MDG was observed in T_5 (0.39%).

4.2.1.3 Peak Value (PV)

The maximum PV was again recorded in T_0 (9.33%) which was at par with T_1 (8.72%), but significantly different from all other treatments (Table 4). The lowest PV was observed in T_5 (0.70%), which differed significantly from all other treatments.

Table 4. Effect of storage period on seed germination of *Salvia sclarea* L.

Treatments	Germination (%)	Mean daily germination (%)	Peak value (%)	Germination value (%)	Germination energy index (%)
T ₀	68.67 (56.90)	4.76	9.33	44.41	118.58
T ₁	62.66 (52.72)	4.48	8.72	39.07	112.72
T ₂	58.33 (49.80)	4.17	7.92	33.03	97.05
T ₃	50.00 (45.00)	3.57	5.28	18.85	90.12
T ₄	41.67 (40.20)	2.98	3.82	11.38	48.26
T ₅	13.33 (21.35)	0.39	0.70	0.27	32.07
T ₆	0.00 (0.00)	0.00	0.00	0.00	0.00
T ₇	0.00 (0.00)	0.00	0.00	0.00	0.00
T ₈	0.00 (0.00)	0.00	0.00	0.00	0.00
CD _{0.05}	(4.19)	0.19	0.68	5.76	9.56

Figures in parenthesis are arcsine transformed values

4.2.1.4 Germination Value (GV)

Data on germination value presented in Table 4 also showed an identical pattern of decrease in their values like germination per cent, mean daily germination and peak value. The highest germination value (44.41%) was recorded in T_0 , which was at par with T_1 (39.07%), but significantly different from all other treatments. The lowest germination value (0.27%) was observed in T_5 .

4.2.1.5 Germination Energy Index (GEI)

The maximum GEI (118.58%) was recorded in T_0 , which was at par with T_1 (112.72%) while the minimum GEI (32.07%) was observed in T_5 . The GEI value obtained in T_2 (97.05%) was at par with T_3 (90.12%), but significantly different from all other treatments.

4.2.2. *Matricaria chamomilla* L.

4.2.2.1 Germination per cent

The data presented in Table 5 revealed that highest germination (63.33%) was recorded in T_1 when seeds of *M. chamomilla* were stored for 3 months which was significantly different from all other treatments. It was followed by T_2 (55.00%) and T_3 (51.67%), whereas, no germination was obtained in T_7 and T_8 . T_8 registered lowest germination (18.33%), which differed statistically from all other values under observation.

Since *M. chamomilla* seeds did not germinate after the storage period of 18 months, so the germination parameters viz., MDG, PV, GV and GEI were not observed after the storage period of 18 months.

4.2.2.2 Mean Daily Germination (MDG)

Going through the value of MDG from Table 5 it is evident that the highest value (4.52%) was found in T_1 and lowest in T_8 (1.31%), which differed significantly from all other treatments.

Table 5. Effect of storage period on seed germination of *Matricaria chamomilla* L.

Treatments	Germination (%)	Mean daily germination (%)	Peak value (%)	Germination value (%)	Germination energy index (%)
T ₀	41.67 (40.17)	2.98	8.02	23.90	61.76
T ₁	63.33 (52.74)	4.52	12.92	58.40	114.71
T ₂	55.00 (47.88)	3.93	10.08	39.61	97.06
T ₃	51.67 (45.96)	3.69	8.86	32.69	88.24
T ₄	40.00 (39.21)	2.86	7.33	20.96	59.72
T ₅	36.67 (37.23)	2.62	5.23	13.70	52.94
T ₆	18.33 (25.31)	1.31	2.71	3.55	20.58
T ₇	0.00 (0.00)	0.00	0.00	0.00	0.00
T ₈	0.00 (0.00)	0.00	0.00	0.00	0.00
CD _{0.05}	(4.69)	0.18	0.63	5.82	9.48

Figures in parenthesis are arcsine transformed values

4.2.2.3 Peak Value (PV)

The data presented in Table 5 showed that the highest peak value (12.92%) was recorded in T_1 when seeds of *M. chamomilla* were stored for 3 months. It was followed by T_2 (10.08%), T_3 (8.86%) and T_0 (8.02%). All the treatments were significantly different from each other. The minimum peak value (2.71%) was observed in T_6 .

4.2.2.4 Germination Value (GV)

Data on germination value given in Table 5 revealed that the maximum germination value (58.40%) was observed in T_1 followed by T_2 (39.61%) and T_3 (32.69%) however, the values were significantly different from each other. The lowest value (3.55%) was observed in T_6 which was statistically different from all other treatments.

4.2.2.5 Germination Energy Index (GEI)

From the data presented in Table 5, it is evident that the maximum GEI value (114.71%) was recorded in T_1 followed by T_2 (97.06%) and T_3 (88.24%). However, all the values were statistically different from each other. The minimum value (20.58%) was observed in T_6 .

4.2.3 *Rosmarinus officinalis* L.

4.2.3.1 Germination per cent

The data presented in Table 6 revealed that the highest germination (49.84%) was recorded in T_2 when seeds of *R. officinalis* were stored for 6 months which was significantly different from all other treatments. It was followed by T_3 (39.49%) and T_1 (32.64%). The minimum germination (2.56%) was recorded in T_8 when seeds were stored for 24 months.

Table 6. Effect of storage period on seed germination of *Rosmarinus officinalis* L.

Treatments	Germination (%)	Mean daily germination (%)	Peak value (%)	Germination value (%)	Germination energy index (%)
T ₀	16.92 (11.27)	1.20	1.85	2.22	19.42
T ₁	32.64 (30.19)	2.33	8.63	20.11	39.48
T ₂	49.84 (42.57)	3.56	14.32	50.98	65.14
T ₃	39.49 (32.89)	2.82	11.16	31.47	46.18
T ₄	26.16 (21.28)	1.87	9.24	17.28	33.43
T ₅	19.54 (13.68)	1.40	8.16	11.42	25.27
T ₆	16.25 (14.60)	1.16	6.23	7.23	18.04
T ₇	9.46 (5.68)	0.68	0.94	0.64	9.48
T ₈	2.56 (1.29)	0.18	0.41	0.07	4.67
CD _{0.05}	(2.82)	0.21	0.94	3.12	3.89

Figures in parenthesis are arcsine transformed values

4.2.3.2 Mean Daily Germination (MDG)

The perusal of data in Table 6 revealed that the MDG value varied from 0.18 per cent to 3.56 per cent. The highest MDG (3.56%) was recorded in T_2 when seeds were stored for 6 months and it was statistically different from all other treatments. The lowest MDG was obtained in T_8 (0.18%).

4.2.3.3 Peak Value (PV)

The data presented in Table 6 showed that the maximum PV (14.32%) was recorded in T_2 , which was statistically different from all other treatments. However, T_3 (8.16%) was found statistically at par with T_1 (8.63%), which was further at par with T_4 (9.24%). The minimum PV (0.41%) was recorded in T_8 when seeds were stored for 24 months and it was statistically at par with T_7 (0.94%).

4.2.3.4 Germination Value (GV)

A critical look of data presented in Table 6 revealed that the highest GV (50.98%) was recorded when seeds were stored for 6 months (T_2) and it was significantly different from all other treatments. The minimum GV (0.07%) was found in T_8 which was statistically at par with T_7 (0.64%) and T_0 (2.22%).

4.2.3.5 Germination Energy Index (GEI)

The maximum GEI value (65.14%) was recorded in T_2 which differed significantly from all other treatments. It was followed by T_3 (46.18%), T_1 (39.48%), T_4 (33.43%) and T_5 (25.27%) and all these were statistically different from each other. However, T_6 (18.04%) was statistically at par with T_0 (19.42%). The lowest GEI was recorded in T_8 (4.67%).

4.3 STUDIES ON THE EFFECT OF STORAGE CONTAINERS ON SEED GERMINATION

The six storage containers viz., T_1 (open tray), T_2 (gunny bag), T_3 (plastic jar), T_4 (paper bag), T_5 (cloth bag) and T_6 (polythene bag) were evaluated based upon their

comparative effects on seed germination and growth. The data pertaining to germination and growth has been presented in Tables 7-9 and illustrated as under:

4.3.1 *Salvia sclarea* L.

4.3.1.1 Germination per cent

From the data presented in Table 7 it can be concluded that the maximum germination (59.50%) was recorded in T_3 when seeds of *S. sclarea* were stored in plastic jar which was at par with T_6 (57.50%), but statistically different from all other treatments. Although the values obtained in T_4 (52.50%) and T_5 (54.00%) were found statistically at par with each other. The minimum germination (41.00%) was recorded in T_1 when seeds were stored in open tray.

4.3.1.2. Mean Daily Germination (MDG)

The appraisal of the data in Table 7 reflected that MDG was maximum (1.91%) in T_3 when seeds were stored in plastic jar which was statistically at par with T_6 (1.85%) when seeds were stored in polythene bag, but significantly different from all other treatments. T_4 (1.69%) and T_5 (1.74%) were statistically at par with each other. The minimum MDG value (1.32%) was recorded in T_1 .

4.3.1.3 Peak Value (PV)

The maximum peak value (2.56%) was observed in T_3 which was at par with T_6 (2.46%) (Table 7). The PV in T_4 (2.17%) and T_5 (2.27%) were at par with each other. Minimum value (1.68%) was found in T_1 when seeds were stored in open tray.

4.3.1.4 Germination Value (GV)

It is evident from the Table 7 that the maximum GV (4.89%) was recorded in T_3 which was at par with T_6 (4.55%). The GV for T_2 and T_4 was 3.67 per cent which was statistically at par with T_5 (3.95%). Minimum value (2.22%) was recorded in T_1 .

Table 7. Effect of storage containers on seed germination of *Salvia sclarea* L.

Treatments	Germination (%)	Mean daily germination (%)	Peak value (%)	Germination value (%)	Germination energy index (%)	Shoot length (cm)	Root length (cm)	Survival (%)
T ₁	41.00 (39.80)	1.32	1.68	2.22	118.52	1.68	8.64	73.75 (60.65)
T ₂	51.50 (45.86)	1.66	2.21	3.67	145.68	1.79	8.70	74.25 (60.80)
T ₃	59.50 (50.48)	1.91	2.56	4.89	172.84	1.86	8.85	78.75 (62.06)
T ₄	52.50 (46.44)	1.69	2.17	3.67	146.91	1.70	8.68	74.50 (60.82)
T ₅	54.00 (47.30)	1.74	2.27	3.95	165.43	1.72	8.75	74.75 (60.86)
T ₆	57.50 (49.32)	1.85	2.46	4.55	170.37	1.80	8.85	76.25 (61.24)
CD _{0.05}	(2.34)	0.07	0.13	0.39	11.14	NS	NS	NS

Figures in parentheses are arcsine transformed values

4.3.1.5 Germination Energy Index (GEI)

The data presented in Table 7 showed that the maximum GEI (172.84%) was registered in T_3 when seeds of *S. sclarea* were stored in plastic jar which was at par with T_8 (170.37%) and T_5 . Minimum GEI was recorded in T_1 (118.52%) when seeds were stored in open tray.

4.3.1.6 Shoot length

The perusal of data presented in Table 7 revealed that shoot length was not affected significantly by different treatments. However, the maximum shoot length (1.86 cm) was recorded in T_3 when seeds were stored in plastic jar and minimum (1.68 cm) in T_1 .

4.3.1.7 Root length

The data presented in Table 7 showed that none of the treatments had any significant effect on root length. However, the maximum root length (8.85 cm) was recorded in T_3 and T_8 while, the minimum (8.64 cm) root length was found in T_1 .

4.3.1.8 Survival per cent

The data presented in Table 7 showed that there was no significant difference in survival per cent among different treatments. The maximum survival (78.75%) was obtained in T_3 and the lowest survival was recorded in T_1 (73.75%).

4.3.2 *Matricaria chamomilla* L.

4.3.2.1 Germination per cent

From the data presented in Table 8 it can be concluded that maximum germination (60.50%) was recorded in T_3 which was at par with T_8 (59.50%), but significantly different from other treatments. The germination values for T_4 (49.50%) and T_5 (51.00) were statistically at par with each other. The minimum germination (38.00%) was recorded in T_1 .

Table 8. Effect of storage containers on seed germination of *Matricaria chamomilla* L.

Treatments	Germination (%)	Mean daily germination (%)	Peak value (%)	Germination value (%)	Germination energy index (%)	Shoot length (cm)	Root length (cm)	Survival (%)
T ₁	38.00 (38.05)	1.22	1.55	1.89	127.16	1.34	6.98	74.00 (60.76)
T ₂	44.50 (41.84)	1.43	2.01	2.87	160.49	1.35	7.00	75.00 (60.82)
T ₃	60.50 (51.07)	1.95	2.60	5.07	202.47	1.45	7.20	77.50 (61.26)
T ₄	49.50 (44.71)	1.60	2.28	3.65	172.84	1.38	7.02	74.50 (60.78)
T ₅	51.00 (45.75)	1.65	2.30	3.80	176.82	1.37	7.10	74.00 (60.76)
T ₆	59.50 (50.48)	1.92	2.48	4.76	190.12	1.47	7.30	76.75 (61.14)
CD _{0.05}	(1.81)	0.07	0.14	0.34	12.38	NS	NS	NS

Figures in parentheses are arcsine transformed values

4.3.2.2 Mean Daily Germination (MDG)

The appraisal of the data in Table 8 reflected that MDG was maximum (1.95%) in T_3 which was at par with T_6 (1.92%). MDG values for T_4 (1.60) and T_5 (1.65) were statistically at par with each other. The minimum MDG (1.22%) was recorded in T_1 .

4.3.2.3 Peak Value (PV)

A perusal of data presented in Table 8 showed that the maximum peak value (2.60%) was observed in T_3 when seeds were stored in plastic jar which was at par with T_6 (2.48%) when seeds were stored in polythene bag. Peak values for T_4 (2.28) and T_5 (2.30) were found at par with each other. The minimum value (1.55%) was recorded in T_1 .

