STUDIES ON THE STANDARDIZATION OF CULTIVATION PRACTICES OF *Andrographis paniculata* Nees UNDER MID HILL CONDITIONS OF HIMACHAL PRADESH

Thesis

by

MADAN LAL PANWAR

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

FORESTRY

(FOREST PRODUCTS)

COLLEGE OF FORESTRY
Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan - 173230 (H.P.), INDIA
2009

Andrographis paniculata **Nees**

Dr. Meenu Sood
Scientist

Department of Forest Products
College of Forestry
Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni-173230, Solan (H.P.)

CERTIFICATE-I

This is to certify that the thesis entitled, "**Studies on the standardization of cultivation practices of *Andrographis paniculata* Nees under mid hill conditions of Himachal Pradesh**" 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, Nauni, Solan (H.P) is a record of bonafied research work carried out by **Mr. Madan Lal Panwar (F-2007-04-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.

Place: Nauni, Solan
Dated:

(Dr. Meenu Sood)
Chairperson
Advisory Committee

CERTIFICATE –II

This is to certify that the thesis entitled, "**Studies on the standardization of cultivation practices of *Andrographis paniculata* Nees under mid hill conditions of Himachal Pradesh**" submitted by **Mr. Madan Lal Panwar (F-2007-04-M)** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, 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.

(Dr. Meenu Sood)
Chairperson
Advisory Committee

External Examiner

Members, Advisory Committee

Dr. N.S. Chauhan
Prof. and Head
Dept. of Forest Products

Dr. R. Raina
(Sr. Scientist)

Dr. P. K. Mahajan
Professor (Statistics)

Dr. J. C. Sharma
Scientist (Soil)

Dean's Nominee

Professor and Head
Department of Forest Products
Dr. Y.S. Parmar UHF Nauni, Solan (H P)

Dean
College of Forestry
Dr. Y.S. Parmar UHF Nauni, Solan (H P)

CERTIFICATE-III

This is to certify that all the mistakes and errors pointed out by the external examiner have been incorporated in the thesis entitled, "**Studies on the standardization of cultivation practices of *Andrographis paniculata* Nees under mid hill conditions of Himachal Pradesh**" submitted to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) by **Mr. Madan Lal Panwar (F-2007-04-M)** in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE** in **FORESTRY (Forest Products).**

(Dr. Meenu Sood)
Chairperson
Advisory Committee

Dr. N. S. Chauhan
Professor and Head
Department of Forest Products
Dr. Y.S. Parmar UHF, Nauni-173 230, Solan (H.P.)

ACKNOWLEDGEMENTS

Humbly I would like to offer my prime heartfelt salutations at the lotus feet of the 'Supreme Being'- (GURU NANAK DEV JI) The Almighty for the unbroken vigour bestowed upon me, throughout the span of my studies in these testing days.

With celestial smiles may I be immensely overwhelmed to express my heartfelt regards towards my AMA JI and PITA JI. Their selfless persuasion, sacrifices, blessings and firm faith has made me come out with flying colours. I owe all my success to them only. I stand beholder to my sisters, Annu and Seema, Brothers Sita Ram and Deep Ram for their incessant warmth, unwavering ecstatic and abounding love showed upon me during the sojourn.

I have no suitable words to express my love to my wife Mrs. Monica Panwar and my little son Akshat Panwar.

It is with adnascent pleasure that I reiterate my encumbrance to Chairperson of my Advisory Committee, Dr. Mrs. Meenu Sood, (Scientist) for her guidance, swift execution and in sight during the entire course of investigation. Her constant encouragement, inspiration and concern to my professional growth will always be cherished.

I am indeed beholden to members of my Advisory Committee Dr. N.S. Chauhan (Professor and Head, Forest Products), Dr. R. Raina (Senior Scientist, Forest Products), Dr. P. K. Mahajan (Scientist Statistics) and Dr. J. C. Sharma (Scientist, Soil) for their generous help blended with valuable suggestions.

I would like to put on my appreciation to Dr. R. C. Rana (Senior Scientist), Dr. K. R. Sharma (Professor), Dr. Y. P. Sharma (Assistant Scientist), Dr. Bhupender Dutt (Assistant Professor) of Department of Forest Products and Dr. S.S. Sharma (Professor) for their guidance and constant encouragement during the discourse of my academic pursuits. Thanks are due to the office, laboratory and field staff for their cooperation and assistance in one or the other way while carrying out the work.

I would like to extend my cordial thanks to Dr. Anil Sood, Dr. K. C. Sharma (Entomologists) and Dr. Ravinder Sharma (Agriculture Economist) for their valuable suggestions and technical guidance as and when required.

Words can not substitute my unfeigned feelings towards Dr. D. K. Mehta (STPC), and my friends Mr. Roop Singh Kashyap and Dr. Med Ram Verma for their selfless sacrifices, prudent persuasion care, support and firm faith alleviated my vexed mind and moored me to ultimate bless.

Dedications, heartfelt blessings, firm faith and sacrifices of my Mummy, Papa and Dadi ji entitle a lot more than this mere acknowledgement. I express my sincere thanks to Tau ji, Tayi ji, Bittu bhai, Bhabi ji, Suman, Jiju, Dinesh, Pawan, Sunil, Sanjeev and well wishers for their eager enthusiastic cooperation, encouragement and perpetual support.

I categorically express my loyal and veneration thanks to my respected classmates and friends, Suresh, Deep Shikha, Dharam, Shesh Kanta Bhandari, Haseeb, Irfan, Arvind, Santosh, Sugna, Shazmeen, Neena, Urvashi, Kennedy and Vinod for their cheerful company and cooperation throughout the study period.

I am highly thankful to Department of Ayurveda (H.P.) for granting me study leave and to Dr. Y. S. Parmar University of Horticulture and Forestry Nauni, Solan for providing me every kind of assistance to complete my Degree.

Needless to say, errors and omissions are solely mine.

Place:
Date: (*Madan Lal Panwar*)

CONTENTS

LIST OF TABLES

Chapter-1

INTRODUCTION

In India, medicinal plant sector has traditionally occupied an important position in the socio-economic, cultural and spiritual arena of rural and tribal lives. About 8000 flowering plants, 650 lichens, 650 algae, 200 pteridophytes and 150 bryophytes are attributed with medicinal properties (Kurian and Asha Sankar, 2007). Indian coded systems encompass a large number of treaties on recognized system of medicine viz. Ayurveda, Unani and Siddha. The Ayurvedic system of medicine, which caters to the health needs of a major segment of population currently, utilizes as many as 1000 single drugs and over 8000 compound formulations of recognized merit. Other systems of medicine viz. Siddha, Unani and Amchi (Tibetan) together utilize about 1800-1900 medicinal species. Many medicinal plants are the source of clinically useful prescription drugs being used in modern systems of medicine. Also incredible knowledge on phyto-medicine is acquired in non-coded form by tribals and rural community, as is clear from evidences related to folklore medicine. Recognizing their importance, medicinal plant sector has been identified as one of the key areas by the Government of India and the Department of Indian System of Medicine and Homoeopathy.

The domestic market comprising of Ayurveda, Unani, Siddha and Homeopathy is estimated to be around 4200 crores and it is growing at a rate of 15-20% per annum. In the domestic market, Ayurvedic medicines alone account for a major portion (84%).

An estimate puts the global market for herbal products at around US $ 120 billion a year. Amongst the various exporting countries, China is the largest exporter contributing to nearly 20% of the market share. As to imports, U.S.A. is the largest importer contributing to 12% of the total import followed by Germany and Japan.

The unsystematic exploitation of important drug yielding plants to support pharmaceutical industry has been identified as one of the biggest cause for loss of many species (Lewin, 1986; Wilson, 1988). Their regeneration and protection in nature is today a challenge to restore our biological heritage. The rich repositories of the past have been ruthlessly exploited and several species of drug plants are facing threat to their survival. The conservation, protection and cultivation of these plants is thus necessary to provide sustainable supply of crude drugs and also to ease pressure on natural resources. Among these medicinal plants, *Andrographis paniculata* Nees is one of the important plant highly demanded by pharmaceutical industry as well as for preparing various ayurvedic preprations. To meet the requirement of this plant, its cultivation is very important. Although, the cultivation of this plant on experimental basis has been done in some parts of the country under inorganic conditions but no information is available on its cultivation under mid hill conditions of Himachal Pradesh.

Global consumers are increasingly looking to organic food i.e. considered safe and hazard free. The demand for organic food is steadily increasing both in developed and developing countries, with annual average growth rate of 20-25 percent (Ramesh *et al.,* 2005).

Andrographis paniculata Nees is a small, erect branched, herbaceous to semiwoody annual herb belonging to family Acanthaceae. The genus *Andrographis* has about 40 species distributed throughout tropical Asia, out of which about 19 species occurs in India. Among these *A. paniculata* Nees is cultivated in West and East India (Anonymous, 1948). Its stem is sharply quadrangular, often narrowly winged in the upper part; erect, stiff, thickened at lower nodes, smooth with divaricate branches, base not pubescent. Leaf is lanceolate, acute, glabrous, slightly undulate, base tapering; slender; petioles-long, opposite, shortly stalked, lanceolate or oval, entire, smooth, dark green above, much paler beneath with prominent lateral veins narrowed at both ends, never spathulate, ovate at base, petiole absent or ¼ inch. Flowers small solitary, distant, in lax spreading axillary and terminal racemes or panicles, the whole forming a large pyramidal paniculate inflorescence; bracts long, lanceolate; bracteoles similar or absent; pedicels long, glandular-pubescent. Cymose panicle, numerous, complete, bisexual on slender divaricate or slightly deflexed pedicels beset with stalked glands, bracts very small. Raceme; pedicels usually pubescent; bract, linear; bracteoles smaller or absent; inflorescence mostly sympodal, the pedicel in the axil of one of each pair of bracts suppressed, solitary, in panicles.

Calyx long; sepals equal, linear-lanceolate, glandular-pubescent, small, divided almost to the base into five equal linear subulate segments covered with stalked glandular hairs. Corolla tubular for about half of its length two lipped for atleast half of its length, hairy; white, spotted, rose-purple. Stamens two, inserted in the throat of corolla and about equaling the lips, filament flattened, tapering, ciliate above, anthers two celled, sub basifixed. Ovary glabrous; style slightly pubescent, small, much latterly compressed , with a small annular disk round the base, smooth, two-celled, with a few ovules in each cell, style about as long as stamens, stigma slightly bifid . Fruit is a capsule, young slightly glandular-hairy, mature glabours oblong-linear, acute, compressed, smooth, two-celled, pericarp thin, dry, dehiscing loculicidally into two valves deeply grouped on the back. Seeds are subquaderate, osseous, rugose, without hairs, yellow or deep brown (Kirtikar and Basu, 1975; Bentlay and Trimen, 1983; Hooker, 1985; Farooqi and Sreeramu, 2001 and Pullaiah, 2006).

The plant as a whole is used in medicines for general bronchitis, influenza, debility, dysentery and certain forms of dyspepsia. A fresh juice of leaves after mixing with cardamom, clove, cinnamom, etc. is dried and made into pills for use as household remedy for the minor digestive ailments of children (Anonymous, 1948). The plant is also used by traditional medicinal practitioners as stomachic, anthelmintic, anti-inflammatory, antipyretic, antiperiodic and in intermittent and remittent fevers (Chopra, 1958; Kirtikar and Basu, 1975; Tomar *et al*., 1982; Balu and Alagesaboopathi, 1993 and Balu *et al*., 1993). *A. paniculata* is also used against snake bite by local traditional medicine practitioners of Tamil Nadu (Gupta and Srivastava, 1994). It is used as a laxative overcoming 'sannipata fevers' and cures cough, oedema, thirst, skin diseases, ulcers and worms (Warrier *et al.,* 1995).

A. paniculata is reported to contain 1.5-2.5% andrographolide (a bitter principle) as the main active constituent in leaves (Anonymous, 1948). In addition to this the plant also contains a number of flavonoids like andrographin, panicotin and aplegenin-4' etc. (Farooqi and Sreeramu, 2001).

Keeping in view the multifarious uses of this plant, the present studies have been undertaken on the cultivation of *Andographis paniculata* in mid hill of Himachal Pradesh under organic condition with the following objectives:

1. To standardize the nursery raising techniques of *Andrographis paniculata*.

2. To study the effect of spacings, organic fertilizers and harvesting stages on its growth and development.

3. To work out the cost of cultivation of this plant.

Chapter-2

REVIEW OF LITERATURE

In this chapter, an attempt has been made to present a brief review of literature on **"Studies on the standardization of cultivation practices of *Andrographis paniculata* Nees under mid hill conditions of Himachal Pradesh".** The literature available is presented in the following heads:

2.1 Medicinal Uses

2.2 Seed treatment and germination

2.3 Mulching

2.4 Spacing and fertilizers

2.5 Harvesting

2.1 Medicinal Uses

Andrographis paniculata (Kalmegh), a bitter herb, is used as a household remedy for the minor digestive ailments of children (Anonymous, 1948). It is also used for the treatment of jaundice (Hemdari and Rao, 1984; Khare, 2004), cholera (Tripathi and Tripathi, 1991) as immunostimulant (Puri *et al*., 1993) and as antidote for snake bite (Gupta and Srivastava, 1994; Selvenayagam *et al.,* 1995). Kalmegh forms a major ingredient of Ayurvedic preparations like tiktaghratam, gorocanadi gulika, candansava and panchatiktam kasayam (Sivarajan and Balachandran, 1994). It is a good substitute for *Swertia chirayita* in the South India (Girach and Aminudin khan, 1994). In an experiment on male rats it appeared that andrographolide could be developed into an antifertilty compound (Murugaian *et al.,* 1995). It is also used for the treatment of cold (Hancke *et al.,* 1995). Extracts of few Indonesian plants (methanolic extract of bark of *Swietenia mahagoni*; water extracts of stem and branches of *Larenthus parasiticus*; fruits of *Helicteres isora*; fruit of *Sindora sumatrana*; leaves of *A. paniculata* and rhizome of *Curcuma aeruginosa*) have shown significant inhibition of human immuno deficiency virus type I (HIV-I) by assays using HIV-I infected cells (Otake *et al*., 1995). It has also been reported effective against allergy (Madev *et al.,* 1996), fever and liver diseases in Ayurveda and Homoeopathy system of medicine (Aminuddin *et al*., 1997). It is known for its hepetoprotective properties in Ayurveda (Mitra *et al.,* 1998). It also possesses analgesic, antipyretic, anti-inflammatory (Habtemariam,1998), anti bacterial (Nurnabi *et al.,* 1998), anti malarial (Rahman *et al.,*1999) properties. Mitra *et al.* (1998) reported that HD-3, a polyherbal formulation containing *A. panicuata* and other medicinal species like *Picrorrhiza kurrooa* led to significant amelioration of toxin induced changes in the biochemical parameters. Herbal preparations containing *A. paniculata* lowered the levels of serum, total cholesterol, phospholipids and triglycerides as reported by Kar *et al.* (2000). Its hypoglycaemic action was more significant and comparable to 'guggulipids'- a standard drug from *Commifora mukul*. Zhang-Xiang *et al.* (2000) observed that ethanolic extracts of aerial parts of Kalmegh suppressed elevated levels of glucose in normal and diabetic rats. Calabrese *et al.* (2000) tried it on HIV positive patients.

Extracts of *A. paniculata* exhibited significant alteration in behaviour pattern and reduction in spontaneous motility (Mandal *et al.,* 2001). Nasara *et al.* (2001) identified the therapeutic efficacy of an indigenous drug formulation containing *Andrographis paniculata*, against nephropathy and hepatopathy in goats**.** Trivedi and Rawal (2001), in their studies confirmed the antioxidant action of *A. paniculata*. Upadhyaya *et al.* (2001) observed that drug containing Kalmegh have cell membrane stabilizing property that prevents toxic effects of bile salts in various hepatic disorders. Zaridah *et al.* (2001) reported that aqueous extract of dried leaves of *A. paniculata* showed antifilarial activity. The plant is used as pesticide (Bright Annie *et al.,* 2001). The extract is reported to cure thread worm infestation in children (Bondya *et al.,* 2002). Anuradha *et al*. (2002) in their studies on effect of plant extracts on *Callosobruchus maculates*, reported 87% mortality of the pests in 7 days in the presence of acetone extract of *A. paniculata*. Singh and Rao (2003) studied the allelopathic effects of leaf, stem and root leachates of *A. paniculata* on rice. Leachates from leaves resulted in the highest reduction in seed germination, seedling growth, chlorophyll content, total sugar, protein and soluble amino acid content. Antimicrobial activity of the aqueous extracts of *A. panniculata* showed considerable inhibitory activity against *Micrococcus luteus*, *M. roseus* and *Staphylococcus aurens* (Ram *et al.,* 2004). Kalmegh is a promising herb for the treatment of many diseases including AIDS and the myriad of symptoms associated with auto immune disorders (Kurian and Asha Sankar, 2007).

Alagesaboopathi and Balu (1996) carried studies on *Andrographis lineate* Nees growing in the Shevary hills, Tamil Nadu during 1991-93 and on plants raised in pots during 1993-94 and reported that the species grows well at altitude of about 1500m, but pot and field studies indicate that it could also be grown on the plains. It is a perennial, but the tops dry after full blooming stage leaving only a small part of the stem green, thus it may appear to be an annual.

The anatomical features of *Andrographis paniculata* were reported different in different growing stages (Chen and Jiang, 1980). Alagesaboopathi and Balu (1999) reported *Andrographis paniculata* with abnormal ternate phyllotaxy instead of regular opposite phyllotaxy.

Gupta and Srivastava (1995) found that IC-111288 genotype of *Andrographis paniculata* Nees gave the maximum andrographolide.

2.2 Seed treatment and germination

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

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.

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

Balu and Alagesaboopathi (1996) reported that under greenhouse conditions (19-20^{0}C), germination began after a month and germination was 75 per cent in the seeds sown in pots containing black soil and leaf mould. In another study they reported that seeds sown in pots germinate after 8 days with 80 per cent germination.

Seeds of *Gentiana scabra* on treatment with 300 ppm GA_3 and *G. lutea* seeds with 500 ppm GA_3 gave 75 to 81 per cent germination (Kretschmer and Franz, 1997).

Alagesaboopathi and Ramchadaran (2000) found that the seeds of *Andrographis paniculata* and *Andrographis echioides* are viable with 90 percent seed germination. However, Alagesaboopathi (2002) found that the seeds of *Andrographis macrobotrys* germinated after 13 days of sowing with 56.6 percent germination. Hot water treatment at 50^0C for 5 minutes recorded 84 percent seed germination in Kalmegh (Sarswathy *et al.,* 2004).

Sarvanan *et al.* (2000) reported that seeds thrived well in sandy loam soils with good humus content and required warm and humid environment for germination. Thus the nursery bed structure improved the phenology of germination by promoting development of healthy roots and leaves in *Andrographis paniculata* seedlings.

2.3 Mulching

Mulching is done to increase soil temperature during winter and lower it during summer (McCalla and Dulley, 1946). 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 up to 90 cm depth.

Khan (1983) found that lower soil density and higher porosity in the 0-7.5 and 7.5-15 cm layers under mulches than in unmulched soil was ascribed to reduction of rain drop impact under mulches and consequent lower soil crust strength.

Maeda (1991) reported that soil temperature in the upper 0-5 cm layer was on an average 5^0C higher under plastic mulch than under unmulched soil. Whereas Galambosi and Szebeni (1992) found that black plastic mulch increased soil temperature by 0.2 to 0.6^0C and increased the yield of *Origanum sp., Thymus sp., Salvia officinalis. Melissa officinalis, Agastachi foenniculum* 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. Koppad and Manjunath (2006) from Sirsi, Karnataka reported that ridge + furrow and broad bed + furrow were the most suitable for Stevia and Tulsi cultivation. Broad bed + furrow was the most suitable for Kalmegh, while ridge + furrow was the most suitable for Ashwagandha. Among the medicinal plants, Stevia was found to be the most economically remunerative, followed by Tulsi.

2.4 Spacing and fertilizers

Azeon *et al.* (1976) conducted an experiment to study the interactions between VAM fungi and PSB in a low phosphate soil amended with 0, 0.1 and 0.5 rock phosphate. Lavender (*Lavandula spicata* var vera L.) plants with mycorrhiza plus bacteria (*Bacillus megaterium*) took up more total 'P' than plants which were not inoculated with *Bacillus megaterium.* Plants not inoculated with bacteria or endogone derived no benefit from the rock phosphate.

Sirohi and Singh (1983) studied the effect of inoculation of peppermint *(Mentha piperita* L.) with *Glomus fasciculatum* in unsterilized soils and differential phosphorus availability and found that inoculation produced better root infection, consistent with significantly higher total root length, shoot dry weight, organic and inorganic 'P' fractions in leaf tissues and oil yield as compared to uninoculated control, both at deficient and high levels of native soil phosphorus.

Pareek *et al.* (1984) found that FYM @ 15 t/ha in *Cymbopogon martini* Stapf. Var. motia gave 8 percent higher biomass and 10 % higher yield i.e., herbage (94.5 q/ha) and oil yield (107.7 l/ha). Increase in ‘P’ uptake was recorded in marigold by Bagyaraj and Powel (1985) due to VAM inoculation.

Studies on the roots of twenty aromatic plants were carried to find out their native mycorrhizal status. It was observed that all the twenty plants examined harboured VAM fungi in their root system, *Mentha piperita* and *M. spicata* showed the highest percentage of mycorrhizal colonization (Govinda Rao *et al.,* 1987). Balasubramanian and Nambisan, (1989) also recorded increased foliar ‘P' levels besides enhanced content of N, K, Mg and Zn in marigold seedlings with VAM inoculation.

Field experiments conducted on palmarosa *(Cymbopogon martini* var. motia) revealed that under rainfed conditions, an average increase in herb yield of 20 and 22 per cent was marked on applying *Azotobacter* and 80 kg N/ha compared to the control, respectively. In irrigated conditions in comparison to control, *Azotobacter* was found to enhance the herbage biomass by 16 per cent, whereas, *Azotobacter* along with 80 kg N/ha resulted in 29 per cent increment. Finally, the use of *Azotobacter* entirely or 80 N/ha singly proved to be most optimum and economic media for higher monetary returns (Maheshwari *et al.,* 1991).

Gowda Narayana *et al.* (1991) found that application of 200, 75 and 125 kg of N, P and K gave higher yield and quality flowers in Tuberose (*Polianthus tuberosus* Linn.). A glass house experiment was conducted by Gupta and Janardhanan (1991) by inoculating *Glomus aggregatum* to palmarosa *(Cymbopogon martini* var. motia). They recorded two fold increase in growth and three fold biomass production in plants inoculated with *G. aggregatum* as compared to non-mycorrhizal plants.

In a field trial with Gundumalli *(Jasminum sambac),* the inoculation of *Azospirillum* along with nitrogenous fertilizer application increased the plant height, number of tertiary branches, shoot and leaf area, dry weight, root biomass, flower weight and yield (Manonmani, 1992).

Per cent colonization of VAM in relation to seasonal changes was observed in *Mentha viridis, Ocimum sanctum, O. basilicum* and *Coleus varigatus.* Lowest VAM colonization during winter and highest during summer was observed (Payal and Mukerji, 1994). Khaliq and Janardhanan (1994) studied the variation in the responses of six cultivated species of mint to the colonization by native VAM and observed VAM in the roots of *Mentha spicata* and *Mentha citrata.*

Das *et al.* (1994) from Karnataka reported that lignite based biofertilizer *Azospirillum brasilense* had better leaf yield, chemical composition, plant growth and silkworm feeding response (weight of larvae and silk quality) as compared to different nitrogen levels which reduced urea fertilizer requirement and costs.

Sen (1995) observed that inoculation of henbane (*Hyoscyamus niger*), *Papaver somniferum* and *Cymbopogon* with *Azotobacter* strains increased the yield of alkaloid, latex and essential oil content in three plants respectively. Several experiments during the last decades have proved conclusively that the use of

Azotobacter, Azospirillum, VAM and Phosphorus Solubilizing Bacteria improve the growth and yield of various medicinal and aromatic crops (Vasundhara *et al*., 2005).

Wange *et al.* (1995) opined that the nitrogen application @ 100 kg/ ha should be supplemented with *Azotobacter* or *Azotobacter* + *Azospirillum* inoculation, whereas, nitrogen application @ 150 kg /ha should be supplemented with *Azospirillum* for getting increased yield of underground parts and floral stalks as well as for more monetary returns in tuberose.

In palmarosa *(Cymbopogon martini* var. motia) dual inoculation of VAM fungus *Glomus aggregatum* and *Azospirillum brasilense* increased the growth, yield and oil content as compared to uninoculated control (Rathi and Janardhanan, 1996). As per Kothari and Singh (1996), *Glomus intraradices* substantially increased root and shoot biomass, root length, nutrients (P, Zn and Cu) uptake per unit root length and nutrient concentration in the plant compared to inoculation with rhizosphere microorganisms when the soil was at low bulk density and was not amended with 'P'.

