DEVELOPMENT OF AGROTECHNOLOGIES FOR DOMESTICATION AND QUALITY ASPECT OF BHRINGARAJ (*Eclipta prostrata* L.)

A

Thesis

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LATE BASANTA KALITA

DECLARATION

I, SIMANTA KUMAR KALITA hereby declare that the subject matter of this thesis is the record of work done by me, that the content of this thesis did not form basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree in any other university/institute.

This is being submitted to Nagaland University for the degree of Doctor of Philosophy in Agronomy.

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CERTIFICATE

This is certified that the thesis entitled, "**Development of Agrotechnologies for Domestication and Quality Aspect of Bhringaraj** (***Eclipta prostrata*** **L.**)" submitted for fulfillment of the requirements for the award of degree of **Doctor of Philosophy** (Agriculture) in **Agronomy** under Nagaland University, Medziphema, Nagaland is a record of bonafide research work carried out by Sri. SIMANTA KUMAR KALITA under our guidance and supervision.

The candidate has fulfilled all the requirements under the Ph. D. regulations of Nagaland University and the thesis or part of it has not been submitted to any other University for any degree or distinction.

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ABBREVIATIONS USED

et al.	:	And others
@	:	At the rate of
BCR	:	Benefit cost ratio
C.D.	:	Critical difference
cm	:	Centimetre
DAS	:	Days after sowing
°C	:	Degrees in Celsius
FYM	:	Farmyard manure
fig.	:	Figure
g	:	Gram
ha	:	Hectare
i.e.	:	That is
K	:	Potash
kg	:	Kilogram
LAI	:	Leafarea index
MOP	:	Murite of potash
m	:	Metre
max.	:	Maximum
min.	:	Minimum
mm	:	Millimetre
N	:	Nitrogen
NS	:	Non significant
No.	:	Number
P	:	Phosphorous
%	:	Percentage
q	:	Quintal
RH	:	Relative humidity
SSP	:	Single super phosphate
viz.	:	Namely

CHAPTER–I

INTRODUCTION

INTRODUCTION

Exploration of the possibilities of "mens sana in corpore sano" *i.e.*, healthy mind in a healthy body is very instinctive in man. His insatiable quest for life, health, knowledge and beauty inspires him to know more about diseases, decay and death, which have always been coexisted with life. Therefore, the study of diseases and their treatment must have also been contemporaneous with the dawn of human intellect. Man has been attached with the plant since antiquity and this bond of man and plant has crossed a considerable time frame in human history.

Any plant, which harbours curative element or properties in one or more of its organs, may be termed as medicinal plant (Brahmam, 2000). From ancient period of civilization, medicinal plants are known as one of the gifts of nature to cure a number of diseases and disorders of human beings. About 7o-80 per cent of the world population still relies on medicinal plants in the rural and remote areas by the way of traditional system. The alarming rise in population in world, inadequate supply of drugs in certain parts of the world, prohibitive cost of treatments for common ailments, side effect of several allopathic drugs and development of resistance to currently used drugs for infectious diseases have led to the increased emphasis on the use of plant materials as a source of medicine for a wide variety of human ailments.

The use of plants as medicines comes from the Rig Veda. From there, it is well known that the Aryans used 'Soma' as a medicinal agent (Kirtikar and Basu, 1954). In Ayurveda also, about 800 herbal remedies have been codified, which are in use at many dispensaries today (Kumar *et al.*, 1997). But in spite of resurgence of interest in the study and use of medicinal plants in health care, a complete inventory of medicinal plants is not yet even completed in this country.

Drugs of herbal origin have greater demand now-a-days in primary health care because of their efficacy, safety and lesser or no side effects. About 121 clinically useful prescribed drugs worldwide are derived from plants and about 74 per cent of them are manufactured by pharmaceutical houses (Singh, 1999). According to W.H.O. report, medicinal plant accounts for 20 per cent of all medicinal prescriptions in industrial countries and for about 80 per cent in developing countries. On an average 80 per cent of world population relies on traditional medicines or herbal medicines (Sandhya *et al.* 2006). Most of these medicinal plants produce biologically active secondary metabolites like alkaloids, steroids, phenols, flavonoides, *etc.* which are active principles for cure of various diseases and disorders (Rai and Sharma, 1994).

India is one of the richest countries in medicinal plant flora and the largest exporter of it. There are about 21,000 plants used for medicinal purpose around the world, out of which about 2,500 species are found in India, of these 2,000 to 2,300 species are used in traditional medicine, while only 150 species are used commercially on a fairly large scale. Cosmetic industries as well as aromatherapy are two important areas where Indian medicinal plants, their extracts and essential oils can contribute globally. Medicinal and aromatic plants have a high market potential with the world demand of herbal products growing at the rate of 7 per cent per annum. Therefore, more emphasis is essential on domestication of medicinal plants by developing improved method of cultivation technique.

The genus *Eclipta* (Family - Asteraceae) has four species of annual herbs is known from time immemorial. Among the four species *Eclipta prostrata* L. commonly known as "Bhringaraj" in Sanskrit, false daisy in English, is considered as a very valuable medicinal plant from pre *vedic* era. The whole plant is used in medicinal industries (Anonymous, 1989). Though *Eclipta* had originated in the United States of America, yet it is widely distributed in warmer parts of Africa, Asia, and Australia along with America.

According to Ayurveda philosophy, *Eclipta prostrata* is bitter, hot fattening alternative anathematic and alexipharmic. In scientific studies it shows good antifungal activities. From the medicinal point of view it is useful in inflammations, hernia, eye diseases, bronchitis, asthma, leucoderma, anemia, heart and skin diseases, night blindness, syphilis, leprosy, ulcers, headache, hypertension, fever, toothache, etc. and is carmanative, diuretic and aphrodisiac (Sharma *et al.* 2001). The plant is commonly used in hair oil for healthy black and long hair all over India for its hair growth-promoting potential (Kanjilal *et al.*, 1982). Hair growth initiation time was markedly reduced to one third on treatment with the prepared formulation of *Eclipta alba* in animals trial. The time required for complete hair growth was also reduced by 32%. The prepared formulation also holds potential for treatment of alopecia (Roy *et al.*, 2007). The fresh juice of leaves is used for increasing appetite, improving digestion and as a mild bowel regulator. It is popularly used to enhance memory. *Eclipta prostrata* is also used as general tonic against debility (Gogate, 1982). It possesses myocardial depressant and hypotensive effects. It was also reported that *in vivo* hepatoprotective activity of ethanolic extract from fresh leaves of *Eclipta prostrata* against carbon tetrachloride (CCl_4) cures liver injury (Singh *et al*. 1993 and Saxena *et al*., 1993).

The plant is an active ingredient of many herbal formulations prescribed for liver ailments and shows effect on liver cell generation, and for the treatment of liver cirrhosis and infective hepatitis (Anonymous, 1982). There are also reports of clinical improvement in the treatment of snake venom poisoning in Brazil (Melo *et al*., 1994) and septic shock in folk medicine in China (Kobori *et al*., 2004). *Eclipta prostrata* leaves showed antihyperglycemic activity (Ananthi *et al*., 2003). The roots were found effective in wound healing (Patil *et al*., 2004). A number of coumestan-type compounds have been isolated from the plants viz. wedelolactone, dimethyl wedelolactone, *etc.* that are responsible for the hepatoprotective activity (Patel and Mishra, 2006, Wagner*et al*., 1986, Singh *et al*., 2001 and Franca *et al*., 1995). *In vivo* tests indicate that wedelolactone neutralizes the lethal and myotoxic activities of rattlesnake venom (Mors*et al*., 1989). The methanolic extracts of aerial parts of *Eclipta alba*, exhibited significant free radical scavenging capacity for 1,1-diphenyl-2-picrylhydrazy DPPH and for hydroxyl radical. Further, the extracts showed considerable inhibition of lipid peroxidation (Anuradha *et al*., 2008). The alcoholic extract of the plant has shown antiviral activity against ranikhet disease. Leaf juice mixed with honey is also used for children with upper respiratory infections (Baskaran and Jayabalan, 2005). *Eclipta alba* is widely used in India as a cholagogne and deobstruent in hepatic enlargement, for ailments of the gall bladder (Orning *et al*., 1980).

Research on the analgesic activity of the total ethanol extract of *Eclipta alba* (Sawant *et al*., 2004) showed that both the ethanol extract as well as the total alkaloids, produce good analgesic activity in all the different models of analgesia used. The total alkaloidal fraction was the most efficacious in all models tested. The neurochemical investigations can unravel the mechanism of action of the plant drug with respect to nootropic activity and help to establish the plant as an armamentarium of nootropic agents (Thakur and Mengi, 2005). The dry leaf powder of the herb showed a marked reduction in mean arterial pressure by 15%, total cholesterol (17%), low-density lipoprotein fraction (24%), triglycerides (14%), very-low-density lipoprotein fraction (14%), and plasma lipid peroxides (18%) in supplemented group of patient over control (placebo) group of patient (Rangineni *et al.*, 2007). Results also revealed a remarkable increase in urine volume (34%), urine sodium (24%), serum vitamin C (17%), and serum tocopherols (23%) due to the *Eclipta* group. It was reported that dietary intake of *Eclipta alba* aqueous leaf extract enhances the non-specific immune responses and disease resistance of *Oreochromis mossambicus* against *Aeromonas hydrophila* (Christybapita *et al.*, 2007). The plant may be used in a synergistic way to remediate and restore the fly-ash (FA) contaminated areas by accumulating various heavy metals (Dwivedi *et al.*, 2008). The leaves have the antibacterial and antioxidant activities, where the fractionated ethanol extract from *Eclipta prostrata* could be used against *Salmonella typhi* pathogen (Karthikumar *et al.*, 2007). Due to high percentage of saponins and tennins in the leaf extract, it can be used as environment friendly and sustainable insecticides to control *Culex qinquifaciatus* mosquito larvae (Khanna and Kannabiran, 2007).

Traditionally, medicinal plants have been obtained from the wild sources *viz.* forest and other common lands. Out of the potential quality medicinal plants, 40 percent are available in forest areas, 50 per cent in non-forest areas and only 10 per cent in cultivated lands (Ravishankar *et al.*, 1999). But now, efforts are being made to change the scenario, to obtain 80 per cent medicinal plants from cultivated field and less than 2o per cent have to be depended on forest. Majority of the present day herbal industry still depends on wild strata and indiscriminate collection by unscientific and unsustainable manner that is causing fast depletion of population in its natural habitat. This makes the Industry to face the difficulty in continuous and sustainable supply and lack of confidence in genuine material. Such situation is already being experienced in most of the medicinal units and this can not be improved unless corrective measures are immediately implemented by domestication of wild medicinal plants. It is thus imperative to bring these medicinal plants under cultivation to meet the regular demand of herbal based products. The commercial cultivation of medicinal plants to enhance the supplies will reduce the pressure on wild sources depletion which is much higher than their regeneration. At present, Government of India has banned the collection of medicinal plants from the jungle as most of the species are going under threat of endangerment due to over exploitation. Therefore, cultivation of medicinal plants in farmer's field is very essential from conservation point of view and sustainable utilization for future generation. The major limitation, however, for the commercial cultivation of the medicinal plants is lack of standard cultivation package or agrotechnology.

In North Eastern India most of the winter rice growing areas are affected by flood every year, there is vast scope for cultivation of *Eclipta prostrata* in flooded areas with a minimum cost. The required agronomical parameters for successful cultivation of crop may be similar or different in nature with respect to the different places of cultivation under varied agro- climatic conditions. Among the various agronomical factors, optimum spacing without causing intra and inter competition, optimum nutrient requirement for proper growth and development, time of transplanting and optimum harvesting stage are some most important factors, which effect the production of herb and essential components as active constituents of medicinal and aromatic plants. But till now no work has been done on the cultivation practices of *Eclipta prostrata* L. for its domestication and enhancing its commercial potential. Hence there is need to domesticate and developed the agrotechnology of *Eclipta prostrata* L. to ensure the sustained supply of drug to herbal industries. Accordingly the present investigation has been undertaken to develop the agrotechnologies for domestication and commercialization of Bhringaraj (*Eclipta prostrata* L.) with the following objectives:

1. To standardize the best spacing for cultivation of *Eclipta prostrata* L.
2. To standardize the economic dose of different sources of nutrients for cultivation of *Eclipta prostrata* L.
3. To study the effect of transplanting time on growth and yield of *Eclipta prostrata* L.
4. To find out the best harvesting stage of *Eclipta prostrata* L.
5. To study the quality aspect effected by different agro practices of *Eclipta prostrata* L.

CHAPTER–II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Bhringaraj (*Eclipta prostrata* L.) is a very important medicinal plant in 'ayurveda' and modern allopathy medicines but still common farmers of North – Eastern region consider it as a weed. Therefore, agronomical studies on cultivation of *Eclipta prostrata* L. has not been made till date, except some chemical investigation on wild *Eclipta prostrata*. The literature relevant to the present investigations is highlighted in this chapter under the following heads.

2.1 Effect of different spacing on growth and herb yield

The closer spacing 30 x 30 cm was found very suitable for realizing maximum yield potentialities of *Artemesia pallens* (Gulati, 1980). Similarly, Singh and Randhawa (1990) reported that 30 cm or 40 cm spacing proved optimum for *Anethum gravedens* under Punjab condition. Rao *et al.*(1990) reported that a closer spacing of 30 x 15 cm was found to be optimum for higher yield on Davana than wider spacing of 30 x 30 cm or 30 x 45 cm. From an experiment on effect of spacing in *Ocium gratissium* L. Balyan *et al.* (1987) reported that 40 cm row spacing produced significantly maximum seed yield of *Ocimum sp.* although it was *at par* with 50 cm row spacing. They also reported that increasing the row spacing from 40 cm to 60 cm and 70 cm resulted significant reduction in seed yield. Saha (1992) reported that 40 cm x 0 cm spacing gave the highest biomass yield (12.36 t/ha) and oil yield (109.60 Kg/ha) of *Mentha piperita* L. followed by 30 cm x 0 cm spacing.

While studying the effect of spacing on Patchouli, Sarma and Kanjilal (2000) reported that wider spacing (90 cm) proved superior to closer spacing (45, 60 and 75 cm) in terms of herb and oil yield. Kasera and Saharan (2001) reported that plantation of *Evolvulus alsinoides* L. at 25 x 25 cm spacing with plant density of three plants in a group gave maximum plant growth and biomass yield. Cultivation of *Asparagus racemosus* and *Asparagus adscendens* at spacing of 30 x 30 cm resulted higher root yield as compared to lower plant density (Ram *et al.*, 2001). Ramachandra *et al.* (2002) also reported that cultivation of patchouli with a spacing of 60 x 45 cm recorded the tallest plant height, more number of leaves and branches/plant, plant spread though it remained same with 45 x 45 cm spacing. On the other hand, 45 x 30 cm spacing recorded increased fresh herb yield, dry yield and oil yield but was *at par* with 45 x 45 cm.