4.3.2.4 Germination Value (GV)

The data presented in Table 8 showed that the maximum germination value (5.07%) was recorded in T_3 which was at par with T_6 (4.76%). The germination value of T_4 (3.65%) was at par with T_5 (3.80%). Minimum germination value (1.89%) was recorded in T_1 .

4.3.2.5 Germination Energy Index (GEI)

The perusal of data in Table 8 showed that the maximum GEI value (202.47%) was registered in T_3 which was statistically at par with T_6 (190.12%). Although the GEI value of T_2 (160.49%) was at par with T_4 (172.84%) which was further at par with T_5 (176.82%). The minimum GEI value was recorded in T_1 (127.16%).

4.3.2.6 Shoot length

Data presented in Table 8 revealed that shoot length was not effected significantly by different treatments. However, the maximum shoot length (1.47 cm) was recorded in T_6 followed by T_3 (1.45 cm), T_4 (1.38 cm), T_5 (1.37 cm), T_2 (1.35 cm) and T_1 (1.34 cm).

4.3.2.7 Root length

The data presented in Table 8 revealed that the different treatments had no significant effect on root length. However, the maximum root length (7.30 cm) was recorded in T_6 and minimum in T_1 (6.98 cm).

4.3.2.8 Survival per cent

The survival per cent was not influenced by different treatments (Table 8). However, the maximum survival (77.50%) was recorded in T_3 which was followed by T_6 (76.75%), T_2 (75.00%), T_4 (74.50%), T_1 and T_5 (74.00%).

4.3.3 *Rosmarinus officinalis* L.

4.3.3.1 Germination per cent

A perusal of data presented in Table 9 showed that the maximum germination (49.33%) was recorded in T_2 when seeds of *R. officinalis* were stored in gunny bag and it was at par with T_5 (48.16%), but statistically different from all other treatments. The minimum germination was recorded in T_6 (12.98%).

4.3.3.2 Mean Daily Germination (MDG)

The appraisal of data in Table 9 reflected that MDG was maximum in T_2 (1.59%) which was statistically at par with T_5 (1.55%). MDG values for T_1 (0.92%) and T_4 (0.96%) were also at par with each other. The minimum MDG (0.42%) was recorded in T_6 when seeds were stored in polythene bag and it was statistically at par with T_3 (0.49%).

4.3.3.3 Peak Value (PV)

The maximum PV was observed in T_2 (2.16%) which was at par with T_5 (2.04%) Table 9. While the minimum PV was recorded in T_6 (0.93%) and it was statistically at par with T_1 (0.98%), T_3 (0.96%) and T_4 (1.09%).

Table 9. Effect of storage containers on seed germination of *Rosmarinus officinalis* L.

Treatments	Germination (%)	Mean daily germination (%)	Peak value (%)	Germination value (%)	Germination energy index (%)	Shoot length (cm)	Root length (cm)	Survival (%)
T ₁	28.46 (20.32)	0.92	0.98	0.90	34.19	17.23	3.42	69.45 (59.92)
T ₂	49.33 (33.41)	1.59	2.16	3.43	59.87	18.88	3.48	78.14 (62.02)
T ₃	15.18 (12.26)	0.49	0.96	0.47	29.29	17.82	3.34	79.92 (62.15)
T ₄	29.84 (24.19)	0.96	1.09	1.05	45.68	17.68	3.38	71.64 (53.06)
T ₅	48.16 (33.02)	1.55	2.04	3.16	58.32	18.86	3.47	74.66 (60.07)
T ₆	12.98 (7.14)	0.42	0.93	0.39	19.68	16.25	3.14	68.23 (59.81)
CD _{0.05}	(2.30)	0.10	0.26	0.43	2.81	NS	NS	NS

Figures in parentheses are arcsin transformed values

4.3.3.4 Germination Value (GV)

It is evident from Table 9 that the maximum GV (3.43%) was recorded in T_2 when seeds were stored in gunny bag, which was at par with T_3 (3.16%) when seeds were stored in cloth bag. The minimum GV was observed in T_6 (0.39%) and it was statistically at par with T_3 (0.47%).

4.3.3.5 Germination Energy Index (GEI)

A perusal of data presented in Table 9 showed that GEI values varied significantly among different treatments. The maximum GEI was registered in T_2 (59.87%), which was at par with T_3 (58.32%). The minimum GEI (19.68%) was recorded in T_6 .

4.3.3.6 Shoot length

From the data presented in Table 9, it is clear that shoot length was not effected significantly by different treatments. However, the maximum shoot length (18.88 cm) was recorded in T_2 and the minimum (16.25 cm) in T_6 .

4.3.3.7 Root length

A perusal of data presented in Table 9 showed that none of the treatments had any significant effect on the root length of *R. officinalis*. However, the maximum root length (3.48 cm) was recorded in T_2 while the minimum (3.14 cm) was in T_6 .

4.3.3.8 Survival per cent

The survival per cent was also not influenced by different treatments. However, the maximum survival (79.92%) was recorded in T_3 and minimum (68.23%) was in T_6 (Table 9).

4.4 EFFECT OF DEPTH OF SOWING ON SEED GERMINATION

The seeds were sown in the beds at various depths viz., T_0 (surface), T_1 (0.5 cm), T_2 (1.0 cm), T_3 (1.5 cm), T_4 (2.0 cm), T_5 (2.5 cm) and T_6 (3.0 cm). The results thus obtained on germination and growth are given in Tables 10-12 and illustrated as under:

4.4.1 *Salvia sclarea* L.

Salvia sclarea seeds did not germinate below 2 cm sowing depth. So all the germination parameters, shoot length, root length and survival per cent was not observed. Thereby these parameters for sowing depth (≤ 2 cm) were discussed below:

4.4.1.1 Germination per cent

A perusal of data presented in Table 10 showed that the germination of *S. sclarea* seeds varied significantly among different treatments. The highest germination (60.50%) was recorded in T_1 when seeds were sown at 0.5 cm depth. It was followed by T_2 (51.50%), T_3 (36.00%), T_0 (13.50%) and minimum germination (10.50%) was observed in T_4 when seeds were sown at 2.0 cm depth.

4.4.1.2 Mean Daily Germination (MDG)

A critical look on the data presented in Table 10 showed that MDG was significantly different in all the treatments. The maximum MDG (1.95%) was recorded in T_1 (0.5 cm depth) followed by T_2 (1.66%) and T_3 (1.16%). While the minimum MDG (0.34%) was found in T_4 followed by T_0 (0.44%).

4.4.1.3 Peak Value (PV)

The data depicted in Table 10 showed the same trend ^{for PV} as for MDG values. The highest peak value (2.58%) was recorded in T_1 followed by T_2 (2.04%) and T_3 (1.27%). While the minimum peak value (0.35%) was recorded in T_4 . All the values were statistically different from each other.

Table 10. Effect of depth of sowing on seed germination of *Salvia sclarea* L.

Treatments	Germination (%)	Mean daily germination (%)	Peak value (%)	Germination value (%)	Germination energy index (%)	Shoot length (cm)	Root length (cm)	Survival (%)
T ₀	13.50 (21.52)	0.44	0.75	0.33	64.19	1.62	7.52	46.25 (43.58)
T ₁	60.50 (51.09)	1.95	2.58	5.03	194.88	1.97	8.82	77.50 (62.62)
T ₂	51.50 (45.86)	1.66	2.04	3.39	174.38	2.02	8.92	78.75 (62.68)
T ₃	36.00 (36.87) -	1.16	1.27	1.47	112.18	1.90	8.40	70.50 (58.92)
T ₄	10.50 (18.85)	0.34	0.35	0.12	49.64	1.90	8.12	54.50 (47.38)
T ₅	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T ₆	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD _{0.05}	(2.46)	0.08	0.23	0.49	13.97	0.10	0.41	(2.68)

Figures in parentheses are arcsine transformed values

4.4.1.4 Germination Value (GV)

The maximum germination value (5.03%) was recorded in T_1 , which was followed by T_2 (3.39%) and the minimum GV (0.12%) was found in T_4 (Table 10). All these values were statistically different from each other.

4.4.1.5 Germination Energy Index (GEI)

It is evident from Table 10 that the highest GEI (194.88%)^{was} found in T_1 followed by T_2 (174.38%) and T_3 (112.18%). The minimum GEI (49.64%) was recorded in T_4 . However, the values differed significantly among different treatments.

4.4.1.6 Shoot length

The data presented in Table 10 showed that the maximum shoot length (2.02 cm) was observed in T_2 , which was at par with T_1 (1.97 cm) and it was further at par with T_3 and T_4 (1.90%). Minimum shoot length was found in T_0 (1.62 cm).

4.4.1.7 Root length

Maximum root length (8.92 cm) was recorded in T_2 , which was at par with T_1 (8.82 cm). It was followed by T_3 (8.40 cm) which was at par with T_4 (8.12 cm). Although minimum root length (7.52 cm) was recorded in T_0 when seeds were sown at surface which differed significantly from all other treatments.

4.4.1.8 Survival per cent

A perusal of data presented in Table 10 revealed that the highest survival (78.75%) was recorded in T_2 , which was at par with T_1 (77.50%), but statistically different from all other treatments. The lowest survival (46.25%) was recorded in T_0 when the seeds were sown at the surface.

4.4.2 *Matricaria chamomilla* L.

The perusal of data in Table 11 showed that below 1.0 cm depth no germination occurred. In the light of this the results thus obtained are illustrated as under:

Table 11. Effect of depth of sowing on seed germination of *Matricaria chamomilla* L.

Treatments	Germination (%)	Mean daily germination (%)	Peak value (%)	Germination value (%)	Germination energy index (%)	Shoot length (cm)	Root length (cm)	Survival (%)
T ₀	60.50 (51.07)	1.95	2.62	5.11	186.78	1.52	6.98	77.50 (61.72)
T ₁	50.50 (45.29)	1.63	2.09	3.41	144.48	1.56	7.18	78.00 (61.80)
T ₂	27.00 (31.30)	0.87	0.98	0.85	69.13	1.42	6.90	66.25 (58.86)
T ₃	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T ₄	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T ₅	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T ₆	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD _{0.05}	(2.78)	0.06	0.06	0.78	11.98	0.02	0.14	(1.72)

Figures in parentheses are arcsine transformed values

4.4.2.1 Germination per cent

The data presented in Table 11 showed that the highest germination (60.50%) was recorded in T_0 when seeds were sown at surface followed by T_1 (50.50%) and T_2 (27.00%). All these values were statistically different from each other.

4.4.2.2 Mean Daily Germination (MDG)

Data on MDG value depicted in Table 11 showed that MDG values decreased as the depth of seed of *M. chamomilla* was increased. The highest MDG (1.95%) was recorded in T_0 and it was followed by T_1 (1.63%). The minimum MDG value (0.87%) was observed in T_2 . The values amongst different treatments were statistically different from each other.

4.4.2.3 Peak Value (PV)

The highest peak value (2.62%) was found when the seeds of *M. chamomilla* were sown at the surface (T_0) ^{and} it was 2.09 per cent when sown at 0.5 cm depth (T_1). Although the peak value decreased to one third (0.98%) when seeds were sown at 1.0 cm depth (T_3) Table 11. The values obtained ^{for} amongst different treatments varied significantly from each other.

4.4.2.4 Germination Value (GV)

The perusal of data presented in Table 11 revealed that the maximum germination value (5.11%) was recorded in T_0 , which was followed by T_1 (3.41%) and the minimum GV was obtained in T_2 (0.85). All these values were statistically different from each other.

4.4.2.5 Germination Energy Index (GEI)

It is evident from Table 11 that the highest GEI (186.78%) was found in T_0 . It was followed by T_1 (144.48%) and minimum GEI value was observed in T_2 (69.13%). However, all these values differed significantly amongst different treatments.

4.4.2.6 Shoot length

The data presented in Table 11 showed that the maximum shoot length (1.56 cm) was recorded in T_1 , which was statistically different from all other treatments. At 1.0 cm depth (T_2) the lowest shoot length was observed (1.42 cm).

4.4.2.7 Root length

The maximum root length (7.18 cm) was recorded in T_1 , which was significantly different from other treatments. While the minimum root length (6.90 cm) was found in T_2 , which was at par with T_0 (6.98 cm).

4.4.2.8 Survival per cent

A look at the data depicted in Table 11 showed that the maximum survival (78.00%) was recorded in T_1 , which was at par with T_0 (77.50%), but significantly different from T_2 (66.25%).

4.4.3 *Rosmarinus officinalis* L.

The perusal of data in Table 12 showed that below 2.0 cm depth no germination occurred. ^{below 2.0 cm depth} In the light of this the results thus obtained are illustrated as under:

4.4.3.1 Germination per cent

The perusal of data presented in Table 12 revealed that the germination varied significantly amongst different treatments. The highest germination (48.43%) was registered in T_1 when seeds were sown at 0.5 cm depth. It was followed by T_2 (40.16%), T_3 (31.19%) and T_4 (15.08%). The minimum germination (5.09%) was recorded in T_0 (surface sowing).

4.4.3.2 Mean Daily Germination (MDG)

The perusal of data in Table 12 on MDG showed that the maximum MDG (1.56%) was recorded in T_1 , which was statistically at par with T_2 (1.30%). Minimum MDG (0.16%) was recorded when seeds were sown at surface (T_0).

Table 12. Effect of depth of sowing on seed germination of *Rosmarinus officinalis* L.