Sukhmal Chand *et al.* (1996) revealed that spacing of 60x30 cm and application of 23.4 t of FYM, 120 kg P_2O_5 and 25 kg Zn/ha/yr produced highest total biomass and essential oil yield in Jamarosa, whereas Jamarosa crop planted during rainy season (July) attained maximum height of 130 cm, gave 4 harvest (October, January, April and July) in a year with highest total herb yield of 99.9 t/ha and highest total essential oil yield of 533.8 l/ha.

Shivalingappa *et al.* (1996) found that in tuberose (*Polianthes tuberosus* L.) the applications of NPK (75, 37.5 & 50 kg/ha) + *Azotobactor*, *Azorospirillium* + VAM (2:2:8) significantly increased various growth and yield parameters. They further found that there is possibility of reducing NPK application by 25 percent with the use of biofertilizers and bringing down the cost of input.

Muniramappa *et al.* (1997) reported that application of 100kg N/ha resulted in the taller plants (34cm), maximum plant spread (646cm), more number of branches (21), and maximum fresh and dry weight per plant (15.3g and 9g) and per ha (3.01and 1.3t). However, it was at par with 75kg N/ha for the most of the yield characters.

Birader *et al.* (1998) in Karnatka studied the effect of vermicompost as potting media mixture on growth and vigour of neem (*Azadirachta indica*). The results indicated that the vermicompost alone was found to be superior over other treatments with respect to plant morphological characters viz. collar girth, root length, leaf area, root-shoot ratio and germination percentage.

Sansamma *et al.* (1998) reported that the roots of *Brachiaria ruziziensis* when inoculated with *Azotobactor* and 50 per cent of the recommended nitrogen fertilizer gave good yield (more than 13 tones dry matter/ha). Puthur *et al.* (1998) observed that the mycorrhizal association help in successful establishment of tissue culture raised plantlets of *Leucaena leucocephala* in field conditions by alleviating the transplantation shock, whereas Priya Rani *et al*. (1999) found that co-inoculation of seedlings of *Acacia nilotica* with *Glomus mosseae and Rhizobium sp*. resulted in maximum plant growth and best nodulation seedlings.

Kapur (1998) revealed that the total dry matter production of the full light grown plants was always more than that of the plants at 45 per cent light. Accumulation of dry matter in leaf and stem was hastened by shading which resulted in negative correlation of light intensity with leaf weight ratio and stem weight ratio, while reverse was true for inflorescence weight ratio and root weight ratio. The inflorescence weight ratio, however increased with the age, while reverse was true for leaf, stem and root.

The study by Naik (1998) revealed that application of phosphorus in the form of 50 per cent superphosphate plus 50 per cent rock phosphate gave the best result with respect to the plant growth, herb yield and oil content of Java citronella and concluded that a source of phosphorus alternate to superphosphate (which is costlier and not easily available) can be better utilized along with inoculation of microorganisms.

Dual inoculation of *Azotobacter* and *Azospirillum* along with fertilizer nitrogen (30 kg/ha) increased the curcumin and protein content in turmeric (Sen and Das, 1998). Increased growth response of *Coleus aromaticus* to VAM fungi and beneficial soil microflora was observed by Earanna *et al.* (1998).

Nageswari *et al.* (1999) reported the application of phosphobacteria through soil as well as slurry method at the time of planting material in per cent rooting with high length and number of roots per cutting in cinnamon.

VAM fungus *Glomus tntraradices* substantially increased root and shoot ratio and total root length, nutrient (P, Zn, Cu) concentrations in root and shoot of the plants, total nutrient uptake and nutrient acquisition per unit root length in bergamot mint *(Mentha citrata)* compared to the soil inoculation with rhizosphere microflora excluding VAM fungi in a phosphorus deficient soil, as reported by Kothari *et al.* (1999).

Seema Paroha *et al.* (2000) from State Forest Research Institute at Jabalpur (Madhya Pradesh) reported that inoculated seedlings exhibited improved growth and biomass. In all species root length development was maximum either with VAM or with VAM + *Azotobacter; Tectona grandis* and *Gmelina arborea* doubled their biomass yield just by mycorrhization. The increase in biomass yield with VAM decreased with the age of the plant and it is suggested that supplementary doses of chemical fertilizers with VAM and *Azotobacter* may be helpful in enriching the microbial population and thereby plant growth.

Rajkhowa *et al.* (2000) observed significant increase in nutrient content in plant due to the addition of vermicompost over control. They further observed that nitrogen applied through vermicompost increased the plant phosphorus and potassium content by 13.5 and 32.5 percent over control, respectively.

The inoculation of exotic strains of VAM gave encouraging results such as early vigour and resistance to infection by *Fusarium* sp. and also led to increased rooting and root mass in cardamom seedlings (Joseph *et al.,* 2000). Application of 50 g each of *Azospirillum* and pbosphobacteria along with 100: 300: 1200 kg NPK/tree/year along with 100 kg FYM/ tree/year increased the yield and growth parameters like tree girth, fruit weight and fruit number of nutmeg (Pugalendhi *et al.,* 2000).

Application of VAM along with *Azotobacter* and *Azospirillum* with 75 per cent nitrogen and phosphorus and 100 per cent 'K' from the recommended dose of fertilizer has been reported to give the best results in patchouli (Manjunath, 2001).

Jandev (2001) reported that a combination of 60 kg N/ha + 3g *Azotobactor* culture per plant led to maximum increase in plant height (71.25 cm), number of leaves (1384), herb yield (155.90 q/ha) and oil content (0.28 %) in *Melissa officinalis*.

Kumari and Kumari (2002) studied that application of vermicompost enriched with rockphosphate increased the growth i.e., root-shoot ratio, yield attributes like number of pods per plant, number of seeds per pod and 100 seed weight of Cowpea (*Vigna unguiculata*).

According to Ajimoddin (2002) application of *Azotobacter*, PSB and VAM with 75% NPK at recommended dose produced the higher herb yield (54.83 t/ha), oil yield (768.13 l/ha) and net profit (1:2.275) as compared to all other treatments in basil.

Dahama (2002) reported that the application of *Azotobactor* increased the yield of wheat, rice, maize, pearl millet and sorghum by 0-30 per cent over control. Apart from N this organism is capable of producing antibacterial, antifungal compounds and hormones beneficial to crop plants.

Chauhan *et al.* (2002) observed that among the different sources, plants supplied with caster cake recorded the highest andrographolide (2.816%), which was at par with plants supplied with urea (2.752%) and groundnut cake (2.751%). Between the two nitrogen levels, N at 40kg/ha resulted in higher andrographolide (2.969%) than N at 20kg/ha (2.452%).

Kanjilal *et al.* (2002) observed that seedlings of Kalmegh transplanted at 30x30cm spacing in the 1st week of May, supplied with 50:30:30kg NPK/ha and harvested after about 6 months yielded 3.0-4.0 tones biomass/ha .

At Solan, 15 tonnes FYM + 40 kg N + 30 kg P_20_5, + 2 kg *Azotobacter* were found to be optimum combination of fertilizer for getting maximum flowering shoot yield, oil content and oil yield in *Salvia sclarea* (Anonymus, 2003).

The bio-fertilizers (*Azotobacter* + *Azospirillum* + VAM) along with reduced levels of nitrogen and phosphorus (50% N, P and 100% K) gave high cumulative herb yield (18.23 t/ha), oil yield (216.44 1/ha) and was found to be highly remunerative and economic dose by recording maximum return/ha/year (1:4.86) in rosemary (Anuradha, 2002).

Application of *Azotobacter,* PSB and VAM with 75% NPK of the recommended dose of fertilizer produced the highest herb yield (54.83 t/ha), oil yield (168.13 1/ha) and net profit (1:2.275) compared to all other treatments in basil (Ajimoddin, 2002).

Bhojvaid *et al.* (2003) found that spacing of 75x75cm is optimum in *A. paniculata* for crown spread (46.8cm), pod formation (130/plant) and biomass yield (86.4 g wt. and 69.37 g dry wt. per plant).

Chezhiyan *et al.* (2003) revealed that highest number of branches per plant, number of leaves per plant, plant spread, specific leaf area, fresh weight per plant (13.08 g/plant), dry weight of leaf per plant (50.90 g/plant) were exhibited by poultry manure with *Azospirillium* and phosphobacteria at wider spacing (45 x 10 cm) in *Phyllanthus amarus.*

Thakur (2003) reported that FYM+ PSB+ *Azotobacter* combination gave maximum plant height (20.81 cm), number of leaves per plant (29.81), number of flowers per plant (2.86), fresh and dry flower weight per plant (0.25 and 0.09 g), fresh and dry herb yield (149.41 and 37.35 q/ha) in *Viola pilosa*.

Kumarvel (2004) observed that application of 15 t of FYM with microbial inoculum (*Azotobacter* + PSB) produced the highest herb yield (27.95 1/ha), oil yield (176.79 1/ha) and a net profit (1:5.76) compared to all other treatments in sweet worm wood.

Saraf and Tiwari (2004) reported maximum seed yield of main and ratoon crop (397.3 and 654.3 kg/ha, respectively) by combined application of 75 per cent NPK + 10t FYM + bio-fertilizers, closely followed by 100 per cent NPK recommended dose (356.7 and 608.6 kg/ha, respectively) in muskadana.

Chauhan *et al*. (2005) studied the effect of NPK (25:25:25 and 50:50:50 kg/ha) and FYM (5, 10 and 15 t/ha) alone and in combination on the growth and yield of *Chlorophytum borivillianum* (safed musli) and found that application of FYM @ 15t/ha produced yield at par with combined application of FYM @ 15t/ha plus lower or higher levels of NPK, suggesting that safed musli can be grown organically without loss in productivity.

Several experiments during the last decade have proved that use of *Azotobacter, Azospirillum*, VAM and Phosphorus Solubilizing Bacteria improve the growth and yield of various medicinal and aromatic plants (Vasundhara *et al.,* 2005).

Kumudha (2005) from Coimbatore (Tamil Nadu) reported that among the biofertilizers, phosphobacteria inoculation was found to be the more effective in general and VAM fungi inoculation was observed to be effective in chlorophyll pigments accumulation. It is concluded that biofertilizer inoculation could improve plant growth, biomass and biochemical constituents of the seedlings and thereby producing elite seedlings and improve the survival rate of planted seedlings.

Muthukumar and Udaiyan (2006) revealed that combined inoculation of VAM fungi, PSB and *Azospirillum brasilense* resulted in maximum growth response both under fertilized and unfertilized conditions in both soil. Fertilizer application enhanced the efficiencies of N, P and K uptake and reduced their usage efficiencies. Though soil type did not affect microbial inoculation response, fertilizer application significantly affected plant response to microbial inoculation**.**

Singh and Singh (2006) found that 30x30 cm. spacing registered the highest plant dry weight (5-26 g), whereas a spacing of 15x15cm registered the highest fresh and dry herb yield per plot (282.62 and 166.08 g) and per ha (1.25 t and 0.75 t) and the highest andrographolide content (4.6%).

At Akola, plant spacing of 30x15 cm produced significantly higher total yield of andrographolide in Kalmegh. Significantly highest fresh and dry foliage yield was recorded in Kalmegh when the harvesting was done 60 days after 50% flowering stage. Whereas, at Faizabad, application of pressmud at 10t/ha resulted in the maximum number of primary branches (12.0) and highest dry herbage yield (44.55 q/ha) in Kalmegh. Application of FYM 10t/ha also produced comparable dry herbage yield in Kalmegh (43.46 q/ha). (Anonymous. 2008).

Li Mei *et al.* (2006) observed that after being inoculated with PSB for six months, the average height of *Bruguiera gymnorrhiza* seedlings were increased by 24.07-10.00% and the biomass was accordingly increased by 32.36-19.71%. The total N and P contents of inoculated seedling leaves were 23.39-4.05% and 32.79-4.99%, respectively, higher than those of the controls. The results also revealed that the growth promoting effects of the bacteria were higher than the nitrogen fixing strains.

Kumudha (2008) observed that in *Tamarindus indica* seeds, single inoculation with phosphobacteria enhanced the growth and biochemical parameters and all the employed biofertilizers in general improved the plant growth, biomass and nutrient uptake of the seedlings.

Azizi *et al.* (2008) reported that 15% vermicompost plus 2 mm irrigation per two weeks was the best method to produce the Goral cultivar of German chamomile (*Matricaria recutita*) in organic system**.**

2.5 Harvesting

Andrographis paniculata has also been successfully propagated by stem cutting in its natural habitat with 81 per cent stem cutting establishment at Shevary hills (Aagesaboopathi and Balu, 1995). *A. paniculata* Nees has also been mass multiplied by stem cutting with 75% establishment (Balu and Alagesaboopathi, 1996).

Namade *et al.* (2001) found that all the growth and yield attributes of Kalmegh were significantly influenced with dates of early planting i.e., 27th meteorological week (MW) being significantly superior. Date of harvesting had no significant influence on growth and yield attributes. Early planting (27thMW) and delayed harvesting (46thMW) produced significantly maximum dry foliage. As regards the quality, planting dates did not affect andrographolide content but it was higher due to early harvesting (42thMW).

Gupta and Srivastva (1995) reported that late harvested nursery raised plants of *Andrographis paniculata* had higher andrographolide per cent. Whereas, Ashoka *et al.* (2002) found that the best time of harvesting was observed at 120 days after sowing to get higher biomass containing maximum andrographolide content. Kanjilal *et al.* (2002) revealed that Kalmegh seedlings transplanted at 30x30cm. in the 1st week of May, supplied with 50:30:30kg NPK/ha and harvested after about 6 months yielded 3.0-4.0 tones biomass/ha .

Maheshwari *et al.* (2002) from Madhya Pradesh reported that planting on 16th July followed by harvesting on 16th November gave the higher herbage yield and andrographolide content. Whereas, Wankhade *et al.* (2005) observed that the pooled dry foliage yield decreased with delay in planting and increased with delay in harvesting whereas the total andrographolide content decreased with delay in harvesting.

Chapter-3

MATERIALS AND METHODS

The present investigations entitled **"Studies on the standardization of cultivation practices of *Andographis paniculata* Nees under mid hill conditions of Himachal Pradesh"** were carried out in the experimental area of the Department of Forest Products, Nauni, Solan (H.P.) during 2007-09. The materials and methods employed during the course of investigations have been detailed under the following heads:

3.1 Experimental site

3.1.1 Location

3.1.2 Climate and weather conditions

3.1.3 Soil characters

3.2 Effect of different growing media on seed germination and growth parameters

3.2.1 Experimental design

3.2.2 Treatment combinations

3.3 Effect of mulching and spacings on seed germination and seedling vigour

3.3.1 Experimental design

3.3.2 Treatment combinations

3.4 Effect of spacings, organic fertilizers and harvesting stage on growth and development of *Andrographis paniculata*

3.4.1 Experimental design

3.4.2 Treatment combinations

3.5 Statistical analysis

In the present investigations on *Andrographis paniculata*, the data recorded were subjected to statistical analysis. Analysis of variance was worked out by using SX model in computer and CD was calculated.

3.1 EXPERIMENTAL SITE

3.1.1 Location

The present studies were undertaken in the experimental farm of the department of Forest Products falling in the mid hill zone of Himachal Pradesh. The geographical location of the site is as under:

Altitude	:	1235 m
Latitude	:	30^0 52' N
Longitude	:	$70^0$11' E

3.I.2 Climate and weather conditions

The climate and weather conditions recorded during the period of crop growth are presented in Appendix-I. From the table it has been found that maximum rainfall (348.9 mm) was recorded in the month of September followed by June (265.5mm) and August (248.3 mm), however no rainfall occurred in the month of March-2009. Maximum average temperature (25.05^{0}C) was recorded in the month of July, 2009 followed by June, 2009 (23.85^{0}C) and August, 2009 (23.80^{0}C). Minimum average temperature was recorded in the month of January, 2009 (10.10^{0}C). Similarly maximum humidity was recorded in the August, 2009 (81%) followed by June, 2009 (80%), whereas minimum humidity (37%) was recorded in the months of February and November, 2009 followed by April, 2009 (42%). It is quite evident from this table that climatic conditions were quite conducive for the cultivation of *Andrographis paniculata* like any other crop.

3.1.2 Soil characteristics

The site was characterized by undulating topography and experimental area was terraced. The soil was sandy loam in texture. Soil samples were taken randomly from the entire experimental area before transplanting and thoroughly mixed together, thus a composite representative sample from whole of the area was taken for chemical analysis to evaluate the fertility status of soil prior to any treatment. Observations recorded on the soil analysis are given below:

Sr. No.	Parameters	Test value
1.	pH	7.72
2.	Electrical conductivity (m hos/cm)	0.42
3.	Organic carbon (%)	0.99
4.	Available nitrogen (kg/ha)	315
5.	Available phosphorus (kg/ha)	12.80
6.	Available potash (kg/ha)	284.8

3.1.3.1.1 pH determination

It was conducted by pH meter in 1:2.5 soil and water suspension using glass electrodes.

3.1.3.2 Electrical conductivity

Electrical conductivity was determined in 1:2.5 soil and water suspension culture as described by Jackson (1967).

3.1.3.3 Organic carbon

Organic carbon was determined by Walkley and Black's rapid titration method as described by Piper (1966).

3.1.3.4 Available nitrogen

It was determined by alkaline permanganate method (Subbiah and Asija, 1956).

3.1.3.5 Available phosphorous

Available phosphorous was determined as per the method of Olsen *et al*. (1954).

3.1.3.6 Available potassium

Available potassium estimation was done by Flame Photometer after extracting the soil with neutral ammonium acetate according to the method described by Merwin and Peech (1951).

3.2 EFFECT OF DIFFERENT GROWING MEDIA ON SEED GERMINATION AND GROWTH PARAMETERS

3.2.1 Experimental design

The experiment was laid out in completely randomized design in field and under glasshouse conditions with ten treatments and three replications as given below**:**

3.2.1.1 Standardization of nursery raising techniques of *A. paniculata.*

It was conducted under following experiments:

3.2.1.1.1 Effect of different growing media on seed germination and growth parameters

Treatments: **Field Conditions**

F_1	:	Open conditions
F_2	:	Glass house conditions

Soil Media:

S_1	:	Sand
S_2	:	Soil
S_3	:	Sand + Soil (1:1)
S_4	:	Sand + FYM (1:1)
S_5	:	Soil + FYM (1:1)
S_6	:	Sand + Soil + FYM (1:1:1)
S_7	:	Soil + Vermicompost (1:1)
S_8	:	Soil + Cocopeat (1:1)
S_9	:	Soil + Cocopeat + Vermicompost (1:1:1)
S_{10}	:	Soil + Cocopeat + FYM (1:1:1)

Design : CRD (10x2 factorial)

No. of replications : 3

Observations recorded:

i. Initiation of germination (days)

It is the time/date/day when the first plumule leaf emerges.

ii. Mean daily germination (%)

It 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 percent germination divided by total days in the test gives the final mean daily germination.

iii. Peak germination period (days)

It was taken from the day on which maximum number of seeds germinated throughout the experiment period (from date of sowing till completion of germination).

iv. Completion of germination (days)

It was taken from the day after which no further germination was noticed.

v. Germination percent

The total number of seeds germinated were counted and germination per cent was worked out by the following formula:

$$\text{Germination (\%)} = \frac{\text{Total cumulative germination}}{\text{Total number of seeds sown}} \times 100$$

vi Number of leaves per seedling

It was counted after 75 days from the date of seed sowing. All the leaves of seedlings were counted and reported as mean.

vi. Root length (cm)

It was recorded from the point where first root started upto the end tip of the main root and reported as mean in cm after 75 days from seed sowing.

vii. Shoot length (cm)

It was recorded from collar region to apical bud in cm. and reported as mean after 75 days from seed sowing**.**

viii. Fresh root weight (g)

It was recorded on 75^{th} day after seed sowing immediately after uprooting and separating the shoot form root, weighed and reported as mean in grams.

ix. Fresh shoot weight (g)

It was recorded on 75^{th} day after seed sowing immediately after uprooting and separating the root from shoot, weighed and reported as mean in grams.

x. Dry root weight (g)

The root was oven dried till there was no further loss in its weight and reported as mean in grams.

xi. Dry shoot weight (g)

The shoot was oven dried till there was no further loss in its weight and reported as mean in grams.

3.3 EFFECT OF MULCHING AND LINE SPACINGS ON SEED GERMINATION AND GROWTH PARAMETERS

Treatments:

Mulching

M_1 : With mulch

M_2 : Without mulch

Spacings:

S_1	:	10cm
S_2	:	15cm
S_3	:	20cm
Design	:	RBD (3x2 factorial)
No. of replications	:	3

Observations recorded:

i. Germination percentage

The total number of seeds germinated were counted and the germination per cent was worked out by the following formula:

$$\text{Germination (\%)} = \frac{\text{Total cumulative germination}}{\text{Total number of seeds sown}} \text{ X } 100$$

ii. Survival percentage

The seedlings survived at transplanting stage after completion of germination were counted and recorded in percent (total number of seedlings survived/total number of seedlings germinated x 100).

iii. Number of leaves per seedling

Numbers of leaves from three plants were counted in each plot and their mean was calculated.

iv. Seedling 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 in cm.

v. Seedling 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 after 75 days from seed sowing.

vi. Fresh root weight (g)

It was recorded on 75th day after seed sowing immediately after uprooting and separating the shoot from root, weighed and reported as mean in grams.

vii. Fresh shoot weight (g)

It was recorded on 75th day after seed sowing immediately after uprooting and separating the root from shoot, weighed and reported as mean in grams.

viii. Dry root weight (g)

The root was oven dried till there was no further loss in its weight and reported as mean in grams.

ix. Dry shoot weight (g)

The shoot was oven dried till there was no further loss in its weight and reported as mean in grams.

3.4 EFFECT OF SPACINGS, ORGANIC FERTILIZERS AND HARVESTING STAGE ON GROWTH AND DEVELOPMENT OF *ANDROGRAPHIS PANICULATA*

Treatments:

Spacings:

S_1	:	15x15 cm
S_2	:	30x30 cm.
S_3	:	45x30 cm
S_4	:	45x45 cm.
S_5	:	60x45 cm
S_6	:	60x60 cm.

Organic fertilizers*:*

F_0	:	Without fertilizer
F_1	:	FYM @ 20 t/ha
F_2	:	Vermicompost @ 20 t/ha
F_3	:	*Azotobacter* @ 10kg/ha
F_4	:	Vesicular Arbuscular Mycorrhizae (VAM) @ 10 kg/ha
F_5	:	Phosphate Solubilizing Bacteria (PSB) @ 10 kg/ha
F_6	:	N: P: K @ 75:75:50 kg/ha

Harvesting stages:

H_1	:	Initiation of flowering
H_2	:	Full blooming
H_3	:	Post-Full blooming
Statistical Design	:	RBD (6x7x3 Factorial)
No. of replications	:	3

Observations recorded:

i. Plant height (cm)

The plant height was recorded in cm from the base of the stem to the highest tip of the plant.

ii. Number of primary branches/plant

The numbers of branches rising from main shoot/plant were counted and were reported as mean.

iii. Fresh aerial biomass (q/ha)

The aerial biomass constitutes the stem, leafy portion along with inflorescence if present. It was recorded in q/ha at three different harvesting stages as mentioned above. Three plants were selected randomly and their fresh aerial biomass was estimated and average was recorded.

iv. Dry aerial biomass (q/ha)

The above mentioned fresh aerial biomass after proper drying in oven was recorded in q/ha and dry aerial biomass was estimated and average was recorded.

v. Fresh underground biomass (q/ha)

The underground biomass constitute root portion and it was recorded in q/ha at three different harvesting stages as mentioned above. Three plants were selected randomly and their fresh underground biomass was estimated and average was recorded.

vi. Dry underground biomass (q/ha)

Fresh underground biomass after drying was recorded and average was reported in q/ha.

vii. Initiation of flowering

This was taken as first harvesting stage after 65 days of transplantation as the initiation of flowering took place when the plants were harvested.

viii. Full blooming stage

This was taken as second harvesting stage after 100 days of transplanting when the plants were harvested.

ix. Post full blooming stage

This was taken as third harvesting stage after 135 days of transplanting as the full blooming was almost over and the whole plants were harvested.

3.5 STATISTICAL ANALYSIS

The data recorded was subjected to statistical analysis. The Analysis of variance was worked out by SX Model in computer and CD values were calculated.

Chapter-4

EXPERIMENTAL RESULTS

The results obtained during present investigations entitled "Studies on the standardization of cultivation practices of *Andrographis paniculata* Nees under mid hill conditions of Himachal Pradesh" are presented in this chapter under the following headings:

4.1 Standardization of nursery raising techniques of *Andrographis paniculata.*

4.2 Effect of spacings, organic fertilizers and harvesting period on its growth and development

4.3 Cost of cultivation

4.1. Standardization of nursery raising techniques of *Andrographis paniculata*

4.1.1. Effect of different field conditions and growing media on seed germination and growth parameters

The experiment comprised of two field conditions i.e., under open conditions and glasshouse conditions and ten different soil media. Observations recorded were on the initiation of germination (days taken), mean daily germination (percentage), peak germination period (days), completion of germination (days taken), germination percentage, number of leaves per seedling, seedling root length (g), seedling shoot length (g), fresh seedling root weight (g), dry seedling root weight (g), fresh seedling shoot weight (g) and dry seedling root weight (g) and the data thus recorded is presented in Tables from 1-12 and detailed as under:

4.1.1.1. Initiation of germination (day)

The data presented in Table 1 revealed that early initiation of seed germination was recorded in S_1, S_2, S_3 and S_4 (7.50 days). It was followed by S_6 (8.17 days) and S_5 (8.33 days). Maximum days taken for initiation of seed germination were found in S_9 (10.50 days).