Saini *et al.* (2002) reported that cultivation of Japanese mint in a row spacing of 45 cm produced maximum plant height, dry herb yield and essential oil yield and remained *at par* with 60 cm but proved significantly superior to 75 cm row spacing. From a two year experiment on plant spacing on herb yield of Marigold, Singh (2002) reported that different plant spacing did not influence the yield and quality of marigold. Singh *et al.* (2002 a.) reported that the tiller production and root yield/plant were recorded higher at low plant population (75 x 60 cm spacing), but total root and oil yield were more at higher plant population (60 x 45 cm spacing) in vetiver cultivation. The root and oil yield of vetiver with higher plant population increased upto 35 % over 1.11 tones dry root and 15.1 kg oil yield/ha obtained from lower plant population. Patel *et al.* (2003) reported no significant variation due to various seed rate or spacing (4, 6, 8 and 10 kg/ha) on growth parameters *viz.* plant height, length and girth of root and dry root yield of ashwagandha. Agarwal *et al.* (2004) also reported that among the 4 different spacing *viz.* 20 x 5 cm, 20 x 7.5 cm, 25 x 5 cm and 25 x 7.5 cm, longer roots were observed with 20 x 5 cm spacing in aswagandha cultivation and maximum fresh and dry root yield were obtained due to 20 x 7.5 cm spacing. Similar trend of result was also reported by Abbas *et al.* (1994). From a field trial Pakkiyanathan *et al.* (2004) reported increased plant height, root length and fresh weight of Ashwagandha with 30 cm x 10 cm whereas, more number of leaves were recorded in 30 x 15 cm spacing under Hyderabad climatic condition. The highest herb yield was recorded in closer spacing 30 x 5 cm. Similar result was also reported by Patidar *et al.* (1990) in WS-20 cultivar of Ashwagandha cultivation.

Kateli (*Solanum surattense*) planted at 60 cm inter-row spacing recorded significantly higher plant spread, number and length of primary and secondary branches, number of fruits and fruit weight/plant and fresh fruit yield, compared to the 45 cm inter row spacing (Khandelwal *et al.*, 2004). Joy *et al.* (2004) reported that the various growth parameters of black musli (*Curcuigo orchioides*) *viz.* plant height, number of leaves, canopy spread and sucker production were not significantly influenced by different spacing, along with the total dry matter per plant. However, dry matter production was higher in lower spacing due to high plant density, whereas, the lowest spacing 10 cm x 10 cm recorded the highest yield and highest harvest index. Joy (2003) also reported similar trend of results. From a field experiment at Rajendra Agricultural University, Pussa, Bihar, Anwar and Maurya (2005) reported that wider spacing (25 x 30 cm) significantly increased the plant height of gladiolus. Similar report was also given by Bhattacharjee *et al.* (1979) and Maurya (2005). Singh *et al.* (2005 a.) reported that closer spacing of fenugreek resulted statistically superior seed yield than wider spacing. Halesh *et al.* (2000) also obtained similar trend of results.

From an experiment at Center for Forestry Research and Human Resource Development, Chhindwara, Madhya Pradesh, Vijayaraghavan *et al.* (2005) reported that closer spacing 30 x 30 cm recorded significantly tallest plant height and biomass yield per hactare of *Andrographis paniculata* due to more number of plants per unit area than the wider spacing. Similar trend of result was also reported by Ram *et al.* (2001) and Tiwari and Misra (1996). Gnanavel and Kathiresan (2006), fom a field trial on *Coleus aromaticus* cultivation, at Department of Horticulture, Annamalai University, Tamilnadu, observed that closer spacing (60 x 30 cm) resulted into tallest plant height, however, more number of branches and plant biomass were recorded in wider spacing (60 x 60 cm) whereas, the medium spacing (60 x 45 cm) showed the highest leaf area index. Similar trend of result was also reported by Singh and Nand (1979). Though the highest plant height and seed yield of fennel were recorded in 45 cm row spacing as compared to 22.5 cm and 30 cm, but the difference remained statistically *at par* among all plant spacings (Singh *et al.*, 2006). Gosh *et al.* (2008) reported that plant under closest spacing in elephant foot yam cultivation recorded the longest pseudostem with maximum yield, whereas, pseudostem girth and canopy coverage were maximum at widest spacing. Planting of turmeric at 30 x 15 cm spacing recorded significantly higher growth characteristics *i.e.* leaf area index, dry matter production and yield of turmeric as compared to wider spacing treatments *viz.* 45 x 15 cm and 60 x 15 cm (Kandiannan and Chandaragiri, 2008). Similar trend of results was also reported by Medhi and Bora (1993).

2.2 Effect of different nutrient sources with varying doses on growth and herb yield

Rai *et al.* (1977) reported that increasing rates of nitrogen application under different agroclimatic condition increased number of branches and leaves per plant of *Mentha arvensis* and also significantly increased the plant height (Kothari and Singh, 1987 and Singh *et al.*, 1989). Nitrogen application increased the herb and essential oil yield of *Cymbopogon martini* (Sarmah *et al.*, 1980 and Chinamma *et al.*, 1988). Hedge *et al.* (1984) reported that incorporation of 120 Kg N/ha significantly increased the plant height, plant spread, number of branches/plant, number of pods, seed yield and seed to husk ratio in ambrette (*Abelmoschus moschatus*). Similar trend of result was also observed by Balyan *et al.* (1987) in *Ocimum americanum* and *Ocimum canum*. Application of 120:60:40 Kg/ha N:P:K exhibited the highest yield of biomass and oil in *Mentha piperita* Linn. (Saha, 1992). From an experiment on celery (*Apium graveolens* L.) at Horticultural research station, G.K.V.K., Bangalore, Sudheendra *et al.* (1993 a.) reported that higher doses of N significantly increased the plant height, number of branch, number of umbels and seed yield as compared to 100 and 150 Kg N/ha. Sankar (1995) reported that application of 200 Kg N/ha gave 6.93 t/ha fresh herb yield but recorded *at par* with 150 kg N/ha on *Pogostemon patchouli*. Effect of various levels of nitrogen (0, 30, 60 and 90 Kg/ha) was examined on the growth and yield of Sarpagandha (*Rauvolfia serpentina*) during the year 1996 under Bihar conditions and it was reported that 60 Kg N/ha was found to be optimum for higher root yield (Maurya *et al.*, 1999).

Munshi and Mukherjee (1982) reported that application of phosphorus increased the herb yield of *Mentha arvensis*. Similar trend was also reported by Kothari and Singh (1987). Neshev and Slavov (1984) observed that phosphorus application increased the herb yield of *Mentha piperita*. Higher doses of P (60 kg P_2O_5/ha) significantly increased the plant height (76.06 cm), number of branch (6.18), number of umbels (37.51) and seed yield (8.95 q/ha) of celery (*Apium graveolens* L.) as compared to 30 Kg/ha and control (Sudheendra *et al.*, 1993a).

In Indian condition, potassium application failed to show marked response on *Mentha arvensis*. Balyan and Sobti (1990) opined that application of potassium had no effect alone or in combination with nitrogen and phosphorus on dry matter accumulation of *Ocimum gratissimum*.

From an experiment on fertilizer management on saffron, Badiyala *et al.* (1993) reported that higher doses of N, P and K ($N_{90}P_{60}K_{60}$) brought about significant improvement in increasing the length of leaf needles, number of leaf needles, total number of flowers/ha, and dry saffron yield as compared to other respective treatments and control. Bhaskar *et al.* (2001) reported that the varying rate of FYM and nitrogen failed to produce significant variation at first harvest on geranium yield, however, at second harvest, the yield increased significantly. Kattimani *et al.* (2001) observed that application of nitrogen 75-225 kg/ha significantly enhanced the biomass yield of Japanese mint as well as nitrogen, phosphorus and potassium uptake. The crop responded to the application of phosphorus only up to 40 kg/ha. Combined application of 225 kg N with 40 kg P_2O_5 per hectare recorded the highest biomass yield and nutrient uptake as compared to other treatment combinations.

Application of nitrogen@ 150 kg/ha or 2.5 t/ha vermicompost + 75 kg N + 25 kg P_2O_5 + 25 Kg K_2O per hectare produced similar plant height, herbage and oil yield and proved significantly superior to control *i.e.* no fertilizer. However, quality of oil due to different sources of nitrogen remained unchanged except methyl chavicol per cent in oil of sweet basil (Singh and Ramesh, 2002). From a field experiment, Prasad *et al.* (2002) reported that NPK in a mixture of 125 Kg/ha in equal proportion enhanced the biomass yield of Meshashiringi (*Gymnema syslvestre*). Application of 100 kg N/ha and 50 kg P/ha in Ajowan (*Trachyspermum ammi*) cultivation, resulted the longest plant height, maximum number of leaves, plant spread, highest number of primary and secondary branches, total dry matter production and maximum seed yield (Krishnamoorthy and Madalageri, 2002). Studies with four nitrogen levels (0, 30, 60, 90 kg N/ha) and three level of phosphorus (0, 25 and 50 kg P/ha) on growth and yield of fennel (*Foeniculum vulgare*). Rai *et al.* (2002) showed that 90 kg N with 50 kg P resulted in marked improvement on plant height, number of branches/plant, stem diameter, number of leaves/plant, length of internodes, number of tillers/plant, plant spread and seed yield of fennel. Application of FYM@ 10 t/ha along with 75 per cent recommended dose of fertilizer gave higher tuber yield of Mudgaparani (*Phaseolus trilobus*) than the recommended dose of fertilizer and FYM alone (Kewalanand, 2002).

Yadav *et al.* (2003) reported that application of nitrogen through urea (25%) and FYM (75%) significantly increased the number of tillers/plant, plant height and dry matter accumulation at all the growth stages and the number of spikes per plant, grains per spike, grain and straw yield at harvest in isabgol (*Plantago ovata*) cultivation. Rahman *et al.* (2003) reported that among the different levels of NPK treatment (N: 0, 100 and 120 kg/ha, P_2O_5 : 0, 60 and 120 Kg/ha, K_2O : 0, 40 and 80 Kg/ha), the treatment combination $N_{200}P_{50}K_{40}$ produced the maximum number of branches, yield of fresh leaves and total herb whereas, the treatment $N_{200}P_{120}K_0$ recorded the maximum dry matter production on Mentha cultivation. The increase in phosphorus level from 0 to 60 kg/ha recorded the highest growth and yield attributing characters with seed yield and highest gross return, net income and benefit: cost ratio at 60 kg P/ha dose in cultivation of chandrasur (Tiwari and Kulmi, 2004). The results of integrated nutrient management trial on muskdana (*Abelmoschus moschatus*) revealed that all the growth, yield attributes and seed yield except plant height and fruit length were significantly influenced by integrated nutrient management treatment. The maximum seed yield of both main and ratoon crop of muskdana was obtained under the plots receiving combined application of 75% NPK + 10 t FYM + biofertilizer (Saraf and Tiwari, 2004).

From an experiment on Keetanelli (*Phyllanthus* amarus) at Agricultural College and Research Institute, TNAU, Madurai, Balakumbahan *et al.* (2005) reported that integrated nutrient management treatment resulted the highest plant height, number of branches, fresh weight of shoot, dry matter production and fresh herb yield. Similar trend of results were also reported by Singh and Kewalanand (1981) in *Mentha citrate*. Chauhan *et al.* (2005) reported that application of FYM 15 t/ha produced root yield of safed musli (*Chlorophytum borivilianum*) almost *on par* with combined application of FYM 15 t/ha along with varying rates of NPK, suggesting that safed musli can be grown organically without loss in productivity. Similar trend of result was also reported by Kedia and Kasera (2006) on *Phyllanthus fraternus* cultivation. From an experiment at G. B. Pant University of Agriculture and Technology, Pantnagar, on rose cultivation, Singh (2006) reported that FYM and higher doses of nitrogen produced superior plant height and LAI.

On the basis of a field trial on *Coleus aromaticus*, at Department of Horticulture, Annamalai University, Tamilnadu, Gnanavel and Kathiresan (2006) reported that higher dose of NPK (100:50:50 Kg/ha) resulted statistically superior plant height, more number of branches, leaf area index, highest plant bio mass and leaf yield/ha. Similar trend of result also reported by Singh and Singh (1979). Puttanna *et al.* (2006) reported that a fertilizer dose of 100:60:60 Kg/ha N:P:K or half of this dose substituted by 10 tone FYM proved best for herb yield without affecting saponin content in cultivation of *Centella asiatica* under Bangalore climatic condition. The integrated nutrient combination, involving organic form of manures

(Cocopeat 5 t/ha + farmyard manure 12.5 t/ha) and inorganic fertilizers (N:P:K = 40:30:30 kg/ha) showed a greater degree of positive influence on the seed yield and yield attributing characters of *Mucuna pruriens viz.* number of flowers/pod, seed weight/pod, single pod dry weight and dry matter production than individual organic or inorganic treatments (Kavitha and Vadivel, 2006). From a field trial on groundnut, Panwar and Munda (2007) reported that growth and yield attributes of groundnut *viz.* plant height, number of branches and leaves, pods/plant, pod weight and test weight were higher in integrated nutrient treatment plots as 10 t/ha FYM supplement with 75 per cent and 50 per cent recommended doses of NPK over other integrated or individual nutrient treatments. It was also concluded that application of 10 t/ha FYM or pig manure in combination with 50 per cent recommended dose of NPK fertilizers registered highest yield and economic return. Similar results were also recorded by Kachot *et al.* (2001). Ray *et al.* (2008) reported that organic cultivation of papaya produced statistically similar yield in comparison to nutrients through organic *viz.* farm yard manure, poultry manure or chemical fertilizers. Application of 50% recommended dose of fertilizers supplemented with vermicompost alone@ 5 t/ha or with vermicompost and farmyard manure@2.5 t/ha and 5 t/ha, respectively produced significantly taller plant height, branch/plant, dry matter accumulation, root characteristics and yield of tomato. (Dass *et al.*, 2008, Nag *et al.*, 2004 and Sarkar *et al.*, 2002).

2.3 Effect of sowing and transplanting time on growth and herb yield

Vadivel *et al.* (1981) reported that the best time of planting *Mentha citrata* is June-July at Kodaikanal area. The plant behaved differently under the climatic condition of Jammu, where the highest herb and oil yield was recorded when planted in March (Baiyan *et al.*, 1982). Time of planting plays a vital role in biomass yield of a crop whether it is medicinal or aromatic plant. *Ocmium grastissium* an essential oil bearing plant produced the highest yield of herb and oil under Jorhat (Assam) condition when planted in May followed by April (Chaoudhury and Bordoloi, 1986). *Anethum graviolens* was successfully grown under Punjab condition by planting in September (Singh and Randhawa, 1990) and delay in sowing resulted decrease in plant height. From an experiment at RRL, Jorhat, branch Itanagar, Saha (1992) reported that February planting in general and 10th February in particular for *Mentha piperita* L produced superior vegetative growth with the highest biomass yield and oil content. The highest percentage of menthol was also obtained when it was planted on 10th February. However, under Jammu condition the optimum time of planting of the same species was last part of December to the end of January.

From a field experiment, Sudheendra *et al.* (1993 b.) reported that June sowing of celery (*Apium graveolens* L.) resulted into significant increase in plant height (105.67 cm), number of branches (8.87), number of umbels (59.70) and early maturing (156.60 days) and also increased the seed yield (25.42 q/ha) than other sowing time viz. July, August, September, October and November sowing. Sowing date played significant role on growth and yield attributes and seed yield of isabgol (*Plantago ovata*) cultivation (Solanki and Shaktawat, 1999). Delay of sowing of isabgol resulted in reduction of growth and yield attributes. The results of an experiment on sowing time revealed that planting of *Plumbago zeylanica* in the month of July is the best time for its cultivation and gave better performance in respect of growth and yield parameters than other time of sowing treatments (Tiwari *et al.*, 2000). Significantly higher herb yield and oil yield of patchouli were recorded when planted in February as compared to March planting under Jorhat, Assam condition (Sarma and Kanjilal, 2000).