Treatments	Germination (%)	Mean daily germination (%)	Peak value (%)	Germination value (%)	Germination energy index (%)	Shoot length (cm)	Root length (cm)	Survival (%)
T ₀	5.09 (2.14)	0.16	0.68	0.11	20.76	9.39	2.52	45.11 (40.02)
T ₁	48.43 (40.36)	1.56	2.97	4.63	57.18	18.84	3.50	79.64 (62.12)
T ₂	40.16 (34.89)	1.30	1.92	2.50	50.86	15.64	3.38	69.84 (59.96)
T ₃	31.19 (27.59)	1.01	1.70	1.72	43.19	9.70	2.77	47.25 (40.98)
T ₄	15.08 (10.21)	0.49	0.72	0.35	35.18	4.28	2.42	30.14 (27.18)
T ₅	0.00 (0.00)	0.00	0.00	0.00	0.00	0.00	0.00	0.00 (0.00)
T ₆	0.00 (0.00)	0.00	0.00	0.00	0.00	0.00	0.00	0.00 (0.00)
CD _{0.05}	(2.10)	0.28	0.32	0.49	2.46	2.27	0.01	(4.08)

Figures in parentheses are arcsine transformed values

4.4.3.3 Peak Value (PV)

The data depicted in Table 12 showed that the highest PV (2.97%) was recorded in T_1 , which differed significantly from all other treatments. While minimum PV (0.68%) was recorded for surface sown seeds (T_0).

4.4.3.4 Germination Value (GV)

The maximum GV (4.63%) was registered in T_1 , which was statistically different from all other treatments. The minimum GV (0.11) was found in T_0 (surface sowing), which was at par with T_4 (2.0 cm sowing depth).

4.4.3.5 Germination Energy Index (GEI)

It is evident from Table 12 that the highest GEI (57.18%) was recorded in T_1 , which differed significantly from all other treatments, while the minimum GEI value (20.76%) was recorded when seeds were sown at surface (T_0).

4.4.3.6 Shoot length

The data presented in Table 12 showed that the maximum shoot length (18.84 cm) was found in T_1 followed by T_2 (15.64 cm). However, it differed significantly from all other treatments. The minimum shoot length (4.28 cm) was attained when seed were sown at 2.0 cm depth (T_4).

4.4.3.7 Root length

The data presented in Table 12 indicated that the maximum root length (3.50 cm) was recorded in T_1 followed by T_2 (3.38 cm). However, it differed statistically from all other treatments. The minimum root length (2.42 cm) was recorded at 2.0 cm sowing depth (T_4).

4.4.3.8 Survival per cent

A perusal of data in Table 12 revealed that the highest survival (79.64%) was recorded in T_1 (0.5 cm sowing depth) followed by T_2 (69.84%), which were statistically at par with each other. The minimum survival per cent (30.14%) was observed at 2.0 cm sowing depth (T_4).

4.5 STUDIES ON THE EFFECT OF DIFFERENT MULCHING MATERIALS ON SEED GERMINATION

The six mulches viz., T_0 (control, no mulch), T_1 (Dry grass), T_2 (black polythene sheet), T_3 (FYM), T_4 (Pine needles), T_5 (Wheat straw) were evaluated based upon their comparative effect on germination and growth of *S. sclarea*, *M. chamomilla* and *R. officinalis*. The data pertaining to germination and growth has been presented in Tables 13-15 and illustrated as under:

4.5.1 *Salvia sclarea* L.

4.5.1.1 Germination per cent

A critical look at Table 13 illustrated that the highest germination (60.50%) was recorded in T_1 , which was at par with T_3 (58.50%). The lowest germination (39.00%) was observed in control (T_0) and it was at par with T_4 (43.00%) and T_5 (41.50%).

4.5.1.2 Mean Daily Germination (MDG)

The appraisal of the data in Table 13 reflected that the highest MDG (1.95%) was found in T_1 , which was at par with T_3 (1.89%). Minimum value (1.26%) was recorded in control (T_0) when no mulch was spread over the beds and it was at par with T_5 (1.33%).

4.5.1.3 Peak Value (PV)

The data presented in Table 13 revealed that the maximum peak value (2.58%) was recorded in T_1 , which was statistically at par with T_3 (2.21%) and it was further at

Table 13. Effect of different mulching materials on seed germination of *Salvia sclarea* L.

Treatments	Germination (%)	Mean daily germination (%)	Peak value (%)	Germination value (%)	Germination energy index (%)	Shoot length (cm)	Root length (cm)	Survival (%)
T ₀	39.00 (38.63)	1.26	1.33	1.68	109.88	1.05	6.55	56.50 (48.28)
T ₁	60.50 (51.09)	1.95	2.58	5.03	189.78	2.00	8.70	78.00 (62.78)
T ₂	54.50 (47.61)	1.76	2.21	3.89	175.30	1.93	8.55	77.50 (62.58)
T ₃	58.50 (49.92)	1.89	2.17	4.10	185.19	2.05	8.90	78.50 (62.58)
T ₄	43.00 (40.80)	1.38	1.43	1.97	119.27	1.73	7.90	60.50 (50.67)
T ₅	41.50 (39.84)	1.33	1.42	1.89	118.79	1.60	6.95	60.00 (50.32)
CD _{0.05}	(4.08)	0.09	0.49	0.95	12.26	0.06	0.39	(3.08)

Figures in parentheses are arcsine transformed values

par with T_3 (2.17%). Again minimum peak value (1.33%) was observed ^{for} in the control (T_0), which was at par with T_4 (1.43%) and T_5 (1.42%).

4.5.1.4 Germination Value (GV)

A perusal of data presented in Tale 13 revealed that the highest GV was recorded in T_1 (5.03%) when dry grass was used ^{as} at mulch and it was at par with T_3 (4.10%), which was further at par with T_2 (3.89%). The lowest GV (1.68%) was recorded in control (T_0), which was at par with T_4 (1.97%) and T_5 (1.89%).

4.5.1.5 Germination Energy Index (GEI)

The data presented in Table 13 showed that the maximum GEI (189.78%) was found in T_1 and it was at par with T_3 (185.19%), which was further at par with T_2 (175.30%). The lowest GEI (109.88%) was recorded in T_0 , which was at par with T_4 (119.27%) and T_5 (118.79%).

4.5.1.6 Shoot length

The data in Table 13 illustrated that the maximum shoot length (2.05 cm) was recorded in T_3 , which was at par with T_1 (2.00 cm), but significantly different from all other treatments. It was followed by T_2 (1.93 cm), T_4 (1.73 cm) and T_5 (1.60 cm) and these were significantly different from each other. In control (T_0) again significantly low (1.05 cm) shoot length was recorded.

4.5.1.7 Root length

The appraisal of data in Table 13 revealed that the maximum root length (8.90 cm) was recorded in T_3 when FYM ^{was used as} mulch ~~was applied~~ which was at par with T_1 (8.70 cm) and T_2 (8.55 cm). While ~~The~~ lowest root length was found in T_0 (6.55 cm) which differed significantly from all other treatments.

4.5.1.8 Survival per cent

The maximum survival (78.50%) was registered in T_3 , which was statistically at par with T_1 (78.00%) and T_2 (77.50%). The survival per cent in T_4 (60.50%) was at par with T_5 (60.00%) and the lowest survival (56.50%) ^{To recording 1st} ~~was found in T_0~~ (Table 13).

4.5.2 *Matricaria chamomilla* L.

4.5.2.1 Germination per cent

A critical look at Table 14 illustrated that the highest germination (60.00%) was obtained in T_1 when dry grass was applied as mulch, which was at par with T_2 (58.00%) and T_3 (58.50%), but significantly different from all other treatments. It was followed by T_4 (42.50%) and T_5 (38.00%). The lowest germination (32.50%) was observed in T_0 .

4.5.2.2 Mean Daily Germination (MDG)

The appraisal of data in Table 14 reflected that the highest MDG value (1.93%) was found in T_1 followed by T_3 (1.89%) and T_2 (1.87%) and these were statistically at par with each other. Minimum MDG value (1.05%) was recorded in control (T_0), ^{and it} varied significantly from all other treatments.

4.5.2.3 Peak Value (PV)

Data depicted in Table 14 showed that the maximum peak value (2.65%) was recorded in T_1 , which was at par with T_2 (2.60%), but significantly different from all other treatment. The PV for T_4 (1.56%) was at par with T_5 (1.54%) and the minimum PV (1.31%) was recorded in control (T_0) when no mulch was applied over the beds.

4.5.2.4 Germination Value (GV)

A perusal of data presented in Table 14 revealed that the highest GV (5.11%) was recorded in T_1 , which was at par with T_2 (4.86%). It was followed by T_3 (4.18%) and T_4 (2.14%). The lowest GV (1.38%) was recorded in T_0 (control), which differed from all other treatments.

Table 14. Effect of different mulching materials on seed germination of *Matricaria chamomilla* L.

Treatments	Germination (%)	Mean daily germination (%)	Peak value (%)	Germination value (%)	Germination energy index (%)	Shoot length (cm)	Root length (cm)	Survival (%)
T ₀	32.50 (34.75)	1.05	1.31	1.38	88.89	0.85	6.80	47.50 (32.29)
T ₁	60.00 (50.78)	1.93	2.65	5.11	181.48	1.26	7.45	78.75 (61.37)
T ₂	58.00 (49.61)	1.87	2.60	4.86	155.56	1.25	7.35	77.50 (61.23)
T ₃	58.50 (49.72)	1.89	2.21	4.18	164.57	1.45	7.48	78.75 (61.37)
T ₄	42.50 (40.34)	1.37	1.56	2.14	121.16	1.10	6.95	64.25 (59.09)
T ₅	38.00 (37.87)	1.22	1.54	1.88	117.28	1.05	6.98	60.75 (56.08)
CD _{0.05}	(2.41)	0.08	0.16	0.29	13.96	0.05	0.18	(1.03)

Figures in parentheses are arcsine transformed values

4.5.2.5 Germination Energy Index (GEI)

A critical look in Table 14 showed that the maximum GEI value (181.48%) was found in T_6 , which varied significantly from all other treatments. It was followed by T_3 (164.57%), which was at par with T_2 (155.56%). The GEI value for T_4 (121.16%) was at par with T_5 (117.28%) and the lowest GEI (88.89%) was recorded in T_0 (control).

4.5.2.6 Shoot length

The maximum shoot length (1.45 cm) was recorded in T_3 when FYM was applied, which differed significantly from all other treatments (Table 14). It was followed by T_1 (1.26), which was at par with T_2 (1.25 cm). Shoot length in T_4 (1.10 cm) was at par with T_5 (1.05 cm). Minimum shoot length (0.85 cm) occurred when no mulch was applied (T_0).

4.5.2.7 Root length

The data presented in Table 14 revealed that the maximum root length (7.48 cm) was registered in T_3 , which was at par with T_1 (7.45 cm) and T_2 (7.35 cm). Minimum root length (6.80 cm) was recorded in control where no mulch was applied and it was at par with T_4 (6.95 cm) and T_5 (6.98 cm).

4.5.2.8 Survival per cent

The perusal of data presented in Table 14 indicated that the maximum survival (78.75%) was recorded in T_1 and T_3 , which was at par with T_2 (77.50%). The minimum survival (47.50%) was recorded in control (T_0) when no mulch was applied and it varied significantly from all other treatments.

4.5.3 *Rosmarinus officinalis* L.

4.5.3.1 Germination per cent

A critical look at Table 15 illustrated that the highest germination (48.54%) was recorded when black polythene sheet was used as mulching material (T_2), which was at

Table 15. Effect of different mulching materials on seed germination of *Rosmarinus officinalis* L.

Treatments	Germination (%)	Mean daily germination (%)	Peak value (%)	Germination value (%)	Germination energy index (%)	Shoot length (cm)	Root length (cm)	Survival (%)
T ₀	15.21 (11.83)	0.49	0.89	0.44	45.21	11.24	2.94	54.14 (46.86)
T ₁	27.91 (20.48)	0.90	1.59	1.43	54.78	17.80	3.46	68.23 (65.12)
T ₂	48.54 (33.25)	1.57	3.95	6.20	62.14	19.42	4.37	82.10 (70.23)
T ₃	39.82 (31.29)	1.28	3.12	3.99	60.45	17.85	3.98	78.18 (72.29)
T ₄	18.45 (12.19)	0.60	1.67	1.00	32.16	14.31	3.00	59.64 (51.89)
T ₅	22.68 (17.46)	0.73	1.75	1.28	34.06	13.85	2.96	60.25 (51.97)
CD _{0.05}	(2.91)	0.18	0.22	0.52	2.91	1.34	0.19	(2.48)

Figures in parentheses are arcsine transformed values

par with T_3 (39.82%). The lowest germination (15.21%) was recorded in T_0 (control), which was statistically at par with T_4 (18.45%).

4.5.3.2 Mean Daily Germination (MDG)

The appraisal of the data in Table 15 reflected that the maximum MDG (1.57%) was observed when black polythene sheet was used as mulching material (T_2), which differed significantly from all other treatments. The minimum MDG (0.49%) was recorded in T_0 (control) which was at par with T_4 (0.60%).

4.5.3.3 Peak Value (PV)

The data presented in Table 15 revealed that the maximum PV (3.95%) was recorded when black polythene sheet was used as mulching material (T_2), which was statistically different from all other treatments. The minimum PV (0.89%) was recorded in T_0 (control).

4.5.3.4 Germination Value (GV)

A perusal of data in Table 15 revealed that the highest GV was recorded in T_2 (6.20%), which was statistically different from all other treatments. However, T_1 (1.43%), T_4 (1.00%) and T_5 (1.28%) were statistically at par with each other. The minimum GV was registered in T_0 (0.44%).

4.5.3.5 Germination Energy Index (GEI)

The data presented in Table 15 showed that the maximum GEI (62.14%) was recorded in T_2 , which was statistically at par with T_3 (60.45%), while the minimum GEI (32.16%) was recorded in T_4 , which was at par with T_5 (34.06%).

4.5.3.6 Shoot length

A perusal of data in Table 15 revealed that the maximum shoot length (19.42 cm) was recorded when black polythene sheet was used as mulching material (T_2). It was followed by T_3 (17.85 cm) and T_1 (17.80 cm), which were statistically at par with

each other. Similarly, the shoot length for T_4 (14.31 cm) and T_5 (13.85 cm) were at par with each other. The minimum shoot length (11.24 cm) was recorded in T_0 (control).