A perusal of data presented in Table 1 also revealed that among the field conditions initiation of seed germination was recorded in F_2 (6.47days) which was statistically higher than F_1 (10.37 days).

Among interaction effects between soil media and field conditions (Table 1) it was observed that initiation of seed germination was recorded in S_1F_2 and S_3F_2 (4.00 days) which was statistically at par with S_2F_2 and S_4F_2 (4.33 days). Whereas the maximum time taken for initiation of seed germination was recorded in S_9F_1 (12.00 days) which was statistically at par with S_1F_1 and S_3F_1 (11.00 days).

4.1.1.2. Mean daily germination (%)

Data presented in Table 2 showed that maximum mean daily germination percentage was found in S_8 (4.42) and it was significantly higher than other values. It was followed by S_3 (3.45 %) and S_1 (3.37 %). The minimum value was found in S_9 (1.17 %). Maximum germination percentage was observed in F_2 (2.95) while it was 2.25 in F_1 (Table 2).

Among the interaction effect of soil media and field conditions the maximum mean daily germination was recorded in S_3F_2 (4.63%) which was statistically at par with S_1F_2 (4.60%) but different from other values. Minimum mean daily germination was found in S_9F_2 (1.39%).

4.1.1.3. Peak germination period (day)

A perusal of data presented in Table 3 revealed that peak germination period was found in S_7 (16.33th day) which was statistically higher than all other values. It was followed by S_9 (13.83th day). Minimum value for this parameter was found in S_4 and S_5 (12.50th day). Peak germination period was found in F_2 (11.63th day) whereas it was 14.87th day in F_1.

Among interaction effect of soil media and field conditions, maximum value for peak germination period was recorded in S_7F_1 (18.33th day) which was statistically at par with S_4F_2 (10.67th day). Minimum value was recorded in S_1F_2 (11th day). It was followed by S_3F_2 and S_5F_2 (11.33th day).

Table 1. Effect of different field conditions and growing media on initiation of seed germination (days)

Date of sowing 19.07.2008

Treatments	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	Mean
F_1	11.00	10.67	11.00	10.67	10.67	10.33	8.67	8.33	12.00	10.33	**10.37**
F_2	4.00	4.33	4.00	4.33	6.00	6.00	9.33	9.00	9.00	8.67	**6.47**
Mean	**7.50**	**7.50**	**7.50**	**7.50**	**8.33**	**8.17**	**9.00**	**8.67**	**10.50**	**9.50**	

$CD_{0.05}$(S) 1.07 **$CD_{0.05}$(F)** 0.48 **$CD_{0.05}$(SXF)** 1.51

Field conditions

F_1 : Open conditions

F_2 : Glass house conditions

Soil media:

S_1 : Sand

S_2 : Soil

S_3 : Sand + Soil (1:1)

S_4 : Sand + FYM (1:1)

S_5 : Soil + FYM (1:1)

S_6 : Sand + Soil + FYM (1:1:1)

S_7 : Soil + Vermicompost (1:1)

S_8 : Soil + Cocopeat (1:1)

S_9 : Soil + Cocopeat + Vermicompost (1:1:1)

S_{10} : Soil + Cocopeat + FYM (1:1:1)

Table 2. Effect of different field conditions and growing media on mean daily germination (per cent)

Date of sowing 19.07.2008

Treatments	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	Mean
F_1	2.13 (**1.46**)	2.21 (1.48)	2.27 (1.50)	2.04 (1.43)	1.87 (1.36)	3.63 (1.90)	1.03 (1.02)	5.38 (2.32)	0.94 (0.97)	1.03 (1.07)	**2.25** (1.45)
F_2	4.60 (2.15)	3.97 (1.99)	4.63 (2.15)	3.13 (1.77)	2.60 (1.61)	2.50 (1.58)	1.77 (1.33)	3.45 (1.86)	1.39 (1.18)	1.44 (1.19)	**2.95 (1.68)**
Mean	**3.37 (1.80)**	**3.09 (1.74)**	**3.45 (1.83)**	**2.59 (1.60)**	**2.23 (1.49)**	**3.06 (1.74)**	**1.40 (1.17)**	**4.42 (2.09)**	**1.17 (1.07)**	**1.24 (1.13)**	

Figures in the parenthesis denotes square root transformed values

$CD_{0.05}$(S) 1.17 **$CD_{0.05}$(F)** 0.52 **$CD_{0.05}$(SXF)** 1.65

Field conditions

F_1 : Open conditions

F_2 : Glass house conditions

Soil media:

S_1 **:** Sand

S_2 **:** Soil

S_3 **:** Sand + Soil (1:1)

S_4 **:** Sand + FYM (1:1)

S_5 **:** Soil + FYM (1:1)

S_6 **:** Sand + Soil + FYM (1:1:1)

S_7 **:** Soil + Vermicompost (1:1)

S_8 **:** Soil + Cocopeat (1:1)

S_9 **:** Soil + Cocopeat + Vermicompost (1:1:1)

S_{10} **:** Soil + Cocopeat + FYM (1:1:1)

Table 3. Effect of different field conditions and growing media on peak germination period (days)

Date of sowing 19.07.2008

Treatments	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	Mean
F_1	14.67	14.33	14.00	14.33	13.67	14.00	18.33	14.33	16.33	14.67	**14.87**
F_2	11.00	11.67	11.33	10.67	11.33	11.67	14.33	11.67	11.33	11.33	**11.63**
Mean	**12.84**	**13.00**	**12.67**	**12.50**	**12.50**	**12.84**	**16.33**	**13.00**	**13.83**	**13.00**	

$CD_{0.05}$(S) 1.17 **$CD_{0.05}$(F)** 0.52 **$CD_{0.05}$(SXF)** 1.65

Field conditions

F_1 : Open conditions

F_2 : Glass house conditions

Soil media:

S_1 : Sand

S_2 : Soil

S_3 : Sand + Soil (1:1)

S_4 : Sand + FYM (1:1)

S_5 : Soil + FYM (1:1)

S_6 : Sand + Soil + FYM (1:1:1)

S_7 : Soil + Vermicompost (1:1)

S_8 : Soil + Cocopeat (1:1)

S_9 : Soil + Cocopeat + Vermicompost (1:1:1)

S_{10} : Soil + Cocopeat + FYM (1:1:1)

Table 4. Effect of different field conditions and growing media on germination percentage

Date of sowing 19.07.2008

Treatments	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	Mean
F_1	73.00 (**58.71**)	33.33 (35.24)	62.00 (52.01)	58.00 (49.62)	40.00 (39.23)	56.33 (48.66)	11.00 (19.36)	78.00 (62.04)	32.33 (34.65)	30.33 (33.42)	**47.43** (**43.23**)
F_2	87.00 (**68.91**)	47.33 (43.47)	80.00 (63.44)	60.33 (50.99)	50.33 (45.19)	65.33 (53.98)	**34.00** (35.63)	62.33 (52.17)	45.00 (42.13)	52.67 (46.53)	**58.43** (**50.24**)
Mean	**80.00** (**63.81**)	**40.33** (**39.35**)	**71.00** (**57.72**)	**59.17** (**50.30**)	**45.17** (**42.21**)	**60.83** (**51.32**)	**22.50** (**27.49**)	**70.17** (**57.10**)	**38.67** (**38.39**)	**41.50** (**39.97**)	

Figures in the parenthesis denotes Arc Sine transformed values

$CD_{0.05}$(S) 1.29 **$CD_{0.05}$(F)** 0.57 **$CD_{0.05}$(SXF)** 1.82

Field conditions

F_1 : Open conditions

F_2 : Glass house conditions

Soil media:

S_1 **:** Sand

S_2 **:** Soil

S_3 **:** Sand + Soil (1:1)

S_4 **:** Sand + FYM (1:1)

S_5 **:** Soil + FYM (1:1)

S_6 **:** Sand + Soil + FYM (1:1:1)

S_7 **:** Soil + Vermicompost (1:1)

S_8 **:** Soil + Cocopeat (1:1)

S_9 **:** Soil + Cocopeat + Vermicompost (1:1:1)

S_{10} **:** Soil + Cocopeat + FYM (1:1:1)

Table 5. Effect of different field conditions and growing media on completion of germination (days)

Date of sowing 19.07.2008

Treatments	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	Mean
F_1	20.00	26.00	24.00	32.00	34.00	23.67	25.00	21.00	22.00	24.00	**25.17**
F_2	14.00	20.00	18.00	25.00	26.00	19.00	21.00	18.00	18.00	16.00	**19.50**
Mean	**17.00**	**23.00**	**21.00**	**28.50**	**30.00**	**21.33**	**23.00**	**19.50**	**20.00**	**20.00**	

$CD_{0.05}$(S) 1.29 **$CD_{0.05}$(F)** 0.57 **$CD_{0.05}$(SXF)** 1.82

Field conditions

F_1 : Open conditions

F_2 : Glass house conditions

Soil media:

S_1 : Sand

S_2 : Soil

S_3 : Sand + Soil (1:1)

S_4 : Sand + FYM (1:1)

S_5 : Soil + FYM (1:1)

S_6 : Sand + Soil + FYM (1:1:1)

S_7 : Soil + Vermicompost (1:1)

S_8 : Soil + Cocopeat (1:1)

S_9 : Soil + Cocopeat + Vermicompost (1:1:1)

S_{10} : Soil + Cocopeat + FYM (1:1:1)

Table 6. Effect of different field conditions and growing media on number of leaves per seedling

Date of sowing 19.07.2008

Treatments	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	Mean
F_1	6.75	6.00	6.25	11.80	4.58	12.56	18.20	4.00	11.00	6.50	**8.76**
F_2	8.00	8.67	8.67	14.67	6.67	15.00	20.67	6.00	11.33	8.67	**10.83**
Mean	**7.38**	**7.33**	**7.46**	**13.23**	**5.62**	**13.78**	**19.43**	**5.00**	**11.17**	**7.58**	

$CD_{0.05}$(S) 0.82 **$CD_{0.05}$(F)** 0.37 **$CD_{0.05}$(SXF)** 1.16

Field conditions

F_1 : Open conditions

F_2 : Glass house conditions

Soil media:

S_1 : Sand

S_2 : Soil

S_3 : Sand + Soil (1:1)

S_4 : Sand + FYM (1:1)

S_5 : Soil + FYM (1:1)

S_6 : Sand + Soil + FYM (1:1:1)

S_7 : Soil + Vermicompost (1:1)

S_8 : Soil + Cocopeat (1:1)

S_9 : Soil + Cocopeat + Vermicompost (1:1:1)

S_{10} : Soil + Cocopeat + FYM (1:1:1)

4.1.1.4. Germination percentage

Maximum germination percentage was observed in S_1 (80.00%) which was statistically higher than all other values (Table 4). It was followed by S_3 (71.00%) and S_8 (70.17%). The minimum value was observed in S_7 (22.50%). Among field conditions maximum germination percentage was found in F_2 (58.43) and minimum in F_1 (47.43%).

Among interaction effects between soil media and field conditions, maximum germination percentage was recorded in S_1F_2 (87.00) which was statistically higher than other values and it was followed by S_3F_2 (80.00%) and S_8F_1 (78.00%).

4.1.1.5. Completion of germination

A perusal of data presented in Table 5 depicted that germination was completed on 17^{th} day in S_1 which was statistically higher than all other values. It was followed by S_8 (19.50^{th} day), S_9 and S_{10} (20.00^{th} day). Maximum days for completion of germination was recorded in S_5 (30.00^{th} day) which was at par with S_4 (28.50 day) but different from other values. Germination was completed on 19.50^{th} day in F_2, whereas it was completed on 25.17th days in $F_{1.}$

Among the interaction effects between field conditions and soil media minimum days for completion of germination was observed in S_1F_2 (14^{th} day). It was followed by $S_{10}F_2$ (16^{th} day) and S_3F_2, S_8F_2 and S_9F_2 (18^{th} day). The maximum number of days taken for completion of germination was observed in S_5F_1 (34 days).

4.1.1.6. Number of leaves per seedling

It was observed that maximum number of leaves per seedling was found in S_7 (19.43) which was statistically higher than all other values (Table 6). It was followed by S_6 (13.78) and S_4 (13.23). Minimum value for this observation was recorded in S_8 (5.00).

In glasshouse conditions (F_2) number of leaves per seedling was recorded as 10.83, whereas it was 8.76 in open conditions (F_1).

For interaction effect between soil media and field conditions maximum number of leaves per seedling was recorded in S_7F_2 (20.67) which was statistically higher than all other values (Table 6). It was followed by S_7F_1 (18.20), S_6F_2 (15.00) and S_4F_2 (14.67).

4.1.1.7. Seedling root length (cm)

Data presented in Table 7 revealed that maximum seedling root length was observed in S_7 (11.73 cm) which was statistically at par with S_6 (10.98 cm) but statistically different from other values. Minimum root length was observed in S_8 (2.77 cm). Under glasshouse conditions (F_2) seedling root length was 7.68 cm while it was 5.37 cm in F_1 (open condition).

Among interaction effects between soil media and field conditions maximum seedling root length was observed in S_7F_2 (12.90 cm) which was statistically at par with S_6F_2 (12.17 cm) but statistically different from all other values. Minimum seedling root length was recorded in S_8F_1 (2.00 cm).

4.1.1.8. Seedling shoot length (g)

Appraisal of data in Table 8 revealed that maximum seedling shoot length was recorded in S_7 (10.77 cm) which was statistically higher than all other values. It was followed by S_6 (8.67 cm) and S_4 (7.86 cm). Minimum value for seedling shoot length was recorded in S_8 (2.18 cm). Maximum seedling shoot length was recorded in F_2 (5.59 cm), whereas it was 4.40 cm in F_1.

Among interaction effect between soil media and field conditions maximum seedling shoot length was recorded in S_7F_2 (11.23 cm) which was statistically at par with S_7F_1 (10.30 cm) and S_6F_2 (9.13 cm) but statistically different from other values. Minimum seedling shoot length was recorded in S_5F_1 (2.00cm).

4.1.1.9. Fresh seedling root weight (g)

Data presented in Table 9 depicted that maximum seedling fresh root weight was found in S_7 (0.48 g) which was at par with S_6 (0.42 g) but statistically different from other values. It was followed by S_4 (0.41 g). Minimum value for this observation was found in S_5 and S_8 (0.01 g). Maximum fresh seedling shoot weight was recorded in F_2 (0.17 g) and minimum in F_1 (0.13 g).

Table 7. Effect of different field conditions and growing media on seedling root length (cm)

Date of sowing 19.07.2008

Treatments	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	Mean
F_1	3.20	3.90	3.50	5.90	3.10	9.80	10.56	2.00	5.50	6.24	**5.37**
F_2	6.13	6.53	6.33	8.93	4.70	12.17	12.90	3.53	8.23	7.33	**7.68**
Mean	**4.67**	**5.22**	**4.92**	**7.42**	**3.90**	**10.98**	**11.73**	**2.77**	**6.87**	**6.79**	

$CD_{0.05}$(S) 0.99 **$CD_{0.05}$(F)** 0.44 **$CD_{0.05}$(SXF)** 1.40

Field conditions

F_1 : Open conditions

F_2 : Glass house conditions

Soil media:

S_1 **:** Sand

S_2 **:** Soil

S_3 **:** Sand + Soil (1:1)

S_4 **:** Sand + FYM (1:1)

S_5 **:** Soil + FYM (1:1)

S_6 **:** Sand + Soil + FYM (1:1:1)

S_7 **:** Soil + Vermicompost (1:1)

S_8 **:** Soil + Cocopeat (1:1)

S_9 **:** Soil + Cocopeat + Vermicompost (1:1:1)

S_{10} **:** Soil + Cocopeat + FYM (1:1:1)

Table 8. Effect of different field conditions and growing media on seedling shoot length (cm)

Date of sowing 19.07.2008

Treatments	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	Mean
F_1	1.20	2.70	2.40	7.38	2.00	8.20	10.30	1.60	4.30	3.90	**4.40**
F_2	3.30	3.97	3.60	8.33	3.23	9.13	11.23	2.77	5.73	4.63	**5.59**
Mean	**2.25**	**3.33**	**3.00**	**7.86**	**2.62**	**8.67**	**10.77**	**2.18**	**5.02**	**4.27**	

$CD_{0.05}$(S) 0.94 **$CD_{0.05}$(F)** 0.42 **$CD_{0.05}$(SXF)** 1.33

Field conditions

F_1 : Open conditions

F_2 : Glass house conditions

Soil media:

S_1 **:** Sand

S_2 **:** Soil

S_3 **:** Sand + Soil (1:1)

S_4 **:** Sand + FYM (1:1)

S_5 **:** Soil + FYM (1:1)

S_6 **:** Sand + Soil + FYM (1:1:1)

S_7 **:** Soil + Vermicompost (1:1)

S_8 **:** Soil + Cocopeat (1:1)

S_9 **:** Soil + Cocopeat + Vermicompost (1:1:1)

S_{10} **:** Soil + Cocopeat + FYM (1:1:1)

Table 9. Effect of different field conditions and growing media on fresh seedling root weight (g)

Date of sowing 19.07.2008

Treatments	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	Mean
F_1	0.02	0.03	0.02	0.34	0.01	0.36	0.42	0.01	0.05	0.03	**0.13**
F_2	0.02	0.03	0.03	0.47	0.02	0.48	0.53	0.01	0.07	0.04	**0.17**
Mean	**0.02**	**0.03**	**0.03**	**0.41**	**0.01**	**0.42**	**0.48**	**0.01**	**0.06**	**0.03**	

$CD_{0.05}$(S) 0.06 **$CD_{0.05}$(F)** 0.03 **$CD_{0.05}$(SXF)** 0.09

Field conditions

F_1 : Open conditions

F_2 : Glass house conditions

Soil media:

S_1 **:** Sand

S_2 **:** Soil

S_3 **:** Sand + Soil (1:1)

S_4 **:** Sand + FYM (1:1)

S_5 **:** Soil + FYM (1:1)

S_6 **:** Sand + Soil + FYM (1:1:1)

S_7 **:** Soil + Vermicompost (1:1)

S_8 **:** Soil + Cocopeat (1:1)

S_9 **:** Soil + Cocopeat + Vermicompost (1:1:1)

S_{10} **:** Soil + Cocopeat + FYM (1:1:1)

Table 10. Effect of different field conditions and growing media on fresh seedling shoot weight (g)

Date of sowing 19.07.2008

Treatments	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**	**S_6**	**S_7**	**S_8**	**S_9**	**S_{10}**	**Mean**
F_1	0.12	0.15	0.18	1.02	0.16	1.08	1.25	0.70	0.59	0.32	**0.56**
F_2	0.22	0.25	0.22	1.10	0.18	1.23	1.78	0.10	0.71	0.45	**0.63**
Mean	**0.17**	**0.20**	**0.20**	**1.06**	**0.17**	**1.16**	**1.51**	**0.40**	**0.65**	**0.38**	

$CD_{0.05}$(S) 0.46 **$CD_{0.05}$(F)** 0.21 **$CD_{0.05}$(SXF)** 0.65

Field conditions

F_1 : Open conditions

F_2 : Glass house conditions

Soil media:

S_1 **:** Sand

S_2 **:** Soil

S_3 **:** Sand + Soil (1:1)

S_4 **:** Sand + FYM (1:1)

S_5 **:** Soil + FYM (1:1)

S_6 **:** Sand + Soil + FYM (1:1:1)

S_7 **:** Soil + Vermicompost (1:1)

S_8 **:** Soil + Cocopeat (1:1)

S_9 **:** Soil + Cocopeat + Vermicompost (1:1:1)

S_{10} **:** Soil + Cocopeat + FYM (1:1:1)

Table 11. Effect of different field conditions and growing media on dry seedling root weight (g)

Date of sowing 19.07.2008

Treatments	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	Mean
F_1	0.002	0.004	0.003	0.027	0.001	0.037	0.038	0.001	0.006	0.004	**0.012**
F_2	0.010	0.014	0.012	0.108	0.005	0.148	0.152	0.003	0.022	0.014	**0.048**
Mean	**0.006**	**0.009**	**0.007**	**0.067**	**0.003**	**0.092**	**0.095**	**0.002**	**0.014**	**0.009**	

$CD_{0.05}$(S) 0.008 **$CD_{0.05}$(F)** 0.002 **$CD_{0.05}$(SXF)** 0.012

Field conditions

F_1 : Open conditions

F_2 : Glass house conditions

Soil media:

S_1 **:** Sand

S_2 **:** Soil

S_3 **:** Sand + Soil (1:1)

S_4 **:** Sand + FYM (1:1)

S_5 **:** Soil + FYM (1:1)

S_6 **:** Sand + Soil + FYM (1:1:1)

S_7 **:** Soil + Vermicompost (1:1)

S_8 **:** Soil + Cocopeat (1:1)

S_9 **:** Soil + Cocopeat + Vermicompost (1:1:1)

S_{10} **:** Soil + Cocopeat + FYM (1:1:1)

Table 12. Effect of different field conditions and growing media on dry seedling shoot weight (g)

Date of sowing 19.07.2008

Treatments	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	Mean
F_1	0.030	0.050	0.060	0.180	0.030	0.280	0.320	0.020	0.240	0.060	**0.127**
F_2	0.061	0.069	0.067	0.291	0.050	0.391	0.425	0.045	0.320	0.091	**0.181**
Mean	**0.045**	**0.059**	**0.063**	**0.235**	**0.040**	**0.335**	**0.372**	**0.032**	**0.280**	**0.075**	

$CD_{0.05}$(S) 0.012 **$CD_{0.05}$(F)** 0.005 **$CD_{0.05}$(SXF)** 0.017

Field conditions

F_1 : Open conditions

F_2 : Glass house conditions

Soil media:

S_1 **:** Sand

S_2 **:** Soil

S_3 **:** Sand + Soil (1:1)

S_4 **:** Sand + FYM (1:1)

S_5 **:** Soil + FYM (1:1)

S_6 **:** Sand + Soil + FYM (1:1:1)

S_7 **:** Soil + Vermicompost (1:1)

S_8 **:** Soil + Cocopeat (1:1)

S_9 **:** Soil + Cocopeat + Vermicompost (1:1:1)

S_{10} **:** Soil + Cocopeat + FYM (1:1:1)

Among interaction effects between soil media and field conditions maximum fresh root weight was observed in S_7F_2 (0.53 g) which was statistically at par with S_6F_2 (0.48 g) and S_4F_2 (0.47 g). Minimum value for seedling fresh root weight was observed in S_8F_1, S_5F_1 and S_8F_2 (0.01 g).

4.1.1.10. Fresh seedling shoot weight (g)

Data presented in Table 10 showed that maximum fresh seedling shoot weight was obtained in S_7 (1.51 g) which was statistically at par with S_6 (1.16 g) and S_4 (1.06 g). The minimum fresh seedling shoot weight was obtained in S_1 and S_5 (0.17 g). In F_2 fresh seedling shoot weight obtained was 0.63 g and it was 0.56 g in F_1.

Among interaction effects between soil media and field conditions maximum fresh shoot weight was obtained in S_7F_2 (1.78 g) which was statistically at par with S_7F_1 (1.25 g) and S_6F_2 (1.23 g). The minimum fresh seedling shoot weight was obtained in S_8F_2 (0.10 g). It was followed by S_1F_1 (0.12 g).

4.1.1.11. Dry seedling root weight (g)

Appraisal of data in Table 11 depicted that maximum dry seedling root weight was recorded in S_7 (0.095g) which was statistically at par with S_6 (0.092 g). It was followed by S_4 (0.67 g) but statistically different from other values. The minimum dry seedling root weight was recorded in S_8 (0.002g). It was followed by S_5 (0.003 g). In F_2 dry seedling root weight was recorded 0.048 g whereas it was recorded 0.012 g in F_1.

Among interaction effects between soil media and field conditions maximum dry root weight was found in S_7F_2 (0.152 g) which was statistically at par with S_6F_2 (0.148 g) but statistically different from other values. It was followed by S_4F_2 (0.108 g). Minimum dry root weight was recorded in S_8F_1 and S_5F_1 (0.001 g).

4.1.1.12. Dry seedling shoot weight (g)

Data presented in Table 12 revealed that maximum dry seedling shoot weight was found in S_7 (0.372 g) which was statistically different with all other values. It was followed by S_6 (0.335 g) and S_9 (0.280 g). Minimum dry seedling shoot weight was found in S_8 (0.032 g) which was followed by S_5 (0.40 g). In $F_{1,}$ 0.127 g dry seedling shoot weight was recorded whereas it was found 0.181 g in F_2.

Among interaction effect between soil media and field conditions maximum dry seedling root weight was obtained in S_7F_2 (0.425 g) which was statistically higher than all other values. It was followed by S_6F2 (0.391 g) and S_9F_2 and S_7F_1 (0.320 g). Minimum dry seedling shoot weight was obtained in S_8F_1 (0.020g).