From a two-year field experiment on time of sowing on dill (*Anetheum graveolens* L.), Kumar *et al.* (2001) reported that sowing of dill on 7th August resulted the highest seed yield and after 7th August, significantly decreased the seed yield in both the years. Tiwari *et al.* (2002) reported that the number of primary and secondary branches per plant were the highest in October 15th sown coriander than October 30th sown at Pantnagar. From a field experiment on Aswagandha at Jobner, Agarwal *et al.* (2004) reported that sowing of aswagandha on 20th July produced the longest roots with maximum diameter, fresh and dry root yield than 5th and 20th August sowing. Similar trend of result was also reported by Kahar *et al.* (1991) on ashwagandha. Singh *et al.* (2005 a.) reported that early sowing (30th Oct.) increased the plant height of fenugreek than delay in sowing (15th and 30th Nov.). Similar trend of results was also reported by Yadav *et al.* (2001). Early transplanting of tomato (10th Dec) recorded the highest plant height, branch number and dry matter production mainly due to availability of sufficient time for vegetative and reproductive phase enabling the sufficient nutrient utilization from soil (Singh *et al.* 2005 b).

Singh *et al.* (2006) had recorded significant reduction in seed yield of fennel due to delayed sowing from 15th November to 6th December. The maximum plant height and branch/plant were recorded in case of 15th November sowing. Similar trend of result was also recorded by Randhawa *et al.* (1978). Bhargava *et al.* (2007) reported that 15th November sowing at 25 cm spacing produced highest foliage yield of *Chenopodim quinoa* leaves. Late sowing around the 15th December gave the lowest yield under all spacing. From an experiment on sowing of chickpea at different planting time *viz.* normal (15th November), late (30th November) and very late (15th December), it was revealed that seed yield and seed protein content were significantly higher in late planting. Higher percentage of protein was recorded in late planting followed by very late and normal planting (Singh *et al.* 2007). Bhatt *et al.* (2007) reported that early sowing of green onion in the month of August recorded the highest plant height and number of leaves than late planting in the month of September.

Planting turmeric during middle of May (15th May) proved superior in all the characteristics of growth and yield as compared to 15th June and 15th July planting (Kandiannan and Chandaragiri, 2008). The 10th and 20th May sowing of groundnut registered no variation on number of branches, pods per plant and 100 kernel weight, however, with each 10 day delay in sowing from 20th May to 20th June it showed decreasing trends. The 10th and 20th May sowing showed statistically similar yield which was superior to other late sowing dates. Similar trend of result was observed on oil content and oil yield of groundnut (Sardana *et al.*, 2008, Kumar *et al.* 2003 and Karanjkar *et al.* 2004).

2.4 Effect of different harvesting stages on growth and herb yield

Peppermint produced the highest essential oil, menthone and herb yield in July harvest under Bangalore climatic condition than April and October harvest (Leela and Angadi, 1993). Randhawa *et al.* (1993) reported that each delay in harvesting from vegetative to complete flowering increased the content of cineole and methyl chavicol in herb oil of french basil (*Ocimum basilicum* L.). Morphological characters exhibited significant correlation with essential oil yield/plant at flowering stage of *Cymbopogon pendulus* (Sharma *et al.*, 2002). The crop *Ocimum* species harvested at full flowering stage resulted higher herb oil and essential oil yield than the crop harvested at 50% flowering stage and ten days after full flowering stage. At full flowering stage, the increase in the oil yield of *O. sanctum* and *O. basilicum* was higher by 17.9 and 49.4, respectively than the 50% flowering stage (Ram *et al.*, 2002).

Field experiment on ashwagandha at Gujrat, revealed no significant difference in total dry yields harvested at 150 and 210 days after sowing however, at 210 days, it showed marginal increase in total dry root yield (Patel *et al.*, 2004). Basil (*Ocimum basilicum*) harvested at 75 days after planting as well as 60 days after first harvest duly supplied with 80 Kg N/ha produced significantly higher biomass and oil yield and increased nitrogen uptake compared to other treatment (Singh *et al.*, 2004, Pareek *et al.*, 1980 and Singh *et al.*, 1970). Pratibha and Konwar (2005) reported that harvesting of indigo at little pod stage increased 20% higher biomass yield and 46% higher dye content than harvesting at vegetative and flowering stage. Puttanna *et al.* (2006) reported that *Centella asiatica* harvested at 140 days after sowing produced maximum herb yield with highest saponin content.

2.5 Effect on N, P and K Uptake and Organic Carbon Content

The uptake of nitrogen, phosphorus and potassium by ajowan increased significantly with application of increasing rates of nitrogen and phosphorus (Krishnamoorthy and Madalageri, 1999). They also reported that maximum uptake of NPK was recorded at 100 kg nitrogen and 50 kg phosphorus per hectare. Nitrogen content in seed and potassium content in straw and seeds increased significantly with application of nitrogen and phosphorus. Meenakshi *et al.* (2001) reported significant increase in NPK uptake by turmeric due to increased level of NPK fertilizers. The treatment 150:100:100 Kg N: P: K per hectare proved superior in NPK uptake of turmeric. Maximum N, P and K content of 1.19, 0.69 and 2.11 % in mother rhizome, 1.51, 0.75 and 2.3 % in the finger rhizome and 2.69, 1.44 and 4.4 % in total content was recorded at 150:100:100 Kg/ha N:P:K level respectively. Sadanandan and Hamza (1998) also reported similar results in ginger and turmeric cultivation. The uptake of N, P and K was more whenever, increased growth and dry matter production were observed.

Different nutrient management practices failed to produce significant variation on N, P, K content of plant in *Centella asiatica* (Puttanna *et al.*, 2006). They recorded highest uptake of nitrogen due to 50:30:30 kg/ha N:P:K + 10 t/ha FYM treatment, uptake of P was highest in 100:60:60 kg/ha N:P:K + 10 t/ha FYM treatment, whereas highest K uptake was noted in the treatment 100:60:60 kg/ha N:P:K. Similarly higher uptake of nutrients by groundnut was observed due to 10 tones FYM blended with 75 per cent and 50 per cent recommended doses of fertilizer (Panwar and Munda, 2007). Joy *et al.* (2004) reported highest nutrient uptake (N, P and K) by black musli was due to closer spacing (10 x 10 cm) over wider spacing. Cultivation at closer spacing of turmeric resulted into higher uptake of major nutrient as compared to wider spacing (Kandiannan and Chandaragiri, 2008, Shashidhar and Sulikeri, 1996).

Singh *et al.* (2004) reported no marked variation in nitrogen concentration in biomass due to different harvesting time and levels of nitrogen in basil cultivation. Similar trend of result was also reported by Dey and Choudhari, (1984) and Pareek *et al.* (1982). Contrary to this Pratibha and Konwar (2005) observed that harvesting of indigo at flowering stage resulted into highest nitrogen, phosphorus and potash content in plant than harvesting in vegetative and little pod stage. The plant nutrient content (N, P and K) increased with application of chemical nutrients.

2.6 Effect of nutrient management, spacing, transplanting time and harvesting stages on quality parameters

Rao *et al.* (1990) reported that the quality of geranium yield was not affected by fertilizer application. Application of N @ 40 kg/ha brought a significant increase in herbal yield and alkaloid content of *Catharanthus roseus*. Application of K @ 20 kg/ha stimulated the alkaloid content of the same herb (Jana and Varghese, 1996). Somnath *et al.* (2005) from an experiment on *Coleus forskohlii* at Bangalore, reported that forskolin content of *Coleus forskohlii* did not vary significantly either due to different level of FYM and fertilizers or their combination. Similar observation was also made with respect to piperine content in *Piper longum* (Rao, 2002). Balakumbahan *et al.* (2005) reported that alkaloid content did not vary significantly with application of inorganic fertilizer alone or in combination with organic sources. There was no significant difference among the different nutrient management treatments on saponin content in *Centella asiatica* (Puttanna *et al.*, 2006). Meena *et al.* (2006) also reported that increasing level of nitrogen fertilization did not show any significant effect on quality parameters of coriander. Similar trends of result were also reported by Hornok (1976) and Venkateswarlu *et al.* (1992). The impact of different organic and chemical fertilizes on quality parameters of papaya *i.e.* fruit size, average fruit weight TSS were found statistically non significant (Ray *et al.*, 2008).

From an experiment on influence of N, P and K on the yield and quality of Gherkin, Shivashankaramurthy *et al.* (2007) reported no significant variation on total sugar content due to different levels of nitrogen (0, 125, 175 and 225 Kg N/ha) as well as phosphorous (0,125 and 175 Kg P_2O_5/ha) and potash (0 and 125 kg K_2O/ha). All the treatment combinations remained statistically on par regarding total sugar content. Reduction in carbohydrate in latter flowering stage might be attributed to ageing of leaf and depletion of endogenous growth substances of the plant. Increase in carbohydrate from one stage to another and then gradual fall of carbohydrate concentration in crop were recorded by Saimbhi and Nandapuri, (1981), Singh *et al.* (1973).

Sowing time and spacing failed to produce any marked variation trial on quality of patchouli, (Sarma and Kanjilal, 2000). However, Patel *et al.* (2003) reported higher total alkaloid content in root of ashwagandha due to lower seed rate of 4 kg seed per hectare than the higher seed rate (8 and 10 kg/ha). Most of the quality parameters of black musli (*Curcuigo orchioides*) were improved at closer spacing than wider spacing (Joy *et al.*, 2004). They also reported that starch, ash, glucose, sucrose, crude fibre and crude fat contents were high in 10 x 10 cm and 20 x 10 cm as compared to 20 x 20 cm and 30 x 20 cm treatments. Similar results were also obtained by Kurian *et al.* (2000). In an experiment on quality control of *Chenopodim quinoa* consistent decrease in carotenoid content was noted with increase row to row spacing. The highest carotenoid and protein content in *Chenopodium quinoa* was recorded at 15 cm spacing with 30th November sowing treatment (Bhargava *et al.*, 2007). The similar trend of results was also reported by Shukla *et al.* (2006) and Yasin *et al.* (2003).

Ito *et al.* (1996) reported the seasonal variation on alkaloid content in *Aconitum japonicum*. Chaudhury and Gupta (2002) observed highest total alkaloid content in *Catharanthus roseus* during winter season and highest amount of root alkaloid in *Catharanthus alba* variety during rainy season in Catharanthus cultivation. From an experiment Bagchi *et al.* (2003) reported that the seedlings of *Aremisia vulgaris*, transplanted in the month of January exhibited maximum concentration of camphor. The seasonal variation of minor tertiary indole alkaloids of *Strychnos-nux-vomica* in all the vegetative plant parts was reported by Bandopadhyay and Dey (2003). They also reported the alkaloid of normal series (Strychnine and brucine) gradually increased till December (winter season), but remained absent in the month of July (rainy season), whereas, gradually increased in pseudostrychnine quantity from the month of September and absent in the month of December. They also observed that vomicine a predominant N-methyt-sec. pseudo-alkaloid of twigs of strychnos – nux vomica and the alkaloids remained highest in the month of March, but decreased up to July,which again increased in September and decreased in December. Bagchi *et al.* (2003) reported there were two peak seasons of vasicine concentration of *Adhatoda vasica* and *Adhatoda beddomeri* during March and September than the other months of the year. Meena *et al.* (2006) reported that the quality of coriander was highly influenced by time of sowing. The maximum chlorophyll (a, b and total chlorophyll) content, carotenoids content in leaves and essential oil content in seed were higher due to 15^{th} October sowing than 30^{th} October and 15^{th} November sowing.

Leela and Angadi (1993) reported that menthone content of peppermint was highest in the oil from July harvested herbage and produced a good quality of essential oil than October harvest of pippermint under Bangalore climatic condition. Analytical work showed that there was no alkaloid synthesis in leaves up to one month of age however; much variation was noted in alkaloid content with age in different plant parts (Pachori, 1995). Gupta and Shahf (1999) reported that harvesting of *Ocimum* at flowering stage resulted highest herb yield as well as quality of yields. From a field experiment on lemon grass at Barapani, Meghalaya region, Sharma *et al.* (2002) reported that oil quality was maximum during flowering stage and it could be ideal stage to harvest the crop. They also reported that elemicin content was maximum at flowering stage (50%) followed by seed setting and vegetative stage with 48.2% and 36.1% respectively. Sarmah *et al.* (2000) reported the similar trend of results.

Singh *et al.* (2004) reported that oil content and quality in biomass of basil remained unaffected due to different harvesting time and levels of nitrogen on basil cultivation. Similar trend of result was also reported by Dey and Choudhari, (1984) and Pareek *et al.* (1982). Baraiya *et al.* (2005) observed that prior to 45 days after sowing of Ashwagandha no alkaloid could be treated analytically in any plant parts. Leaves showed the highest percentage of alkaloid at 45 days after sowing; thereafter it decreased at each successive growth stage while increase in total alkaloid content continued up to 135 days after sowing.

Chemically, presence of a number of constituents has been reported in *Eclipta prostrata* L. Coumestan wedelolactone and desmethyl wedelolactone have been identified as active components responsible for antihepatotoxic activity on the basis of *in vitro* studies on primary cultured rat hepatocytes against CCl_4, galactosamine and phalloidin induced cytotoxicity (Govindachari *et al.*, 1965, Krishnaswamy *et al.*, 1966 and Bhargava *et al.*, 1970). From an experiment Singh *et al.* (2001) reported that the alcoholic extract of fresh leaves of plant *Eclipta alba* fractionated into three parts, chemically proved the most bioactive fraction. The fraction Ea II containing coumestan wedelolactone and desmethylwedelolactone as the major constituents is responsible for *in vivo* hepatoprotective activity of *E. alba*. However, some contribution of fraction Ea I containing phytosterols and oleane triterpenoids like stigmasterol and β-amyrin can not be ruled out for hepatoprotective activity of *Eclipta alba*.

2.7 Effect on physico-chemical properties of soil

While studying the residual available N, P and K status of soil after harvesting of *Centella asiatica*, Puttanna *et al.* (2006) reported no marked variation in their content due to varying nutrient treatments. However, the 50:30:30 kg/ha NPK + 10 t/ha FYM treatment recorded the highest available K content of soil which was statistically superior to other nutrient management treatments. Kumar *et al.* (2006) reported that application of nitrogen and phosphorus @ 125 kg/ha each, along with Azospirillum @ 2 Kg/ha recorded the highest soil available nitrogen and potassium whereas, application of nitrogen and phosphorous @ 125 kg/ha in addition to VAM @ 2 kg/ha recorded the highest soil available phosphorus in both main and ratoon crops of davana. Similar trend of result was also reported by Singh *et al.* (2004) on cultivation of basil.

Kavitha and Vadivel (2006) reported that availability of nutrients especially nitrogen, phosphorus and potash in soil after harvesting of *Mucuna pruriens* and nutrient uptake by the plant were highest in the integrated nutrient treatment (Cocopeat 5 t/ha + farmyard manure 12.5 t/ha and inorganic fertilizers, NPK @ 40:30:30 kg/ha) than either alone fertilizer and organic sources or combination treatments. Sanwal *et al.* (2007) reported that continuous application of organic manures resulted in progressive improvement in organic matter status over control. The available nitrogen content in soil marginally improved with the incorporation of organics over initial status after harvest of second crops in cotton – wheat rotation. They reported that application of organic sources of nitrogen showed higher available P and K rather than direct addition through inorganic sources. Percentage of carbon content in soil was statistically higher in FYM and rabbit manure applied treatment than control and 100 % NPK through inorganic fertilizer in turmeric cultivation under Meghalaya condition. Application of vermicompost and farmyard manure with 50 % recommended dose of fertilizer had favorable impact on bulk density, organic carbon and available nitrogen and phosphorus in soil (Dass *et al.*, 2008).

Planting turmeric earlier (15th May) recorded the highest uptake of nutrients mainly N, P and K as compared to late planting *viz.* 15th June and 15th July (Kandiannan and Chandaragiri, 2008). On the basis of review of literature, conclusively it may be summarized that *Eclipta prostrata* L. which is so significant and potent medicinal plant has yet not attracted the attention of agronomist to popularize its cultivation on commercial basis by developing suitable agrotechniques to obtain higher yield and economic return particularly in northeastern region.