4.5.3.7 Root length

The appraisal of data in Table 15 revealed that the maximum root length (4.37 cm) was recorded when black polythene sheet was used as mulching material (T_2), which was statistically different from all other treatments. The minimum root length (2.94 cm) was recorded in control (T_0), which was at par with T_4 (3.00 cm) and T_5 (2.96 cm).

4.5.3.8 Survival per cent

A critical look in Table 15 showed that the maximum survival (82.10%) was found when black polythene sheet was used as mulching material (T_2), which was at par with T_3 (78.18%). The survival in T_4 (59.64%) and T_5 (60.25%) were statistically at par with each other and the lowest survival (54.14%) was recorded in control (T_0).

4.6 STUDIES ON THE EFFECT OF SEED RATES ON GROWTH AND YIELD

The eight seed rates viz., T_1 (0.5 kg/ha), T_2 (1.0 kg/ha), T_3 (1.5 kg/ha), T_4 (2.0 kg/ha), T_5 (2.5 kg/ha), T_6 (3.0 kg/ha), T_7 (3.5 kg/ha) and T_8 (4.0 kg/ha) were evaluated based upon their comparative effect on growth and yield of *S. sclarea*, *M. chamomilla* and *R. officinalis*. The results thus obtained are illustrated as under:

4.6.1 *Salvia sclarea* L.

4.6.1.1 Plant height

From the perusal of data in Table 16 it can be concluded that the maximum plant height (91.85 cm) was recorded in T_8 when seed rate was kept 4.00 kg/ha and it was statistically at par with T_3 (85.42 cm), T_4 (88.08 cm), T_5 (90.83 cm), T_6 (91.75 cm) and T_7 (91.80 cm). The lowest plant height (61.75 cm) was recorded at 0.5 kg/ha seed rate (T_1).

Table 16. Effect of seed rates on growth and yield of *Salvia sclarea* L.

Treatments	Plant height (cm)	Flowering shoot yield (q/ha)	Oil content (%)	Oil yield (kg/ha)
T ₁	61.75	13.25	0.70	9.28
T ₂	83.08	24.05	0.71	17.08
T ₃	85.42	35.17	0.74	26.03
T ₄	88.08	43.87	0.74	32.46
T ₅	90.83	50.12	0.78	39.09
T ₆	91.75	60.24	0.82	49.40
T ₇	91.80	68.26	0.84	57.34
T ₈	91.85	69.57	0.84	58.44
CD _{0.05}	7.28	3.86	0.02	2.89

4.6.1.2 Flowering shoot yield

The appraisal of data in Table 16 reflected that the flowering shoot yield was maximum (69.57 q/ha) at 4.0 kg/ha seed rate (T_8) and it was statistically at par with T_7 (68.26 q/ha). The minimum flowering shoot yield (13.25 q/ha) was found in T_1 .

4.6.1.3 Oil content

A critical look at Table 16 revealed that the maximum oil content (0.84%) was recorded in T_7 and T_8 which was at par with T_6 (0.82%). However, T_3 and T_4 were also statistically at par with each other. The minimum oil content (0.70%) was recorded in T_1 and it was statistically at par with T_2 (0.71%).

4.6.1.4 Oil yield

A perusal of data in Table 16 showed that the maximum oil yield (58.44 kg/ha) was recorded in T_8 , which was statistically at par with T_7 (57.34 kg/ha), while the minimum oil yield (9.28 kg/ha) was recorded in T_1 . However, the oil yield amongst other treatments varied significantly.

4.6.2 *Matricaria chamomilla* L.

4.6.2.1 Plant height

From the data presented in Table 17, it can be concluded that maximum plant height (41.33 cm) was recorded in T_8 , which was statistically at par with T_7 (41.12 cm) and T_6 (40.86 cm). It was followed by T_3 (38.75 cm), T_4 (36.33 cm), T_3 (34.17 cm) and T_2 (30.25 cm), which were significantly different from each other. The minimum plant height (29.10 cm) was obtained in T_1 .

4.6.2.2 Number of branches per plant

The perusal of data presented in Table 17 showed that the maximum number of branches per plant (14.17) were found when seed rate was kept 0.5 kg/ha (T_1) and it

Table 17. Effect of seed rates on growth and yield of *Matricaria chamomilla* L.

Treatments	Plant height (cm)	No. of branches/plant	Flower yield (q/ha)	Oil content (%)	Oil yield (kg/ha)
T ₁	29.10	14.17	6.37	0.42	2.68
T ₂	30.25	13.25	8.92	0.48	4.28
T ₃	34.17	11.08	8.18	0.48	3.93
T ₄	36.33	10.98	7.18	0.50	3.59
T ₅	38.75	7.05	6.05	0.51	3.09
T ₆	40.86	4.12	5.65	0.51	2.88
T ₇	41.12	3.75	4.25	0.54	2.30
T ₈	41.33	2.08	3.85	0.54	2.08
CD _{0.05}	0.80	0.19	0.14	0.02	0.27

Table 18. Effect of seed rates on growth and yield of *Rosmarinus officinalis* L.

Treatments	Plant height (cm)	No of branches/plant	Leaf yield (q/ha)	Oil content (%)	Oil yield (kg/ha)
T ₁	29.64	28.92	35.21	0.92	32.39
T ₂	34.28	28.14	44.63	0.96	42.84
T ₃	41.19	26.16	59.27	0.96	56.90
T ₄	48.50	23.43	64.15	0.97	62.23
T ₅	53.17	22.78	68.75	1.02	70.13
T ₆	54.15	21.86	72.18	1.03	74.35
T ₇	60.65	21.82	75.95	1.08	82.03
T ₈	61.15	18.02	74.92	1.08	80.91
CD _{0.05}	3.15	2.13	3.09	0.04	3.29

varied significantly from all other treatments. It was followed by T_2 (13.25), T_3 (11.08) and T_5 (7.05). The minimum number of branches per plant (2.08) were found in T_8 .

4.6.2.3 Flower yield

The appraisal of data from Table 17 reflected that the flower yield varied significantly among all the treatments. The maximum flower yield (8.92 q/ha) was recorded in T_2 followed by T_3 (8.18 q/ha), T_4 (7.18 q/ha) and T_1 (6.37 q/ha). The minimum flower yield (3.85 q/ha) was found in T_8 .

4.6.2.4 Oil content

Maximum oil content (0.54%) was recorded in T_7 and T_8 (Table 17) which was statistically different from all other treatments. While, the oil content in T_4 (0.50%) was found at par with T_5 (0.51%) and T_6 (0.51%). Similarly, oil content in T_2 (0.48%), T_3 (0.48%) and T_4 (0.50%) were at par with each other. The minimum oil content (0.42%) was recorded in T_1 .

4.6.2.5 Oil yield

The perusal of data presented in Table 17 revealed that the maximum oil yield (4.28 kg/ha) was recorded in T_2 and it was followed by T_3 (3.93 kg/ha), T_4 (3.59 kg/ha) and T_5 (3.09 kg/ha). However, these values were found statistically different from each other. The minimum oil yield (2.08 kg/ha) was obtained in T_8 , which was statistically at par with T_7 (2.30 kg/ha).

4.6.3 *Rosmarinus officinalis* L.

4.6.3.1 Plant height

The data presented in Table 18 indicated that the maximum plant height (61.15 cm) was recorded when seed rate was 4.0 kg/ha (T_8) which was statistically at par with T_7 (60.65 cm). The values for T_5 (53.17 cm) and T_6 (54.15 cm) were also at par with each other. The minimum plant height (29.64 cm) was recorded in T_1 .

4.6.3.2 Number of branches per plant

The appraisal of data in Table 18 showed that the maximum number of branches per plant (28.92) were found at 0.5 kg/ha seed rate (T_1) which was statistically at par with T_2 (28.14) but significantly different from all other treatments. The number of branches per plant in T_4 (23.43) were at par with T_5 (22.78), T_6 (21.86) and T_7 (21.82). The minimum number of branches per plant were recorded in T_8 (18.02).

4.6.3.3 Leaf yield

From the perusal of data presented in Table 18 it can be concluded that maximum leaf yield (75.95 q/ha) was obtained when the seed rate was 3.50 kg/ha (T_1) and it was statistically at par with T_8 (74.92 q/ha). It was followed by T_6 (72.18 q/ha), T_5 (68.75 q/ha) and T_4 (64.15 q/ha) and the minimum leaf yield (35.21 q/ha) was recorded in T_7 .

4.6.3.4 Oil content

From the data presented in Table 18, it was found that the maximum oil content (1.08%) per cent was recorded in T_7 and T_8 . It was followed by T_6 (1.03%) and T_5 (1.02%) which were at par with each other. The minimum oil content (0.92%) was recorded in T_1 .

4.6.3.5 Oil yield

A perusal of data from Table 18 showed that the maximum oil yield (82.03 kg/ha) was found when seed rate was kept 3.50 kg/ha (T_1) and it was statistically at par with T_8 (80.91 kg/ha). The oil yield amongst other treatments varied significantly and the minimum oil yield (32.39 kg/ha) was recorded in T_7 .

DISCUSSION

The results obtained during the study are summarized in the following tables and figures and lead to the following conclusions:

1. Effect of processing and treatment on the production of methane.
2. Effect of the effect of a single period of feed presentation.
3. Effect of the effect of a single period of feed presentation.
4. Effect of depth of feeding on feed intake.
5. Effect of the effect of a single period of feed presentation.
6. Effect of the effect of a single period of feed presentation.

1.1.1. EFFECT OF PRE-HEATING OF TREATMENTS ON THE PRODUCTION OF METHANE

DISCUSSION

The results of the study are summarized in the following tables and figures and lead to the following conclusions:

The results of the study are summarized in the following tables and figures and lead to the following conclusions:

Chapter 5

DISCUSSION

The results obtained during the present investigations entitled, "Studies on seed germination and seed rate of some aromatic plants" are discussed under the following heading:

- 5.1 Effect of pre-sowing seed treatments on seed germination
- 5.2 Studies on the effect of storage period on seed germination
- 5.3 Studies on the effect of storage containers on seed germination
- 5.4 Effect of depth of sowing on seed germination
- 5.5 Studies on the effect of different mulching materials on seed germination
- 5.6 Studies on the effect of seed rates on growth and yield

5.1 EFFECT OF PRE-SOWING SEED TREATMENTS ON SEED GERMINATION

The results presented in Table 1, 2, 3 (Figs. 1, 2, 3) revealed that under laboratory conditions, maximum germination of 80.00 and 73.33 per cent was recorded in *S. sclarea* and *M. chamomilla*, respectively when the seeds were soaked in 200 mg/l GA_3 solution for two hours. In *R. officinalis* the maximum germination (59.33%) occurred when the seeds were immersed in 2.0 per cent HCl for 10 minutes and then washed thoroughly with tap water. Whereas, the seeds of this crop when soaked in 200 mg/l GA_3 for two hours gave 47.14 per cent germination which was, however, significantly higher than the control (16.81%). Although, the germination per cent in the seeds of all the three crops treated with 100 mg/l or 200 mg/l of GA_3 for two hours was statistically at par with each other.

The increase in germination per cent due to application of GA_3 can be ascribed due to the fact that GA_3 not only break the dormancy but also increased the amino acid content in the embryo when the seeds renew growth at germination. Similar results has

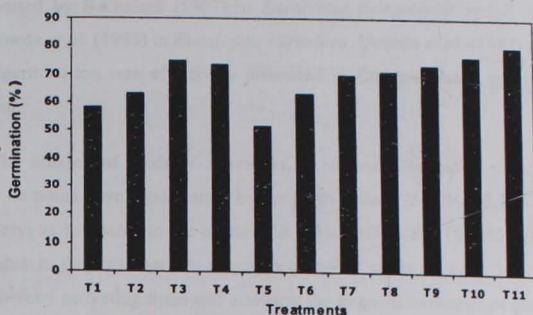


Fig. 1. Effect of pre-sowing seed treatments on seed germination of *Salvia sclarea* L.

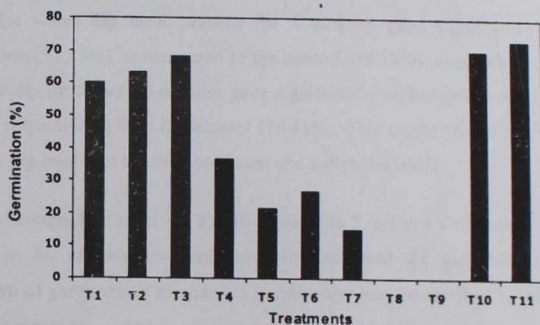


Fig. 2. Effect of pre-sowing seed treatments on seed germination of *Matricaria chamomilla* L.

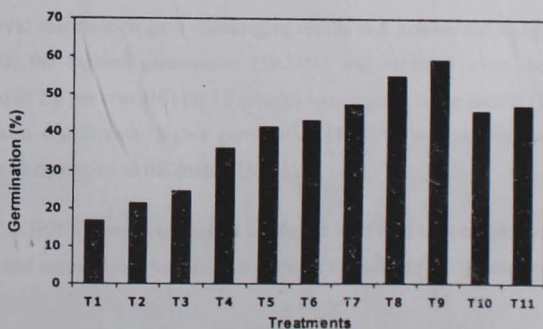


Fig. 3. Effect of pre-sowing seed treatments on seed germination of *Rosmarinus officinalis* L.

been reported by Bachelard (1967) in *Eucalyptus delegatensis* and *E. regnans*, and Rudre Gowda *et al.* (1993) in *Eucalyptus citriodora*. Yoneda *et al.* (1992) also observed that the germination was effectively promoted in *Gentiana lutea* when treated with gibberellin.