4.1.2 Effect of mulching and line spacings on seed germination and seedling vigour

This experiment was conducted with two treatments of mulch as M_1 (With mulch) and M_2 (Without mulch) and three line to line spacings as S_1 (10cm), S_2 (15cm) and S_3 (20cm). Observations were recorded on germination percentage, survival percentage, number of leaves per seedling, seedling root length (cm), seedling shoot length (cm), fresh seedling root weight (g), fresh seedling shoot weight (g), dry seedling root weight (g) and dry seedling shoot weight (g). The results thus obtained are presented in Tables 13-16 parameter-wise under the following headings:

4.1.2.1 Germination percentage

A perusal of data of Table 13 revealed that highest germination of seeds was recorded in S_1 (41.34%) which was statistically higher than all other values. It was followed by S_2 (32.46%). The minimum germination percentage (29.71) was recorded in S_3. With application of mulch (M_1) maximum germination (40.15%) was recorded which was statistically different form the value obtained for without mulch (M_2) i.e., 28.85 per cent.

Among interaction effect between line spacings and mulch maximum germination was found in S_1M_1 (51.20%) which was statistically higher than all other values, however it was followed by S_2M_1 (34.91%) and S_3M_1 (34.34%). Minimum value for this observation was found in S_3M_2 (25.08%).

4.1.2.2 Seedling survival percentage

Maximum seedling survival percentage was observed in S_1 (83.78%) which was statistically higher than all other values. It was followed by S_3 (81.52%). The minimum seedling survival was observed in S_2 (78.09%). The seedling survival was 84.79% with mulch (M_1) and without mulch (M_2) it was recorded as 77.47% (Table 13).

Among interaction effect between spacings and mulching maximum seedling survival was recorded in S_1M_1 (88.41%) which was statistically at par with S_3M_1 (84.36%), whereas minimum value for seedling survival was recorded in S_2M_2 (74.58%).

Table 13. Effect of mulching and line spacings on seed germination, seedling survival and number of leaves per seedling

Date of sowing 06.08.08

Treatments	Germination %age			Survival %age			Number of leaves per plant		
	M_1	**M_2**	**Mean**	**M_1**	**M_2**	**Mean**	**M_1**	**M_2**	**Mean**
S_1	51.20 (45.69)	31.48 (34.12)	**41.34 (39.91)**	88.41 (70.48)	79.15 (62.88)	**83.78 (68.68)**	28.29	14.67	**21.48**
S_2	34.91 (36.19)	30.00 (33.21)	**32.46 (34.70)**	81.61 (64.76)	74.58 (59.74)	**78.09 (62.25)**	26.43	12.72	**19.57**
S_3	34.34 (35.85)	25.08 (30.04)	**29.71 (32.94)**	84.36 (66.73)	78.68 (62.58)	**81.52 (64.66)**	18.83	11.61	**15.22**
Mean	**40.15 (39.24)**	**28.85 (23.46)**		**84.79 (67.32)**	**77.47 (61.73)**		**24.52**	**13.00**	

$CD_{0.05}$ (M)	2.02	3.13	2.40
$CD_{0.05}$ (S)	3.18	3.84	2.94
$CD_{0.05}$ (MxS)	3.50	5.42	4.16

Mulching		Line spacings	
M_1	With mulch	**S_1**	10cm
M_2	Without mulch	**S_2**	15cm
		S_3	20cm

4.1.2.3 Number of leaves per seedling

Appraisal of data presented in Table 13 revealed that maximum number of leaves per seedling was found in S_1 (21.48) which was statistically at par with S_2 (19.57). Minimum value was found in S_3 (15.22 number of leaves/seedling). With mulch (M_1) 24.52 leaves per seedling were found which was statistically different from M_2 (13.00 leaves/seedling).

Maximum number of leaves per seedling were obtained in S_1M_1 (28.29) which was statistically at par with S_2M_1 (26.43) and minimum were found in S_3M_2 (11.61).

4.1.2.4 Seedling root length (cm)

Appraisal of data presented in Table 14 revealed that the maximum seedling root length was recoded in S_1 (8.72 cm) and it was followed by S_2 (7.86 cm). The minimum value for seedling root length was recorded in S_3 (7.43 cm). With application of mulch (M_1) 8.56 cm seedling root length was obtained which was statistically at par with the value for without mulch (M_2) i.e., 7.45 cm.

Among interaction effects between line spacings and mulching maximum seedling root length was obtained in S_1M_1 (9.56 cm) which was statistically at par with S_2M_1 (8.21 cm) and S_3M_1 (7.91 cm), whereas the minimum value for this observation was recorded in S_3M_2 (6.95 cm).

4.1.2.5 Seedling shoot length (cm)

Data presented in Table 14 depicted that maximum seedling shoot length was observed in S_1 (6.88 cm) which was statistically higher than other values, however it was followed by S_2 (5.69 cm). Minimum value of 5.30 cm for this character was observed in S_3.Maximum shoot length (6.70 cm) was observed with mulch (M_1) and without mulch (M_2) it was 5.21 cm and both were at par with each other.

Table 14. Effect of mulching and line spacings on root and shoot length (cm)

Date of sowing 06.08.08

Treatments	Root length (cm)			Shoot length (cm)		
	M_1	**M_2**	**Mean**	**M_1**	**M_2**	**Mean**
S_1	9.56	7.89	**8.72**	7.94	5.81	**6.88**
S_2	8.21	7.50	**7.86**	6.29	5.09	**5.69**
S_3	7.91	6.95	**7.43**	5.87	4.73	**5.30**
Mean	**8.56**	**7.45**		**6.70**	**5.21**	

	Root length	Shoot length
$CD_{0.05}$ (M)	NS	0.91
$CD_{0.05}$ (S)	NS	1.12
$CD_{0.05}$ (MxS)	2.55	1.58

Mulching		Line spacings	
M_1	With mulch	S_1	10cm
M_2	Without mulch	S_2	15cm
		S_3	20cm

Among interaction effects between line spacings and mulching the maximum value for seedling shoot length was recorded in S_1M_1 (7.94 cm) which was statistically higher than all other values. It was followed by S_2M_1 (6.29 cm) and S_3M_1 (5.87 cm). Minimum value (4.73 cm) for seedling shoot length was observed in S_3M_2.

4.1.2.6 Fresh seedling root weight (g)

Maximum fresh seedling root weight was recorded in S_3 (0.343 g) which was statistically higher than other values (Table 15). It was followed by S_1 (0.109 g) and minimum value was observed in S_2 (0.078 g). Statistically higher value for fresh seedling root weight was recorded in M_2 (0.234 g), whereas with mulch (M_1) it was 0.0119g.

Among interaction effects between line spacings and mulching maximum fresh seedling root weight was recorded in S_3M_2 (0.0567 g) which was statistically different from all other values. It was followed by S_3M_1 (0.119 g) and S_2M_1 (0.093 g). Minimum value of 0.063 g was recorded in S_2M_2.

4.1.2.7 Fresh seedling shoot weight (g)

Data presented in Table 15 showed that maximum fresh seedling shoot weight was recorded in S_3 (1.148 g) which was statistically higher than other values. It was followed by S_3 (1.431 g). Minimum value of 0.781 g was observed in S_2. With mulch (M_1) 1.606 g fresh seedling shoot weight was recorded which was statistically higher than that recorded for without mulch (M_2) i.e., 0.634 g.

Among interaction effects between line spacings and mulching it was found that maximum fresh seedling shoot weight was recorded in S_1M_1 (2.097 g) which was at par with S_3M_1 (1.673 g) but significantly different from other values. The minimum value for this character was recorded in S_2M_2 (0.513 g).

4.1.2.8 Dry seedling root weight (g)

Data presented in Table 16 revealed that maximum dry seedling root weight was recorded in S_1 (0.046 g) which was statistically at par with S_2 (0.038 g). The minimum value for dry seedling root weight was recorded in S_3 (0.030 g). With mulch (M_1) 0.050 g and without mulch (M_2) 0.025 g of dry seedling root weight was recorded.

The interaction effect indicated that maximum dry root weight was found in S_1M_1 (0.060 g) which was statistically at par with S_2M_1 (0.053 g). Minimum value (0.023 g) for dry seedling root weight was found in S_2M_2 and S_2M_3.

Table 15. Effect of mulching and line spacings on fresh seedling root and shoot weight (g)

Date of sowing 06.08.08

Treatments	Fresh seedling root weight (g)			Fresh seedling shoot weight (g)		
	M_1	**M_2**	**Mean**	**M_1**	**M_2**	**Mean**
S_1	0.146	0.073	**0.109**	2.097	0.766	**1.431**
S_2	0.093	0.063	**0.078**	1.050	0.513	**0.781**
S_3	0.119	0.567	**0.343**	1.673	0.623	**1.148**
Mean	**0.119**	**0.234**		**1.606**	**0.634**	

$CD_{0.05}$(M)	0.001	0.540
$CD_{0.05}$(S)	0.014	0.661
$CD_{0.05}$(MxS)	0.020	0.935

Mulching		Line spacings	
M_1	With mulch	S_1	10cm
M_2	Without mulch	S_2	15cm
		S_3	20cm

Table 16. Effect of mulching and line spacings on dry root and shoot weight (g)

Date of sowing 06.08.08

Treatments	Dry root weight (g)			Dry shoot weight (g)		
	M_1	**M_2**	**Mean**	**M_1**	**M_2**	**Mean**
S_1	0.060	0.033	**0.046**	0.516	0.196	**0.356**
S_2	0.053	0.023	**0.038**	0.443	0.147	**0.295**
S_3	0.037	0.023	**0.030**	0.253	0.133	**0.193**
Mean	**0.050**	**0.025**		**0.404**	**0.159**	

$CD_{0.05}$(M)	0.011	0.043
$CD_{0.05}$(S)	0.013	0.053
$CD_{0.05}$ (MxS)	0.019	0.075

Mulching		Line spacings	
M_1	With mulch	S_1	10cm
M_2	Without mulch	S_2	15cm
		S_3	20cm

4.1.2.9 Dry seedling shoot weight (g)

A perusal of data presented in Table 16 depicted that maximum dry seedling shoot weight was recorded in S_1 (0.356 g) which was statistically higher than all other values. It was followed by S_2 (0.295 g). Minimum dry shoot weight was recorded in S_3 (0.193 g). With mulch (M_1) maximum dry seedling shoot weight was recorded as 0.404 g which was statistically different than that recorded in M_2 (0.159 g).

Among interaction effect between line spacings and mulching dry seedling shoot weight was found maximum in S_1M_1 (0.516 g) which was statistically at par with S_2M_2 (0.443 g). It was found minimum in S_3M_2 (0.147 g).

4.2 Effect of spacings, organic fertilizers and harvesting stages on growth and development of *Andrographis paniculata*

In this experiment, different spacings, fertilizers and harvesting stages were compared for their performance with regard to the plant height (cm), number of primary branches per plant, fresh aerial biomass (q/ha), dry aerial biomass (q/ha), fresh underground biomass (q/ha) and dry underground biomass (q/ha). The results thus obtained for different parameters are presented in Tables 17 to 22 and detailed under the following headings:

4.2.1 Plant height (cm)

The data presented in Table 17 revealed that maximum plant height (47.71 cm) was recorded in S_1 which was statistically at par with S_2 (46.77 cm) but statistically different from other values. The minimum plant height (38.51 cm) was recorded in S_5 which was statistically different from all other values.
Among different fertilizers maximum plant height (50.44 cm) was recorded in F_6 (Table 17) which was statistically higher than all other values. It was followed by F_5 (47.47 cm) and F_4 (45.82 cm). The minimum plant height (37.02 cm) was recorded for control (F_0).

Maximum plant height (45.47 cm) was recorded with H_3 (post full blooming stage) which was statistically at par (44.49 cm) with H_2 (full blooming stage) and minimum plant height (41.78 cm) was recorded in H_1 (initiation of flowering).

Among interaction effect between spacings and fertilizers maximum plant height was recorded in S_1F_6 (53.40 cm) which was statistically at par with S_1F_5 (51.94 cm), S_3F_6 (51.80 cm), S_2F_6 (51.10 cm), S_1F_4 (50.42 cm), S_4F_6 (50.00 cm), S_2F_5 (49.64 cm), S_2F_4 (48.15 cm), S_3F_5 (48.06 cm), S_1F_2 (47.33 cm) and S_2F_2 (47.04 cm). Minimum plant height (28.38 cm) was observed in S_5F_0 (Table 17).

Among interaction effects between fertilizers and harvesting stages maximum plant height was recorded in F_6H_3 (51.50 cm) which was statistically at par with F_6H_2 (51.30 cm), F_5H_3 (48.63 cm), F_6H_1 (48.60 cm), F_5H_2 (47.56 cm) and F_4H_3 (47.13 cm). Minimum value for this parameter was recorded in F_0H_1 (32.48 cm).

Maximum plant height for spacings and harvesting stages for interaction effect was recorded in S_1H_3 (49.50 cm) which was statistically at par with S_1H_2 (49.25 cm), S_2H_3 (47.59 cm), S2H_2 (47.19 cm), S_3H_3 (46.98 cm) S_2H_1 (45.54 cm) and S_4H_3 (45.32 cm). Minimum plant height was recorded in S_6H_1 (35.83 cm).

4.2.2 Number of primary branches per plant

A perusal of data presented in Table 18 revealed that maximum number of primary branches per plant were recorded in S_1 (22.03) which was statistically higher than all other values. It was followed by S_2 (20.89) and S_3 (19.68). The minimum number of primary branches per plant were recorded in S_4 (18.86).

Maximum number of primary branches per plant were observed in F_6 (23.24) which was statistically higher than all other values. It was followed by F_5 (21.59) and F_4 (20.61). Minimum number of primary branches per plant were observed in control i.e., F_0 (16.36).

Maximum number of primary branches per plant (21.19) were recorded in H_3 which was statistically higher than other values. However it was followed by H2 (19.75) and minimum number of primary branches per plant were recorded in H_1 (18.27).

Among the interaction effect between spacings and fertilizers maximum number of primary branches were found in S_1F_6 (24.70) which was statistically at par with S_2F_6 (24.20), S_3F_6 (24.00), S_1F_5 (23.11), S_4F_6 (23.10), S_1F_4 (22.67), S_2F_5 (22.44), S_1F_2 (22.00) and S_5S_6 (21.80). Minimum number of primary branches per plant (14.00) were found in S_4F_0 (Table 18).

Table 17. Response to spacings and fertilizers on plant height (cm) at different harvesting stages

Treatments	F_0	F_1	F_2	F_3	F_4	F_5	F_6	Mean	S_1	S_2	S_3	S_4	S_5	S_6
H_1	32.48	38.00	41.95	40.49	44.75	46.23	48.60	**41.78**	44.38	45.54	38.88	41.05	37.01	35.83
H_2	39.31	41.50	43.77	42.47	45.58	47.56	51.30	**44.49**	49.25	47.19	45.10	42.55	41.13	38.72
H_3	39.26	41.10	46.02	44.62	47.13	48.63	51.50	**45.47**	49.50	47.59	46.98	45.32	37.40	36.06
S_1	40.32	44.90	47.33	45.89	50.42	51.94	53.40	**47.74**				**$CD_{0.05}$**	(S)	**2.49**
S_2	41.84	43.10	47.04	46.53	48.15	49.64	51.10	**46.77**				**$CD_{0.05}$**	(F)	**2.69**
S_3	35.65	37.70	44.50	42.31	45.56	48.06	51.80	**43.65**				**$CD_{0.05}$**	(H)	**1.76**
S_4	36.71	40.90	41.74	41.34	44.10	46.07	50.00	**42.98**				**$CD_{0.05}$**	(SXF)	**6.58**
S_5	28.38	34.60	38.56	37.08	41.65	42.54	46.80	**38.51**				**$CD_{0.05}$**	(FXH)	**4.65**
S_6	39.19	40.30	44.48	42.01	45.06	46.59	49.50	**43.87**				**$CD_{0.05}$**	(SXH)	**4.31**
Mean	**37.02**	**40.25**	**43.94**	**42.53**	**45.82**	**47.47**	**50.44**					**$CD_{0.05}$**	(SXFXH)	**NS**

Spacings:

S_1	:	15x15 cm
S_2	:	30x30 cm.
S_3	:	45x30 cm
S_4	:	45x45 cm.
S_5	:	60x45 cm
S_6	:	60x60 cm.

Organic fertilizers*:*

F_0	:	Without fertilizer
F_1	:	FYM @ 20 t/ha
F_2	:	Vermicompost @ 20 t/ha
F_3	:	*Azotobacter* @ 10kg/ha
F_4	:	VAM @ 10 kg/ha
F_5	:	PSB @ 10 kg/ha
F_6	:	NPK @ 75:75:50 kg/ha

Harvesting stages*:*

H_1	:	Initiation of flowering
H_2	:	Full blooming
H_3	:	Post full blooming

Table 18. Response to spacings and fertilizers on number of primary branches/plant at different harvesting stages

Treatments	F_0	F_1	F_2	F_3	F_4	F_5	F_6	Mean	S_1	S_2	S_3	S_4	S_5	S_6
H_1	15.00	15.90	18.06	16.67	19.33	20.78	22.20	**18.27**	20.57	20.57	17.24	17.52	16.90	16.81
H_2	16.78	18.30	19.67	19.11	20.28	21.00	23.10	**19.75**	22.29	20.95	20.38	17.33	19.14	18.38
H_3	18.11	19.00	21.11	20.44	22.22	23.00	24.40	**21.19**	23.24	21.14	21.43	21.71	16.29	23.33
S_1	20.00	20.44	22.00	21.33	22.67	23.11	24.70	**22.03**				**$CD_{0.05}$**	(S)	**1.10**
S_2	18.89	19.70	20.22	19.78	21.00	22.44	24.20	**20.89**				**$CD_{0.05}$**	(F)	**1.19**
S_3	15.11	16.20	20.22	18.67	21.33	22.22	24.00	**19.68**				**$CD_{0.05}$**	(H)	**0.78**
S_4	14.00	16.10	18.67	17.56	20.78	21.78	23.10	**18.86**				**$CD_{0.05}$**	(SXF)	**2.91**
S_5	14.78	15.90	17.00	16.00	17.78	18.89	21.80	**17.45**				**$CD_{0.05}$**	(FXH)	**2.06**
S_6	17.00	18.00	19.56	19.11	20.11	21.11	21.70	**19.51**				**$CD_{0.05}$**	(SXH)	**1.90**
Mean	**16.63**	**17.72**	**19.61**	**18.74**	**20.61**	**21.59**	**23.24**					**$CD_{0.05}$**	(SXFXH)	**NS**

Spacings:

S_1 : 15x15 cm

S_2 : 30x30 cm.

S_3 : 45x30 cm

S_4 : 45x45 cm.

S_5 : 60x45 cm

S_6 : 60x60 cm.

Organic fertilizers*:*

F_0 : Without fertilizer

F_1 : FYM @ 20 t/ha

F_2 : Vermicompost @ 20 t/ha

F_3 : *Azotobacter* @ 10kg/ha

F_4 : VAM @ 10 kg/ha

F_5 : PSB @ 10 kg/ha

F_6 : NPK @ 75:75:50 kg/ha

Harvesting stages*:*

H_1 : Initiation of flowering

H_2 : Full blooming

H_3 : Post full blooming

Table 19. Response to spacings and fertilizers on fresh aerial biomass (q/h) at different harvesting stages

Treatments	F_0	F_1	F_2	F_3	F_4	F_5	F_6	Mean	S_1	S_2	S_3	S_4	S_5	S_6
H_1	14.52	17.80	23.42	21.85	26.02	33.05	41.40	**25.44**	71.34	30.65	22.56	13.75	8.54	5.83
H_2	24.62	32.30	43.16	34.15	47.46	51.52	62.70	**42.27**	112.70	48.97	44.10	22.62	14.61	10.63
H_3	30.92	47.30	59.13	54.59	63.12	68.19	89.40	**58.95**	141.30	81.93	59.93	36.59	20.84	13.07
S_1	54.54	85.93	112.20	98.25	119.00	128.00	161.00	**108.42**				**$CD_{0.05}$**	(S)	**6.41**
S_2	36.86	39.90	50.29	41.60	52.41	62.72	93.20	**53.85**				**$CD_{0.05}$**	(F)	**6.92**
S_3	22.28	34.10	43.44	38.09	47.09	51.84	58.60	**42.19**				**$CD_{0.05}$**	(H)	**4.53**
S_4	12.02	15.90	23.30	19.95	29.22	34.16	35.60	**24.32**				**$CD_{0.05}$**	(SXF)	**16.95**
S_5	8.33	11.40	13.20	14.92	14.78	17.17	22.80	**14.66**				**$CD_{0.05}$**	(FXH)	**11.98**
S_6	6.11	7.70	8.96	8.38	10.68	11.61	15.50	**9.84**				**$CD_{0.05}$**	(SXH)	**11.09**
Mean	**23.36**	**32.48**	**41.90**	**36.86**	**45.53**	**50.92**	**64.50**					**$CD_{0.05}$**	(SXFXH)	**NS**

Spacings:

S_1 : 15x15 cm

S_2 : 30x30 cm.

S_3 : 45x30 cm

S_4 : 45x45 cm.

S_5 : 60x45 cm

S_6 : 60x60 cm.

Organic fertilizers*:*

F_0 : Without fertilizer

F_1 : FYM @ 20 t/ha

F_2 : Vermicompost @ 20 t/ha

F_3 : *Azotobacter* @ 10kg/ha

F_4 : VAM @ 10 kg/ha

F_5 : PSB @ 10 kg/ha

F_6 : NPK @ 75:75:50 kg/ha

Harvesting stages*:*

H_1 : Initiation of flowering

H_2 : Full blooming

H_3 : Post full blooming

Among fertilizers and harvesting stages interaction effect maximum number of primary branches per plant were found in F_6H_3 (24.40) which was statistically at par with F_6H_2 (23.10) and F_5H_3 (23.00) and minimum values for this observation was found in F_0H_1 (15.00).

Among interaction effect of spacings and harvestings maximum number of primary branches per plant were found in S_6H_3 (23.33) which was statistically at par with S_1H_1 (23.24), S_1H_2 (22.29) and S_4H_3 (21.71). Minimum number of primary branches per plant were recorded in S_6H_1 (16.81).

4.2.3 Fresh aerial biomass (q/ha)

The data presented in Table 19 revealed that maximum fresh aerial biomass was recorded in S_1 (108.42 q/ha) which was statistically higher than all other values. It was followed by S_2 (53.85 q/ha) and S_3 (42.19). The minimum fresh aerial biomass was recorded in S_6 (9.84 q/ha).

Among different fertilizers maximum fresh aerial biomass (64.50 q/ha) was recorded in F_6 which was statistically different from all other values. It was followed by F_5 (50.92 q/ha) and F_4 (45.53 q/ha). The minimum fresh aerial biomass was recorded in control i.e., F_0 (23.36 q/ha).

In different harvesting stages maximum fresh aerial biomass was recorded in H_3 (58.95 q/ha) which was statistically higher than H_1 and H_2. It was followed by H_2 (42.27 q/ha) and minimum fresh aerial biomass (25.44 q/ha) was recorded in H_1 (initiation of flowering stage).

Among interaction effect between different spacings and fertilizers, maximum fresh aerial biomass was obtained in S_1F_6 (161.00 q/ha) which was statistically higher than all other values. It was followed by S_1F_5 (128.00 q/ha) and S_1F_5 (119.00q/ha) and minimum fresh aerial biomass (Table 19) was recorded in S_6F_0 (6.11 q/ha).

Among interaction effect between different spacings and harvesting stages maximum fresh aerial biomass was recorded in S_1H_3 (141.30 q/ha) which was statistically higher than all other values. It was followed by S_1H_2 (112.70 q/ha) and S_2H_3 (81.93 q/ha). The minimum fresh aerial biomass was recorded in S_6H_1 (5.83 q/ha).

Interaction effect among different fertilizers and harvesting stages revealed that maximum fresh aerial biomass was observed in F_6H_3 (89.40 q/ha) which was statistically higher than all other values. It was followed by F_5H_3 (68.19 q/ha) and F_4H_3 (63.12 q/ha). The minimum fresh aerial biomass was recorded in F_0H_1 (14.52 q/ha).

4.2.4 Dry aerial biomass (q/ha)

A perusal of data presented in Table 20 depicted that among different spacings maximum dry aerial biomass was recorded in S_1 (41.80 q/ha) which was statistically higher than all other values. This was followed by S_2 (21.18 q/ha) and S_3 (16.73 q/ha). The minimum dry aerial biomass was recorded in S_6 (3.76 q/ha).

Among different fertilizers maximum dry aerial biomass was recorded in F_6 (24.45 q/ha) which was statistically higher than all other values. It was followed by F_5 (20.09 q/ha) and F_4 (18.93 q/ha) and minimum (08.85 q/ha) dry aerial biomass was recorded in control (F_0).

Data for different harvesting stages revealed that maximum dry aerial biomass was observed in H_3 (26.33 q/ha) which was statistically higher than all other harvestings and it was followed by H_2 (16.13 q/ha). Minimum dry aerial biomass (Table 20) was recorded in H_1 (7.40 q/ha).