CHAPTER – III

MATERIALS AND METHODS

MATERIALS AND METHODS

A project entitled "Development of Agrotechnologies for Domestication and Quality Aspect of Bhringaraj (*Eclipta prostrata* L.)" was carried out with two field experiments namely I. Effect of spacing and sources of nutrients with varying doses on yield and quality of *Eclipta prostrata* L. and II. To standardize the time of transplanting and harvesting stage of *Eclipta prostrata* L. at the Research-cum-Experimental farm, Department of Forestry, North Eastern Regional Institute of Science and Technology (NERIST), Nirjuli, Arunachal Pradesh. The experiments were conducted for two consecutive years *i.e.* 2005-06 and 2006-07 during kharif season. In this chapter, the geographical position of the experimental site, prevailing weather condition, physico-chemical properties of experimental site, experimental materials used and methods adopted during the whole course of investigation are described in detail.

3.1 Geographical position and description

The study site, Research-cum-Experimental farm Department of Forestry, North Eastern Regional Institute of Science and Technology (NERIST), Nirjuli, Arunachal Pradesh falls in the foothills of eastern Himalayan region. The site is located at 27°08'30"N latitude and 93°44' 36"E longitude with an altitude of 120 m from the mean sea level. "The land of the rising sun" Arunachal Pradesh, recognized as one of the 25 mega biodiversity "hotspots" in the world, is situated in the extreme northeastern region of India (Myers *et al.*, 2000).

3.2 Weather condition

The climatic condition of Nirjuli, Arunachal Pradesh, as a whole is tropical warm humid where monsoon normally sets in the first week of June, extends up to the end of September and recedes in October. The site has 4 distinct seasons, namely, autumn (mid October- November), winter (December-February), spring (March-April) and rainy (May-mid October). The mean annual maximum and minimum temperature varies between 37°C and 12°C respectively. More than 80% of rainfall occurs during monsoon (June-September) registering about 60-80% RH. However, the fact that occasional rainfall also occurs during winter season cannot be completely ruled out. Data pertaining to mean daily maximum and minimum temperature, mean daily relative humidity, total rainfall and bright sunshine hours of both the year 2005-06 and 2006-07 are presented in Appendix I and Appendix II and graphically in **Fig. 3.1.a.** and Fig. 3.1.b.

3.3 Site selection and cropping history

The experimental site is located along the flood plains of mighty river Dikrong basin. Geologically, the parent rock exposed around Nirjuli area is consisted of alluvium (newer and older terrace deposits), represented by valley field deposits, mainly the sediments. A rectangular shaped medium land of plot measuring 46.5 m in length and 8 m in breath of total area 372 m^2 equivalent to 0.037 hectare for the first experiment and 24 m in length and 10.5 m in breath, total area 252 m^2 equivalent to 0.0252 hectare for the second experiment were selected. The land was occupied by kharif maize and winter vegetable (potato) with normal practices prior to initiation of the proposed experiments.

3.4 Physico-chemical properties of soil of experimental site

Before starting the experiments soil samples were collected randomly from the entire field up to 30 cm depth with the help of steel core (7.5 cm inner diameter) and brought to the laboratory, mixed thoroughly and the foreign materials were discarded and sieved through 2mm mesh screen and divided into two parts. One part was used in field moist to determine soil pH, moisture content. The other part was air-dried then ground with a wooden roller and finally passed through 2 mm sieve for the determination of soil texture, water-holding capacity, organic C and available Nitrogen, Phosphorus and Potash. The results of the soil analysis for different physico-chemical Properties are presented in Table 3.1

3.5 Composition of farm yard manure

The organic sources of nutrient *i.e.* farmyard manure were analyzed for total nitrogen by using rapid titration method and semi-micro Kjeldhal apparatus, (Anderson and Ingram, 1993), total phosphorus by calorimetrically molybdenum blue method (Anderson and Ingram, 1993) and total potash by flame photometer method (Anderson and Ingram, 1993) method. The values of these parameters of farmyard manure are presented in table 3.2.

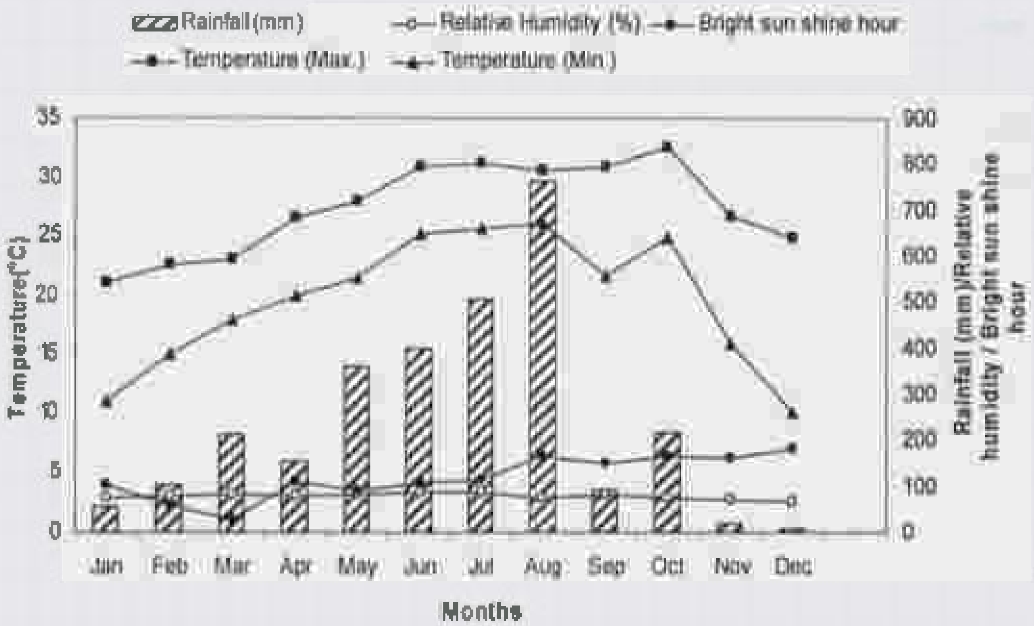

Fig. 3.1. a Weather parameters during 2005

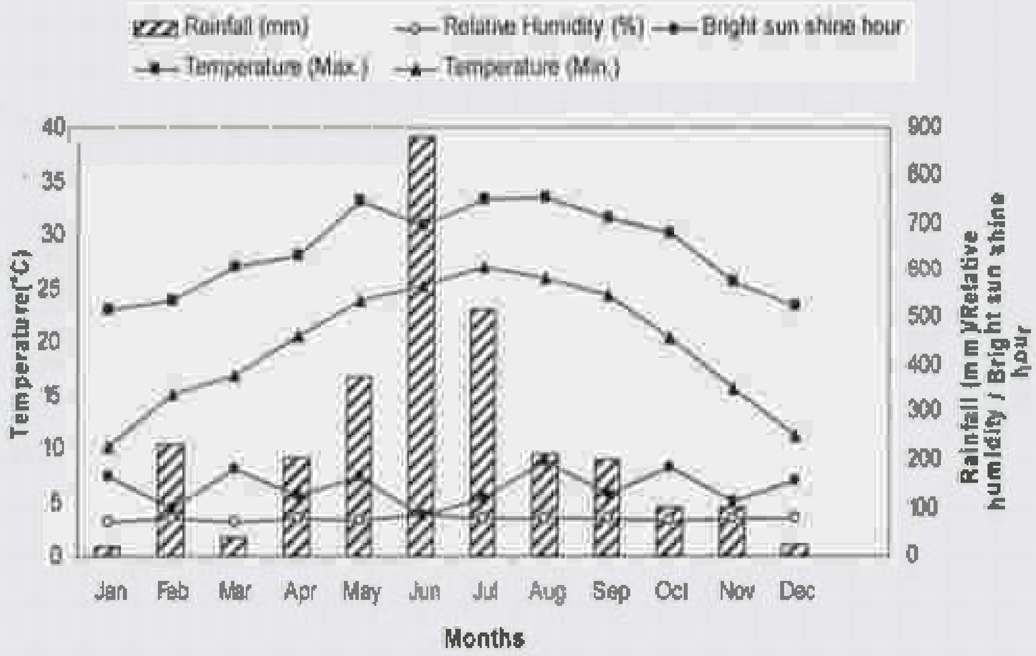

Fig. 3.1. b Weather parameters during 2006

3.6 Details of the experiments

3.6.1 Experiment I. Effect of spacing and sources of nutrients with varying doses on yield and quality of *Eclipta prostrata* L.

There were three different spacing and six different nutrient management treatments with total 18 different treatment combinations in this experiment. The detailed technical programme of the experiment is given below:

Experimental Design	: Split plot
Main plot	: Spacing– 3 spacing *viz.* S_1- 20 cm x 20 cm, S_2- 25 cm x 25 cm and S_3 - 30 cm x 30cm
Sub plot	: Six nutrient management treatments viz. F_0 – $N_0P_0K_0$, F_1-$N_{30}P_{20}K_{10}$, F_2 – $N_{60}P_{40}K_{20}$, F_3– $N_{90}P_{60}K_{30}$, F_4– 10 t FYM/ha and F_5– $N_{60}P_{40}K_{20}$+ 5 t FYM/ha
Number of total treatment Combinations	: 18
Number of replications	: 3
Number of total plots	: 54
Plot size	: 2 m x 2 m
Net plot size	: 1.8 m x 1.8 m
Gap between plots	: 50 cm
Gap between replication	: 1m
Total length and breath	: 46.5 m and 8 m respectively
Total area	: 372 m^2

3.6.1.1 Technique for imposing treatments

In this experiment spacing was considered as first factor and assigned to main plot whereas, sources of nutrients were considered as second factor and were kept in sub plots. After final land preparation lay out of the experiment was done (Fig.3.2). The required amount of fertilizers (urea, single super phosphate and murate of potash) and farm yard manure were weighed as per treatments. The full doses of phosphorus and potassium was applied at the time of final land preparation, however, the required amount of farmyard manure as per treatments were applied after preparation of plots.

Table 3.1 Physico-chemical properties of the experimental field

Particulars	Year		Textural class/rating	Method adopted
	2005-06	2006-07		
A. Mechanical analysis				
Sand(%)	83.36	83.12	Loamy sand	Bouyoucos hydrometric method (Allen, 1989)
Silt(%)	9.93	10.31		
Clay(%)	6.71	6.57		
Moisture content (%)	15.65	16.08	--	Gravimetrically by oven-drying 10 g fresh soil for 24 h at 105°C
Water holding capacity	41.59	41.95	--	Keens box method using copper cups of 5.6 cm inner diameter and 1.6 cm height (Piper, 1942)
Bulk density (g/cm^3)	2.03	1.98		Gravimetric method (Allen, 1989)
B. Chemical analysis				
Soil pH	5.64	5.70	Acidic	Digital pH meter
Organic carbon (%)	0.66	0.87	Medium	Walkey and Blacks method (Jackson, 1973)
Available N (Kg/ha)	265.47	268.23	Low	Alkaline permanganate method (Subbia and Asija, 1956)
Available P_2O_5 (Kg/ha)	21.56	22.54	Low	Bray's I method, (Jackson, 1973)
Available K_2O (Kg/ha)	97.53	98.25	Low	Flame photometric method, (Jackson, 1973)

Table 3.2 Composition of farmyard manure

Organic sources	Total Nitrogen (%)	Total Phosphorous (%)	Total Potash (%)
Farm yard manure	0.75	0.2	0.5

Urea was applied in two equal splits. First split of urea was applied during final land preparation and second split was top dressed at full vegetative growth stage of *Eclipta prostrata* L. However, in the control treatment no fertilizer and farmyard manures were applied. The seedlings of *Eclipta prostrata* were transferred at three different spacing as per treatments *viz.* 20 x 20 cm, 25 x 25 cm and 30 x 30 cm with proper treatment combinations of fertilizers. Thirty days old seedlings were transferred on 6th June in both the years. Harvesting was done by uprooting the whole plants.

3.6.1.2 Details of treatment combinations

There are total 18 numbers of treatment combinations in this first experiment of spacing and sources of nutrients with varying rates. The details of the treatment combinations with their symbols are given in the table 3. 3.

3.6.1.3 Amount of urea, SSP, MOP and farmyard manure per plot

The required amount of urea, single super phosphate, murate of potash and farmyard manure were calculated and weighed in electronic balance according to the treatments for each and every plot. The required amount of these fertilizers and manures per plot are presented in the table 3.4.

3.6.2 Experiment 2. Standardization of the time of transplanting and harvesting stage of *Eclipta prostrata* L.

There were four different transplanting times and three different harvesting stage with total of 12 treatment combinations in this second experiment. The details of technical programme of the experiment are given below:

Experimental Design	: Split plot Design
Main plot	: Time of transplanting, 4 transplanting time *viz.* ST_1- 15th April, ST_2-15th May, ST_3- 15th June and ST_4- 15th July
Sub plot	: Harvesting stage – 3 harvesting stage *viz.* H_1- Vegetative stage, H_2-50 % flowering stage and H_3- Maturity stage
Fertilizer dose	: 60:40:20 kg/ha N: P: K respectively
Spacing	: 25 cm x 25 cm
Number of total treatment combinations	: 12

Number of replications	: 3
Number of total plots	: 36
Plot size	: 2 m x 2 m
Net plot size	: 1. 8 m x 1. 8 m
Gap between plots	: 50 cm
Gap between replication	: 1m
Total length and breath	: 24 m and 10.5 m respectively
Total area	: 252 m^2

3.6.2.1 Technique for imposing treatments

In this experiment, transplanting time of *Eclipta prostrata* L. was considered as first factor and laid out in main plot and harvesting stage was considered as second factor and was kept in sub plot. After final land preparation lay out of the experiment were done (Fig. 3.3). The required amount of fertilizers per plot (urea 39.13 g, single super phosphate 75.00 g and murate of potash 10.00 g) was weighed for each and every treatment. The whole amount of fertilizers *viz*. urea, single super phosphate and murate of potash were applied as basal at the time of final land preparation one day before transplanting of seedlings and mixed well in soil. The seedlings were transferred at the spacing 25 cm x 25 cm. The seedlings were transferred at four different dates as per treatment and harvesting of the plant was done by uprooting plants at three particular growth stages according to treatments.

3.6.2.2 Details of treatment combinations

There are total 12 numbers of treatment combinations in this experiment. The details of the treatment combinations with their symbols are presented in the table 3.5.

3.7 Description of the selected crop Bhringaraj (*Eclipta prostrata* L.)

Bhringaraj, botanically *Eclipta prostrata* L. is a very important medicinal plant under Asteraceae family. This is annual water loving medicinal herb about 90 – 95 days duration with average dry herb yield of 4.5 t/ha. naturally grow in swampy areas. Botanically the stems and branches are strigose and hairy, leaves are 2.5 - 7.5 cm long, opposite, sessile, oblong-lanceolate; strigose and hairy, flowers are white in heads, involucral bracts, axillary, ray flowers ligulate; disk ones tubular, heads are about 6-8 mm in diameter contains 90-120 numbers of seeds. The plants are erect or to some extent spreading in nature, about 2 feet in height.

The whole plant is used for medicinal purpose. The plant contains a medicinally important alkaloid ecliptine. Other chemicals identified are wedelolactone, wedelic acid, apigenin, luteolin, β-amyrin, resin, *etc.* The roots are very rich in thiophene acetylenes. The plant is a goodsource ofthiophene derivatives.