The soaking of seeds of *S. sclarea*, *M. chamomilla* and *R. officinalis* in cold water for 48 hours gave significantly higher germination (75.00%, 68.33% and 24.58%, respectively) as compared to the control (58.33%, 60.00% and 16.81%, respectively). It may be due to the fact that pre-sowing soaking of seeds in water hydrates the seed tissues, thereby activating them and allowing the frequent exchange of gases leading to germination. Kemp (1975) reported that seeds, which had little resistance to germination may respond well to soaking in water at ambient temperature.

Hot water dip in *S. sclarea* for 5 minutes gave significantly higher seed germination (73.33%) as compared to the control (58.33%). Similarly, in *R. officinalis* hot water dip for 5 and 10 minutes gave significantly higher germination (35.92% and 41.64%, respectively) than the control (16.81%). This might be due to the reason that hot water dip modified the hard seed coat and soften the seeds.

Although, hot water dip for 10 minutes in *S. sclarea* seeds and 5 as well as 10 minutes in *M. chamomilla* seeds severely paralysed the germination. The severe breakdown of germination mechanism in hot water may be ascribed to the lethal action of boiling water on enzyme activity responsible for initiation of germination in seeds. Similar results were also reported by Nagaveni and Srimathi (1981) in sandal seeds.

Acid scarification gave encouraging results in *S. sclarea* and *R. officinalis*. In *R. officinalis*, the highest germination (59.33%) was recorded when the seeds were immersed in 2.0 per cent HCl for 10 minutes as compared to the control (16.81%). In *S. sclarea* also significantly higher germination (73.33%) was obtained with the same treatment as compared to the control (58.33%).

The HCl treatment seemed to soften the hard seed coat causing uniform inflow of water and unrestricted expansion of embryo. Bachelard (1967) observed the increase

in germination percentage in *Eucalyptus* spp. with acid treatment. Singh and Srivastava (1990) observed 40.00 per cent germination in lavender seeds when treated with 1.0 per cent HCl for 12 hours. However, HCl treatment in *M. chamomilla* paralysed the germination and there was no germination when 1.5 per cent and 2.0 per cent HCl treatment was given for 10 minutes which indicated that the acid treatment was toxic to the minute seeds of *M. chamomilla*. From this, it can be concluded that seeds of *M. chamomilla* did not require pre-sowing acid treatment as it paralysed the germination.

5.2 STUDIES ON THE EFFECT OF STORAGE PERIOD ON SEED GERMINATION

The seeds were tested at an interval of three months for their germination parameters under laboratory conditions for two years. The results presented in Table 4 and Fig. 4 revealed that maximum germination (68.67%) in *S. sclarea* was recorded when the seeds were sown immediately after harvesting and it was at par with the germination (62.66%) obtained after three months storage period.

The results obtained in *S. sclarea* indicated that germination per cent decreased with the progressive increase in storage period and only 13.33 per cent germination was recorded after storage period of 15 months. Thereafter no germination occurred.

Although, in *M. chamomilla* the maximum germination (63.33%) was recorded when the seeds were sown after three months which was significantly higher than all other treatments (Table 5 and Fig. 5). Afterward the germination decreased with progressive increase in storage period and only 18.33 per cent germination was recorded in the seeds stored for 18 months and no germination was obtained in the seeds stored for 21 and 24 months.

In *R. officinalis*, seeds showed maximum germination (49.84%) (Table 6 and Fig. 6) after the storage period of six months which decreased with progressive increase in the storage period and only 2.56 per cent germination was obtained after a storage period of 24 months. The same trend was also observed in other germination parameters.

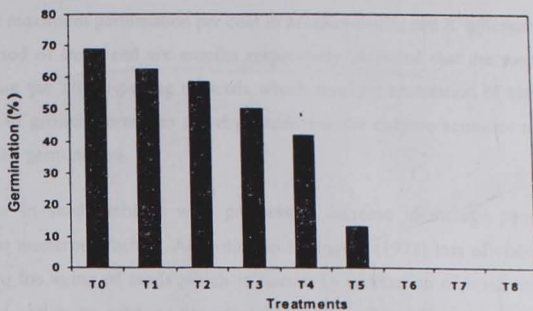


Fig. 4. Effect of storage period on seed germination of *Salvia sclarea* L.

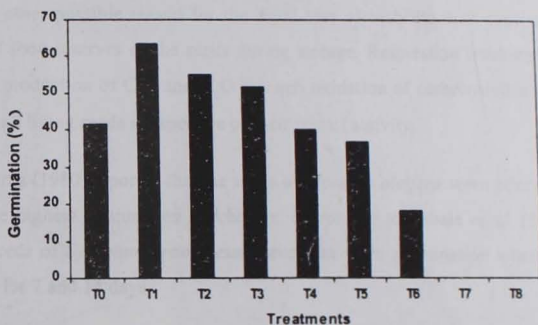


Fig. 5. Effect of storage period on seed germination of *Matricaria chamomilla* L.

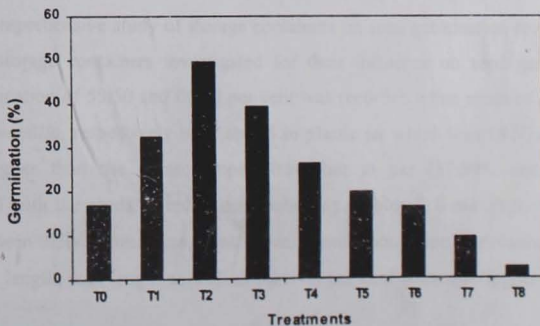


Fig. 6. Effect of storage period on seed germination of *Rosmarinus officinalis* L.

The maximum germination per cent in *M. chamomilla* and *R. officinalis* after the storage period of three and six months respectively indicated that the seeds of these crops require the after ripening of seeds, which result in maturation of seed embryo, production of growth hormones thereby improving the enzyme activities required for triggering the germination.

Loss in seed viability with progressive increase in storage period can be attributed to numerous factors. According to Harington (1973) loss of viability can be attributed to the aging of seeds, which is caused by production of toxic end products. The loss of ability to produce the plant hormones, gibberellic acid, phytotoxin and ethylene necessary for triggering germination is the other cause of aging of seeds.

The other possible reason for the rapid loss of viability with time can be the depletion of food reserves of the seeds during storage. Respiration resulting in energy release and production of CO_2 and H_2O through oxidation of carbohydrates and fats is common to all living seeds irrespective of their rate of activity.

Sharma (1980) reported that the seeds of *Moringa oleifera* sown after one month storage gave highest germination percentage. According to Sabale *et al.* (1992) fresh harvested seeds of *Syzygium aromaticum* gave maximum germination when the seeds were stored for 7 and 14 days.

5.3 STUDIES ON THE EFFECT OF STORAGE CONTAINERS ON SEED GERMINATION

A comprehensive study of storage containers on seed germination revealed that out of six storage containers investigated for their influence on seed germination, higher germination of 59.50 and 60.50 per cent was recorded when seeds of *S. sclarea* and *M. chamomilla*, respectively were stored in plastic jar which was 18.50 and 20.50 per cent higher than the control (open tray) but at par (57.50% and 59.50%, respectively) with the seeds stored in polythene bag (Tables 7, 8 and Figs. 7, 8). The results for mean daily germination, peak value, germination value, germination energy index, shoot length, root length as well as survival per cent were also higher when the

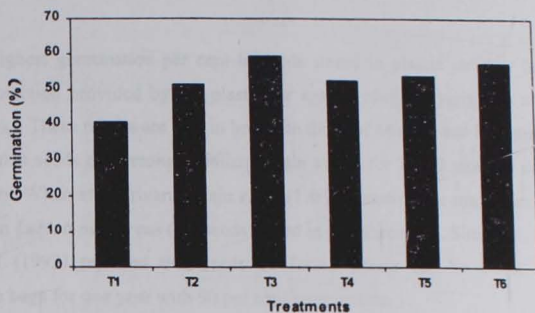


Fig. 7. Effect of storage containers on seed germination of *Salvia sclarea* L.

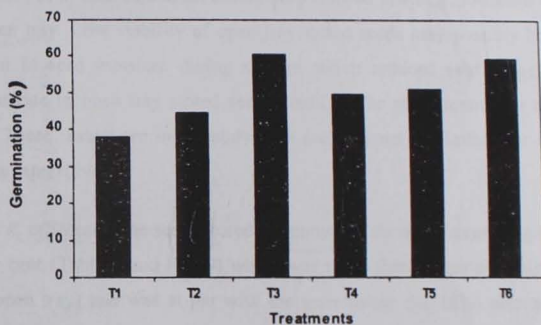


Fig. 8. Effect of storage containers on seed germination of *Matricaria chamomilla* L.

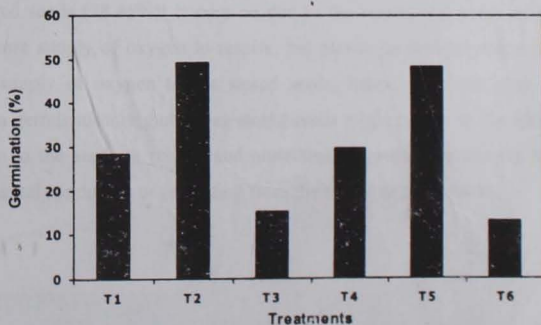


Fig. 9. Effect of storage containers on seed germination of *Rosmarinus officinalis* L.

seeds of both the crops were stored in the plastic jar and were at par with the polythene bag.

Highest germination per cent in seeds stored in plastic jar may be due to the better protection provided by the plastic jar against climatic variations and fungal or pest attacks. These results are also in line with those of Murthy and Krishna (1973) who reported that seeds of *Tectona grandis* remain viable for 2 to 3 years in dry storage in plastic jars. Whereas, Karivaratharaju *et al.* (1989) observed the maximum germination per cent in *Lablab purpureus* (L.) seeds stored in polythene bag. Similarly, Nautiyal and Thapliyal (1993) reported that seeds of *Toona ciliata* can be stored at 5-8°C in polythene bags for one year with 90 per cent germination.

Seeds of *S. sclarea* and *M. chamomilla* showed lowest germination when stored in the open tray. Low viability of open tray stored seeds may possibly be due to the fluctuation in seed moisture during storage which reduced seed longevity. Higher respiration rate in open tray stored seeds could be the other reason for rapid loss of viability. These results are in harmony with the findings of Maithani *et al.* (1987) in *Holoptelia integrifolia*.

In *R. officinalis*, the seeds stored in gunny bag showed maximum germination of 49.33 per cent (Table 9 and Fig. 9) which was more than 20 per cent higher than the control (open tray) and was at par with the germination (48.16%) obtained when the seeds were stored in cloth bag. The seeds stored in plastic jar as well as in polythene bag showed very poor germination (15.18% and 12.98%, respectively) in comparison to open stored seeds (28.46%). It may be due to the reason that seeds of *R. officinalis* require more supply of oxygen to respire, but plastic jar and polythene bag restricted frequent supply of oxygen to the stored seeds, hence, gave the poor germination. Maximum germination in gunny bag stored seeds might be due to the optimum supply of oxygen to the seeds to respire and protection of seeds from adverse or fluctuating environmental conditions or protection from the fungal or pest attacks.

Maithani *et al.* (1989) also found that seeds of *Azadirachta indica* stored in sealed containers at low temperature lost the germination capacity in 1-4 months while the use of aerated container at room temperature inhibited deterioration of seeds.

5.4 EFFECT OF DEPTH OF SOWING ON SEED GERMINATION

The seeds of *S. sclarea* and *R. officinalis* when sown at 0.5 cm depth gave maximum germination of 60.50 and 48.43 per cent, respectively. While in *M. chamomilla* the surface sown seeds showed maximum germination of 60.50 per cent (Tables 10-12 and Figs. 10-12). In *S. sclarea* and *R. officinalis* no germination occurred when the seeds were sown below 2.0 cm depth, whereas in *M. chamomilla* no germination was obtained below 1.0 cm depth.

The results revealed that shallow as well as deep sowing greatly reduced the germination. It might be the reason for low germination in *S. sclarea* and *R. officinalis* when the surface sowing was done. In deep sowing, the radical of seedlings remain embedded too deep and are not able to emerge out, hence no germination occurred below 2.0 cm sowing depth in *S. sclarea* and *R. officinalis* and below 1.0 cm in *M. chamomilla*. These results are in conformity with the findings of Hartmann and Kester (1976).

According to Singh (1977) the seed germination was more in superficial than from the covered sowing in *M. chamomilla*. The present investigations are congruous to those reported by Hildebrandt and Schulz (1987) who found that on an average, more herbs emerged from soil covered seeds than from surface sown seeds but the species with low thousand seed weight (*Alchillea millefolium*, *Companula glomerata*) did better with surface sowing. Similarly, Fonseca *et al.* (1994) reported that *Dipteryx alata* seeds should be sown at a depth of 1-3 cm and for *Hancornia speciosa* surface sowing was recommended so as to get optimum germination. Further Letchamo and Gosselin (1996) advocated that if faster, uniform emergence and plant establishment is desired, dandelion (*Taraxacum officinale*) seeds should not be sown more than 1.0 cm deep.

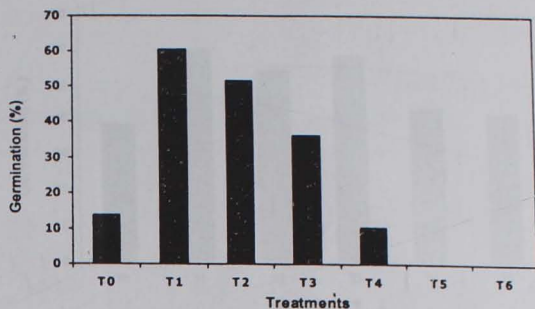


Fig. 10. Effect of depth of sowing on seed germination of *Salvia sclarea* L.