Among interaction effect between different spacings and fertilizers maximum dry aerial biomass (63.60 q/ha) was recorded in S_1F_6 which was statistically higher than other values. It was followed by S_1F_5 (49.27 q/ha) and S_1F_4 (47.33 q/ha). The minimum dry aerial biomass was recorded in S_6F_0 (2.45 q/ha).

Interaction effect among different fertilizers and harvesting stages revealed that maximum dry aerial biomass was recorded in S_1H_3 (63.34 q/ha) which was statistically higher than other harvesting stages. It was followed by S_1H_2 (42.58 q/ha) and S_2H_3 (35.53 q/ha) and minimum dry aerial biomass (Table 20) was recorded in S_6H_1 (1.78 q/ha).

Table 20. Response to spacings and fertilizers on dry aerial biomass (q/h) at different harvesting stages

Treatments	**F_0**	**F_1**	**F_2**	**F_3**	**F_4**	**F_5**	**F_6**	**Mean**	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**	**S_6**
H_1	3.83	4.79	6.73	5.48	8.58	9.26	13.10	**7.40**	19.48	8.97	7.18	4.04	2.93	1.78
H_2	9.56	12.40	16.55	13.22	18.29	19.75	23.10	**16.13**	42.58	19.05	16.79	8.48	5.76	4.13
H_3	13.15	21.20	26.46	25.16	29.91	31.26	37.20	**26.33**	63.34	35.53	26.23	15.96	11.58	5.36
S_1	19.71	32.84	42.85	36.97	47.33	49.27	63.60	**41.80**				$CD_{0.05}$	(S)	2.46
S_2	10.54	13.40	20.57	18.19	27.04	27.96	30.60	**21.18**				$CD_{0.05}$	(F)	2.66
S_3	9.00	14.50	17.76	14.83	18.71	19.65	22.70	**16.73**				$CD_{0.05}$	(H)	1.74
S_4	6.82	7.46	8.60	8.33	9.68	11.11	14.50	**9.49**				$CD_{0.05}$	(SXF)	6.51
S_5	4.57	5.56	6.13	6.04	6.99	8.40	9.59	**6.75**				$CD_{0.05}$	(FXH)	4.60
S_6	2.45	3.16	3.56	3.36	3.83	4.16	5.79	**3.76**				$CD_{0.05}$	(SXH)	4.26
Mean	**8.85**	**12.82**	**16.58**	**14.62**	**18.93**	**20.09**	**24.45**					$CD_{0.05}$	(SXFXH)	NS

Spacings:

S_1 : 15x15 cm

S_2 : 30x30 cm.

S_3 : 45x30 cm

S_4 : 45x45 cm.

S_5 : 60x45 cm

S_6 : 60x60 cm.

Organic fertilizers*:*

F_0 : Without fertilizer

F_1 : FYM @ 20 t/ha

F_2 : Vermicompost @ 20 t/ha

F_3 : *Azotobacter* @ 10kg/ha

F_4 : VAM @ 10 kg/ha

F_5 : PSB @ 10 kg/ha

F_6 : NPK @ 75:75:50 kg/ha

Harvesting stages*:*

H_1 : Initiation of flowering

H_2 : Full blooming

H_3 : Post full blooming

Table 21. Response to spacings and fertilizers on fresh underground biomass (q/h) at different harvesting stages

Treatments	F_0	F_1	F_2	F_3	F_4	F_5	F_6	Mean	S_1	S_2	S_3	S_4	S_5	S_6
H_1	1.18	1.42	1.75	1.64	2.11	2.60	2.76	**1.92**	6.52	1.86	1.32	0.84	0.58	0.41
H_2	1.59	1.87	2.26	2.07	2.42	2.61	3.00	**2.26**	7.74	2.16	1.47	0.98	0.71	0.50
H_3	2.04	2.43	2.68	2.60	2.95	3.11	4.03	**2.83**	8.87	2.96	2.15	1.38	0.94	0.70
S_1	5.46	6.35	7.21	6.96	7.80	9.13	11.10	**7.71**				**$CD_{0.05}$**	(S)	**0.49**
S_2	1.73	2.07	2.33	2.17	2.51	2.66	2.84	**2.33**				**$CD_{0.05}$**	(F)	**0.53**
S_3	0.91	1.17	1.61	1.37	1.96	2.14	2.38	**1.65**				**$CD_{0.05}$**	(H)	**0.34**
S_4	0.78	0.90	1.02	0.96	1.14	1.19	1.47	**1.07**				**$CD_{0.05}$**	(SXF)	**1.29**
S_5	0.44	0.60	0.72	0.70	0.80	0.85	1.12	**0.75**				**$CD_{0.05}$**	(SXH)	**0.84**
S_6	0.30	0.40	0.50	0.45	0.73	0.70	0.72	**0.54**				**$CD_{0.05}$**	(FXH)	**0.91**
Mean	**1.60**	**1.92**	**2.23**	**2.10**	**2.49**	**2.78**	**3.26**					**$CD_{0.05}$**	(SXFXH)	**NS**

Spacings:

S_1 : 15x15 cm

S_2 : 30x30 cm.

S_3 : 45x30 cm

S_4 : 45x45 cm.

S_5 : 60x45 cm

S_6 : 60x60 cm.

Organic fertilizers*:*

F_0 : Without fertilizer

F_1 : FYM @ 20 t/ha

F_2 : Vermicompost @ 20 t/ha

F_3 : *Azotobacter* @ 10kg/ha

F_4 : VAM @ 10 kg/ha

F_5 : PSB @ 10 kg/ha

F_6 : NPK @ 75:75:50 kg/ha

Harvesting stages*:*

H_1 : Initiation of flowering

H_2 : Full blooming

H_3 : Post full blooming

Table 22. Response to spacings and fertilizers on dry underground biomass (q/ha) at different harvesting stages

Treatments	F_0	F_1	F_2	F_3	F_4	F_5	F_6	Mean	S_1	S_2	S_3	S_4	S_5	S_6
H_1	0.47	0.46	0.89	0.59	1.00	1.06	1.14	**0.80**	2.79	0.79	0.52	0.34	0.23	0.15
H_2	0.75	0.87	1.03	0.93	1.15	1.15	1.33	**1.03**	3.42	1.07	0.71	0.44	0.33	0.23
H_3	1.07	1.17	1.38	1.30	1.54	1.70	2.13	**1.47**	4.62	1.47	1.20	0.68	0.47	0.35
S_1	2.59	2.75	3.67	2.96	4.09	4.17	5.03	**3.61**				**$CD_{0.05}$**	(S)	**0.22**
S_2	0.88	0.89	1.10	1.04	1.20	1.26	1.37	**1.11**				**$CD_{0.05}$**	(F)	**0.23**
S_3	0.39	0.49	0.8	0.67	0.91	1.13	1.27	**0.81**				**$CD_{0.05}$**	(H)	**0.15**
S_4	0.38	0.42	0.48	0.44	0.53	0.55	0.60	**0.49**				**$CD_{0.05}$**	(SXF)	**0.57**
S_5	0.21	0.27	0.34	0.30	0.37	0.39	0.51	**0.34**				**$CD_{0.05}$**	(SXH)	**0.38**
S_6	0.14	0.16	0.20	0.19	0.27	0.31	0.4	**0.24**				**$CD_{0.05}$**	(FXH)	**0.41**
Mean	**0.76**	**0.83**	**1.10**	**0.93**	**1.23**	**1.30**	**1.53**					**$CD_{0.05}$**	(SXFXH)	**NS**

Spacings:

S_1 : 15x15 cm

S_2 : 30x30 cm.

S_3 : 45x30 cm

S_4 : 45x45 cm.

S_5 : 60x45 cm

S_6 : 60x60 cm.

Organic fertilizers*:*

F_0 : Without fertilizer

F_1 : FYM @ 20 t/ha

F_2 : Vermicompost @ 20 t/ha

F_3 : *Azotobacter* @ 10kg/ha

F_4 : VAM @ 10 kg/ha

F_5 : PSB @ 10 kg/ha

F_6 : NPK @ 75:75:50 kg/ha

Harvesting stages*:*

H_1 : Initiation of flowering

H_2 : Full blooming

H_3 : Post full blooming

4.2.5 Fresh underground biomass (q/ha)

Appraisal of Table 21 revealed that maximum fresh underground biomass was observed in S_1 (7.71 q/ha) which was statistically higher than all other values. It was followed by S_2 (2.33 q/ha) and S_3 (1.65 q/ha). The minimum fresh underground biomass was observed in S_6 (0.54 q/ha).

Among different fertilizers maximum fresh underground biomass (3.26 q/ha) was recorded in F_6 which was statistically at par with F_5 (2.78 q/ha). It was followed by F_4 (2.49 q/ha) and F_3 (2.10 q/ha). The minimum fresh underground biomass was recorded in control i.e., F_0 (1.60 q/ha).

H_3 resulted in maximum fresh underground biomass (2.83 q/ha) which was statistically higher than all other harvesting stages, however it was followed by H_2 (2.26 q/ha). Minimum fresh underground biomass (Table 21) was recorded in H_1 (1.92 q/ha).

Among interaction effect between different spacings and fertilizers data revealed that the maximum fresh underground biomass was observed in S_1F_6 (11.10 q/ha) which was statistically higher than all other values and it was followed by S_1F_5 (9.13 q/ha) and S_1F_4 (7.80 q/ha). The minimum fresh underground biomass was observed in S_6F_0 (0.30 q/ha).

Data for interaction effect between different spacings and harvesting stages revealed that maximum fresh underground biomass was recorded in S_1H_3 (8.87 q/ha) which was statistically higher than other harvesting stages. It was followed by S_1H_2 (7.74 q/ha). Minimum value for this observation (Table 21) was recorded in S_6H_1 (0.41 q/ha). However, among the interaction effect between different fertilizers and harvesting stages, the maximum fresh underground biomass was recorded in F_6H_3 (4.03 q/ha) which was statistically higher than all other values. It was followed by F_5H_3 (3.11 q/ha) and F_6H_2 (3.00 q/ha).

4.2.6 Dry underground biomass (q/ha)

Appraisal of data in Table 22 depicted that maximum dry underground biomass was recorded in S_1 (3.61 q/ha) which was statistically higher than all other values. It was followed by S_2 (1.11 q/ha) and S_3 (0.81 q/ha). Minimum dry underground biomass was recorded in S_6 (0.24 q/ha).

Maximum dry underground biomass was observed in F_6 (1.53 q/ha) which was statistically at par with F_5 (1.30 q/ha). It was followed by F_4 (1.23 q/ha) and F_2 (1.10 q/ha). The minimum dry underground biomass was recorded in F_0 (0.76 q/ha).

Among different harvesting stages H_3 resulted in maximum dry underground biomass (1.47 q/ha) which was statistically higher than all other values. It was followed by H_2 (1.03 q/ha). Minimum dry underground biomass (Table 22) was recorded in H_1 (0.80 q/ha).

Interaction effect between different spacings and fertilizers revealed that maximum dry underground biomass was recorded in S_1F_6 (5.03 q/ha) which was statistically higher than all other values. It was followed by S_1F_5 (4.17 q/ha) and S_1F_4 (4.09 q/ha). The minimum dry underground biomass was recorded in S_6F_0 (0.14 q/ha). Among interaction effect between different spacings and harvesting stages, maximum dry underground biomass was recorded in S_1H_3 (4.62 q/ha) which was statistically higher than other harvesting stages. It was followed by S_1H_2 (3.42 q/ha). Minimum fresh underground biomass (Table 22) was recorded in S_6H_1 (0.15 q/ha).

The interaction effect between different fertilizers and harvesting stages showed that maximum dry underground biomass was recorded in F_6H_3 (2.13 q/ha) which was statistically higher than other values. It was followed by F_5H_3 (1.70 q/ha), whereas minimum value for this observation (Table 22) was recorded in F_0H_1 (0.46 q/ha).

4.3 Cost of cultivation

Benefit cost ratio was calculated on the basis of cost of cultivation and returns (Tables 23 and 24). Thus the data presented in Table 24 revealed that at initiation of flowering stage (H_1) for individual parameters of different spacings and fertilizers negative benefit: cost ratio was obtained. Among the interaction effect between different spacings and fertilizers, maximum benefit: cost ratio was obtained in 15x15 cm (S_1) spacing with the application of NPK, PSB and VAM i.e., 1.89:1, 1.22:1 and 1.20:1, respectively. All other combinations of spacings and fertilizers showed negative benefit: cost ratio. However minimum benefit: cost ratio (Table 24) was found in S_6F_2 i.e., 0.02:1 followed by S_5F_2 (0.04:1) and S_4F_2 (0.05:1).

Table 23. Cost of cultivation and returns of *Andrographis paniculata* at three harvesting stages on per hectare basis (Rs.)

	Cost of cultivation							Total Returns						
	H_1 (Initiation of flowering)							H_1 (Initiation of flowering)						
	S_1	S_2	S_3	S_4	S_5	S_6	Mean	S_1	S_2	S_3	S_4	S_5	S_6	Mean
F_0	68431	45965	43469	41806	40973	40349	**46832**	27213.31	17069.98	12661.47	8686.79	8063.70	3796.56	**12915.30**
F_1	85431	62965	60469	58806	57973	57349	**63832**	35497.74	20596.65	15651.84	10381.08	8074.81	4474.04	**15779.36**
F_2	268431	245965	243469	241806	240973	240349	**246832**	61902.16	25888.86	23105.90	12664.01	8790.36	4988.75	**22890.01**
F_3	69031	46565	44069	42406	41573	40949	**47432**	40786.63	20734.42	22474.05	11842.30	8599.25	4763.76	**18200.07**
F_4	69031	46565	44069	42406	41573	40949	**47432**	82875.47	34891.08	26505.16	13403.76	9731.10	5239.85	**28774.40**
F_5	69031	46565	44069	42406	41573	40949	**47432**	84328.80	41994.40	27468.86	15335.58	10738.51	5971.22	**30972.90**
F_6	71641	49175	46679	45016	44183	43559	**50042**	135066.53	43759.96	33966.63	19772.06	12292.58	11362.46	**42703.37**
Mean	**100147**	**77681**	**75184.7**	**73522**	**72689**	**72064.7**		**66810.09**	**29276.48**	**23119.13**	**13155.08**	**9470.043**	**5799.52**	

Contd…

H_2 (Full blooming)								H_2 (Full blooming)						
	S_1	**S_2**	**S_3**	**S_4**	**S_5**	**S_6**	**Mean**	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**	**S_6**	**Mean**
F_0	72531	50065	47569	45906	45073	44449	**50932**	72088.82	38477.74	37807.37	20365.14	9107.40	7920.06	**30961.09**
F_1	89531	67065	64569	62906	62073	61449	**67932**	107022.12	48944.40	38755.52	20646.61	13288.88	10931.36	**39931.48**
F_2	272531	250065	247569	245906	245073	244449	**250932**	153910.96	59077.72	56081.43	22044.12	13929.62	11360.24	**52734.01**
F_3	73131	50665	48169	46506	45673	45049	**51532**	118399.88	54322.17	35955.52	21535.49	13455.54	11199.69	**42478.05**
F_4	73131	50665	48169	46506	45673	45049	**51532**	160564.28	68166.60	60674.01	26221.84	20770.35	13423.51	**58303.43**
F_5	73131	50665	48169	46506	45673	45049	**51532**	173510.94	69633.26	65888.82	26310.73	24214.79	16721.75	**62713.38**
F_6	75741	53275	50779	49116	48283	47659	**54142**	180310.93	83722.14	72281.41	50251.12	33062.93	19907.78	**73256.05**
Mean	**104247**	**81781**	**79284.7**	**77622**	**76789**	**76164.7**	**82648**	**137972.60**	**60334.86**	**52492.01**	**26767.87**	**18261.36**	**13066.34**	

Contd…

H_3 (Post full blooming)								H_3 (Post full blooming)						
	S_1	**S_2**	**S_3**	**S_4**	**S_5**	**S_6**	**Mean**	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**	**S_6**	**Mean**
F_0	76631	54165	51669	50006	49173	48549	**55032**	101377.68	47233.29	34096.26	35782.20	25862.94	11571.90	**42654.04**
F_1	93631	71165	68669	67006	66173	65549	**72032**	177777.60	59044.39	80785.10	39905.59	31114.78	14541.26	**67194.79**
F_2	276631	254165	251669	250006	249173	248549	**255032**	202933.13	110066.56	87918.43	47065.98	35551.82	17549.51	**83514.24**
F_3	77231	54765	52269	50606	49773	49149	**55632**	200133.13	98033.24	81111.03	45564.77	34981.45	16032.88	**79309.42**
F_4	77231	54765	52269	50606	49773	49149	**55632**	219288.67	151099.85	89466.58	52344.92	35796.26	18238.38	**94372.44**
F_5	77231	54765	52269	50606	49773	49149	**55632**	223155.33	151366.52	93644.35	63342.29	44229.59	17577.29	**98885.89**
F_6	79841	57375	54879	53216	52383	51759	**58242**	302355.25	160066.51	109029.52	65594.11	45618.47	24518.76	**117863.8**
Mean	**108347**	**85881**	**83384.7**	**81722**	**80889**	**80264.7**		**203860.1**	**110987.2**	**82293.04**	**49942.84**	**36165.04**	**17147.14**	

Table 24. Benefit cost ratio analysis for *Andrographis paniculata* on per hectare basis at three harvesting stages

	S_1	S_2	S_3	S_4	S_5	S_6	Mean
H_1 (Initiation of flowering)							
F_0	0.40	0.37	0.29	0.21	0.20	0.09	**0.26**
F_1	0.42	0.33	0.26	0.18	0.14	0.08	**0.24**
F_2	0.23	0.11	0.09	0.05	0.04	0.02	**0.10**
F_3	0.59	0.45	0.51	0.28	0.21	0.12	**0.26**
F_4	1.20	0.75	0.60	0.32	0.23	0.13	**0.54**
F_5	1.22	0.90	0.62	0.36	0.26	0.15	**0.59**
F_6	1.89	0.89	0.73	0.44	0.28	0.26	**0.75**
Mean	**0.85**	**0.54**	**0.44**	**0.26**	**0.19**	**0.12**	
H_2 (Full blooming)							
F_0	0.99	0.77	0.79	0.44	0.20	0.18	**0.56**
F_1	1.20	0.73	0.60	0.33	0.21	0.18	**0.54**
F_2	0.56	0.24	0.23	0.09	0.06	0.05	**0.20**
F_3	1.62	1.07	0.75	0.46	0.29	0.25	**0.74**
F_4	2.20	1.35	1.26	0.56	0.45	0.30	**1.02**
F_5	2.37	1.37	1.37	0.57	0.53	0.37	**1.10**
F_6	2.38	1.57	1.42	1.02	0.68	0.42	**1.25**
Mean	**1.62**	**1.01**	**0.92**	**0.50**	**0.35**	**0.25**	
H_3 (Post full blooming)							
F_0	1.32	0.87	0.66	0.72	0.53	0.24	**0.72**
F_1	1.90	0.83	1.18	0.60	0.47	0.22	**0.86**
F_2	0.73	0.43	0.35	0.19	0.14	0.07	**0.32**
F_3	2.59	1.79	1.55	0.90	0.70	0.33	**1.31**
F_4	2.84	2.76	1.71	1.03	0.72	0.37	**1.57**
F_5	2.89	2.76	1.79	1.25	0.89	0.36	**1.66**
F_6	3.79	2.79	1.99	1.23	0.87	0.47	**1.86**
Mean	**2.29**	**1.75**	**1.32**	**0.85**	**0.62**	**0.29**	

Spacings

S_1	15x15 cm
S_2	30x30 cm
S_3	45x30 cm
S_4	45x45 cm
S_5	60x45 cm
S_6	60x60 cm

Organic Fertilizers

F_0	Without Fertilizer
F_1	FYM @ 20 t/ha
F_2	Vermicompost @ 20 t/ha
F_3	*Azotobacter* @ 10 kg/ha
F_4	VAM @ 10 kg/ha
F_5	PSB @ 10 kg/ha
F_6	NPK @ 75:75:50 kg/ha

Harvesting stages

H_1	Initiation of flowering
H_2	Full blooming stage
H_3	Post-Full blooming stage

At full blooming stage (H_2) maximum benefit: cost ratio (1.62:1) was obtained in S_1 followed by S_2 (1.01:1). Similarly with different fertilizers maximum benefit: cost ratio was obtained in F_6 (1.25:1) followed by F_5 (1.10:1) and F_4 (1.02:1). Among interaction effect between different spacings and fertilizers maximum benefit: cost ratio was obtained in S_1F_6 (2.38:1). It was followed by S_1F_5 (2.37:1), S_1F_4 (2.20:1), S_1F_3 (1.62:1) and S_2F_6 (1.57:1) (Table 24).

Similar trend was observed at post full blooming stage (H_3), where in addition to the previous two harvesting stages some other combinations of spacings and fertilizers also showed positive benefit: cost ratio (Table 24). Maximum benefit: cost ratio among different spacings was recorded in S_1 (2.29:1). It was followed by S_2 (1.75:1) and S_3 (1.32:1). In case of different fertilizers maximum benefit: cost ratio was obtained in F_6 (1.86:1), however it was followed by F_5 (1.66:1), F4 (1.57:1) and F_3 (1.31:1). Similarly among the different combinations between different spacings and fertilizers maximum benefit: cost ratio was found in S_1F_6, S_1F_5, S_1F_4 i.e., 3.79:1, 2.89:1, 2.84:1 and 2.59:1, respectively. It was followed by F_1S_1 (1.90:1). At 30x30 cm and 45x30 cm also showed positive benefit: cost ratio was as S_2 F_6 (2.79:1), S_2 F_5; S_2F_4 (2.76:1), S_3 F6 (1.99:1), S_1F_1 (1.90:1), S_2F_3; S3F5 (1.79:1), S_3 F_4 (1.71:1) and F_3S_3 (1.55:1) (Table 24).

From the data it was apparent that benefit: cost ratio decreased with the increase in spacings as maximum benefit: cost ratio was obtained with 15x15 cm spacings and minimum benefit: cost ratio was found with 60x60 cm spacing.

Further it also indicated that with the application of vermicompost, benefit: cost ratio was lowest, whereas, it was maximum with the application of NPK followed by PSB, VAM and *Azotobacter* application.

Chapter-5

DISCUSSION

The present investigations were carried out with the objective to identify the best growing media, field condition, mulching, spacing, fertilizer and harvesting stage for the cultivation of *Andrographis paniculata* Nees. The results thus obtained are discussed in this chapter under the following headings:

5.1 Relative response of different growing media on seed germination and growth parameters of *A. paniculata*.

5.2 Relative response of mulching and line spacings on seed germination and seedling vigour of *A. paniculata*.

5.3 Relative response of spacings, organic fertilizers and harvesting stages on growth and development of *A. paniculata*.

5.4 Cost of cultivation of *A. paniculata*.

5.1 Relative response of different growing media on seed germination and growth parameters of *A. paniculata*.

The germination of seeds is dependent on both internal and external conditions. The most important external factors are temperature, water, oxygen and sometimes light or darkness. Different seeds require distinctive variables for successful germination.

5.1.1 Relative response of different soil media on seed germination and growth parameters of *A. paniculata*.

In the present studies, it was observed that minimum days (7.50) were taken for initiation of seed germination each in sand + sand + soil (1:1:1) and sand+ FYM 1:1 proportion. Similarly maximum germination was recorded in sand (80.00%). In all these soil media, sand is common and it has very good stratification properties which led to fast initiation of seed germination and maximum seed germination. These findings are in line with those of Nautiyal and Chauhan (2007) in *Nardostachys jatamansi* DC where they observed that soil media containing more proportion of sand favoured fast completion of germination.

Maximum mean daily germination was found in soil+cocopeat (1:1)(4.42 %) which was statistically higher than all other values. It was followed by sand+soil (1:1) (3.45 %) and sand (3.37%). This may be due to the fact that cocopeat has high water holding capacity, thus availability of enough moisture which favoured the high daily seed germination.

Soil+vermicompost (1:1) media gave maximum peak germination period (16.33 days), number of leaves per seedling (19.43), seedling root length (11.73 cm), seedling shoot length (10.77 cm), fresh seedling root weight (0.48 g), fresh seedling shoot weight (1.51 g) and dry seedling root weight (0.095 g).

Maximum root length (11.73 cm) in which was statistically at par with sand + soil + FYM (1:1) (10.98 cm), maximum shoot length (10.77 cm) in soil + vermicompost (1:1) which was statistically at par with sand +soil + FYM (1:1) (10.77 cm), maximum fresh root weight (0.48 g) in soil+vermicompost (1:1) which was at par with S_6 (0.42 g), maximum dry root weight (0.09 g) in soil+vermicompost (1:1) which was statistically at par with S_6 (0.09 g), maximum fresh shoot weight (1.51 g) which was statistically at par with sand + soil + FYM (1:1:1) and sand + FYM (1:1) (i.e., 1.16 g and 1.06 g, respectively). Maximum dry root weight (0.09 g) in soil + vermicompost (1:1) which was statistically at par with sand + soil + FYM (1:1:1) (0.09 g). Maximum dry shoot weight was found in soil+vermicompost (1:1) (0.53 g) which was statistically higher than all other values. It was followed by soil + cocopeat + vermicompost (1:1:1) and sand + soil + FYM (1:1:1) as 0.34 g and 0.28 g, respectively. These findings are in line with those of Singh and Bammi (1971) in *Dioscorea deltoidea* and Thankmani *et al.* (1996) in *Piper longum*. This may be due to the fact that vemicompost and FYM has presence of readily available plant nutrient, growth enhancing substances and number of beneficial micro-organisms like nitrogen fixing, phosphorus solubilising and cellulose decomposing organisms (Sultan, 1997).