Table 3.3 Treatment combinations with symbols of spacing and sources of nutrient with varying doses experiment

Sl. No.	Treatment combinations	Expression of treatment combinations	Symbol
01	S_1F_0	(20 cm x 20 cm) ($N_0P_0K_0$)	T_1
02	S_1F_1	(20 cm x 20 cm) ($N_{30}P_{20}K_{10}$)	T_2
03	S_1F_2	(20 cm x 20 cm) ($N_{60}P_{40}K_{20}$)	T_3
04	S_1F_3	(20 cm x 20 cm) ($N_{90}P_{60}K_{30}$)	T_4
05	S_1F_4	(20 cm x 20 cm) (10 t FYM/ha)	T_5
06	S_1F_5	(20 cm x 20cm) ($N_{60}P_{40}K_{20}$+ 5 t FYM/ha)	T_6
07	S_2F_0	(25 cm x 25 cm) ($N_0P_0K_0$)	T_7
08	S_2F_1	(25 cm x 25 cm) ($N_{30}P_{20}K_{10}$)	T_8
09	S_2F_2	(25 cm x 25 cm) ($N_{60}P_{40}K_{20}$)	T_9
10	S_2F_3	(25 cm x 25 cm) ($N_{90}P_{50}K_{30}$)	T_{10}
11	S_2F_4	(25 cm x 25 cm) (10 t FYM/ha)	T_{11}
12	S_2F_5	(25 cm x 25 cm) ($N_{60}P_{40}K_{20}$+ 5 t FYM/ha)	T_{12}
13	S_3F_0	(30 cm x 30 cm)($N_0P_0K_0$)	T_{13}
14	S_3F_1	(30 cm x 30 cm) ($N_{30}P_{20}K_{10}$)	T_{14}
15	S_3F_2	(30 cm x 30 cm) ($N_{60}P_{40}K_{20}$)	T_{15}
16	S_3F_3	(30 cm x 30 cm) ($N_{90}P_{60}K_{30}$)	T_{16}
17	S_3F_4	(30 cm x 30 cm) (10 t FYM/ha)	T_{17}
18	S_3F_5	(30 cm x 30 cm) ($N_{60}P_{40}K_{20}$+ 5 t FYM/ha)	T_{18}

Table 3.4 Required amount of urea, single super phosphate, murate of potash and farmyard manure per plot

Doses	Urea(g)	SSP (g)	MOP(g)	Farmyard manure (Kg)
0:0:0 kg/ha N:P:K	0	0	0	0
30:20:10 kg/ha N:P:K	19.50	37.50	5.00	0
60:40:20 kg/ha N:P:K	39.13	75.00	10.00	0
90:60:30 kg/ha N:P:K	58.69	112.50	15.00	0
10 t FYM/ha	0	0	0	3.00
60:40:20 kg/ha N: P: K + 5 t FYM/ha	39.13	75.00	10.00	1.50

Table 3.5 Treatment combinations with symbols of transplanting time and harvesting stage experiment

Sl. No.	Treatment combination	Expression of treatment combinations	Symbol
01	ST_1H_1	(15th April transplanting) (Harvesting at vegetative stage)	T_1
02	ST_1H_2	(15th April transplanting)(Harvesting at 50% flowering stage)	T_2
03	ST_1H_3	(15th April transplanting) (Harvesting at maturity stage)	T_3
04	ST_2H_1	(15th May transplanting) (Harvesting at vegetative stage)	T_4
05	ST_2H_2	(15th May transplanting) (Harvesting at 50% flowering stage)	T_5
06	ST_2H_3	(15th May transplanting) (Harvesting at maturity stage)	T_6
07	ST_3H_1	(15th June transplanting) (Harvesting at vegetative stage)	T_7
08	ST_3H_2	(15th June transplanting) (Harvesting at 50% flowering stage)	T_8
09	ST_3H_3	(15th June transplanting) (Harvesting at maturity stage)	T_9
10	ST_4H_1	(15th July transplanting) (Harvesting at vegetative stage)	T_{10}
11	ST_4H_2	(15th July transplanting) (Harvesting at 50 % flowering stage)	T_{11}
12	ST_4H_3	(15th July transplanting) (Harvesting at maturity stage)	T_{12}

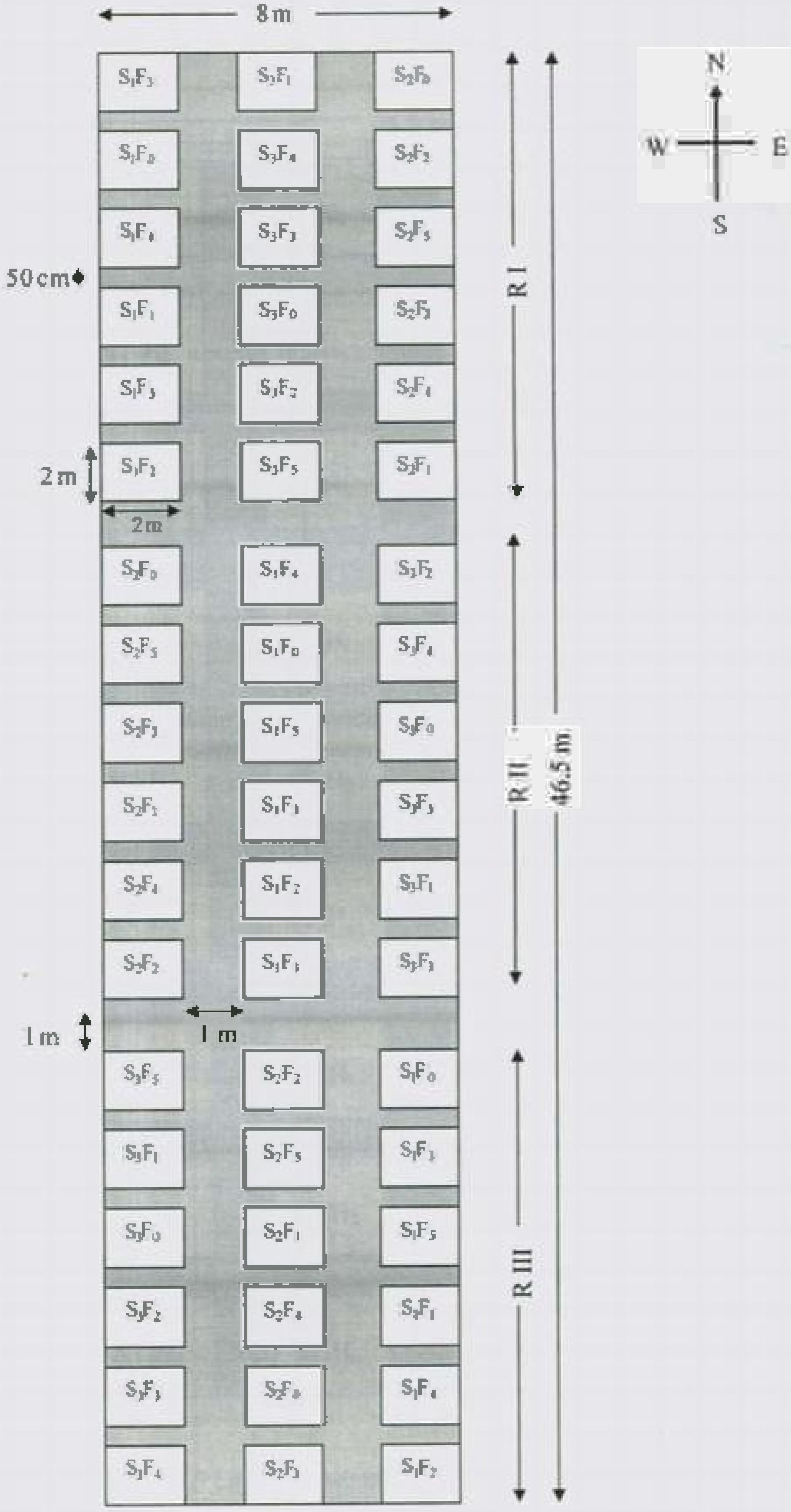

Figure 3.2 Layout of first experiment

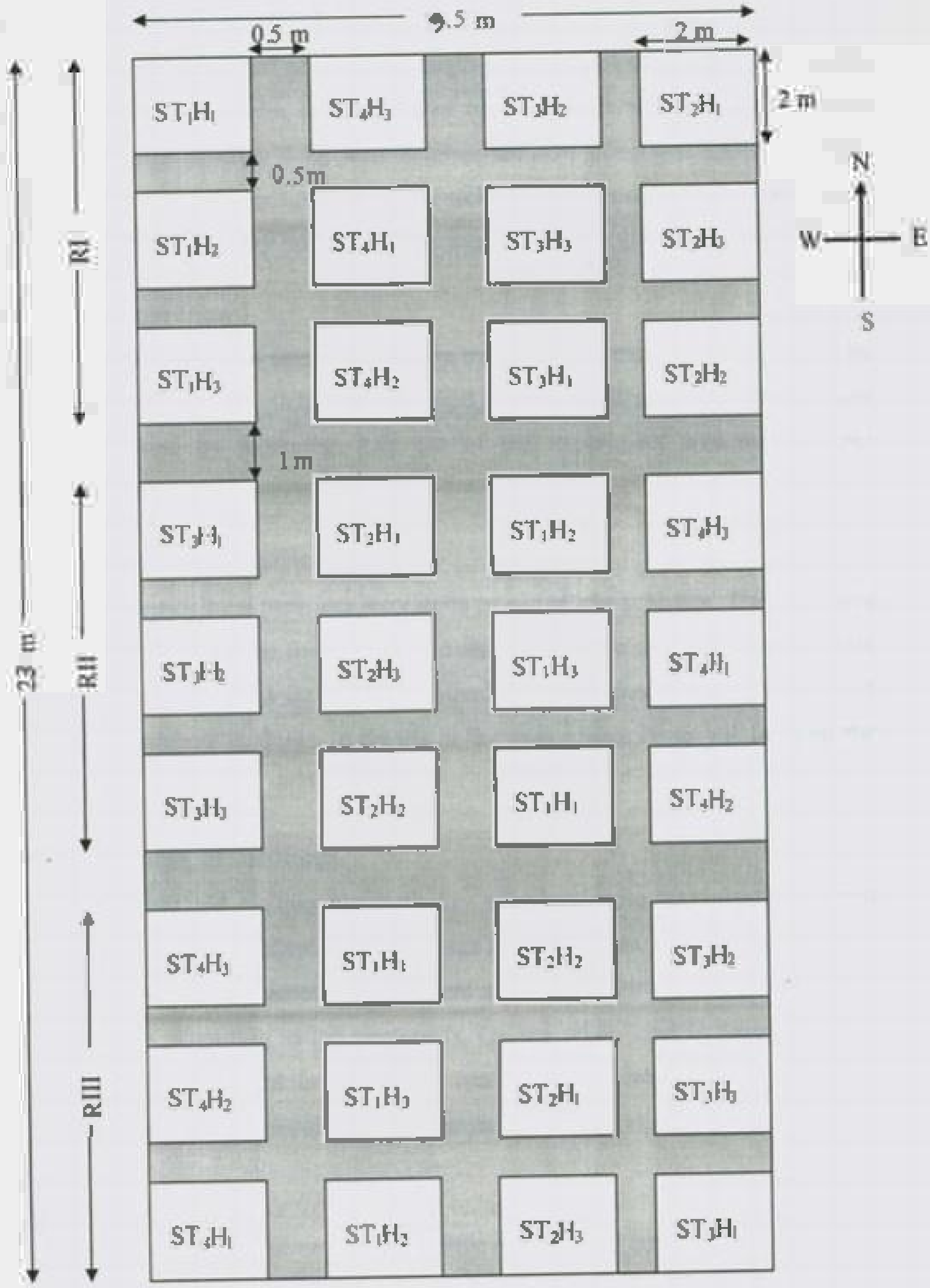

Figure 3.3 Layout of second experiment

3.8 Agronomic practices

3.8.1 Nursery for raising seedlings

The raise nursery bed of size 2 m length and 1.25 m breath and 25 cm height was prepared in the nursery, Department of forestry, NERIST, Nirjuli, Arunachal Pradesh. After first spading 5 kg well decomposed cow dung was applied on bed. Fully matured collected seeds were sown in well-prepared nursery before one month of transplanting. The nursery bed was kept in moist condition and kept it weed free.

3.8.2 Land preparation

The main field was first ploughed by tractor drawn disc plough followed by harrowing. Then the same field was ploughed by bullock drawn deshi plough and leveling was done by laddering. Lay out of the experiment was done as per treatments.

3.8.3 Other agronomic practices

All the agricultural practices were done as per proper schedule. The schedules of operation of works of the first experiment are presented in details in the appendix III for the year 2005-06 and 2006-07 respectively and the schedules of operations of the second experiment is shown in details in the appendixes IV to VII for both the years.

3.9 Transplanting of seedlings

One month old *Eclipta prostrata* L. seedlings were transplanted in well prepared plots. After transplanting of seedlings light irrigation was done. In the first trial seedlings were transplanted at 3 different spacing *viz*. 20 x 20 cm, 25 x 25 cm and 30 x 30 cm according to the treatments. On the other hand in second trial all seedlings were transplanted in a uniform spacing of 25 cm x 25 cm, whereas, transplanting date varied according to the treatments.

3.10 Gap filling

After transplanting some seedlings were damaged by cutworm and few could not survive. Gap filling was carried out with new seedlings within a week of transplanting.

3.11 Water management

Generally *Eclipta prostrata* L. is grown as rainfed crop, however, light irrigation was given just after transplanting of seedlings. Subsequent irrigation was done at 3 days interval up to establishment of seedlings.

3.12 Weed management

Both the nursery and main field was kept weed free. Two manual weeding was done in nursery at 10 days and in main field at 20 - 24 days interval.

3.13 Plant protection measures

No serious pests and diseases were observed during the cultivation of *Eclipta prostrata* L. However, just after transplanting few seedlings were cut down by cutworm. Malathion dust was applied surrounding the seedlings as a control measure. The crop was slightly affected by fungal disease after flowering stage during the first year of cultivation. Bavistin was applied to overcome this problem.

3.14 Observation recorded on crop

The observations on the following parameters were taken at three different growth stages *viz.* vegetative stage, 50% flowering stage and maturity stage by appropriate methods.

3.14.1 Plant height

The observation of plant height was measured in centimeter (cm) from the base of the plant to the tip of the plant. From each plot, plant height was recorded from randomly selected ten plants and average of these ten plants was considered as plant height of the particular treatment.

3.14.2 Number of primary branch

The average number of branches produced from the main plant of 10 randomly selected plants from each plot were counted and the average value was considered as number of primary branch.

3.14.3 Number of secondary branch

The average number of laterals/branches, come out from the primary branches of 10 randomly selected plants from each plot were counted and the average was considered as number of secondary branch.

3.14.4 Number of leaves

The number of leaves of 10 selected plants of each plot was recorded. The average value was worked out and expressed as number of leaves per plant.

3.14.5 Dry matter production (%)

The plant samples were collected fom each and every plot. The samples were cleaned by removing soil attached to root, kept for some time to evaporate the adhering water, if any, and weighed and recorded as fresh weight. The fresh samples were air dried for 3-4 days, then dried in oven at 70°C till a constant weight was obtained and expressed as dry weight. Per cent of dry matter production was obtained by the following formula

$$\text{Per cent of dry matter production} = \frac{\text{Dry weight of the sample (g)}}{\text{Fresh weight (g)}} \times 100$$

3.14.6 Leafarea index

Twenty five number of leaves were taken from each and every randomly selected 10 plants from each plot and leaf area was measured (cm^2) with digital leaf area meter (Systronics). The average value was calculated and expressed as leaf area of individual leaf. The total leaf area of plant was calculated by multiplication of individual leafarea and total number of leaves. The ground area covered by the same selected plant was measured with a scale, and the average value was considered as ground area covered (cm^2). The leafarea index was obtained by the following formula

$$\text{Leafarea index} = \frac{\text{Total leafarea}}{\text{Ground cover}}$$

3.14.7 Number of primary root

Ten randomly selected plants were uprooted from each plot and washed carefully without damaging root and number of roots was calculated. The average value was considered as number of roots.