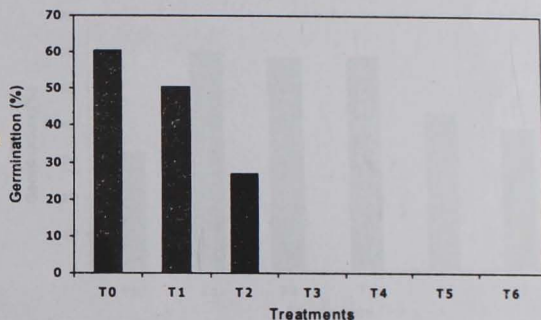


Fig. 11. Effect of depth of sowing on seed germination of *Matricaria chamomilla* L.

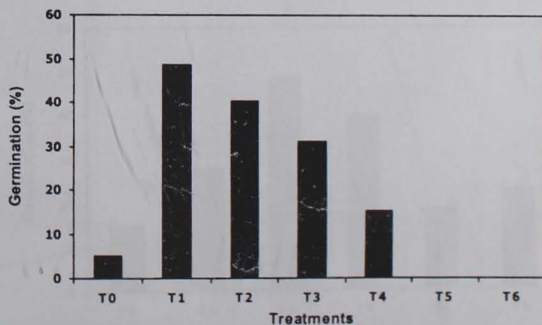


Fig. 12. Effect of depth of sowing on seed germination of *Rosmarinus officinalis* L.

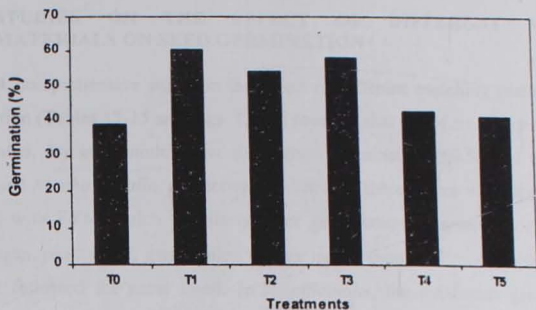


Fig. 13. Effect of different mulching materials on seed germination of *Salvia sclarea* L.

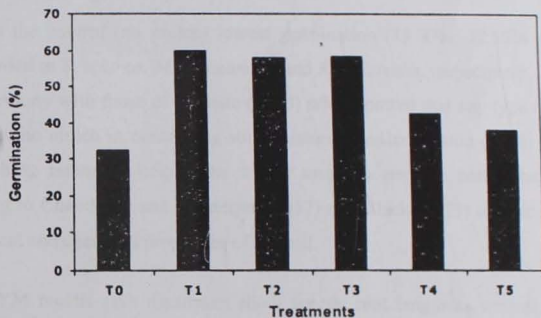


Fig. 14. Effect of different mulching materials on seed germination of *Matricaria chamomilla* L.

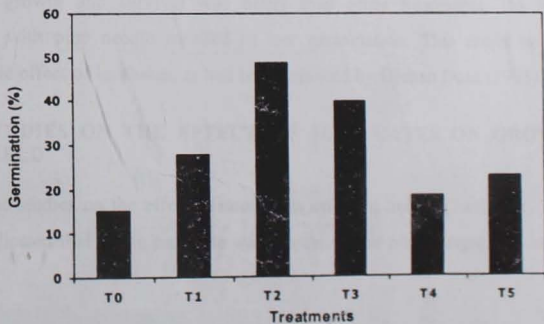


Fig. 15. Effect of different mulching materials on seed germination of *Rosmarinus officinalis* L.

5.5 STUDIES ON THE EFFECT OF DIFFERENT MULCHING MATERIALS ON SEED GERMINATION

A comprehensive study on the effect of different mulching materials on seed germination (Tables 13-15 and Figs. 13-15) revealed that out of six mulching treatments investigated, dry grass mulch gave the highest germination (60.50 and 60.00%) in *S. sclarea* and *M. chamomilla*, respectively. Although, these values were at par with those obtained with FYM mulch. Similarly other germination parameters viz., mean daily germination, peak value, germination energy index, shoot and root length and survival per cent followed the same trend. In *R. officinalis*, the maximum germination was recorded when nursery beds were covered with black polythene sheet mulch (48.54%) followed by FYM mulch (39.82%).

In the control (no mulch) lowest germination (39.00%, 32.50% and 15.21%) was recorded in *S. sclarea*, *M. chamomilla* and *R. officinalis*, respectively. These results are in harmony with those of Othieno (1980) who reported that any type of mulch was better than no mulch in conserving soil moisture. Similarly, Attia (1970) reported that the mulching treatment helped the winter crops to perform better than no mulch. According to Chaudhary and Chatterjee (1967) and Black (1973) organic mulch effect the physical and chemical properties of the soil.

FYM mulch gave maximum shoot length, root length as well as survival per cent in all the three crops. This can be attributed to the fact that FYM mulching acted as rich source of nutrients, may had provided good aeration and due to high water holding capacity, growth and survival was better than other treatments. On the contrary mulching with pine needle resulted in low germination. This could be imputed to allelopathic effect of leachates, as had been reported by Bishan Dass (1995).

5.6 STUDIES ON THE EFFECT OF SEED RATES ON GROWTH AND YIELD

The studies on the effect of seed rates on plant height (Tables 16-18 and Figs. 16-18) indicated that as the seed rate was increased, the plant height also increased and

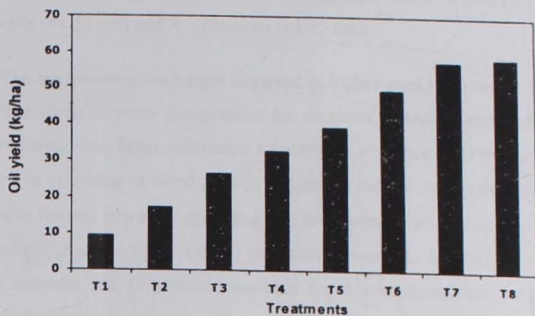


Fig. 16. Effect of seed rates on oil yield of *Salvia sclarea* L.

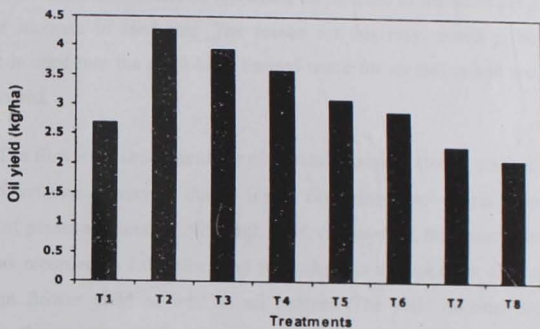


Fig. 17. Effect of seed rates on oil yield of *Matricaria chamomilla* L.

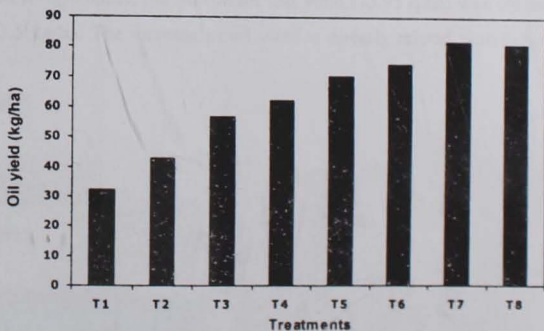


Fig. 18. Effect of seed rates on oil yield of *Rosmarinus officinalis* L.

the maximum plant height was attained at 4.0 kg seed rate in *S. sclarea* (91.85 cm), *M. chamomilla* (41.33 cm) and *R. officinalis* (61.15 cm).

The maximum plant height observed at higher seed rate may be assigned to the reason that there is more competition for nutrients, moisture and light between the plants, resulting into faster utilization of nutrients available from the small areas. This also helps in checking of weed growth and makes more nutrients available to the crop. Plants have limited space for spreading and are forced to attain more height in order to have sunlight. Jha and Singh (1979) in *Mentha spicata* L. and Balyan *et al.* (1987) in *Ocimum cannum* and *O. americanum* also found maximum plant height by keeping closer spacing between rows.

In *M. chamomilla* and *R. officinalis* the number of branches per plant decreased with the increase in seed rate. The reason for this may, possibly, be that with the increase in seed rate the plant have limited space for spreading and are thus forced to grow upward.

The flowering shoot yield per plant was maximum (69.57 q/ha) at 4.0 kg/ha seed rate in *S. sclarea*. It may be due to longer flowering shoot length coupled with more number of plants per hectare. Although in *M. chamomilla*, maximum flower yield (8.92 q/ha) was recorded at 1.0 kg/ha seed rate, which is the optimum seed rate for getting maximum flower yield as well as oil content. The yield declined thereafter and a minimum flower yield (3.85 q/ha) was attained at the seed rate of 4.0 kg/ha.

In *R. officinalis*, the maximum leaf yield (75.95 q/ha) was obtained at the seed rate of 3.5 kg/ha. The increase in oil yield is directly related with the increase in leaf yield.

Chapter 9

SUMMARY

The present investigation is a study of the effect of the treatment of the seeds of the laboratory and agricultural seeds of the laboratory of seeds. In the laboratory and agricultural seeds of the laboratory of seeds. In the laboratory and agricultural seeds of the laboratory of seeds. In the laboratory and agricultural seeds of the laboratory of seeds.

1.1 EFFECT OF PRE-TREATMENT OF SEEDS ON SEED GERMINATION

1.1.1 Summary of results

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1.1.2 Summary of results

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1.1.3 Summary of results

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Chapter 6

SUMMARY

The present investigations entitled "Studies on seed germination and seed rate of some aromatic plants" were carried out during the years 1998-1999 and 1999- 2000 in the laboratory and experimental area of the department of Forest Products, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni-Solan 173 230 (HP). The results obtained are summarized below:

6.1 EFFECT OF PRE-SOWING SEED TREATMENTS ON SEED GERMINATION

6.1.1 *Salvia sclarea* L.

Seed germination in *S. sclarea* enhanced from 58.33% in control to 80.00% in 200 mg/l GA₃ treated seeds, which was closely followed by 100 mg/l GA₃ (76.67%). On the other hand mean daily germination as well as germination energy index also increased significantly at this concentration. Although the minimum germination (51.67%) was recorded when the seeds were immersed in boiling water for 10 minutes.

6.1.2 *Matricaria chamomilla* L.

There was enhancement of seed germination from 60.00% in control to 73.33% in 200 mg/l GA₃ treated seeds. At this concentration significantly higher values were also obtained for all other germination parameters viz., mean daily germination, peak value, germination value and germination energy index. Although no germination was recorded when seeds were treated with 1.5% HCl and 2.0 HCl for 10 minutes.

6.1.3 *Rosmarinus officinalis* L.

In this plant, the maximum seed germination (59.33%) occurred when seeds were treated with 2.0 per cent HCl for 10 minutes followed by 1.5 per cent HCl

(54.91%) for 10 minutes whereas, in control only 16.81% germination was recorded. The growth parameters also followed the same trend.

6.2 EFFECT OF STORAGE PERIOD ON SEED GERMINATION

In this experiment the seed germination studies were undertaken immediately after harvesting, after a storage period of 3, 6, 9, 12, 15, 18, 21 and 24 months, respectively in the following crops:

6.2.1 *Salvia sclarea* L.

Seeds sown immediately after harvesting showed maximum germination (68.67%). Higher values for mean daily germination, peak value, germination value and germination energy index were also recorded at this concentration. While there was no germination after storage period of 15 months.

6.2.2 *Matricaria chamomilla* L.

The maximum germination (63.33%) was recorded when the seeds were sown after 3 months storage period, while no germination was observed after the storage period of 18 months.

6.2.3 *Rosmarinus officinalis* L.

Maximum seed germination (49.84%) was recorded when the seeds were stored for 6 months. Thereafter, the germinability of the seeds decreased and the minimum germination (2.56%) was recorded after the storage period of 24 months. Germination energy index was also high at storage period of 6 months.

6.3 EFFECT OF STORAGE CONTAINERS ON SEED GERMINATION

Freshly harvested seeds were stored at room temperature in six types of containers viz., open tray, gunny bag, plastic jar, paper bag, cloth bag and polythene bag and the germinability of the seeds were tested. The results thus obtained are summarised as under:

6.3.1 *Salvia sclarea* L.

Highest germination (59.50%) and survival (78.75%) was shown by the seeds stored in plastic jar, followed by the seeds stored in polythene bag, but the effect of different storage containers on shoot length, root length and survival per cent was non-significant. The minimum germination (41.00%) was recorded when the seeds were stored in open tray.

6.3.2 *Matricaria chamomilla* L.

Seeds stored in plastic jar showed highest germination (60.50%) and survival (77.50%) followed by the seeds stored in polythene bag, but the effect of different storage containers on shoot length, root length and survival per cent was statistically non-significant. The minimum germination (38.00%) was found when the seeds were stored in the open tray.

6.3.3 *Rosmarinus officinalis* L.

Seeds stored in gunny bag showed maximum germination (49.33%) and maximum survival (79.92%) was shown by the seeds stored in polythene bag although the effect of storage containers on survival per cent was statistically non-significant.

6.4 EFFECT OF DEPTH OF SOWING ON SEED GERMINATION

Seeds of *S. sclarea*, *M. chamomilla* and *R. officinalis* were sown at seven different depths viz., surface sowing, 0.5 cm, 1.0 cm, 1.5 cm, 2.0 cm, 2.5 cm and 3.0 cm and their effect on germination and other related parameters was studied.

6.4.1 *Salvia sclarea* L.

The maximum germination (60.50%) was registered at 0.5 cm sowing depth. The values for mean daily germination, peak value, germination value and germination energy index were also maximum in the same treatment. Although, the maximum shoot length, root length and survival per cent was found in 1.0 cm sowing depth which was at par with 0.5 cm sowing depth. No germination was obtained below 2.0 cm sowing depth.

6.4.2 *Matricaria chamomilla* L.