5.1.2 Relative response of field conditions on seed germination and growth parameters of *A. paniculata*.

The said experiment was conducted under two field conditions viz., open conditions and glasshouse conditions. Maximum values for all the growth and development parameters viz., initiation of seed germination (6.47days) , germination percentage (1.68), peak germination period (14.60^{th} day), maximum germination percentage (50.24), completion of germination (19.50^{th} day), number of leaves per plant (10.83), root length (7.68 cm), maximum shoot length (5.59 cm), maximum fresh root weight (0.17 g), fresh shoot weight (0.63 g), dry root weight (0.05 g), dry shoot weight (0.19 g) were recorded under glasshouse conditions which were significantly higher than the seeds sown in different soil media in open conditions.

The higher values may be due to the fact that controlled conditions are provided in glasshouse as a combined effect of increased temperature, moisture and low light intensity which facilitates the seeds to germinate and grow early. These findings are in line with those of Nautiyal and Chauhan (2007) in *Nardostachys jatamansi* DC where they reported poor seed germination in field conditions compared to polyhouse. Similar results were also reported by Nautiyal *et al.* (2001) in *Picrorhiza kurrooa* and Vashistha *et al.* (2009) in *Angelica archangelica* Linn.

From the above experiment it has been concluded that the seeds sown under glasshouse conditions with soil + vermicompost (1:1) media is the best conditions for getting early and healthy seedlings.

5.2 Relative response of mulching and line spacings on seed germination and seedling vigour of *A. paniculata*.

In the present investigations it was found that all parameters recorded for seed germination and seedling vigour responded better with application of mulch than without mulch. The observations were recorded on germination percentage (40.15), survival percentage (84.79), number of leaves per seedling (24.52), root length (8.56 cm), shoot length (6.70 cm), fresh root weight (0.112 g), fresh shoot weight (1.61 g), dry root weight (0.05 g) and dry shoot weight (0.40 g) (Tables 13-16. These studies are in harmony with those of Othieno (1980) who found that any kind of mulch is better than no mulch in soil moisture conservation. Similarly, Manipura (1972), Fairbourn and Gardner (1979) and Thakur (2003) reported higher growth and yield with the application of different mulches.

Under nursery conditions 10 cm line to line spacing performed better than other spacings which gave more number of plants per unit area, hence, it has been concluded from this experiment that use of mulch and sowing the seeds at 10 cm line spacing performed better for getting healthy seedlings of *Andrographis paniculata*.

5.3 Effect of spacings, organic fertilizers and harvesting stages on growth and development of *Andrographis paniculata* under field conditions.

5.3.1 Relative response of spacings on growth and development of *Andrographis paniculata*

Spacing plays an important role in growth and development of any plant as different plant respond differently at different spacings, which gets reflected in terms of different yield attributes. In the present investigations the effect of plant spacings on different growth and development parameters (plant height, number of primary branches per plant, fresh aerial biomass, dry aerial biomass, fresh underground biomass, and dry underground biomass) in *Andrographis paniculata* revealed that the spacing of 15x15 cm gave significant increase in all above mentioned growth and yield parameters (47.74 cm, 22.03 cm,108.42 q/ha, 41.80 q/ha, 7.71 q/ha and 3.61 q/ha, respectively (Tables 17, 18, 19, 20, 21, and 22 respectively). It may be due to more number of plants per unit area which contributes more towards increased herb yield. Such a phenomenon of higher yield at closer spacing has been reported by Kanjilal *et al.* (2002) and Singh and Singh (2006). Low herb yield in *Andrographis paniculata* may be due to less number of plants per unit area at wider spacings and moreover wider row spacings does not cover the space between two rows, thus resulting in more weed growth and lesser radiant energy utilization. The present studies are also in line with those of Katoch *et al.* (1979), Jha and Singh (1979) and Chandra *et al.* (2004).

5.3.2 Relative response of fertilizers on growth and development of *Andrographis paniculata*

Nitrogen is an important and vital plant nutrient. An appropriate quantity of nitrogen is associated with vigorous vegetative growth and development (Tisdale and Nelson, 1969). The effects of nitrogen on various crop plants have been studied and reported by many workers. Nitrogen fertilization has a definite role in getting higher economic yield as it is an important constituent of protein, nucleic acid, chlorophyll and indirectly interacting with phytohormones. It is also essential for cell division, vegetative and reproductive growth (Bhatia and Widge, 1986).

Phosphorus is an important structural unit of nucleic acid and phospholipids. Despite playing an indispensable role in energy metabolism, it is actively involved in metabolic processes like photosynthesis, respiration, protein synthesis and in cambial activity. Potassium on the other hand is needed for the proper growth and development of plants, maintenance of permeability of cell membrane, osmotic pressure of the cell and enzymatic activity. It is also needed in chlorophyll formation and photosynthesis (Dhami and Mahindru, 1996).

Biofertilizers, more appropriately called microbial inoculants are the products containing living cells of different micro organisms, which have the ability to mobilize nutritionally important elements from non usable to usable form through biological processes. Biofertilizers improve the health and productivity of soil and plants, as they provide different essential nutrients to encourage plant growth. Organic nutrients increase the abundance of soil organisms by providing organic matter and micronutrients for organisms such as fungal mycorrhiza, which aid plants in absorbing nutrients and results in the overall growth and development of plants. These are apparently environmental and farmer's friendly renewable resources. They play an important role in improving nutrient availability of crop plants. These include a diverse category of bio-inoculants such as nitrogen fixers, phosphate solubilizers and plant growth promoters (Arora and Dan, 2003). Microorganisms also play an important role in restoring the physico-chemical and biological properties of soil. The application of efficient strains of nitrogen fixing, phosphate solubilizing or cellulytic microorganisms to seed, soil or composting areas, effectively increase the number of such microorganisms and accelerate certain microbial processes to augment the extent of availability to nutrients in the form which can be assimilated by plants (Somani, 1987).

Production of growth regulators by phosphate solubilizing bacteria has been reported by Ponmurugan and Gopi, (2006). Several results suggested that phosphate-solubilizing bacteria have the ability to solubilize rock phosphate thereby increasing its availability to plants (Goenadi *et al.,* 2000 and Lal, 2002).

Inoculation of VAM fungi during an early stage of acclimatization process has become an alternative strategy for better establishment by improving the plant growth. The occurrence of micro organisms especially VAM fungi on the medicinal plants have been reported. The VAM fungi association had not only enhanced the growth of medicinal plants but also improve the productivity of medicinal compounds. Mycorrhiza is the mutualistic symbiotic association (non-pathogenic) between soil borne fungi with the roots of higher plants (Sieverding, 1991). Vesicular Arbuscular Mychorrhiza (VAM) is an obligate biotroph, which mainly improves phosphorus nutrition, greater ability to withstand water stress and offers a natural potential for biological control of root pathogen. The non-nutritional effects of VAM would be due to increased survival ratio of transplanted seedlings, control of root diseases, increased tolerance to saline condition and increased soil aggregation by the external hyphal network (Marx, 1969). The carbohydrates are translocated from their source location (usually leaves) to the root tissues and then to the fungal partners. In return, the plant gains the use of the mycelium's very large surface area to absorb water and mineral nutrients from the soil, thus improving the mineral absorption capabilities of the plant roots. About 80% of all terrestrial plant species form this type of symbiosis (Smith and Read, 1997) and 95% of the world's present species of vascular plants belong to families that are characteristically mycorrhizal (Quilambo, 2000).

Azotobacter is well known for its capacity to increase growth by fixing atmospheric nitrogen and also producing growth promoting substances like hetero-auxins and gibberellins (Mohammad and Parsad, 1998).

In the present studies, application of NPK fertilizers@ 75:75:50 kg/ha increased the values of all growth and development parameters considerably as compared to other treatments (organic fertilizers). Maximum plant height (50.44 cm), number of primary branches per plant (23.24), fresh aerial biomass (64.40 q/ha), dry aerial biomass (24.45 q/ha), fresh underground biomass (3.26 q/ha) and dry underground biomass (1.53 q/ha) was recorded in *Andrographis paniculata* with the application of NPK (75:75:50) (Table 17-22, respectively). These values were statistically higher than all other values for organic fertilizers. These findings are in accordance with those of Muniramappa *et al.* (1997) in *Andrographis paniculata*, Vomel and Ceylan (1979) in *Viola tricolor*, Hegde *et al.* (1984) in *Abelmoschus moschatus*, Balyan *et al.* (1987) in *Ocimum spp.* and Chauhan *et al.* (2000) in *Cymbopogon martini* var. motia.

However under organic fertilizers maximum plant height (47.74 cm), number of primary branches per plant (21.59), fresh aerial biomass (50.92 q/ha), dry aerial biomass (20.09 q/ha), fresh underground biomass (2.78 q/ha), and dry underground biomass (1.30 q/ha) (Table 17- 22 respectively) was recorded with the application of PSB @ 10 kg/ha. The increase in growth parameters may be attributed to release of plant growth promoting substances. Plant growth promoting microbes are an important contributor to biofertilization of agricultural crops. There is increasing evidence that phosphobacteria improve plant growth due to biosynthesis of plant growth substances rather than their action in releasing available phosphorus. Such phenomenon of increasing growth and yield parameters by use of PSB has been reported by Chaykovskaya *et al*. (2001) in pea and barley, Sharma *et al.,* (2007) in *Cicer arietinum* and Han and Lee (2005) in egg plant.

With the application of VAM @ 10 kg/ha, maximum plant height (45.82 cm), number of primary branches per plant (20.61), fresh aerial biomass (45.53 q/ha), dry aerial biomass (18.93 q/ha), fresh underground biomass (2.49 q/ha), and dry underground biomass (1.23 q/ha) (Table 17-22 respectively) was recorded. Increase in the yield attributes may be due to the fact that VAM fungi are known to improve phosphate nutrition, which in turn enhances plant growth and N_2 fixation. These findings are in line with those reported by Karthikeyan *et al.* (2007) in *Ocimum sanctum, Catharanthus roseus, Coleus forskholii* and *Cymbopogon flexuosus*; Kung'u (2008) in *Senna spectabilis* and Zalzaleh *et al.,* (2009) in *Acacia acuminata, Parkinsonia aclueata, Prosopis spicigera, Nerium oleander* and *Vitex negundo*.

In the present studies with the application of *Azotobactor* @10kg/ha, the maximum plant height (42.53 cm), number of primary branches per plant (18.74), fresh aerial biomass (36.86 q/ha), dry aerial biomass (14.62 q/ha), fresh underground biomass (2.10 q/ha), and dry underground biomass (0.93 q/ha) (Table 17-22) was recorded. The higher growth and yield parameters may be due to proliferation of inoculated and other beneficial microorganisms which might have affected the plant growth by nitrogen fixation, mobilization of soil phosphates by providing growth promoting metabolites that stimulate plant and by suppression of pathogenic microorganisms as reported by Kennedy and Chillapillai (1998). Such phenomenons were also reported in *Setaria italica* and *Zea mays* by Fallik and Okon (1996), in chick-pea by Del Gallo and Fabbri (1990).

However, with the application of vermicompost @ 20 t/ha, the values for plant height, number of primary branches per plant, fresh aerial biomass, dry aerial biomass, fresh underground biomass, and dry underground biomass were recorded as 43.94 cm, 19.61, 41.90 q/ha, 16.58 q/ha, 2.23 q/ha and 1.10q/ha, respectively (Table 17-22). This may be due to the fact that vermicompost has the presence of readily available plant nutrients, growth enhancing substances and number of beneficial microorganisms like N_2 fixing, P solubilising and cellulose decomposing organisms (Sultan, 1997). Biradar *et al.* (1998) from Karnataka reported that vermicompost was found to be superior over other treatments in respect to growth and vigour of neem seedlings. Similar results have also been reported by Rajkhowa *et al.* (2000) who found that application of nitrogen through vermicompost produced the highest nodule and dry weight per plant in green gram. Ansari Abdullah (2008) in spinach (*Spinacia oleracea*), onion (*Allium cepa*) and potato (*Solanum tuberosum*), Kumari Sailaja and Ushakumari (2002) reported the similar results.

Whereas with the application of FYM @ 20 t/ha, the values for plant height, number of primary branches per plant, fresh aerial biomass, dry aerial biomass, fresh underground biomass, and dry underground biomass were reported as 40.25 cm, 17.72, 32.48 q/ha, 12.82 q/ha, 1.92 q/ha and 0.83 q/ha, respectively (Table 17- 22). This could be due to the positive effect of adding FYM as a good source of plant nutrients. Furthermore, FYM acts as a natural soil conditioner which improves soil properties and consequently soil productivity (More, 1994). Higher yield response due to organics is ascribed to improvement in physical and biological properties of soil resulted in better supply of nutrients led to good crop growth and yield. Further it could be attributed to solubilisation effect of plant nutrients by the addition of FYM leading to increased uptake of NPK (Sendurkumaran *et al.*, 1998). FYM would also have helped the soil to improve the nutrients status and water holding capacity. These findings are in line with those of Tolba *et al.* (2003) on eggplant (*Solanum melongena*, L.), Premsekhar and Rajashree (2009) in Okra and Ghamry *et al*., (2009) in wheat.

5.3.3 Relative response of harvesting stages on growth and development of *Andrographis paniculata*

In the present studies at 3rd harvest, maximum values for all growth and development parameters viz., plant height, number of primary branches per plant, fresh aerial biomass, dry aerial biomass, fresh underground biomass, and dry underground biomass were reported as 45.47 cm, 21.19, 58.95 q/ha, 26.33 q/ha, 2.83 q/ha and 1.47 q/ha, respectively (Table 17- 22). All the values for these observations were found in descending order for 3rd to1st harvests. The increase in the growth and development parameters with delayed harvesting was due to the reason that plant got longer period for its growth and development before its harvests. These findings are in line with those of Maheshwari *et al.* (2002) and Wankhade *et al.* (2005) in Kalmegh (*Andrographis paniculata*) Menon Jalaja *et al.* (2001) in *Plumbago* spp. with late harvest.

5.4 Cost of cultivation

The cost of cultivation includes all the inputs like seed cost, labour involved in nursery raising, transplanting, intercultural operations till final harvesting of the crop were taken into consideration in terms of money involved in rupees. Similarly while calculating the returns, the total dry plant biomass obtained was multiplied by the average of prevailing market rate (Rs. 30/kg) as per the National Medicinal Plant Board during the year 2009 of *Andrographis paniculata*. (Table 23, 24 and Appendix-I).

A. paniculata, in all three harvesting stages was raised through organic (FYM, Vermicompost, *Azotobactor*, PSB and VAM) and inorganic (NPK) conditions at different spacings. *Azotobactor*, PSB and VAM resulted in lowest cost of cultivation on per hectare basis to the tune of Rs. 55,632.17, whereas cost rose to Rs. 2, 55,032.20 with the application of vermicompost. Under inorganic condition the cost of cultivation was to the tune of Rs. 58,242.17 (Table 20) however, maximum yield was obtained under inorganic condition. Similar results have earlier been reported by Vomel and Ceylan (1979) in *Viola tricolor*, Hegde *et al.* (1984) in *Abelmoschus moschatus*, Balyan *et al.,* (1987) in *Ocimum spp*. and Chauhan *et al.* (2000) in *Cymbopogon martini* var. *motia* where the application of NPK registered higher herb yield.

Benefit: cost ratio was calculated by dividing the total returns obtained with the total cost involved during the cultivation. The lowest benefit: cost ratio was obtained with the application of Vermicompost due to its higher rate (@ 10/kg) followed by FYM application. If farmer make his own vermicompost than it will definitely gives better returns. Whereas with the application of NPK fertilizer the benefit: cost ratio was obtained 1.86:1. It was followed by PSB (1.66:1), VAM (1.57:1) *Azotobactor* (1.31:1). Almost similar results were reported earlier by Hegde *et al.* (1984) in *Abelmoschus moschatus* and Muhammad Din *et al.* (2007) in cabbage.

Maximum net returns/ha (total returns - cost of cultivation) of rupees 222514 was obtained with the application of NPK @ 75:75:50 kg/ha. Similarly, net returns of rupees 145924, 142057, 122902 and 84146 with the application of PSB, VAM, *Azotobactor* @ 10 kg/ha and FYM 20 t/ha, respectively at 15x15 cm spacing. Net loss of rupees 73697 was obtained with the application of vermicompost @ 20 t/ha.

It is quite evident from the returns and benefit: cost ratio that farmers can opt for the cultivation of medicinal plants like *Andrographis paniculata* as an alternate source of income. Like other agricultural crops cultivating medicinal plants on profitable basis can improve the economy of farmers by diversification of cropping system/pattern. If the market of the medicinal plants is well organized then farmers can get better benefits than some of the agricultural crops which are grown by them traditionally.

Chapter-6

SUMMARY AND CONCLUSION

The present investigations entitled "Studies on the standardization of cultivation practices of *Andrographis paniculata* Nees under mid hill conditions of Himachal Pradesh" were carried out in the laboratory and experimental farm area of Department of Forest Products, Dr YS Parmar University of Horticulture and Forestry Nauni- Solan (HP) during 2007-09. The results thus obtained are summarized below:

6.1 Relative response of different growing media on seed germination and growth parameters of *A. paniculata*.

The aspect was undertaken to evaluate the comparative efficacy of ten soil media with two field conditions (open conditions and glasshouse conditions).

The results indicated that minimum days for initiation of germination were taken in sand (7.50 days), which was statistically at par with soil, sand + soil and sand + FYM, whereas, maximum mean germination percentage was recorded in sand (80.00) and maximum mean daily germination was (4.42%) registered in soil + cocopeat.

Soil + vermicompost (1:1) medium registered maximum peak germination period (16.33th day), number of leaves per seedling (19.43), seedling root length (11.73 cm) which was statistically at par with sand + soil + FYM (10.98 cm), seedling shoot length (10.77 cm) which was statistically at par with sand + soil + FYM (10.77 cm), fresh seedling root weight (0.48 g) which was at par with sand + soil + FYM (0.42 g), dry seedling root weight (0.095 g) which was statistically at par with sand + soil + FYM (0.092g) and fresh seedling shoot weight (1.51 g) and dry seedling shoot weight (0.372 g) which were statistically at par with sand + soil + FYM (0.092 g).

The glasshouse conditions excelled over open conditions in all seed germination and growth parameters. Initiation of seed germination (6.47days), mean daily germination (2.95%) germination percentage (58.43), peak germination period (11.63 day), completion of germination (19.50th day), number of leaves per plant (10.83), seedling root length (7.68 cm), seedling shoot length (5.59 cm), fresh seedling root weight (0.17 g), fresh seedling shoot weight (0.63 g), dry root weight (0.0048 g) and dry shoot weight (0.181 g).

6.2 Relative response of mulching and line spacings on seed germination and seedling vigour of *A. paniculata*.

In the present investigations it was found that mulching had significant effect on all parameters recorded for seed germination and seedling vigour. Dry grass mulch gave the maximum germination percentage (40.15), survival percentage (84.79), number of leaves per plant (24.52), seedling root length (8.56 cm), seedling shoot length (6.70 cm), fresh seedling root weight (0.112 g), fresh seedling shoot weight (1.61 g), dry seedling root weight (0.05 g) and dry seedling shoot weight (0.40 g) as compared to control, where no mulch was applied.

6.3 Relative response of spacings, organic fertilizers and harvesting stages on growth and development of *Andrographis paniculata*

The effect of six spacings (15x15 cm, 30x30 cm, 45x30 cm, 45x45 cm, 60x45 cm, 60x60 cm), seven fertilizers (Without fertilizer, FYM @ 20 t/ha, vermicompost @ 20 t/ha, NPK @ 75:75:50 kg/ha, VAM @ 10 kg/ha, PSB @ 10 kg/ha, *Azotobacter* @ 10 kg/ha) and three harvesting stages (Initiation of flowering, full blooming and post-full blooming) were evaluated on the growth and development of *Andrographis paniculata*.

Significant effect of spacings was noticed on growth and development of *Andrographis paniculata*. Maximum plant height (47.74 cm), number of primary branches per plant (22.03), fresh aerial biomass (108.42 q/ha), dry aerial biomass (41.80 q/ha), fresh underground biomass (7.71 q/ha), and dry underground biomass (3.61 q/ha) were recorded at spacing of 15x15cm.

Among different fertilizers, it was noticed that FYM, vermicompost, VAM, PSB, Azotobacter and NPK had significant effect on the growth and development of *Andrographis paniculata* as compared to control. However, NPK @ 75:75:50 kg/ha registered maximum plant height (50.44 cm), number of primary branches per plant (23.24), fresh aerial biomass (64.40 q/ha), dry aerial biomass (24.45 q/ha), fresh underground biomass (3.26 q/ha) and dry underground biomass (1.53 q/ha).

The effect of three harvesting stages had significant effect on growth and development of *Andrographis paniculata*. The crop at 3^{rd} harvest (post-full blooming stage) gave the maximum values for all growth and development parameters viz ., plant height, number of primary branches per plant, fresh aerial biomass, dry aerial biomass, fresh underground biomass, and dry underground biomass as 45.47 cm, 21.19, 58.95 q/ha, 26.33 q/ha, 2.83 q/ha and 1.47 q/ha, respectively.

6.4 Cost of cultivation

Higher benefit: cost ratio was obtained with the application of NPK fertilizers in all spacings. However, the benefit cost ratio decreased with application of FYM and vermicompost. Maximum benefit: cost ratio was found in 15x15 cm (S_1) spacing with the application of NPK, PSB and VAM and *Azotobacter* i.e., 3.79:1, 2.89:1, 2.84:1 and 2.59:1. It was followed by F_1S_1 (1.90:1). Spacing 30x30 cm and 45x30 cm also showed significant benefit: cost ratio as F_6S_2 (2.79:1), F_5S_2; F_4S_2 (2.76:1), F_3S_2 (1.79:1), F_6S_3 (1.99:1), F_5S_3 (1.79:1) F_4S_3 (1.71:1) and F_3S_3 (1.55:1).

Conclusions

The studies undertaken on the standardization of cultivation practices of *Andrographis paniculata* Nees under mid hill conditions of Himachal Pradesh are concluded as under:

- Soil + vermicompost (1:1) medium under glasshouse conditions gave best results for seed germination and growth parameters.
- Dry grass mulch and 10 cm line spacing in nursery bed can be used to get optimum seed germination and seedling vigour.
- 15x15 cm spacing with the application of NPK @ 75:75:50 kg/ha was found most effective to get maximum herbage yield (fresh and dry) at post full blooming stage. Among organic fertilizers, application of PSB @ 10 kg/ha gave best herbage yield.
- Maximum benefit: cost ratio (3.79:1) was obtained at 15x15 cm spacing with the application of NPK @ 75:75:50 kg/ha at post full blooming stage. Among different organic fertilizers benefit cost ratio found were PSB (2.89:1) VAM (2.84:1) and *Azotobacter* (2.59:1) @ 10 kg/ha application, FYM (1.90:1) and vermicompost (0.73:1) @ 20t/ha at 15x15 cm spacing.

Chapter-7

REFERENCES

Ajimoddin L. 2002. Productivity and quality of Sweet basil (*Ocimum basilicum* L.) as influenced by integrated nutrient management and biofertilizers. M.Sc. Thesis, University of Agriculture Sciences, Bangalore.

Alagesaboopathi C and Balu S. 1996a. Ecological observations on *Andrographis lineate* Nees. *Journal of Living World,* **3**(2): 1-4.

Alagesaboopathi C and Balu S. 1998. Seed germination studies on *Andrographis echioides* Nees. *Crop Research* (Hissar), **12**(3): 383-386.

Alagesaboopathi C and Balu S. 1999. Abnormal leaves in *Andrographis paniculata* Nees (Acanthaceae). *Journal of Economics and Taxonomy,* **22**(2): 627-628.

Alagesaboopathi C and Ramachandaran V S. 2000. Methods of mass multiplication of Indian *Andrographis wallichi* ex Nees and its chemical analysis. *Journal of Economic and Taxonomic Botany,* **24**(3): 659-662.

Aminuddin, Girach R D and Wasiuddin D. 1997. Medicinal potential of *Andrographis paniculata* Nees. (Bhuineem) a less known medicinal plant in Unani medicine. *Hamdard Medicines*, **40**(2): 55-58.

Anonymous. 1948. The wealth of India: *Raw Materials*. Vol. I. New Delhi. 77-78 pp.

Anonymous. 2003. *Medicinal and Aromatic Plants,* Annual Report, DARE / ICAR. 69-70 pp.

Anonymous. 2008. All India Networking Research Project on Medicinal and Aromatic Plants: Biennial Report. ICAR. p.vi

Ansari Abdullah Adil. 2008. Effect of Vermicompost and Vermiwash on the productivity of spinach (*Spinacia oleracea*), onion (*Allium cepa*) and potato (*Solanum tuberosum*). *World Journal of Agricultural Sciences,* **4**(5): 554-557

Anuradha M N. 2002. Influence of bio-fertilizers on growth, yield and quality of essential oil in Rosemary *(Rosmarinus officinalis* L.). M.Sc. (Hort.) Thesis, University of Agricultural Sciences, Bangalore.