3.14.8 Root length

The length of root of uprooted plants was measured with a scale, and the average value of 10 randomly selected roots of each and every uprooted plant was considered as root length (cm).

3.14.9 Stem and secondary branch diameter

The diameter of the main stem and secondary branches arises from primary stem was measured in three position with the help of verniear scale and the average of these three positions were considered. Thus the average value of all the stems and secondary branches of 10 randomly selected plants of each plots were expressed as stem diameter and secondary branch diameter and expressed in mm.

3.14.10 Number of flower

The total number of flowers at full blooming stage of 10 randomly selected plants from each plot were counted and the average value was considered as number of flower per plant.

3.14.11 Number of head

The total number of heads at maturity stage of 10 randomly selected plants fom each plot were counted and the average value was calculated and considered as number of head per plant.

3.14.12 Harvesting

Harvesting was done by uprooting the plants by judging visual maturity of plant (blackening of leaves and head) for the first experiment. For the second experiment harvesting was done as per treatments *i.e.* at vegetative, at 50 % flowering stage and at maturity stage. At first, boarder plants from pre-demarcated area for yield assessment were removed. Afterwards, net plots were harvested and properly tagged.

3.14.13 Total biological yield

The net plot was harvested after removing the boarder plants. The net plot produce was used to record the total biological yield after removing the soil attached to root and cleaning. There after the plant is kept in open for some time to evaporate the adhering water, weighed and recorded as herb yield per plot. The yield per plot was converted in terms of quintals per hectare. Multiplication of fresh weight with dry matter production gave dry herb yield of the crop.

3.15 Determination of total nitrogen uptake

Samples of whole plants were collected after harvesting, dried, ground and analyzed separately for nitrogen content by using rapid titration method and semi-micro Kjeldhal apparatus, (Anderson and Ingram, 1993). The total uptake of nitrogen was estimated by multiplying the nitrogen content of plant and dry herb yield and expressed in kilogram per hectare.

3.16 Determination of total phosphorus uptake

After harvesting,sample of whole plants was collected dried, ground and analyzed separately for phosphorus content by subjecting to acid-digestion and were estimated calorimetrically using molybdenum blue method (Anderson and Ingram, 1993). The uptake of phosphorus was estimated by multiplying the phosphorus content of plant and dry herb yield and expressed in kilogram per hectare.

3.17 Determination of total potassium uptake

Samples of whole plants were collected after harvesting, dried, ground and analyzed separately for potassium content after acid-digestion and K contents were estimated using flame-photometer (Anderson and Ingram, 1993). The uptake of potassium was estimated by multiplying the potassium content of plant and dry herb yield and expressed in kilogram per hectare.

3.18 Determination of plant organic carbon

The ash content was determined by igniting 1 g ground sample at 550°C for 6 hour in a muffle furnace and a total of 50% of the ash-free mass was calculated as the organic carbon content (Allen *et al.*, 1974) and expressed as percentage.

3.19 Detefmination of total alkaloids

The plant samples of *Eclipta prostrata* L. were shade dried properly as per treatment ground and extracted in organic solvent methanol using soxhlet extraction apparatus for 20 hours till the colourless extract came out. The solvent was recovered from the extraction by rotary evaporimeter distillation unit. This methanol extraction was made acidified by adding 5% citric acid and stirred in electrically heated stirrer for about 5 hours. The filtrate was made alkaline by adding ammonia solution and then further extracted with chloroform. The organic chloroform part was separated by separating funnel and made alkaline free by extraction with water. The pure chloroform part was dried and added with anhydrous sodium sulphate to remove moisture if any, and the light yellowish dried part was considered as total alkaloids content of the sample (Sawant *et al.*, 2004). This chloroform extract was checked for presence of alkaloids by using Dragendroff reagent.

3.20 Determination of sugar

3.20.1 Determination of reducing sugar

The whole plant samples were uprooted, initially cleaned, air dried and ground in Wiley mill. 5 gm of grounded material was weighed in an electronic balance, 80% alcohol was added with $CaCO_3$ to neutralize any acidity, boiled for one hour in a steam bath, cooled and filtered in to a volumetric flask and further washed with 80% alcohol to adjust the volume at room temperature. 10 ml of the prepared aliquot was purified by using equal volume of 5% $Ba(OH)_2$ and 5% $ZnSO_4$ followed by filtration and further adjusted to 50 ml volume in a volumetric flask at room temperature. The aliquot was used to estimate the reducing sugar following the Shaffer-Somogy micro-method (Anon, 1984).

3.20.2 Determination of total sugar

The total sugar was estimated by hydrolyzing the purified extract with 0.2 ml of concentrated hydrochloric acid and then boiled for half hour, cooled and neutralized the solution with Na_2CO_3 crystals. This aliquot after acidifying with 0.5 N acetic acid was used to estimate the total sugar following the same procedure as that of the reducing sugar.

3.20.3 Determination of non-reducing sugar

Non-reducing sugar was calculated by subtracting the value of reducing sugar from total sugar.

3.21 Soil parameters

3.21.1 Determination of available N, P and K content in soil

The soil samples were collected from 0-30 cm depth of each treatment with soil auger and marked properly. Soil samples were dried under room condition, ground, passed through 2 mm mesh sieve and analyzed for available soil nitrogen, phosphorus and potassium. The available nitrogen content of soil was determined by using modified Kjeldahl method (Subbia and Asija, 1956), available phosphorus was determined by Bray's 1 method, (Jackson, 1973) and available potassium was determined by Flame photometric method, (Jackson, 1973) and expressed in kilogram per hectare.

3.21.2 Determination of organic carbon content in soil

Soil samples collected for determination of available N, P and K in soil were also used for determination of organic carbon content in soil. The organic carbon was estimated by Walkey and Black's method (Jackson, 1973) and expressed as percentage.

3.22 Economic indices

3.22.1 Cost of different treatments

Cost of all treatments were worked out and it was calculated as cost per hectare for each treatment by taking all the operational cost, variable inputs and labour wages in account (Appendix VIII).

3.22.2 Gross return of different treatments

Gross return is the value of the economic yield *i.e.* herb yield of *Eclipta prostrata* L., calculated at prevailing market price. For both the experiments gross return was calculated separately for all the treatments.

3.22.3 Net return of different treatments

Net return was worked out by subtracting the cost of cultivations from gross return.

3.22.4 Benefit - Cost ratio of the treatments

For the both experiments it was calculated by the following formula.

$$\text{Benefit : Cost} = \frac{\text{Net return of the treatment}}{\text{Total cost of the treatment}}$$

3.23 Statistical analysis

The data recorded from both the experiments conducted during 2005-06 and 2006-07 were statistically analyzed under split plot design adopting the procedure of "Analysis of Variance" out lined by Fisher and Yates (1963). Whenever, variance ratio (F) is significant. Critical Difference (C.D.) reported at 5% level, otherwise only S. Ed. is mentioned.

CHAPTER–IV

EXPERIMENTAL FINDINGS

EXPERIMENTAL FINDINGS

Two field experiments were conducted to study the effect of varying spacing, sources and rate of nutrients; date of transplanting and stages of harvesting on growth, yield, quality and economics of *Eclipta prostrata* L in two consecutive years 2005-06 and 2006-07 at NERIST, Nirjuli, Arunachal Pradesh. The results of the investigations of both the trials are presented in this chapter under following heads.

4. 1 Spacing and nutrient management trial

4.1. 1 Growth

Variation on the growth of *Eclipta prostrata* L. due to different treatments of spacing and sources and rate of nutrients were observed in terms of plant height, number of primary and secondary branches, diameter of main stem and branches, number of leaves and leaf area index, number of roots and root length, dry matter production at vegetative, flowering and maturity stages. Results thus obtained were subjected for statistical analysis and conclusions drawn are described here under.

4. 1. 1. 1 Plant height (cm)

The result of plant height (cm) of both the years 2005-06 and 2006-07 are presented in Table 4.1.1. and the gradual increase in plant height is expressed diagrammatically in Fig. 4.1 and Fig. 4.2. Data revealed that both the variables produced significant variation on plant height. However, the plant height gradually increased with increase in plant spacing at all the three stages of growth. The tallest plant height was recorded under 30 x 30 cm spacing at all the stages *i. e.* 19.55 and 20.63 cm at vegetative stage, 42.06 and 42.84 cm at 50 % flowering stage, 47.15 and 48.43 cm at maturity stage, respectively in both the years and remained *at par* with 25 x 25 cm spacing, but proved statistically superior to the treatment 20 x 20 cm spacing.

Sources and rates of nutrient also brought about significant variation on plant height over control. Application of N P K @ $N_{90}P_{60}K_{30}$, 0 t FYM/ha, and $N_{60}P_{40}K_{20}$ + 5 t FYM/ha were proved statistically *at par*, but recorded statistical superiority over other treatments *viz.* $N_{30}P_{20}K_{10}$ and $N_{60}P_{40}K_{20}$. Similarly application of $N_{60}P_{40}K_{20}$ proved statistically superior to the treatment $N_{30}P_{20}K_{10}$ at all the three growth stages in both the years. The tallest plant height was recorded in the treatment $N_{60}P_{40}K_{20}$ + 5 t

Table 4.1.1 Effect of spacing and various sources and rates of nutrients on plant height (cm) at different growth stages

Treatments	Vegetative stage		Flowering stage		Maturity stage	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Spacing						
S_1 - 20 cm x 20 cm	18.35	19.58	38.13	38.79	42.26	43.62
S_2 - 25 cm x 25 cm	19.26	20.32	40.59	41.54	46.53	47.97
S_3 - 30 cm x 30 cm	59.55	20.63	42.06	42.84	47.15	48.43
S. Ed. (±)	0.20	0.21	0.57	0.75	0.56	0.51
C. D. (5%)	0.55	0.59	1.60	2.09	1.57	1.44
Doses of nutrients						
F_0 – $N_0P_0K_0$	14.28	15.19	31.85	32.63	36.88	38.27
F_1 – $N_{30}P_{20}K_{10}$	16.67	17.77	39.76	40.54	44.71	46.04
F_2 – $N_{60}P_{40}K_{20}$	18.08	19.49	41.28	42.06	46.41	47.41
F_3 – $N_{90}P_{60}K_{30}$	21.45	22.47	42.54	43.32	47.64	49.27
F_4 – 10 t FYM/ha	21.65	22.99	43.11	44.11	48.18	49.48
F_5 – $N_{60}P_{40}K_{20}$ + 5 t FYM/ha	22.19	23.17	43.02	43.68	48.06	49.55
S. Ed. (±)	0.67	0.74	0.55	0.57	0.59	0.53
C. D. (5%)	1.37	1.51	1.12	1.17	1.20	1.10
Interaction (S x F)						
S. Ed. (±)	1.16	1.28	0.95	0.99	1.02	0.93
C. D. (5%)	NS	NS	NS	NS	NS	NS

FYM = Farmyard manure, NS = Non significant

FYM/ha as 22.19 and 23.17 cm at vegetative stage, 43.02 and 43.68 cm at 50% flowering stage and 48.06 and 49.55 cm at maturity stage in both the years respectively.

The interaction effect of spacing and fertilizer was found not significant at all stages.

4.1.1.2 Primary branches

The data on number of primary branches/plant (Table 4.1.2) revealed significant increase at successive growth stages. It gradually increased with every increase in plant spacing from 20 x 20 cm to 30 x 30 cm. The highest number of primary branches (6.42 and 7.40 at vegetative stage, 16.58 and 17.59 at 50% flowering stage and 18.62 and 19.68 at maturity stage) in both the years 2005-06 and 2006-07 respectively were recorded due to 30 x 30 cm spacing, which remained statistically similar to 25 x 25 cm spacing. However, both spacing proved statistically superior to 20 x 20 cm.

Nutrient applied treatments produced significant variation irrespective of sources and doses and remained superior to control. Highest number of primary branches (7.18 and 8.08 in both the years respectively) were recorded due to treatment $N_{60}P_{40}K_{20}$ + 5 t FYM/ha which was statistically *at par* with the treatment $N_{90}P_{60}K_{30}$ but proved superior to other treatments. The treatment $N_{60}P_{40}K_{20}$ and 10 t FYM/ha also established its statistical superiority over $N_{30}P_{20}K_{10}$. Production of primary branches at flowering and maturity stage were recorded maximum due to $N_{60}P_{40}K_{20}$ + 5 t FYM/ha during both the years and proved statistically similar to the treatment 10 t FYM/ha and $N_{90}P_{60}K_{30}$ but superior to other treatments. The treatment $N_{60}P_{40}K_{20}$ was superior to the treatment $N_{30}P_{20}K_{10}$ at maturity stage but at flowering stage both remained same.

The interaction effect of both the spacing and nutrient management treatments failed to produce significant variation in both the years.

4.1.1.3 Secondary branches

The data on secondary branches/plant (Table 4.1.3) revealed that at vegetative stage, no significant difference could be observed among the various spacing treatments on bhringaraj cultivation in both the years. At flowering and maturity stages however, 30 x 30 cm spacing treatment produced highest number of secondary

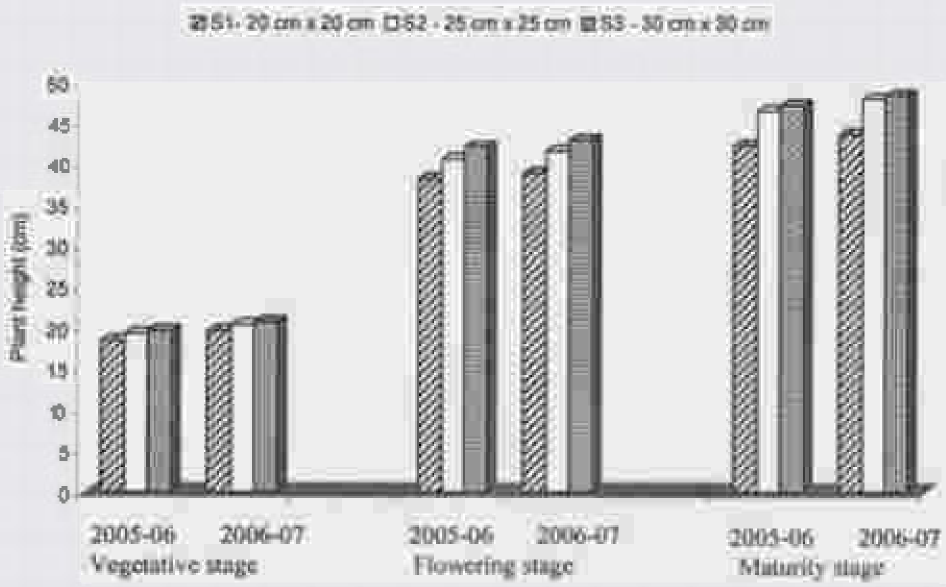

Fig. 4.1 Effect of spacing on plant height at different growth stages

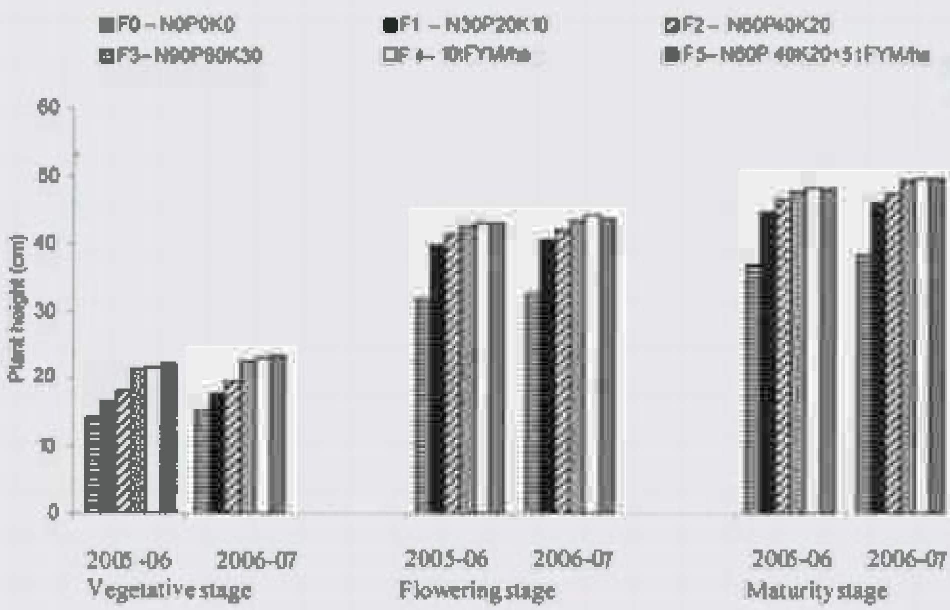

Fig. 4.2 Effect of sources and rates of nutrient on plant height at different growth stages