The maximum germination (60.50%) as well as mean daily germination, peak value, germination value and germination energy index was recorded at surface sowing. However, the shoot length, root length and survival per cent was maximum at 0.5 cm sowing depth. There was no germination below 1.0 cm sowing depth in this plant.

6.4.3 *Rosmarinus officinalis* L.

The maximum germination (48.43%) was recorded at 0.5 cm sowing depth. The other germination and growth parameters also registered the maximum values in the same treatment. On the other hand, there was no germination below 2.0 cm sowing depth.

6.5 EFFECT OF DIFFERENT MULCHING MATERIALS ON SEED GERMINATION

Six different mulching materials viz., control (no mulch), dry grass, black polythene sheet, FYM, pine needles and wheat straw were evaluated for their effect on seed germination.

6.5.1 *Salvia sclarea* L.

Highest germination (60.50%) and as well as mean daily germination, peak value, germination value and germination energy index was recorded when dry grass mulch was used whereas, shoot length (2.05 cm), root length (8.90 cm) and survival per cent (78.50%) was obtained with FYM mulch. The minimum value for germination per cent and growth parameters were found in control, when no mulch was used.

6.5.2 *Matricaria chamomilla* L.

Grass mulch gave the maximum germination (60.00%) followed by FYM mulch while shoot length and root length was maximum in FYM mulch. All the germination and growth parameters registered lowest values in the control when no mulch was used.

6.5.3 *Rosmarinus officinalis* L.

Mulching with black polythene sheet gave the maximum germination (48.54%). Similarly, the higher values for mean daily germination, peak value, germination value, germination energy index, shoot length, root length and survival per cent was obtained in the same treatment. The minimum germination (15.21%) and survival (54.14%) was recorded in control when no mulch was used.

6.6 EFFECT OF SEED RATES ON GROWTH AND YIELD

The studies on the seed rates viz., 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5 and 4.0 kg/ha, respectively were conducted to evaluate their effects on growth and yield. The results thus obtained are summarised below:

6.6.1 *Salvia sclarea* L.

Maximum plant height (91.85 cm), flowering shoot yield (69.57 q/ha) was obtained at 4.0 Kg/ha seed rate. While the minimum plant height (61.75 cm) and oil yield (9.28 Kg/ha) was recorded when the seed rate was 0.5 Kg/ha.

6.6.2 *Matricaria chamomilla* L.

The plant height increased with the increase in seed rate and maximum plant height (41.33 cm) was obtained at 4.0 kg/ha seed rate. Whereas, the maximum number of branches per plant (13.25), flower yield (8.92 q/ha) and oil yield (4.28 kg/ha) were recorded at 1.0 kg/ha seed rate.

6.6.3 *Rosmarinus officinalis* L.

In this crop also the plant height increased with the increase in seed rate and maximum value (61.15 cm) was observed at 4.0 kg/ha seed rate followed by 3.5 kg/ha seed rate (60.65 cm). Whereas, the maximum leaf yield (75.95 q/ha), oil content (1.08%) and oil yield (82.03 kg/ha) were recorded at 3.5 kg/ha seed rate.

From these investigations, it can be concluded that:

1. In *S. sclarea* and *M. chamomilla* soaking of seeds in 200 mg/l GA₃ for two hours gave maximum germination, however it is economic to use cold water pre-sowing seed treatment for 48 hours as it also gave good germination per cent. In *R. officinalis* 2.0% HCl treatment gave maximum seed germination.
2. Maximum seed germination in *S. sclarea* was found when the seeds were sown immediately after harvesting whereas, in *M. chamomilla* and *R. officinalis* the maximum germination per cent occurred after 3 and 6 months storage period, respectively.
3. In *S. sclarea* and *M. chamomilla* plastic jar as well as polythene bag can be used for getting optimum germination. While in *R. officinalis*, gunny bag as well as cloth bag can be used for seed storage so as to get optimum seed germination.
4. The seeds of *S. sclarea* and *R. officinalis* should be sown at 0.5 cm, whereas that of *M. chamomilla* should be surface sown so as to get optimum seed germination and related parameters.
5. Grass mulch as well as FYM mulch can be used to get optimum seed germination in *S. sclarea* and *M. chamomilla*. While in *R. officinalis* it could be attained through mulching with black polythene sheet.
6. The seed rate of 4.0 kg/ha, 1.0 kg/ha and 3.5 kg/ha is sufficient to get optimum growth and yield in *S. sclarea*, *M. chamomilla* and *R. officinalis*, respectively.

REFERENCES

REFERENCES

REFERENCES

- Ammon, H.P.T. and Kaul, R. 1992. Chamomile : Pharmacology of chamomile and its components. *Deutsche Apotheker Zeitung*. 132: 3-26.
- Anderson, J.D. 1973. Metabolic changes associated with senescence. *Seed Science and Technology*. 1: 401-460.
- Aqel, M. 1992. A vascular smooth muscle relaxant effect of *Rosmarinus officinalis*. *International Journal of Pharmacognosy*. 30(4): 281-288.
- Attia, A.M.I. 1970. Effect of surface mulches and seed bed pattern on growth and yield of late sown wheat varieties. M.Sc. Thesis, IARI, New Delhi.
- Bachelard, E.P. 1967. Effect of gibberellic acid; kinetin and light on dormant seeds of some species of *Eucalyptus*. *Australian Journal of Botany*. 15: 393-401.
- Balyan, S.S., Pal, S., Sharma, S.N., Singh, S.N. and Sobti, S.N. 1987. Effect of spacing, nitrogen and phosphorus on the growth and yield of two *Ocimum* species. *Indian Perfumer*. 31(2):89-96.
- Barton, L.V. 1953. Seed storage and viability. *Contrib. Boyce Thompson Institute*. 17:87-103.
- Berdun, C., Guillen, A., Aloy, M., Casanas, F. and Bosch, L. 1988. Maize culture under plastic mulch. *IFTA*. 17: 7-16.
- Bewley, J.D. and Black, M. 1985. *Seeds : Physiology of development and germination*. Plenum Press, New York, USA, p. 367.
- Bhati, D.S. 1992. Effect of crop geometry and seed rate on yield of cumin. *Indian Perfumer*. 36(2): 144-146.
- Bhattacharjee, S.K. 2000. *Handbook of Aromatic Plants*. Pointer Publishers, Jaipur, 284p.
- Bishan Dass. 1995. System behaviour under *Pinus roxburghii* Sargent in Solan district (H.P.), M.Sc. Thesis, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.).
- Bisht, P.S. and Kediya, V.K. 1995. Effect of chemical treatments on germination and survival of the seedlings of *Atropa belladonna* L. *Indian Journal of Forestry*. 18(3): 208-210.

- Black, A.L. 1973. Soil property changes associated with crop residue management in wheat fallow rotation. *Soil Science Society of America. Proceedings.* 37: 943-946.
- Bowen, M.R. and Eusibio, T.V. 1981. *Acacia mangium*. Updated information on seed collection, handling and germination testing. Occasional Technology and Scientific Notes, Seed Series No. 5, Forest Research Centre, Sepilok, Sabah.
- Carpenter, S.B. and Smith, N.D. 1981. Germination of Paulownia seeds in the presence and absence of light. *Tree Planters Note.* 32(4): 27-29.
- Chaisurisri, K., Ponoy, B. and Wasuwanich, P. 1986. Storage of *Azadirachta indica*. *A. Juss. Seeds. Embryo.* 2: 19-27.
- Chaudhary, P.C. and Chatterjee, B.N. 1967. Moisture conservation under mulches in eroded terraced soil of Ranchi. *Journal of Soil and Water Conservation.* 15: 61-67.
- Choi, B.H., Park, K.Y. and Park, R.K. 1990. Cultural techniques and productivity of buckwheat sown in spring. *Research of the Rural Development Administration Upland Industrial Crops.* 32: 38-45.
- Czabator, F.J. 1962. Germination value : an index combining speed and completeness of pine seed germination. *Forest Science.* 8:386-396.
- Dahab, A.M.A., Shafiq, Y. and Al-Kinary, A. 1979. Effect of GA₃ and scarification on the germination of seed of *Pistacia khinjuk* stocks. *Mesopotamia Journal of Agriculture.* 10: 13-19.
- Danthu, P., Roussel, J., Dia, M. and Sarr, A. 1992. Effect of different pre-treatments on the germination of *Acacia senegal* seeds. *Seed Science and Technology.* 20: 111-117.
- Donnelly, E.D. 1970. Persistence of hard seed in *Vicia* lines derived from inter specific hybridization. *Crop Science.* 10: 661-62.
- Fairbourn, M.L. and Gardner, W.R. 1979. Vertical mulch effects on soil water storage. *Soil Science Society of America. Proceedings.* 36: 823-827.
- Fonseca, CEL-da, Figueiredo, S.A. and Silva, JA-da. 1994. Effect of depth of sowing and light intensity on germination of 'baru' seeds (*Dipteryx alata* Vog.). *Pesquisa Agropecuaria Brasileira.* 29(4):653-659.
- Foray, L., Bertrand, C., Pinguet, F., Soulier, M. and Astre, C. 1999. *In vitro* cytotoxic activity of essential oils from *Salvia* species. *Journal of Essential Oil Research.* 11(4): 522-526.
- Galambosi, B. and Szebeni, G.Z. 1992. The use of black plastic mulch and ridges in production of herbicides free herbs. *Acta Horticulture.* 30(6): 353-356.

- Gomez, K.A. and Gomez, A.A. 1984. *Statistical Procedures for Agricultural Research*. John Wiley and Sons, New York.
- Haq, I. and Mina, K. 1988. Germination studies on *Hyoscyamus niger* L. *Hamdard Medicus*. 31(2): 53-61.
- Harington, J.F. 1970. Seed and pollen storage for conservation of plant gene resources. **In:** *Genetic Resources in Plants - Their Exploration and Conservation Handbook* No. 11. International Biological Programme, London.
- Harington, J.F. 1972. Seed storage and longevity. **In:** *Seed Biology*. Vol. 3 (Ed. T.T. Kozolowski). Academic Press, New York and London, 145-245.
- Harington, J.F. 1973. Problems of seed storage. **In:** *Seed ecology* (Ed. Heydecker, W.), Butterworths, London, pp. 251-263.
- Hartmann, H.T. and Kester, D.E. 1976. *Plant Propagation Principles and Practices*. Prentice Hall, New Delhi. 662 p.
- Hashemi, A. and Estilai, A. 1994. Seed germination response of golden chia (*Salvia columbariae* Benth.) to low temperature and gibberellin. *Industrial Crops and Products*. 2(2): 107-109.
- Hildebrandt, K. and Schulz, H. 1987. Sowing trials of some selected herbaceous plants. *Zeitschrift fur Vegetation stechnik in Landschafts Und Sport Stattendbau*. 10(3): 106-110.
- Husain, A., Virmani, O.P., Sharma, A., Kumar, A. and Misra, L.N. 1988. *Major Essential Oil Bearing Plants of India*. CIMAP, Lucknow.
- Hussain, A., Waheed, A. and Zabar, M.A. 1969. Effect of mulches on germination, growth and yield of turmeric (*C. longa*). *Journal of Agricultural Research*. 7(3): 153-157.
- Janick, J. 1974. *Horticultural Sciences*. W.H. Freeman and Co., USA, 188 p.
- Jha, P.K. and Singh, N.P. 1979. Response of *Mentha spicata* L. (Spearment) to different levels of nitrogen application and row spacing. *Indian Perfumer*. 23(2):95-99.
- Karivaratharaju, T.V., Palanisamy, V. and Vanangamudi, K. 1989. Influence of seed treatment and storage container on the viability of Lablab (*Lablab purpureus* (L.) Sweet) seeds. *South Indian Horticulture*. 37(2):121-123.
- Kemp, R.H. 1975. Seed pre-treatment and principles of nursery handling. In Reports on FAO/DANIDA training course on forest Seed Collection and Handling, Vol. II FAO, Rome.

- Khalifa, F.M. 1984. Effect of spacing on growth and yield of sunflower under two systems of dry farming in Sudan. *Journal of Agricultural Science Cambodia*. 103(1): 213-222.
- Koopmann, M.J.F. 1967. Trocknungsgrad für samereien für die Abfüllung in Keimschutzpackungen. *SAFA*. 13:8-10.
- Kozłowski, J. and Szczygłowska, D. 1995. Biology of germination of medicinal plant seeds. IXb. Seeds of medicinal species of *Verbascum* genus from Scrophulariaceae family. *Herba Polonica*. 41(3):120-124.
- Kretschmer, M. 1989. Influence of different storage conditions on germination of spice seeds. *Acta Horticulture*. 253: 99-103.
- Kretschmer, M. and Franz, C. 1997. Trials on field ecology of *Gentiana lutea* L. *Gewächse* (Minchar). 33(1):8-11.
- Kundu, M., Sharma, P., Kachari, J. and Sett, R. 1997. Effect of pre-treatment on germination and seedling vigour in *Alstonia scholaris*. *Seed Research*. 25(1): 16-18.
- Letchamo, W. and Gosselin, A. 1996. Light, temperature and duration of storage govern the germinator and emergence of *Taraxacum officinale* seed. *Journal of Horticultural Science*. 71(3):373-377.
- Maeda, M.C. 1991. Effect of mulching with plastic film of different colour and thickness on soil temperature. In informes de investigation - CENID - RASPA. 375-398.
- Maithani, G.P., Bahuguna, V.K., Rawat, M.M.S. and Sood, O.P. 1987. Effect of temperature and containers on the *Holoptelia integrifolia* seeds for maximum retention of viability and vigour. *Indian Forester*. 113(7): 466-470.
- Maithani, G.P., Bahuguna, V.K., Rawat, M.M.S. and Sood, O.P. 1989. Fruit maturity and interrelated effects of temperature and container on longevity of neem (*Azadirachta indica*) seeds. *Indian Forester*. 15(2): 89-97.
- Manipura, W.B. 1972. Influence of mulch and cover crop on surface run-off and soil erosion in tea lands during the early growth of replanted tea. *Tea Quarterly*. 43: 95-102.
- Massey, J.H. 1971. Effects of nitrogen rates and plant spacing on sunflower seed yields and other characteristics. *Agronomy Journal*. 63(1): 137.
- Matias, A.R., Betancourt, A., Zayas, A., Pena, A. and Rivero, R. 1973. Forest seed in Cuba. In: Seed Processing Proceedings Symposium IUFRO Working Group on Seed Problems, Bergen. Vol. II, Paper 31.