Anuradha V, Gowari Neelima Daniel J and Neelima G. 2002. Effect of certain plant extract on *Callosobruchus maculates* as pest on stored pulses. *Journal of Ecobiology,* **14**(1): 67-71.

Arora S and Dan S. 2003. Biofertilizers for sustainable agriculture. *Kisan World*, **5**(3): 35-36.

Ashoka K, Amit A, Sujatha M, Murali B and Anand M S. 2002. Effect of ageing on andrographololide content in *Andrographis paniculata*. *Journal of Natural Remedies,* **2**(2): 179-181.

Azeon R. Barea J.M. and Hayman D.S. 1976. Utilization of rock phosphate in alkaline soils by plants inoculated with mycorrhizal fungi and P solubilizing bacteria. *Soil Biology and Biochemistry,* **8:** 135-138.

Azizi M, Rezwanee F, Hassanzadeh Khayyat M and Lackzian A. 2008. Effect of different levels of vermicompost and irrigation on morphological properties and essential oil content of german chamomile (*Matricaria recutita*) C.V. *Planta Medica*, **74**(9).

Bagyaraj D J and Powel C L. 1985. effect of VAM inoculation and fertilizers on growth of marigold. *New Zeland Journal of Agricultural Research,* **28**(1): 169-173.

Balasubramanian J and Nambisan K M P. 1989. Studies on the combined effect of Azospirillum, VA-mycorrhizae and inorganic fertilizers on growth and performance of French marigold *(Tagetes patula* L.). *South Indian fort.,* 311-312.

Balu S and Alagesaboopathi C. 1993. Anti-inflammatory activities of some species of *Andrographis* Wall. *Ancient Science of Life*, **13**: 180-184.

Balu S, Alagesaboopathi S and Elango V. 1993. Antipyretic activites of some species of *Andrographis* Wall. *Ancient Science of Life*, **12**: 399-402.

Balyan S S, Pal S, Sharma S N, Singh S N and Sobti S. 1987. Effect of spacing, nitrogen and phosphorus on the growth and yield of two *Ocimum* species. *Indian Perfumer,* **31**(2):89-96.

Bentley R and Trimen H. 1983. *Medicinal Plants*. International Book Distributors 9/3, Rajpur Road, Dehradun. Vol (3). 197p.

Bhatia K N and Widge S S. 1986. *Elementary Botany*. Truman Book Company, Jalandhur City. 60-68 pp.

Bhojvaid P P, Dobriyal M J R and Joshi D N. 2003. Cultivation techniques for *Andrographis paniculata* and Shatavar. *International Journal of Forest usfructs Management,* **4**(2): 70-72.

Biradar A P, Deveranavadagi S B, Teggelli R G, Balikai R A, Nidagundi J M and Vastard S M. 1998. Effect of vermicompost as potting media mixture on growth and vigour of neem seedlings (*Azadirachta indica*). *Advances in Horticulture in Forestry Research in India*, **17**: 84-89.

Bondya S L, Sharma J P, Jyotikumar Sahu V B and Kumar J. 2002. Native medicinal uses of plants for anthelmenthis at Ranchi district of Jharkhand. *Journal of Phytological Research,* **15**(1): 109-110.

Bright Annie A, Babu A, Ignacimuthu S and Dron S. 2001. Efficacy of crude extracts of *Andrographis paniculata* Nees. on *Callosobruchus chinensis* L. during post harvest storage of cowpea. *Indian Journal of Experimental Biology,* **39**(7): 715-718.

Calabrese C, Berman S H, Babish J G, Ma X, Shinto L L, Darr M, Wells K, Wenner C A and Standish L J. 2000. A phase I trial of andrographoloide in HIV positive patients and normal volunteers. *Phytotherapy Research,* **14**(5): 333-338.

Chandra S, Gupta R, Shahi A K, Dutt Prabhu and Kaul M K. 2004. Yield of *Mentha piperita* L. in relation to different levels of phosphorus and spacing under subtropical environment. **In**: *Proceedings on Research and Development in Production, Protection, Quality, Processing and Marketing of Medicinal and Aromatic Plants*.

Chauhan H S, Aprabal Singh, Singh H P, Singh A K, Chattopadhay A, Raj Kumari and Prasad A. 2005. Influence of FYM and NPK fertilizers on growth and yield of safed musli (*Chlorophyttum borivillianum*). *Journal of Medicinal and Aromatic Plant Sciences,* **27**(2):280-282.

Chauhan H S, Kamla Singh and Singh H B. 2000. Response of palmarosa (*Cymbopogon martini* var. motia) to N and P fertilization in Uttar Pradesh foot-hills of Himalayas. *Indian Perfumer,* **42**(2): 61-64

Chauhan S K, Gyanendra Tiwari, Gangrade S K and Tripathi N K. 2002. Influence of nitrogen application levels through different sources on andrographolide content in Kalmegh [(*Andrographis paniculata,*Burm)Wall ex. Nees]. *Crop Improvement, Production Technology,Ttrade and Commerce*: 121-124.

Chaykovskaya L A, Patyka V P and Melnychuk T M. 2001. Phosphorus mobilizing microorganisms and their influence on the productivity of plants. pp. 668-669. **In**: Plant Nutrition-Food Security and Sustainability of Agroecosystem. *Ed: Horst W.J.*

Chen J and Jiang R. 1980. Morphological and histological studies on *Andrographis paniculata* (Burm. F.) Nees. and comparison with four other *Acanthaceae* herbs. *Acta Pharm. Sin.,* **15** (12): 750-760.

Chezhiyan N, Saraswathi S and Vasumathi R. 2003. Studies on organic manures, biofertilizers and plant density on growth, yield and alkaloid content of bhumiamalika (*Phyllanthus amarus* Schum and Thonu.). *South Indian Horticulture,* **51**(1-6): 96-101.

Chopra R N. 1958. Chopra's Indigenous Drugs of India, 2nd Edition, Calcutta. p. 278.

Dahama A K. 2002. Use of non-traditional additives for organic farming for sustainable agriculture pp. 140.

Das P K, Choudhury P C, Ghosh A, Katiyar R S, Rao Y R M, Mathur V B and Mazumder M K. 1994. Studies on the effect of bacterial biofertilizers in irrigated mulberry (*Morus alba* L.). *Indian Journal of Sericulture,* **33**(2): 170-173.

Del Gallo M and Fabbri P. 1990. Inoculation of *Azospirillum brasilense* Cd on chickpea (*Cicer arietinum*). *Symbiosis,* **9**: 283- 287.

Dhami P S and Mahindru R C. 1996. Growth and development of flowering Plants. **In**: Text Book of Biology. Pradeep Publications, Jalandhur. 320-372.

Donelly E D. 1970. Persistence of hard seed in *Vicia* lines derived from inter specific hybridization. *Crop Science,* **10**:661-662

Earanna N. Suresh C K, Mallikarjunaiah R R and Bagyaraj D J. 1998. Response of *Coleus aromaticus* and some plant growth promoting microorganisms. **In**: *Abstract of Proceeding of Diamond Suliter Symposium and 39th Annual*

Conference of Association of Microbiologists of India, Dec. 5-7. Organised by College of Fisheries, Mangalore. Karnataka. 202-203.

Fairbourn M L and Gardner W R. 1979. Vertical mulch effects on soil water storage. *Soil Science Society of America Proceedings,* **36**: 823-827.

Fallik E and Okon Y. 1996. Inoculants of *Azospirillum brasilense*: biomass production, survival and growth promotion of *Setaria italica* and *Zea mays*. *Soil Biology and Biochemestry,* **28**: 123-126.

Farooqi A A and Sreeramu B S. 2001. Cultivation of Medicinal and Aromatic Crops. Universities Press (India) Limited; Hyderguda, Hydrabad. 151-156.

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.

Ghamry A.M. El, Hamid A.M. Abd El and Mosa A.A. 2009. Effect of Farmyard Manure and foliar application of micronutrients on yield characteristics of wheat grown on salt affected soil. *American-Eurasian Journal of Agriculture and Environmental Sciences,* **5** (4): 460-465.

Goenadi D H, Siswanto Y and Sugiarto Y. 2000. Soil Science Society of America Journal, **64**: 927-932.

Govinda Rao Y S, Suresh C K, Suresh N S and Mallikarjunaiah R R.1987. Rhizosphere population of *Azotobacter* in aromatic and medicinal plants. *Current Research,* **16:** 144-145.

Gowda Narayana J V, Jacob Susamma and Huddar A G. 1991. Effect of N, P and K on growth and flowering of Tuberose (*Polianthus tuberose* Linn.) cv. Double. *Indian Perfumer,* **35**(2): 100-101.

Gupta M L and Janardhanan K K. 1991. Mycorrhizal association of *Glomus aggregatum* with palmarosa enhance growth and biomass. *Plant Soil* **131** (2)**:** 261-264.

Gupta V and Srivastava V K. 1994. Kalmegh from ethnobotanical realm to modern medication. ***In:*** Fourth International Congress Ethanobiology, 17-21 Nov. Organised by NBRI Lucknow p. 323

Gupta V and Srivastava V K. 1995. Evaluation studies on Kalmegh (*Andrographis paniculata* Nees). *Indian Journal of Plant Genetic Resources* (Special Issue 2), **8**(1): 141-143.

Habtemariam S. 1998. Andrographoloide inhibits the tumor necrosis factor alpha-induced up regulation of ICAM-1 expression and endothelial-monocyte adhesion. *Phytochemistry Research,* **12**(1): 37-40.

Han H S and Lee K D. 2005. Phosphate and Potassium Solubilizing Bacteria effect on mineral uptake, soil availability and growth of eggplant. *Research Journal of Agriculture and Biological Sciences,* **1**(2): 176-180.

Hancke J, Burgos R, Caceres D and Wikman G. 1995. A double blind study with a new monodrug Kan Jang: decrease of symptoms and improvement in the recovery from common colds. *Phytotherapy Research,* **9**(8): 559-562.

Haq I and Mina K. 1988. Germination studies on *Hyoscyamus niger* L. *Hamdard Medicus,* **31**(2): 53-61.

Hartmann, H T and Kester D E. 1976. Plant propagation principles and practices. Prentice Hall, New Delhi. 662p.

Hegde Mahabaleshwar, Farooqi A A and Singh N S. 1984. Studies on the effect of nitrogen, phosphorus and potassium on growth and yield of ambrette (*Abelmoschus moschatus* Medic.). *Indian Perfumer,* **20**(2):112-115.

Hemdari K and Rao S S. 1984. Jaundice: Tribal medicine Ancient Science Life, **3**(4): 209-212.

Hooker J D. 1985. *Flora of British India*. Bishen Singh Mahendra Pal Singh, New Connaught Place, Dehradun. Vol IV. 501p.

Jackson M L.1967. Soil Chemical Analysis. Prentice Hall in India, Pvt Ltd. New Delhi.

Jandev A. 2001. The effect of plant growth regulators and fertilizers on herb and oil yield of *Melissa officinalis* Linn. M.Sc. (Forestry). Thesis, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan (HP).

Janick J. 1974. *Horticulture Sciences*. W. H. Freeman and Co., USA, 188p.

Jha P K and Singh N P. 1979. Response of *Mentha spicata* L (spearmint) to different levels of nitrogen application and row spacings. *Indian Perfumer,* **23**(2):95-99.

Joseph T. Suseela Bhai R and Polty S N. 2000. VA Mycorrhiza - A growth promoter for cardamom seedlings. *Spice India* **13** (12)**:** 5-8.

Kanjilal P B, Bordoloi S, Kalita R, Burman P and Singh R S. 2002. Cultivation practices of Kalmegh (*Andrographis paniculata*) and spiderling *(Boerhaavia diffusa*) in Assam, India. *Crop Improvement, Production Technology, Trade and Commerce*, 175-180.

Kapur P. 1998. Dry matter allocation in *Andrographis paniculata* (Burm. F) Wall ex Nees with varying light. *Advances in Plant Sciences,* **11** (2): 171-176.

Kar A, Chander R, Mathur S K, Choudhry B K, Khanna A K and Rastogi A K. 2000. Lipid lowering and .antioxidant activities of some herbal preparations. *Ethnobotany,* **12**: 86-90.

Karthikeyan B, Joe M M and Jaleel C A. 2007. Response of some medicinal plants to vesicular arbuscular mycorrhizal inoculations. *J. Sci. Res*., **1**(1):381-386.

Katoch P C, Bhardwaj S D and Kaushal A N. 1979. Effect of time of planting and row spacings on herb yield and oil content in spearmint. (*Mentha spicata* Linn.). *Indian Perfumer,* **23**(2)91-94.

Kennedy W R and Chillapillai K L. 1998. Synergistic effect of VAM, *Azorospirillum* and Phosphobacteria on growth response and nutrient uptake of shoal tree species. *Indian Jouranal of Forestry*, **21**(4):308-312.

Khaliq A and Janardhanan K K.1994. Variation of native mycorrhizal association on cultivated species of mint. *Symbiosis*, **16**(1)**:** 75-82.

Khan A R. 1983. Influence of mulching on bulk density and aeration porosity of soil in relation to groundnut production. *Archiv fur Acker und Pflanzenbau und Bodenkunde,* **27**(7): 439-444.

Khare C P.2004. *Encyclopaedia of Indian medicinal plants*. Springer- Verlag Berlin Heidelberg New York. 57-59 pp.

Kirtikar K R and Basu B D. 1975. *Indian medicinal plants*. Bishen Singh Mahendra Pal Singh, New Connaught Place, Dehradun, **3**: 1884-1886.

Koppad A G and Manjunath G. 2006. Effect of soil moisture conservation methods on performance of medicinal plants. *Karnataka Journal of Agricultural Sciences,* **19**(4): 972-974.

Kothari S K and Singh V B. 1996. Response of Citronella Java *(Cymbopogon winterianus* Jowitt) to VA Mycorrhizal fungi and soil compaction in relation to P supply, *Plant and Soil,* **178**: 231-237.

Kothari S K, Singh Saudan, Singh V B and Sushil Kumar. 1999. Response of Bergamot mint *(Mentha citrata)* to vascular arbuscular mycorrhizal fungi and phosphorus supply. *Jr of Med and Arom. Pl. Sci.,* **21:** 990-995.

Kretschmer M and Franz C. 1997. Trials on field ecology of *Gentiana lutea* L. *Gemiise* (Minchar), **33**(1): 8-11.

Kumari Sailaja M S and Usha Kumari K. 2002. Effect of vermicompost enriched with rock phosphate on the yield and uptake of nutrients in cowpea (*Vigna unguiculata* L. Walp). *Journal of Tropical Agriculture,* **40**:27-30.

Kumarvel R. 2004. *Productivity and quality* of *Artemisia annua* L. *(sweet worm wood) under organic cultivation.* M.Sc. (Hort.) Thesis, University of Agricultural Sciences, Bangalore.

Kumudha P. 2005. Studies on the effect of biofertilizers on the germination of *Acacia nilotica Linn.* seeds. *Advances in Plant Sciences,* **18**(2): 679-684.

Kumudha P. 2008. Studies on the effect of biofertilizers on the germination of *Tamarindus indica* Linn. *Biochemical and Cellular Archives,* **8**(1): 11-14.

Kurian Alice and Asha Sankar M. 2007. *Horticulture Science Series* Vol. 2: *Medicinal Plants*. New India Publishing Agency, Pitam Pura, New Delhi. 365p.

Lal L. 2002. Phosphatic Biofertilizers. **In**: *Phosphate mineralizing and solubilizing microorganisms*. Agrotech Pub. Academy, Udaipur, p. 224.

Li Mei, Liao BaoWen, Kang LiHua, Zheng Song Fa and Chen Yu Jun. 2006. Effects of inoculation with plant growth promoting bacteria on *Bruguiera gymnorrhiza* seedlings. *Forest Research Beijing,* **9**(1): 109-113.

Madev S, Tandon S K, Lal J and Tripathy A C. 1996. Antiinflammatory activity of andrographolide. *Fitoterapia,* **67**(5): 452-458.

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.

Maheshwari S K, Gangrade S K and Trivedi K C. 1991. Comparative responses of palmarosa to *Azotobacter* and nitrogen under rainfed and irrigated situations. *Indian Perfumer,* **35** (2)**:** 108-111.

Maheshwari S K, Sharma R K, Mishra PK and Gangrade S K. 2002. Response of Kalmegh (*Andrographis paniculata*) to dates of planting and harvesting in shallow black soils. *Journal of Medicinal and Aromatic Plant Sciences,* **24**(4): 969-971.

Mandal S C, Dhara A K and Maiti B C. 2001. Studies on pscychopharmacological activity of *Andrographis paniculata* extract. *Phytotherapy Research,* **15**(3): 253-256.

Manipura W B. 1972. Influence of mulch ad cover crop on surface run-off and soil erosion in tea lands during the early growth of replanted tea. *Tea Quarterely,* **43**: 95-102.

Manjunath R. 2001. *Effect of bio-fertilizers on growth, yield and essential oil content in patchouli (Pogostemon patchouli Pellet.).* M.Sc. (Hort.) Thesis University of Agricultural Sciences, Bangalore.

Manonmani R. 1992. Effect of soil inoculation of Azospirillum and phosphobacteria and graded levels of nitrogen and phosphorus biofertilizers on growth and yield of *Jasminum sambac*. Ajit Gundumalli. M.Sc. (Hort.) Thesis, TNAU, Coimbatore. 87p.

Marx, D. H., 1969. The influence of ectotrophic mycorrhizal fungi on the resistance of pine roots to pathogenic infections- antagonism of mycorrhizal fungi to root pathogenic fungi and soil bacteria. *Phytopathology*, **59**: 158-163.

McCalla T M and Dulley F L. 1946. Effect of crop residues on soil temperature. *Journal of American Society of Agronomy,* **38**: 75-89.

Menon Jalaja S, Prasannakumari Amma S and Nybe EV. 2001. Analysis of Growth and Yield in *Plumbago spp*. *Journal of Tropical Agriculture,* **39**: 114-119.

Merwin H W and Peech P M. 1951. Exchangeability of soil potassium in the sand by nature of complementary exchangeable cation. *Proc. Soil Sci. Sec. Am*, **15**: 125-128.

Mitra S K, Venkataranganna M V, Sundaram R and Gopumadhavan S.1998. Protective effect of HD-03, a herbal formulation against various hepatotoxic agents in rats. *Journal of Ethnopharmacology,* **63**(3): 181-186.

Mohamad A and Parsad R. 1998. Influence of microbial fertilizres on biomass accumulated in polypotted *Eucalyptus camaldulensis* Dehn seedlings. *Journal of Tropical Forestry,* **4**(1):74-77.

More S D.1994. Effect of farm wastes and organic manure on soil properties, nutrient availability and yields of rice and wheat grown on sodic Vertsoils. *J. Ind. Soc. Sci.,* **46**: 253.

Muhammad Din, Muhammad Qasim and Maraj Alam. 2007. Effect of Different Levels of N, P and K on the Growth and yield of cabbage. *Journal of Agricultural Research*, **45**(2):171-176.

Muniramappa R P, Farooqi A A, Gowda H G R and Maricapu S. 1997. Influence of macronutrients on yield and active principle content in kalmegh. *Journal of Medicinal and Aromatic Plant Sciences,* **19**(4): 1039-1040.

Murugaian P, Palanisamy M, Stanley A and Akbarsha M A. 1995. Prospective use of andrographolide in male antifertility. **In**: *International Symposium on Male Contraception*: *Present and Future*. Organized by New Delhi. 34-35.

Muthukumar T and Udaiyan K. 2006. Growth of nursery-grown bamboo inoculated with arbuscular mycorrhizal fungi and plant growth promoting rhizobacteria in two tropical soil types with and without fertilizer application**.** *New Forests,* **31**(3): 469-485.

Nageswari K, Pugalendhi L and Balkrishnamurthy G. 1999. Effect of bio-fertilizers on rooting *of* cinnamon. *Spice India,* **12:** 9-11.

Naik K L. 1998. *Inoculation effect of VAM fungi and phosphate solubilizing bacterium on growth of Java citronella (Cymbopogon winterianus Jowitt).* M.Sc. (Agri.) Thesis, University of Agricultural Sciences, Bangalore.

Namade S, Ravankar H N, and Sarap P A. 2001. Effect of planting and harvesting dates on yield and quality of Kalmegh (*Andrographis paniculata*). **In**: *National Research Seminar on Herbal Conservation, Marketing and Utilization with special emphasis on Chhatisgarh, The Herbal State, Raipur, Chhatisgarh*, p. 49.

Nautiyal B P, Prakash V, Chauhan R. S, Purohit, H and Nautiyal M C. 2001. Assessment of germinability, productivity and cost benefit analysis of *Picrorhiza kurrooa* cultivated at lower altitude. *Current Sciences,* **81**: 579–585.

Nautiyal M C and Chauhan R S. 2007. Seed germination and seed storage behaviour of *Nardostachys jatamansi* DC., an endangered medicinal herb of high-altitude himalaya. C*urrent Science,* **92**(11): 1620-1624.

Nurnabi M D, Ali M A and Rashid M A. 1998. Antibacterial activity of compound isolated from *Andrographis paniculata Bangladesh Journal of Botany,* **27**(1): 57-59.

Olsen S R, Cole W, Watanable F S and Dean L A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. In: Methods of soil analysis. Black C A. (ed.) Madison. *American Society of Agronomy* 1044-1046.

Otake T, Mori H, Morimoto M, Ueba N, Sutardjo S, Kusumoto I T, Hatlori M and Namba T. 1995. Screening of Indonesian plant extracts for anti-human immuno-deficiency virus type I (HIV-I) activity. *Phytotherapy Research,* **9**(1): 6-10.

Othieno C O. 1980. Effect of mulches on soil water content and water status of tea plants in Kenya. *Experimental Agriculture,* **16**: 295-302.

Pareek S K, Maheshwari M L and Gupta Rajendra. 1984. Effect of farm yard manure and micronutrients on yield and quality of palmarosa oil grass (*Cymbopogon martini* Var. motia). *Indian Perfumer,* **28**(2): 108-111.

Payal M and Mukerji K G. 1994. Vesicul arbuscular mycorrhizae in Lamiaceae I seasonal variation in some member. *Phytomorphology,* **44**: 83-88.

Piper C S. 1966. Soil and Plant Analysis. Hans Publishers Bombay. 368p.

Ponmurugan P and Gopi C. 2006. *African J. Biotechnol*, **5**(4): 348-350.

Premsekhar M and Rajashree V. 2009. Influence of organic manures on growth, yield and quality of okra. *American-Eurasian Journal of Sustainable Agriculture,* **3**(1): 6-8.

Priya Rani, Ashok Aggarwal and Mehrotra R S. 1999. Growth responses in *Acacia nilotica* inoculated with VAM fungi (*Glomus mosseae), Rhizobium sp. and Trichoderma harzianum. Indian Phytopathology,* **52**(2): 151-153.

Pugalendhi L, Nageswari K and Azhakiamanavalan R S. 2000. Studies on the influence of bio-fertilizers in nulme. *Spice India,* **13:** 16-18.

Pulliah T. 2006. *Encyclopedia of World Medicinal Plants*. Regency Publication, 20/36-G, Old Market, West Patel Nagar, New Delhi. Vol. (I). 155-157.

Puri A, Sexena R, Sexena R P, Sexena K C, Srivastava V and Tandon J S. 1993. Immunostimulant agents from *Andrographis paniculata* Nees. *Journal of Natural Products*, **56**(7): 995-999.

Puthur J T, Prasad K V S K, Sharmila P and Saradhi P P.1998.Vesicular arbuscular mycorrhizal fungi improves establishment of micropropagated *Leucaena leucocephala* plantlets**.** *Plant Cell, Tissue and Organ Culture,* **53**(1): 41-47.

Quilambo O A. 2000. Functioning of peanut (*Arachis hypogaea*L.) under nutrient deficiency and drought stress in relation to symbiotic associations. PhD thesis. University of Groningen, the Netherlands.Van Denderen B.V., Groningen ISBN 903671284X.

Rahman N N N A, Furuta T, Kojima S, Takane K and Ali Mohd M. 1999. Antimalarial activity of extracts of Malaysian medicinal plants. *Journal of Ethnopharmacology* , **64**(3): 249-254.

Rajkhowa D J, Gogoi A K, Kandali R and Rajkhowa K M. 2000. Effect of vermicompost on green gram nutrition. *Journal of the Indian Society of Soil Sciences,* **48**(1):207-208.

Ram A J, Bhaksu L M and Raju R R V. 2004. *In vitro* antimicrobial activity of certain medicinal plants from Eastern Ghats, used for skin disease. *Journal of Ethanopharmacology,* **90**(2-3): 353-357.

Rathi N and Janadhan K K. 1996. Response of dual inoculation with VAM and Azospirillum on the yield and oil content of palmarosa (*Cymbopogon martini* var. motia). *Microbiological Research,* **151**(3): 325-328.

Rey C. 1995. Comparision of direct sowing and planting of common sage (*Salvia officinalis* L.). *Revue Suissede Viticulture d Arboriculture d Horticulture,* **27**(6): 375-381.