Table 4.1.2 Effect of spacing and various sources and rates of nutrients on number of primary branches per plant at different growth stages

Treatments	Vegetative stage		Flowering stage		Maturity stage	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Spacing						
S_1 - 20 cm x 20 cm	5.75	6.66	13.66	14.71	15.69	16.69
S_2 - 25 cm x 25 cm	6.31	7.36	15.77	16.73	17.98	18.98
S_3 - 30 cm x 30 cm	6.42	7.40	16.58	17.59	18.62	19.68
S. Ed. (±)	0.09	0.13	0.56	0.53	0.62	0.61
C. D. (5%)	0.25	0.38	1.55	1.48	1.71	1.71
Doses of nutrients						
$F_0 - N_0P_0K_0$	4.21	5.24	10.07	11.13	12.15	13.17
$F_1 - N_{30}P_{20}K_{10}$	5.41	6.31	14.48	15.46	16.10	17.11
$F_2 - N_{60}P_{40}K_{20}$	6.18	7.14	14.53	15.55	17.30	18.32
$F_3 - N_{90}P_{60}K_{30}$	7.46	8.49	17.07	17.96	19.75	20.85
F_4 - 10 t FYM/ha	6.51	7.59	17.75	18.76	19.13	20.11
$F_5 - N_{60}P_{40}K_{20}$ + 5 t FYM/ha	7.18	8.08	18.12	19.20	20.16	21.13
S. Ed. (±)	0.17	0.22	0.56	0.55	0.56	0.56
C. D. (5%)	0.36	0.45	1.15	1.14	1.15	1.15
Interaction (S x F)						
S. Ed. (±)	0.25	0.38	1.19	0.96	1.16	1.15
C. D. (5%)	NS	NS	NS	NS	NS	NS

FYM = Farmyard manure, NS = Non significant

branches closely followed by 25 x 25 cm, but both proved statistically superior to the treatment 20 x 20 cm spacing irrespective of years.

All the nutrient management treatment recorded significant superiority over control. At vegetative stage the treatments $N_{60}P_{40}K_{20}$ + 5 t FYM/ha and 10 t FYM/ha though produced statistically similar number of secondary branches but proved superior to the treatments $N_{90}P_{60}K_{30}$, $N_{60}P_{40}K_{20}$ and $N_{30}P_{20}K_{10}$. However, at flowering and maturity stages the treatments $N_{60}P_{40}K_{20}$ + 5 t FYM/ha, 10 t FYM/ha and $N_{90}P_{60}K_{30}$ proved statistically similar on production of secondary branches but superior to the other treatments.

The interaction between spacing and nutrient management treatments failed to bring any significant effect on secondary branches/plant in both the years.

4.1. 1. 4 Stem and branch diameter(mm)

The data (Table 4.1.4 and Table 4.1.5) on stem and branch diameter (mm) revealed significant improvement only on flowering and maturity stage, whereas at vegetative stage all the spacing treatments were found statistically *at par*. At flowering and maturity stages, spacing 30 x 30 cm and 25 x 25 cm though remained *on par* but proved superior to the treatment 20 x 20 cm spacing for both attributes. The maximum stem diameter (5.24 and 5.27 mm at 50 % flowering stage, 5.29 and 5.30 mm at maturity stage) and branch diameter (3.08 and 3.12 mm at 50 % flowering stage, 3.15 and 3.17 mm at maturity stage) were recorded respectively in both the years 2005-06 and 2006-07 under 30 x 30 cm spacing followed by the treatment 25 x 25 cm (stem diameter: 4.99 and 5.05 mm at 50% flowering stage, 5.05 and 5.10 mm at maturity stage; branch diameter: 2.89 and 2.93 mm at 50% flowering stage, 2.99 and 3.01 mm at maturity stage respectively in both the years). The lowest value of stem and branch diameter was recorded in the spacing 20 x 20 cm.

The data on nutrient management (Table 4.1.4. and Table 4.1.5) revealed their significant superiority over control at all the growth stages on stem and branch diameter (mm). Among the nutrient incorporation, $N_{90}P_{60}K_{30}$, 10 t FYM/ha and $N_{60}P_{40}K_{20}$ + 5 t FYM/ha remained statistically *at par* but proved superior to the treatments $N_{30}P_{20}K_{10}$ and $N_{60}P_{40}K_{20}$ at vegetative stage. However, at flowering and maturity stages nutrient application@ $N_{90}P_{60}K_{30}$, 10 t FYM/ ha and $N_{60}P_{40}K_{20}$ + 5 t FYM/ ha and $N_{60}P_{40}K_{20}$ treatments were found statistically similar but superior to the

Table 4.1.3 Effect of spacing and various sources and rates of nutrients on number of secondary branches/ plant at different growth stages

Treatments	Vegetative stage		Flowering stage		Maturity stage	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Spacing						
S_1 - 20 cm x 20 cm	3.62	4.08	18.19	19.22	21.54	22.60
S_2 - 25 cm x 25 cm	3.98	4.44	20.93	21.99	24.43	25.77
S_3 - 30 cm x 30 cm	4.17	4.62	22.80	23.86	26.26	27.23
S. Ed. (±)	0.21	0.22	0.89	0.88	0.77	0.81
C. D. (5%)	NS	NS	2.478	2.45	2.15	2.25
Doses of nutrients						
$F_0 - N_0P_0K_0$	2.29	2.73	13.16	14.25	16.65	17.70
$F_1 - N_{30}P_{20}K_{10}$	3.71	4.17	20.00	21.04	23.41	24.51
$F_2 - N_{60}P_{40}K_{20}$	3.86	4.30	21.14	22.19	24.59	25.64
$F_3 - N_{90}P_{60}K_{30}$	3.91	4.37	22.89	23.95	26.43	27.76
F_4 – 10 t FYM/ha	4.81	5.27	22.99	24.02	26.27	27.54
$F_5 - N_{60}P_{40}K_{20}$ + 5 t FYM/ha	4.97	5.46	23.65	24.69	27.11	28.04
S. Ed. (±)	0.20	0.19	0.60	0.60	0.59	0.64
C. D. (5%)	0.41	0.39	1.24	1.22	1.21	1.31
Interaction (S x F)						
S. Ed. (±)	0.35	0.33	1.05	1.03	1.03	1.11
C. D. (5%)	NS	NS	NS	NS	NS	NS

FYM = Farmyard manure, NS = Non significant

treatment $N_{30}P_{20}K_{10}$. The highest stem diameter 3.20 and 3.46 mm at vegetative stage, 5.27 and 5.31 mm at flowering stage and 5.32 and 5.33 mm at maturity stage in both the years respectively were recorded in the treatment F_5– $N_{60}P_{40}K_{20}$ + 5 t FYM/ha.

Branch diameter remained unaffected due to application of nutrient irrespective of rates at vegetative stage. But at flowering and maturity stage, it showed significant effect. Treatment F_5– $N_{60}P_{40}K_{20}$ + 5 t FYM/ha recorded the highest branch diameter (3.20 and 3.23 at 50 % flowering stage; 3.27 and 3.29 at maturity stage in both the years respectively) but remained statistically similar to F_3– $N_{90}P_{60}K_{30}$ (3.08 and 3.12 at 50 % flowering stage; 3.21 and 3.23 at maturity stage) and proved superior to other treatments. Similarly incorporation of 10 t FYM/ha produced branch diameter of 2.92 and 2.95 mm at 50 % flowering and 2.99 and 3.01 mm at maturity stage respectively during both the years as well as $N_{60}P_{40}K_{20}$ with 2.81 and 2.86 mm at 50% flowering stage; 2.91 and 2.93 mm branch diameter at maturity stage were statistically similar but proved superior to F_1 – $N_{30}P_{20}K_{10}$ (2.63, 2.67 and 2.69, 2.70 in both the years and stages respectively) on branch diameter.

The combined effect of spacing and fertilizers in all treatment combinations were found non significant on branch diameter.

4. 1. 1. 5 Number of leaf

The data on number of leaves/plant (Table 4.1. 6 and Fig. 4.3, Fig. 4.4) revealed marked variation in production of leaves. Highest number of leaves were produced due to 30 x 30 cm spacing at all the stages of observation *i.e.* 70.19 and 71.64 at vegetative stage; 255.08 and 257.88 at 50% flowering stage and 257.42 and 247.66 at maturity stage in 2005-06 and 2006-07 respectively, and remained statistically *at par* with 25 x 25 cm spacing. However, both these spacing recorded superior number of leaves to 20 x 20 cm spacing.

Varying rates and form of nutrient application produced significant improvement in production of leaves over control (F_0) at all the growth stages. It was also observed that application of $N_{60}P_{40}K_{20}$ +5 t FYM/ha, $N_{90}P_{60}K_{30}$ and 10 t FYM/ha though remained statistically *at par* but showed their marked superiority over $N_{60}P_{40}K_{20}$ and $N_{30}P_{20}K_{10}$. At vegetative growth stage the later two remained equally effective. Similarly at flowering and maturity stages it was observed that the treatments F_5– $N_{60}P_{40}K_{20}$ + 5 t FYM/ ha, F_3– $N_{90}P_{60}K_{30}$, F_4– 10 t FYM/ ha and F_2–

Table 4.1.4 Effect of spacing and various sources and rates of nutrients on stem diameter (mm) at different growth stages

Treatments	Vegetative stage		Flowering stage		Maturity stage	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Spacing						
S_1 - 20 cm x 20 cm	2.83	2.94	4.49	4.52	4.51	4.57
S_2 - 25 cm x 25 cm	2.94	3.08	4.99	5.05	5.05	5.10
S_3 - 30 cm x 30 cm	2.96	3.16	5.24	5.27	5.29	5.30
S. Ed. (±)	0.05	0.13	0.08	0.07	0.09	0.08
C. D. (5%)	NS	NS	0.22	0.22	0.26	0.23
Doses of nutrients						
$F_0 - N_0P_0K_0$	2.21	2.27	4.12	4.17	4.10	4.20
$F_1 - N_{30}P_{20}K_{10}$	2.84	2.92	4.72	4.74	4.77	4.79
$F_2 - N_{60}P_{40}K_{20}$	2.94	3.00	5.06	5.15	5.13	5.19
$F_3 - N_{90}P_{60}K_{30}$	3.10	3.28	5.08	5.13	5.14	5.17
F_4 - 10 t FYM/ha	3.16	3.44	5.17	5.20	5.23	5.25
$F_5 - N_{60}P_{40}K_{20}$ + 5 t FYM/ha	3.20	3.46	5.27	5.31	5.32	5.33
S. Ed. (±)	0.07	0.10	0.11	0.13	0.14	0.15
C. D. (5%)	0.16	0.20	0.24	0.28	0.29	0.32
Interaction (S x F)						
S. Ed. (±)	0.13	0.17	0.20	0.23	0.24	0.27
C. D. (5%)	NS	NS	NS	NS	NS	NS

FYM = Farmyard manure, NS = Non significant

Table 4.1.5 Effect of spacing and various sources and rates of nutrients on branch diameter (mm) at different growth stages

Treatments	Vegetative stage		Flowering stage		Maturity stage	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Spacing						
S_1 - 20 cm x 20 cm	1.20	1.22	2.52	2.55	2.60	2.62
S_2 - 25 cm x 25 cm	1.19	1.22	2.89	2.93	2.99	3.01
S_3 - 30 cm x 30 cm	1.22	1.26	3.08	3.12	3.15	3.17
S. Ed. (±)	0.06	0.05	0.11	0.11	0.11	0.11
C. D. (5%)	NS	NS	0.31	0.31	0.32	0.30
Doses of nutrients						
$F_0 - N_0P_0K_0$	0.97	1.01	2.33	2.36	2.40	2.42
$F_1 - N_{30}P_{20}K_{10}$	1.21	1.24	2.63	2.67	2.69	2.70
$F_2 - N_{60}P_{40}K_{20}$	1.23	1.26	2.81	2.86	2.91	2.93
$F_3 - N_{90}P_{60}K_{30}$	1.26	1.27	3.08	3.12	3.21	3.23
F_4 – 10 t FYM/ha	1.26	1.30	2.92	2.95	2.99	3.01
$F_5 - N_{60}P_{40}K_{20}$ + 5 t FYM/ha	1.29	1.32	3.20	3.23	3.27	3.29
S. Ed. (±)	0.04	0.05	0.08	0.09	0.10	0.11
C. D. (5%)	0.08	0.10	0.17	0.18	0.21	0.22
Interaction (S x F)						
S. Ed. (±)	0.07	0.08	0.14	0.15	0.18	0.18
C. D. (5%)	NS	NS	NS	NS	NS	NS

FYM = Farmyard manure, NS = Non significant

$N_{60}P_{40}K_{20}$ were statistically *on par* in producing leaves but proved superior to the treatment $F_1 - N_{30}P_{20}K_{10}$

Production of number of leaves/plant remained unaffected due to the interaction effect of spacing and nutrient management irrespective of stages of growth and year of cultivation.

4.1.1. 6 Number of root and root length (cm)

All the experimental variables brought about significant variation on the production of roots/plant as well as their length. Scanning of the data (Table 4.1.7 and Table 4.1.8) revealed that the number of roots/plant and root length (cm) irrespective of spacing at vegetative stage remained *on par*. Notwithstanding, spacing produced marked effect on these attributes at flowering and maturity stages. Spacing of 30 x 30 cm recorded the highest number of root/plant (73.71, 75.36; 77.08, 77.74) as well as longest root (16.24, 16.97 and 18.67, 19.07 cm) at flowering and maturity stages during both the years respectively. Spacing of 30 x 30 cm and 25 x 25 cm, however proved equally effective but established their marked superiority over 20 x 20 cm.

Almost all the nutrient management practices proved much effective in increasing the number of root/plant and root length at all the stages and proved significantly superior to control. Perusal of data on number of roots/plant indicated differential response due to different nutrient treatments. By and large incorporation of F_5– $N_{60}P_{40}K_{20}$ + 5 t FYM/ha as well as F_3–$N_{90}P_{60}K_{30}$ proved equally effective in increasing the production of roots per plant at all the stages. However, at flowering and maturity stages F_4– 10 t FYM/ha also showed marked effect *at par* to above treatments, but all recorded significant superiority over $F_1 - N_{30}P_{20}K_{10}$ and control ($N_0P_0K_0$).