- McCalla, T.M. and Dulley, F.L. 1946. Effect of crop residues on soil temperature. *Journal of American Society of Agronomy*. 38: 75-89.
- Milhau, G., Valentin, A., Benoit, F., Mallie, M., Bastide, J.M., Pelissier, Y. and Bessiere, J.M. 1997. *In vitro* antimalarial activity of eight essential oils. *Journal of Essential Oil Research*. 9(3): 329-333.
- Miller, D.E. 1968. Emergence and development of sweet corn as influenced by various soil mulches. *Agronomy Journal*. 60: 369-371.
- Mohanty, D.C., Sarma, Y.N. and Panda, B.S. 1990. Influence of mulch materials and cover crops on the yield of turmeric crop under rainfed condition in Orissa. *Indian Cocoa, Arecanut and Spices Journal*. 14: 97-99.
- Moretti, M.D.L., Peana, A.T. and Satta, M. 1997. A study on anti-inflammatory and peripheral analgesic action of *Salvia sclarea* oil and its main components. *Journal of Essential Oil Research*. 9(2): 199-204.
- Murthy, A.V. and Krishna, R.G. 1973. Problems of teak seed. I. Flower and fruit studies 2. Germination studies. International Symposium of Seed Processing Vol. II. Bergen. The Royal College of Forestry, Stockholm.
- Nagaveni, H.C. and Srimathi, R.A. 1981. Studies on germination of sandal (*Santalum album* L.) pre-treatments of sandal seeds. *Indian Forester*. 107(6):348-354.
- Nargaraja, C. and Farooqi, A. 1989. Studies on the seed germination influenced by various pre-treatments in *Bursera*. *Indian Perfumer*. 33(1): 48-53.
- Nautiyal, A.R. and Thapliyal, P. 1993. On the cause of loss of seed viability in *Toona ciliata* Roem. *Indian Journal of Forestry*. 16: 167-169.
- Nutile, G.E. 1964. Effect of desiccation on viability of seeds. *Crop Science*. 4:325-328.
- Othieno, C.O. 1980. Effect of mulches on soil water content and water status of tea plants in Kenya. *Experimental Agriculture*. 16: 295-302.
- Perrucci, S., Mancionti, F., Cioni, P.L., Flamini, G., Morelli, I. and Macchioni, G. 1994. *In vitro* antifungal activity of essential oils against some isolates of *Microsporum canis* and *Microsporum gypseum*. *Planta Medica*. 60(2): 184-187.
- Pital, J.A., Wang, B.S.P. and Cheliak, W.M. 1984. Improving germination of Hop-Hornbean seeds. *Canadian Journal of Forest Research*. 14(3): 464-466.
- Prihar, S.S., Singh, R., Singh, N. and Sandhu, K.S. 1979. Effect of mulching previous crops for fallow on dry land maize and wheat. *Experimental Agriculture*. 15: 129-134.

- Rao, B.G.V. and Nigam, S.S. 1970. *In vitro* antimicrobial efficiency of essential oils. *Indian Journal of Medical Research*. 58(5):627-633.
- Rey, C. 1995. Comparison of direct sowing and planting of common sage (*Salvia officinalis* L.). *Revue Suisse de Viticulture d'Arboriculture d'Horticulture*. 27(6): 375-381.
- Ricotta, J.A. and Masiunas, J.B. 1991. The effects of black plastic mulch and weed control strategies on herb yield. *Horticulture Science*. 26(5): 539-541.
- Robinson, R.G., Ford, J.M., Luescha, W.E., Robar, D.L., Smith, C.J., Warnes, D.D. and Wiersma, J.V. 1980. Response of sunflower to plant population. *Agronomy Journal*. 72(6): 869-871.
- Rowe-Dutton, P. 1957. The mulching of vegetables. Tech. Commn. No. 24. Commonwealth Agricultural Bureau, England.
- Rudre Gowda, H., Farooqi, A.R. and Subbaiah, T. 1993. Studies on the seed germination of lemon-scented gum as influenced by various pre-treatments. *Indian Perfumer*. 37(3): 256-262.
- Sabel, S.S., Nadkarni, H.R. and Nawale, R.N. 1992. Effect of seed storage on germination and seedling development in clove. *Indian Cocoa Arecanut and Spices Journal*. 16(1):27-28.
- Sasaki, S. 1980. Storage and germination of dipterocarp seeds. *Malaysian Forester*. 43: 438-451.
- Schmidt, E. and Silva, P.R.F.D.A. 1986. Effect of density and spacing on sunflower II. Agronomic characteristics and interception of solar radiation. *Pesquisa Agropecuaria Brasileira*. 21(8): 853-863.
- Sharma, G.K. 1980. Propagation techniques of *Moringa oleifera* Lam. M.Sc. thesis, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.).
- Sheikh, M.I. 1980. Effect of different treatments to hasten tree seed germination. *Pakistan Journal of Forestry*. 30(4): 176-80.
- Shyalaja, M.R., Sankar, M.A., Nair, G.S. and Mercy, K.A. 1997. Influence of seed treatments and storage on the germination of *Catharanthus roseus* L. *Indian Cocoa, Arecanut and Spices Journal*. 21(2): 45-47.
- Singh, A. 1977. Cultivation of *Matricaria chamomilla*. In: *Cultivation and Utilization of Aromatic Plants* (Eds. Atal, C.K. and Kapur, B.M.). Regional Research Laboratory, Jammu-Tawi, pp. 653-658.
- Singh, J.M. and Srivastava, L.J. 1990. Seed germination in lavender with acid treatment. *Indian Perfumer*. 18(1): 86-87.

- Singh, R.P., Singh, Y. and Singh, J.P. 1989. Effect of varieties, row spacing and plant densities on growth and yield of mustard under dry land conditions. *Journal of Oil Seed Research*. 6(2): 349-352.
- Singh, R.V., Chandra, J.P. and Sharma, S.N. 1973. Effect of depth of sowing on germination of kail (*Pinus wallichiana*) seeds. *Indian Forester*. 9(6): 367-71.
- Steer, B.T., Coaldrakes, P.D., Pearson, C.J. and Canty, C.P. 1986. Effect of nitrogen supply and population density on plant development and yield components of irrigated sunflower. *Field Crops Research*. 13(2): 99-115.
- Stein, W.I., Slabaugh, P.E. and Plummer, A.P. 1974. Harvesting, processing and storage of fruits and seeds. In: *Seeds of Woody Plants in the United States*. Agriculture Handbook No. 450. Forest Service, USDA, Washington D.C., USA, pp. 300-320.
- Sunderesh, I. 1982. India's position in world trade of essential oils and future export potentialities. *Indian Perfumer*. 26(2-4): 167-182.
- Svoboda, K. and Deans, S.G. 1992. A study of variability of rosemary and sage and their volatile oils on the British market : Their antioxidative properties. *Flavour and Fragrance Journal*. 7(2): 81-87.
- Tang, H.T. and Tamari, C. 1973. Seeds description and storage tests of some dipterocarps. *Malaysian Forester*. 36: 38-53.
- Thompson, J.A. 1982. Influence of plant population on phasic development, growth, yield and water use of irrigated sunflower in a semi-arid environment. In: *Proceedings 10th International Sunflower Conference*. Australian Sunflower Association. 67-69.
- Thompson, P.A. 1969. Comparative effect of gibberellins GA₃ and GA₄ on the germination of seeds of several different species. *Horticulture Research*. 9: 130-138.
- Tompsett, P.B. 1985. The influence of moisture content and storage temperature on the viability of *Shorea almon*, *Shorea robusta* and *Shorea roxburghii* seed. *Canadian Journal of Forest Research*. 15: 1074-1079.
- Touzard, J. 1975. Theorie et pratique de la conservation des semences. In: *La germination des semences* (Eds. Chaussat, R. and LeDenuff, Y.). Bordas, Paris, pp. 157-170.
- Tylkowski, T. 1984. The effect of storing silver maple (*Acer saccharinum* L.) samaras on the germinative capacity of seeds and seedling growth. *Arbor. Korni*. 29: 131-141.

- Ungaro, M.R.G., Veiga, A.D.E.A. and Toledo, N.M. DE. 1983. Studies on spacing of sunflower sown in the dry season. *Revista de Agricultura Piracicaba, Brazil*. 58:95-107.
- Vaenica, A.R. 1973. Germination of *Albizia falcata* seeds soaked in hot water. *Bureau of Forestry Philippines* 50: 6.
- Van Bavel, C.H.M. and Hillel, D. 1975. A simulation study of soil heat and moisture dynamics as affected by a dry mulch. *Proceedings of Summer Simulation Conference, San Francisco, California*.
- Van Wijk, W.R., Larson, W.E. and Burrow, W.C. 1959. Soil temperature and early growth of corn from mulched and unmulched soil. *Soil Science Society of America. Proceedings*. 23: 423-434.
- Vijayalakshmi, K., Sing, N.K., Pelton, W.L. and Anderson, C.H. 1975. Effect of plant population and row spacing on sunflower agronomy. *Canadian Journal of Plant Science*. 55(2): 491-499.
- Willington, W.J. 1973. Genetic regulation of germination. *Seed Ecology*. 5-30.
- Woodstock, L.W., Furman, K. and Solomos, T. 1984. Changes in respiratory metabolism during aging in seeds and isolated axes of soyabean. *Plant Cell Physiology*. 25: 15-26.
- Ynove, C.K., Ono, E.O. and Furlan, M.R. 1996. Effect of growth regulators on seed germination in roselle (*Hibiscus sabdariffa* L.). *Revista de Agricultura Piracicaba*. 71(2): 233-242.
- Yoneda, K., Kodama, M., Hatakeyama, V. and Homma, N. 1992. Seed biology of medicinal plants (XI Germination of *Gentiana lutea* L.). *Shoyakugako Zasshi*. 46(9):348-351.

APPENDIX

Appendix-I

Meteorological data at the nursery site during 1998-2000

Year/ Month	Temperature (°C)		Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum		
1998				
August	28.20	20.20	79.00	100.80
September	27.30	17.80	81.00	193.70
October	26.30	12.50	69.00	264.00
November	24.30	6.30	56.00	-
December	22.10	2.40	44.00	-
1999				
January	17.80	2.40	60.00	97.50
February	22.50	5.10	62.00	17.30
March	24.70	8.00	36.90	15.60
April	32.24	12.62	41.98	-
May	31.65	16.80	55.82	63.76
June	30.50	16.80	62.80	18.10
July	28.00	19.80	85.70	139.10
August	28.00	19.70	73.57	37.60
September	28.08	17.20	86.40	30.08
October	26.95	10.32	30.15	-
November	24.42	58.12	30.07	-
December	21.24	2.78	30.54	3.00
2000				
January	18.60	3.80	55.00	64.70
February	16.80	2.40	43.00	121.50
March	22.70	7.70	44.00	47.90
April	30.80	12.70	34.00	59.40
May	31.80	17.80	54.00	113.00
June	28.60	18.40	70.00	392.50
July	27.30	20.00	86.00	592.20

Source: Meteorological Observatory, Department of Soil Science and Water Management, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.).

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45966

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No. of words in Abstract	:	350

ABSTRACT

The studies on seed germination and seed rate of some aromatic plants were carried out during 1998-2000. Three crops viz. *Salvia sclarea*, *Matricaria chamomilla* and *Rosmarinus officinalis* were undertaken for the study. In the first experiment, the effect of pre-sowing seed treatments on seed germination was studied. Among the eleven different pre-sowing seed treatments GA₃ 200 mg/l for two hours gave 80.00 and 73.33 per cent germination for *S. sclarea* and *M. chamomilla*, respectively. Whereas, in *R. officinalis* 2.0 per cent HCl treatment for 10 minutes gave 59.33 per cent germination. In the second experiment, the effect of storage period on seed germination was studied. In *S. sclarea*, seeds sown immediately after harvesting gave 68.67 per cent germination whereas, in *M. chamomilla* and *R. officinalis*, the maximum germination of 63.33 per cent and 49.84 per cent was obtained when the seeds were sown after the storage period of 3 months and 6 months, respectively. In third experiment, the effect of storage containers on seed germination was studied. The seeds of *S. sclarea* and *M. chamomilla* stored in plastic jar gave maximum germination of 59.50 per cent and 60.50 per cent, respectively, whereas, in *R. officinalis* the seeds stored in gunny bag gave maximum germination of 49.33 per cent. In fourth experiment, the effect of depth of sowing on seed germination was studied. Among seven different sowing depths the seeds sown at 0.5 cm depth gave maximum germination of 60.50 per cent and 48.43 per cent for *S. sclarea* and *R. officinalis*, respectively, whereas, surface sowing of *M. chamomilla* seeds gave maximum germination (60.50%). In fifth experiment, the effect of different mulching materials on seed germination was studied. Among six different mulching materials, dry grass mulch gave maximum germination of 60.50 and 60.00 per cent for *S. sclarea* and *M. chamomilla*, respectively, whereas, black polyethylene sheet mulch gave maximum germination of 48.54 per cent for *R. officinalis*. In sixth experiment, the effect of seed rates on growth and yield was studied. Among eight different seed rates, the seed rates of 4.0, 1.0 and 3.5 kg/ha gave oil yield of 58.44, 4.28 and 82.03 kg/ha for *S. sclarea*, *M. chamomilla* and *R. officinalis*, respectively.

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