Sansamma G, Pillari G R anjd George S. 1998. Influence of microbial biofertilizers on growth and yield of congosignal (*Brachiaria ruziziensis*). *Forage Research,* **24**(2): 101-106.

Saraf R K and Tiwari J P. 2004. Influence of integrated nutrient management on growth and yield of main and ratoon crop of muskadana *(Abelmoschus moschatus). J of Med and Arom. P. Sci,* **26:** 24-27.

Sarswathy S, Manavalan R S A, Vadilvel E, Manian K and Subramanium S. 2004. Studies on seed germination in kalmegh (*Andrographis paniculata* Nees). *South Indian Horticulture,* **52**(1/6): 286-290.

Sarvanan P, Kalachelvan P T and Lalithakumari D. 2000. Seed germination pattern in *Andrographis paniculata*. *Journal of Medicinal and Aromatic Plant Sciences,* **22**(1): 69.

Seema Paroha, Chandra K K and Tiwari K P. 2000. Synergistic role of VAM and *Azotobacter* inoculation on growth and biomass production in forestry species. *Journal of Tropical Forestry,* **16** (1): 13-21.

Selvenayagam Z E, Gnavavendhan S G, Balakrishana K, Bhima rao R and Ali S U. 1995. Survey of medicinal plants with antisnake venom activity in Chengalpattu district, Tamilnadu, India. *Fitoterapia,* **66**(6): 488-494.

Sen A N. 1995. Effect of nitrogen fixing bacteria on medicinal and aromatic plants. *International Conference Programme on Medicinal Research,* pp.50-51.

Sen M K and Das P K. 1998. Influence of microbial inoculants on quality of turmeric, *Indian Cocoa. Arecanut and Spices Journal,* **21:** 31-33.

Sendurkumaran S, Natrajan S and Thamburaj S.1998. Effect of organic and inorganic fertilizers on growth, yield and quality of tomato. *South Indian Horticulture,* **46**(364): 203-205.

Sharma K, Dak G, Agrawal A, Bhatnagar M and Sharma R. 2007. Effect of phosphate solubilizing bacteria on the germination of *Cicer arietinum* seeds and seedling growth. *Journal of Herbal Medicine and Toxicology,* **1**(1): 61-63.

Sharma Ravinder. 2004. Agrotechniques of medicinal plants. Day Publishing House, Delhi. 264 p.

Shivalingappa J, Khan M M, Farooqi A A, Vasundhra M, Sreeramu B S and Srinivasappa K N. 1996. Influence of various biofertilizers on growth, flower yield and concrete content in tuberose. *Indian Perfumer,* **45**(3): 179-183.

Shivalingappa J. 1998. Influence of bio-fertilizers on growth, yield and essential oil content in tuberose (*Polianthes tuberosa*). M.Sc. Thesis, University of Agricultural Sciences, Bangalore.

Sieverding E. 1991. Vesicular-arbuscular mycorrhiza management intropical agrosystems. Technical Cooperation, Federal Repuplic of Germany Eschborn. ISBN 3-88085-462.

Singh A K, Bisen S S, Singh R B and Biswas S C. 1998. Effectiveness of compost towards increasing productivity of some medicinal plants in skeletal soils. *Advances in Forestry Research in India,* **18**: 64-83.

Singh D and Rao Y. 2003. Allelopathic evaluation of *Andrographis paniculata* aqueous leachates in rice (*Oryza sativa* L.). *Allelopathy Journal,* **11**(1): 71-76.

Singh V and Singh R K. 2006. Effect of season, time of planting and plant density on the growth, yield and andrographolide content of kalmegh (*Andrographis paniculata* Nees) under North Indian conditions. *International Journal of Plant Sciences,* **1**(1): 6-9.

Sirohi S S and Singh O S.1983. Relationship of endomycorrhizal association in unsterilized soils with available soil phosphorus, plant growth, phosphorus uptake and soil synthesis in peppermint. *Scientia Horticulture,* **22** (2)**:** 185-191.

Sivarajan V V and Balachandran I. 1994. *Ayurvedic Drugs and their Plant Sources*. Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi.

Smith SE and Read DJ.1997. Mycorrhizal symbiosis. Academic Press, Inc San Diego

Somani L L. 1987. Biofertilizers in Indian agriculture (an annotated bibliography 1906-84). Concept Publish Company.

Subbiah B V and Asija G L. 1956. A rapid procedure for the estimstion of available nitrogen in soils. *Current Science*, **25**: 259-260.

Sukhmal Chand, Kaul P N, Bhattacharya, A K, Singh K, Singh C P and Rajeshwara Rao B R. 1996. Response of Jamarose (*Cymbopogan sp.*) to spacings, FYM, nitrogen, phosphorus and zinc. *Indian Perfumer*, **40**(2): 41-46.

Sultan, A.I. 1997. Vermicology – The Biology of Earthworms. Orient Longman Ltd, New Delhi, 92p.

Thakur V. 2003. Development of agrotechniques of *Viola pilosa* Blume. M.Sc. (Forestry). Thesis Dr Y S Parmar University of Horticulure and Forestry, Nauni Solan (HP) 77p.

Thankamani C K, Sivaraman K and Kandiannam K. 1996. Effect of clove (*Syzygium aromaticum*) (L.) (Merr, and Perry) seedling and black pepper (*Piper nigrum* L.) cutting to propagating media under nursery conditions. *Journal of spices and aromatic crops,* **5**(2): 99-101.

Tisdale Samuel and Nelson Warner. 1969. Soil fertility and fertilizers, Canada. Macmillan Company. p133.

Tolba M H, Baddour G A and. El-Ghamry A M. 2003. Effect of different sources of organic manures on eggplant (*Solanum melongena*, L.) and some soil properties. *J. Agric. Sci. Mansoura Unive*., **18**: 127-135.

Tomar G S, Tiwari S K and Chaturvedi G N. 1982. Kalmegh (*Andrographis paniculata* Nees.) and its medicinal status. *Nagarjun*, **26**(4): 76-78.

Tripathi G S and Tripathi Y B. 1991. Choleretic action of andrographolide obtained from *Andrographis panniculata* in rats. *Phytochemistry Research,* **5**(4): 176-178.

Trivedi N P and Rawal U M. 2001. Hepatoprotective and antioxidants property of *Andrographis paniculata* (Nees) in BHC induced liver damage in mice. *Indian journal of Experimental Biology*, **39**(1): 41-46.

Upadhyaya L, Mehrotra A, Srivastava A K, Rai N P and Tripathi K. 2001. An experimental study of some indigenous drugs with special reference to hydraulic permeability. *Indian Journal of Experimental Biology,* **39**(12): 1308-1310.

Vashistha R K, Nautiyal B P and Nautiyal M C. 2009. Chemical stimulation of seed germination in *Angelica archangelica* Linn. (Apiaceae), a threatened high altitude aromatic herb. *Journal of American Science,* **5**(5): 59-70.

Vasundhara M, Birader S L, Rao G G E and Srinivasappa K N. 2005. Role of biofertilizers in aromatic crops (a review article). *Indian Perfumer,* **49**(4): 457-466.

Vomel A and Ceylan A. 1979. Studies on *Viola tricolor*. *Ege Universities iract Fakultesi Dergisi,* **16**(3): 97-104.

Wange S S, Patil P L and Patel J J**.** 1995. Effects of bio-fertilizers alone and with nitrogen levels on tuberose cv. Single petaled. *Journal of Soils and Crops,* **52** (2)**:** 97-99.

Wankhade S G, Khode P P, Wanjari S S, Paturde J T and Sakure S M. 2005. Herb yield and quantity of Kalmegh (*Andrographis paniculata*) as influenced by time of planting and harvesting. *Indian Journal of Agricultural Research,* **39**(4): 303-306.

Warrier P K, Nambiar V P K and Ramankutty C. 1995. *Indian Medicinal Plants-a compendium of 500 species* Vol. 1-5. Orient Longman Ltd, Chennai.

Zalzaleh- Hani A AL, -Zalzaleh -Majid A AL and Anu Ray Mathew. 2009. Vam inoculation for selected ornamental plants in bioremediated and agricultural soils. *European Journal of Scientific Research,* **25** (4):559-566.

Zaridah M Z, Idid S Z, Wan-Omar A and khozirah S. 2001. *In vitro* antifilarial effects of three plant species against adult worms of subperiodic *brugia malang*. *Journal of Ethanopharmacolology,* **78**(1): 79-84.

Zhang-Xiang F, Tan B K H and Ziang X J. 2000. Antidiabetic property of ethanolic extract of *Andrographis paniculata* in streptozotocin-diabetic rats. *Acta Pharmacologica Sinica,* **21**(2): 1157-1164.

Dr. Y. S. Parmar University of Horticulture and Forestry,

Nauni, Solan-173230, Solan (H.P.), INDIA

Department of Forest Products

Title of the thesis	**:**	**Studies on the standardization of cultivation practices of *Andrographis paniculata* Nees under mid hill conditions of Himachal Pradesh**
Name of the student	**:**	Madan Lal Panwar
Admission number	**:**	F-2007-04-M
Major Advisor	**:**	Dr. Meenu Sood
Major Field	:	Forest Products
Minor Field	:	Soil Science
Degree awarded	**:**	M.Sc (Forestry)
Year of award of Degree	:	2009
Number of pages in thesis	**:**	77+III
Number of words in abstracts	**:**	247

ABSTRACT

The present investigations entitled "Studies on the standardization of cultivation practices of *Andrographis paniculata* Nees under mid hill conditions of Himachal Pradesh" were carried out in the experimental field and laboratory of the Department of Forest Products, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) during the year 2008-09. The effect of nursery practices, spacings, fertilizers and harvesting stages was studied on growth and yield parameters of *Andrographis paniculata* and further cost of cultivation was also calculated. The results revealed that application of different soil media and field conditions had significant effects on growth and development of *A. paniculata.* Soil + vermicompost (1:1) medium in glasshouse conditions was found to give best results for seed germination and growth parameters. Line spacing of 15x15 cm with grass mulch gave best result for seed germination and seedling vigour. Among spacings, fertilizers and harvesting stages, 15x15 cm with application of NPK @ 75:75:50 kg/ha at post full blooming stage registered the maximum fresh and dry aerial and underground biomass followed by the application of PSB, VAM and *Azotobacter* @ 10 kg/ha in *A. paniculata*. Maximum benefit: cost ratio (3.79:1) was obtained at 15x15 cm spacing with the application of NPK @ 75:75:50 kg/ha at post full blooming stage. Among different organic fertilizers, benefit: cost ratio was found maximum with the application of PSB (2.89:1) followed by VAM (2.84:1) and *Azotobacter* (2.59:1) @ 10 kg/ha application, FYM (1.90:1) and vermicompost (0.73:1) @ 20t/ha at 15x15 cm spacing.

Signature of Major Advisor **Signature of the Student**

Countersigned

Professor and Head
Department of Forest Products
Dr. Y. S. Parmar, UHF Nauni-Solan (H P)

APPENDIX-I

Response to spacings and fertilizers on dry aerial biomass (q/ha) at three harvesting stages

	H_1							H_2							H_3						
	S_1	S_2	S_3	S_4	S_5	S_6	**Mean**	S_1	S_2	S_3	S_4	S_5	S_6	**Mean**	S_1	S_2	S_3	S_4	S_5	S_6	**Mean**
F_0	7.56	5.10	3.94	2.67	2.55	1.16	**3.83**	21.33	12.01	12.30	6.44	2.80	2.48	**9.56**	30.24	14.50	10.76	11.36	8.35	3.70	**13.15**
F_1	10.44	6.27	4.92	3.20	2.55	1.39	**4.79**	32.64	15.47	12.47	6.49	4.11	3.45	**12.44**	55.44	18.43	26.18	12.68	10.02	4.64	**21.23**
F_2	17.30	7.85	7.08	3.89	2.72	1.55	**6.73**	47.88	18.66	17.96	6.89	4.31	3.59	**16.55**	63.38	35.21	28.23	15.01	11.36	5.54	**26.46**
F_3	11.69	6.24	7.06	3.66	2.72	1.48	**5.48**	36.50	17.11	11.26	6.76	4.15	3.54	**13.22**	62.71	31.21	26.18	14.56	11.23	5.05	**25.16**
F_4	23.91	10.79	8.17	4.07	2.94	1.61	**8.58**	49.72	21.50	19.43	8.28	6.57	4.22	**18.29**	68.36	48.82	28.53	16.70	11.45	5.64	**29.91**
F_5	24.31	13.09	8.47	4.66	3.27	1.77	**9.26**	54.06	21.97	21.17	8.30	7.71	5.31	**19.75**	69.45	48.82	29.31	20.36	14.22	5.41	**31.26**
F_6	41.16	13.43	10.63	6.13	3.72	3.52	**13.10**	55.90	26.61	22.93	16.18	10.64	6.28	**23.09**	93.78	51.70	34.40	21.08	14.42	7.57	**37.16**
Mean	**19.48**	**8.97**	**7.18**	**4.04**	**2.93**	**1.78**		**42.58**	**19.05**	**16.79**	**8.48**	**5.76**	**4.13**	**16.13**	**63.34**	**35.53**	**26.23**	**15.96**	**11.58**	**5.36**	

Spacings

- **S_1** : 15x15 cm
- **S_2** : 30x30 cm
- **S_3** : 45x30 cm
- **S_4** : 45x45 cm
- **S_6** : 60x60 cm
- **S_5** : 60x45 cm

Organic Fertilizers

- **F_0** : Without Fertilizer
- **F_1** : FYM @ 20 t/ha
- **F_2** : Vermicompost @ 20 t/ha
- **F_3** : *Azotobacter* @ 10 kg/ha
- **F_4** : VAM @ 10 kg/ha
- **F_5** : PSB @ 10 kg/ha
- **F_6** : NPK @ 75:75:50 kg/ha

Harvesting stages

- **H_1** : Initiation of flowering
- **H_2** : Full blooming
- **H_3** : Post full blooming

Response to spacings and fertilizers on dry underground biomass (q/ha) at three harvesting stages

	H_1							H_2							H_3						
	S_1	S_2	S_3	S_4	S_5	S_6	**Mean**	S_1	S_2	S_3	S_4	S_5	S_6	**Mean**	S_1	S_2	S_3	S_4	S_5	S_6	**Mean**
F_0	1.51	0.59	0.28	0.23	0.14	0.10	**0.48**	2.70	0.81	0.31	0.35	0.23	0.16	**0.76**	3.56	1.25	0.60	0.57	0.27	0.16	**1.07**
F_1	1.39	0.60	0.29	0.26	0.14	0.11	**0.47**	3.04	0.85	0.45	0.39	0.32	0.19	**0.87**	3.82	1.25	0.75	0.63	0.36	0.20	**1.17**
F_2	3.33	0.78	0.62	0.33	0.21	0.12	**0.90**	3.42	1.04	0.73	0.45	0.34	0.20	**1.03**	4.27	1.47	1.07	0.68	0.49	0.31	**1.38**
F_3	1.90	0.67	0.43	0.29	0.14	0.11	**0.59**	2.96	1.00	0.73	0.41	0.33	0.19	**0.94**	4.00	1.47	0.86	0.63	0.43	0.29	**1.28**
F_4	3.72	0.84	0.66	0.40	0.30	0.13	**1.01**	3.80	1.23	0.80	0.46	0.35	0.25	**1.15**	4.74	1.55	1.29	0.75	0.49	0.44	**1.54**
F_5	3.80	0.91	0.69	0.45	0.31	0.22	**1.06**	3.78	1.24	0.80	0.47	0.36	0.26	**1.15**	4.93	1.64	1.90	0.75	0.52	0.45	**1.70**
F_6	3.87	1.16	0.69	0.46	0.38	0.26	**1.14**	4.21	1.29	1.17	0.57	0.38	0.36	**1.33**	7.01	1.66	1.94	0.79	0.79	0.60	**2.13**
Mean	**2.79**	**0.79**	**0.52**	**0.35**	**0.23**	**0.15**		**3.42**	**1.07**	**0.71**	**0.44**	**0.33**	**0.23**	**1.03**	**4.62**	**1.47**	**1.20**	**0.68**	**0.48**	**0.35**	

Spacings

S_1 : 15x15 cm
S_2 : 30x30 cm
S_3 : 45x30 cm
S_4 : 45x45 cm
S_6 : 60x60 cm
S_5 : 60x45 cm

Organic Fertilizers

F_0 : Without Fertilizer
F_1 : FYM @ 20 t/ha
F_2 : Vermicompost @ 20 t/ha
F_3 : *Azotobacter* @ 10 kg/ha
F_4 : VAM @ 10 kg/ha
F_5 : PSB @ 10 kg/ha
F_6 : NPK @ 75:75:50 kg/ha

Harvesting stages

H_1 : Initiation of flowering
H_2 : Full blooming
H_3 : Post full blooming

	H₁							H₂							H₃						
	S_1	S_2	S_3	S_4	S_5	S_6	**Mean**	S_1	S_2	S_3	S_4	S_5	S_6	**Mean**	S_1	S_2	S_3	S_4	S_5	S_6	**Mean**
F_0	9.07	5.69	4.22	2.90	2.69	1.27	**4.31**	24.03	12.83	12.60	6.79	3.04	2.64	**10.32**	33.79	15.74	11.37	11.93	8.62	3.86	**14.22**
F_1	11.83	6.87	5.22	3.46	2.69	1.49	**5.26**	35.67	16.31	12.92	6.88	4.43	3.64	**13.31**	59.26	19.68	26.93	13.30	10.37	4.85	**22.40**
F_2	20.63	8.63	7.70	4.22	2.93	1.66	**7.63**	51.30	19.69	18.69	7.35	4.64	3.79	**17.58**	67.64	36.69	29.31	15.69	11.85	5.85	**27.84**
F_3	13.60	6.91	7.49	3.95	2.87	1.59	**6.07**	39.47	18.11	11.99	7.18	4.49	3.73	**14.16**	66.71	32.68	27.04	15.19	11.66	5.34	**26.44**
F_4	27.63	11.63	8.84	4.47	3.24	1.75	**9.59**	53.52	22.72	20.22	8.74	6.92	4.47	**19.43**	73.10	50.37	29.82	17.45	11.93	6.08	**31.46**
F_5	28.11	14.00	9.16	5.11	3.58	1.99	**10.32**	57.84	23.21	21.96	8.77	8.07	5.57	**20.90**	74.39	50.46	31.21	21.11	14.74	5.86	**32.96**
F_6	45.02	14.59	11.32	6.59	4.10	3.79	**14.23**	60.10	27.91	24.09	16.75	11.02	6.64	**24.42**	100.79	53.36	36.34	21.86	15.21	8.17	**39.29**
Mean	**22.27**	**9.76**	**7.71**	**4.39**	**3.16**	**1.93**		**45.99**	**20.11**	**17.50**	**8.92**	**6.09**	**4.36**		**67.95**	**37.00**	**27.43**	**16.65**	**12.06**	**5.72**	

Response to spacings and fertilizers on total dry biomass (aerial + underground in q/ha) at three harvesting stages

Spacings

S_1 : 15x15 cm
S_2 : 30x30 cm
S_3 : 45x30 cm
S_4 : 45x45 cm
S_6 : 60x60 cm
S_5 : 60x45 cm

Organic Fertilizers

F_0 : Without Fertilizer
F_1 : FYM @ 20 t/ha
F_2 : Vermicompost @ 20 t/ha
F_3 : *Azotobacter* @ 10 kg/ha
F_4 : VAM @ 10 kg/ha
F_5 : PSB @ 10 kg/ha
F_6 : NPK @ 75:75:50 kg/ha

Harvesting stages

H_1 : Initiation of flowering
H_2 : Full blooming
H_3 : Post full blooming

APPENDIX-II

Monthly meteorological data for the year 2008 (January- November)

MONTH	RAINFALL (MM)	TEMPERATURE (^{0}C)			HUMIDITY (%)
		MAXIMUM	MINIMUM	AVERAGE	
JANUARY	44.1	17.2	3.0	10.10	56
FEBRUARY	30.0	20.0	4.0	12.00	51
MARCH	--	27.2	8.9	18.05	37
APRIL	38.4	29.1	12.5	20.80	42
MAY	95.9	31.0	15.5	23.25	47
JUNE	265.5	28.4	19.3	23.85	80
JULY	120.2	29.8	20.3	25.05	72
AUGUST	248.3	27.9	19.7	23.80	81
SEPTEMBER	348.9	26.6	15.8	21.20	68
OCTOBER	13.5	27.0	11.0	19.00	65
NOVEMBER	5.4	18.2	4.4	11.30	37

Source: Meteorological observatory, deptt. Environmental Sciences, COF, Dr. Y S Parmar UHF, Nauni, Solan (H.P.)

APPENDIX-III

Analysis of Variance (ANOVA)
Effect of different field conditions and growing media on seed germination and growth parameters of *Andrographis paniculata*

SOURCE OF VARIATION	MEAN SUM OF SQUARE												
	D.F.	1	2	3	4	5	6	7	8	9	10	11	12
SOIL MEDIA (S)	09	6.23*	0.71*	7.33*	742.67*	98.55*	125.62*	48.34*	52.95*	0.23*	1.43*	0.009*	0.17*
FIELD CONDITIONS (F)	01	228.15*	0.82*	153.60*	725.27*	481.67*	60.82*	73.17*	25.12*	0.02*	0.08	0.018*	0.014*
S X F	09	13.22*	0.21*	0.93	79.19*	4.44*	1.16*	1.30	0.57	0.004	0.09	0.003*	0.095*
ERROR	40	0.83	0.005	1.00	5.65	1.21	0.49	0.72	0.65	0.003	0.15	0.00004	0.0001

* Significant at 5% level

1. Initiation if germination (days)
2. Mean daily germination (per cent)
3. Peak germination period (day)
4. Germination percentage
5. Completion of germination (days)
6. Number of leaves per plant
7. Root length (cm)
8. Shoot length (cm)
9. Fresh root weight (g)
10. Fresh shoot weight (g)
11. Dry root weight (g)
12. Dry shoot weight (g)

Effect of mulching and line spacings on seed germination and seedling vigour of *Andrographis paniculata*

SOURCE OF VARIATION	MEAN SUM OF SQUARE									
	D.F.	1	2	3	4	5	6	7	8	9
MULCH (M)	1	207.30*	140.71*	597.08*	5.55	10.03*	0.012*	4.25*	0.02*	0.27*
LINE SPACING (S)	2	78.55*	29.52	61.68*	2.60	4.07*	0.0019*	0.63	0.006*	0.04*
REPLICATION (R)	2	3.52	15.94	41.78*	0.04	3.64*	0.0011*	1.16*	0.007*	0.002
M X S	2	28.76*	4.80	20.76	0.37	0.46	0.0053*	0.24	0.001	0.017*
ERROR	10	3.70	8.88	5.23	1.98	0.75	0.0012	0.26	0.001	0.0017

* Significant at 5% level

1. Germination percentage
2. Survival percentage
3. Number of leaves per plant
4. Root length (cm)
5. Shoot length (cm)
6. Fresh Root Weight (g)
7. Fresh Shoot Weight (g)
8. Dry Root Weight (g)
9. Dry Shoot Weight (g)

Effect of spacings, organic fertilizers and harvesting stages on growth and development of *Andrographis paniculata*

SOURCE OF VARIATION	MEAN SUM OF SQUARE						
	D.F.	1	2	3	4	5	6
SPACING (S)	5	663.77*	159.74*	83811.00*	12200.00*	462.69*	101.32*
FERTILIZER (F)	6	1099.00*	280.86*	9560.20*	1417.7*	16.87*	4.08*
HARVEST (H)	2	461.00*	268.71*	35362.00*	11318.00*	26.76*	14.23*
REPLICATION (R)	2	160.96*	16.87	570.37	59.29	1.74	0.35
SXF	30	15.88	7.02	1277.2*	223.11*	3.92*	0.89*
SXH	10	84.62	58.18*	3216.10*	1141.7*	3.17	2.02*
FXH	12	22.63	3.43	443.23	113.33*	0.37	0.22
SXFXH	60	19.425	4.58	192.68	36.44	0.42	0.15
ERROR	250	50.24	9.83	333.26	49.22	1.92	0.38

* Significant at 5% level
1. Plant height (cm)
2. Number of primary branches per plant
3. Fresh aerial biomass (q/ha)
4. Dry aerial biomass (q/ha)
5. Fresh underground biomass (q/ha)
6. Dry Underground biomass (q/ha)

CURRICULUM VITAE

Name : Madan Lal Panwar

Father's Name : Sh. Bir Singh

Date of Birth : 05.12.1974

Sex : Male

Marital Status : Married

Nationality : Indian

Education Qualifications:

Certificate/Degree	**Class/Grade**	**Board/University**	**Year**
Matric	First	CBSE (JNV Port Blair, South Andaman- Andaman and Nicobar Islands)	1991
10+2	First	CBSE (JNV Nahan, Sirmour, H.P.)	1993
B.Sc. Forestry	First	UHF, Nauni	1997

Whether sponsored by some state/Central Govt/ Univ/SAARC : Yes (Department of Ayurveda, H.P.)

Scholarship/Stipend/Fellowship any other assistance received during study period : No

(Madan Lal Panwar)