Data on length of root (cm), revealed that among the nutrient applied treatments, the treatment F_5– $N_{60}P_{40}K_{20}$ + 5 t FYM/ha, F_3– $N_{90}P_{60}K_{30}$, F_4– 10 t FYM/ha and $F_2 - N_{60}P_{40}K_{20}$ produced statistically similar root length but recorded superior to $F_1 - N_{30}P_{20}K_{10}$ at vegetative stages. However, at flowering and maturity stages, treatment F_5– $N_{60}P_{40}K_{20}$ + 5 t FYM/ha, F_3– $N_{90}P_{60}K_{30}$ and F_4– 10 t FYM/ha were statistically *at par* but recorded marked superiority over other two treatments *viz.* $F_2 - N_{60}P_{40}K_{20}$ and $F_1 - N_{30}P_{20}K_{10}$ which were also remained *on par*. The longest root was recorded in the treatment F_5– $N_{60}P_{40}K_{20}$ + 5 t FYM/ ha (10.47 and 10.84 cm

Table 4.1.6 Effect of spacing and various sources and rates of nutrients on number of leaves/plant at different growth stages

Treatments	Vegetative stage		Flowering stage		Maturity stage	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Spacing						
S_1 - 20 cm x 20 cm	59.17	61.37	215.21	206.25	211.15	214.31
S_2 - 25 cm x 25 cm	67.08	69.37	239.96	242.70	238.39	237.83
S_3 - 30 cm x 30 cm	70.19	71.64	255.08	257.88	257.42	247.66
S. Ed. (±)	1.43	1.46	7.84	10.10	7.36	4.36
C. D. (5%)	3.96	4.06	21.77	28.05	20.45	12.11
Doses of nutrients						
F_0 – $N_0P_0K_0$	46.68	48.57	156.98	160.06	164.91	153.77
F_1 – $N_{30}P_{20}K_{10}$	60.26	62.14	203.64	206.40	204.58	189.19
F_2 – $N_{60}P_{40}K_{20}$	68.69	70.89	256.64	258.95	253.45	254.10
F_3 – $N_{90}P_{60}K_{30}$	70.00	71.83	262.39	241.79	258.35	259.52
F_4 – 10 t FYM/ha	72.43	75.55	269.03	271.85	264.79	270.15
F_5 – $N_{60}P_{40}K_{20}$ + 5 t FYM/ha	74.81	75.78	271.80	274.61	267.84	272.87
S. Ed. (±)	4.09	4.14	11.11	19.62	11.23	11.64
C. D. (5%)	8.35	8.46	22.69	40.06	22.93	23.76
Interaction (S x F)						
S. Ed. (±)	7.08	7.17	19.24	33.97	19.45	20.15
C. D. (5%)	NS	NS	NS	NS	NS	NS

FYM = Farmyard manure, NS = Non significant

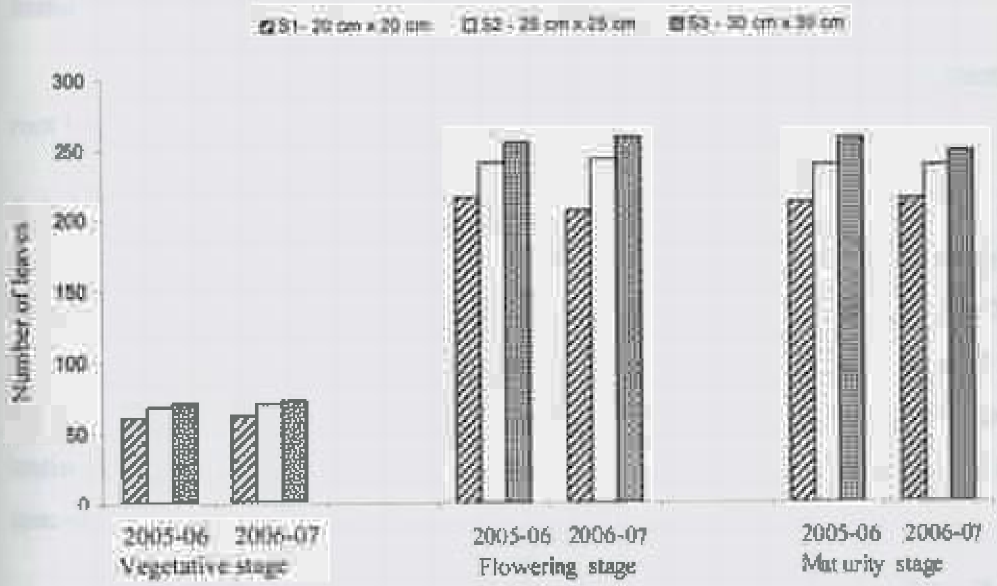

Fig. 4.3 Effect of spacing on number of leaves at different growth stages

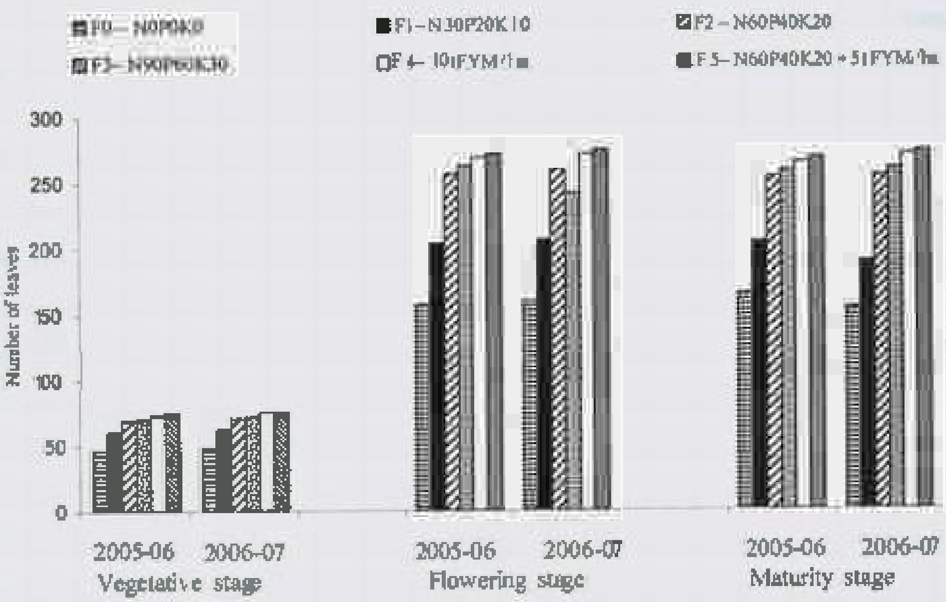

Fig. 4.4 Effect of sources and rates of nutrient on number of leaves at different growth stages

at vegetative stage, 17.18 and 17.80 cm at flowering stage, 20.00 and 20.43 cm at maturity stage in both the years respectively) followed by 10 t FYM/ha.

The interaction effect of spacing and fertilizer on number of roots/plant and root length failed to bring any significant difference in all the combinations.

4. 1. 1. 7 Number of flower

Study of data on number of flowers per plant (Table 4.1.9) revealed effectivity of spacing 25 x 25 cm which produced maximum number of flowers 78.21 and 79.84 in both the years respectively, though it was statistically *at par* with spacing 30 x 30 cm (76.06 and 77.24) at flowering stage. Both these two treatments were proved statistically superior to the closer spacing 20 x 20 cm. At maturity stage all the three spacing were found statistically similar.

Data further revealed significant superiority of all the nutrient treatments over control at all the growth stages. Among the nutrient treatments, F_3– $N_{90}P_{60}K_{30}$, F_4–10 t FYM/ha and F_5– $N_{60}P_{40}K_{20}$ + 5 t FYM/ha though remained similar but proved superior to F_2 – $N_{60}P_{40}K_{20}$ and F_1–$N_{30}P_{20}K_{10}$. At maturity stage, effectivity of all the nutrient treatments were statistically similar in both the years.

The interaction effects of spacing and fertility was found statistically similar on number of flowers in 2005-06 and 2006-07.

4. 1. 1. 8 Number of head

The data on number of head (Table 4.1.9) revealed that at flowering stage no significant difference in all the three spacing trial could be observed. Whereas, at maturity stage the spacing 25 x 25 cm (76.16 and 77.81) and 30 x 30 cm (72.4 and 73.73) remained statistically similar in both the years respectively but proved superior to closer spacing 20 x 20 cm in production of heads.

It was also observed that all the nutrient treatments produced statistically superior number of head in comparison to control. However, no significant difference could be established due to varying nutrient treatments at flowering stage. On contrary at maturity stage, the treatments F_3– $N_{90}P_{60}K_{30}$, F_4– 10 t FYM/ha and F_5– $N_{60}P_{40}K_{20}$ + 5 t FYM/ha though remained statistically *at par* but proved superior to F_2– $N_{60}P_{40}K_{20}$ and F_1–$N_{30}P_{20}K_{10}$.

Table 4.1.7 Effect of spacing and various sources and rates of nutrients on number of roots/plant at different growth stages

Treatments	Vegetative stage		Flowering stage		Maturity stage	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Spacing						
S_1- 20 cm x 20 cm	37.56	38.19	65.23	65.95	69.70	70.36
S_2- 25 cm x 25 cm	41.86	42.25	72.71	73.41	76.75	77.39
S_3- 30 cm x 30 cm	42.19	42.62	73.71	75.36	77.08	77.74
S. Ed. (±)	1.70	1.73	0.83	0.82	1.30	1.30
C. D. (5%)	NS	NS	2.32	2.28	3.61	3.60
Doses of nutrients						
F_0= $N_0P_0K_0$	25.64	26.31	58.73	59.73	62.87	63.49
F_1= $N_{30}P_{20}K_{10}$	33.44	33.39	67.84	68.99	71.89	72.18
F_2= $N_{60}P_{40}K_{20}$	39.44	39.98	69.18	70.16	73.37	74.02
F_3= $N_{90}P_{60}K_{30}$	48.61	49.19	74.13	75.14	78.28	78.91
F_4= 10 t FYM/ha	42.11	42.78	75.31	76.39	78.96	79.60
F_5= $N_{60}P_{40}K_{20}$ + 5 t FYM/ha	53.97	54.49	78.09	79.03	81.70	82.38
S. Ed. (±)	2.81	3.08	2.05	2.20	1.86	2.01
C. D. (5%)	5.74	6.29	4.18	4.49	3.80	4.10
Interaction (S x F)						
S. Ed. (±)	4.87	5.33	3.54	3.80	3.22	3.47
C. D. (5%)	NS	NS	NS	NS	NS	NS

FYM = Farmyard manure, NS = Non significant

Table 4.1.8 Effect of spacing and various sources and rates of nutrients on root length (cm)/plant at different growth stages

Treatments	Vegetative stage		Flowering stage		Maturity stage	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Spacing						
S_1 - 20 cm x 20 cm	9.25	9.61	14.18	14.61	16.61	16.98
S_2 - 25 cm x 25 cm	9.42	9.78	15.33	15.92	17.94	18.43
S_3 - 30 cm x 30 cm	9.91	10.26	16.24	16.97	18.67	19.07
S. Ed. (±)	0.19	0.19	0.37	0.42	0.30	0.29
C. D. (5%)	NS	NS	1.04	1.16	0.85	0.80
Doses of nutrients						
$F_0 - N_0P_0K_0$	7.66	8.03	10.63	11.11	13.07	13.43
$F_1 - N_{30}P_{20}K_{10}$	8.91	9.27	14.77	15.06	17.21	17.59
$F_2 - N_{60}P_{40}K_{20}$	9.84	10.19	15.48	16.00	17.76	18.00
$F_3 - N_{90}P_{60}K_{30}$	10.23	10.61	16.38	17.48	18.95	19.54
F_4 – 10 t FYM/ha	10.05	10.37	17.05	17.55	19.47	19.97
$F_5 - N_{60}P_{40}K_{20}$ + 5 t FYM/ha	10.47	10.84	17.18	17.20	20.00	20.43
S. Ed. (±)	10.39	0.42	0.36	0.65	0.58	0.73
C. D. (5%)	0.79	0.86	0.74	1.33	1.19	1.49
Interaction (S x F)						
S. Ed. (±)	0.67	0.73	0.63	1.13	1.01	1.27
C. D. (5%)	NS	NS	NS	NS	NS	NS

FYM = Farmyard manure, NS = Non significant

All the combination of spacing and nutrient applied treatments remained ineffective in increasing the number of heads per plant in both the years.

4.1.1.9 Dry matter production (%)

Progressive increase in dry matter accumulation was noted from earlier stage to maturity (Fig. 4.5 and Fig. 4.6). The data on dry matter production/plant (Table 4.1.10) showed no significant variation due to various spacing on dry matter production at vegetative stage. The widest spacing 30 x 30 cm produced highest dry matter production (14.28 and 14.54) at flowering stages and (15.06 and 15.18) at maturity stage respectively in both the years, but remained statistically similar to 25 x 25 cm spacing. Both the wider spacing however, produced superior dry matter to the spacing 20 x 20 cm.

All the nutrient applied treatments proved superior to control on dry matter production. Among the nutrient applied treatments, the treatment F_5– $N_{60}P_{40}K_{20}$ + 5 t FYM/ha produced the highest dry matter production (11.28 and 11.62 at vegetative stage; 15.89 and 16.06 at flowering stage; 16.70 and 16.74 at maturity stage in both the years 2005-06 and 2006-07 respectively) but were recorded statistically similar to the treatment F_3– $N_{90}P_{60}K_{30}$ though they proved superior to F_4– 10 t FYM/ha, F_2 – $N_{60}P_{40}K_{20}$ and F_1 – $N_{30}P_{20}K_{10}$. The later two (F_2 and F1) treatments also remained statistically *at par* in dry matter production.

The dry matter production in all the treatment combinations of spacing and fertilizers were found statistically similar at all the growth stages during both the years 2005-06 and 2006-07.

4.1.1.10 Leaf area and ground cover (cm^2)

The data on leaf area (Table 4.1.11) revealed that there was no significant difference among the three spacing irrespective of year of cultivation and growth stages on size of leaves. Spacing of 30 x 30 cm resulted into the largest ground cover (cm^2) at all the stages *i.e.* 10.84 and 10.82 cm^2 at vegetative stage; 20.96 and 21.27 cm^2 at flowering stage; 23.40 and 24.16 cm2 at maturity stage in both the years 2005-06 and 2006-07 respectively and remained similar to 25 x 25 cm spacing but proved statistically superior to the closer spacing 20 x 20 cm (Table 4.1.12).

Table 4.1.9 Effect of spacing and various sources and rates of nutrients on number of flowers and heads/plant at different growth stages

Treatments	Number of flowers				Number of heads			
	Flowering stage		Maturity stage		Flowering stage		Maturity stage	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Spacing								
S_1 - 20 cm x 20 cm	71.97	72.93	6.34	17.04	8.24	8.60	65.72	66.81
S_2 - 25 cm x 25 cm	78.21	79.84	6.57	17.35	8.32	8.70	76.16	77.81
S_3 - 30 cm x 30 cm	76.06	77.24	16.76	17.42	9.14	9.69	72.40	73.73
S. Ed. (±)	1.45	1.52	0.22	0.16	0.37	0.36	1.54	1.48
C. D. (5%)	4.01	4.21	NS	NS	NS	NS	4.28	4.10
Doses of nutrients								
$F_0 - N_0P_0K_0$	49.56	50.84	12.34	13.02	6.84	7.19	54.75	55.82
$F_1 - N_{30}P_{20}K_{10}$	63.52	64.23	17.18	17.88	8.83	9.21	65.62	66.71
$F_2 - N_{60}P_{40}K_{20}$	69.56	71.11	17.25	18.05	8.83	9.22	69.33	70.64
$F_3 - N_{90}P_{60}K_{30}$	85.04	86.82	17.52	18.25	8.91	9.27	77.50	78.85
F_4 – 10 t FYM/ha	90.13	91.84	17.27	18.01	8.98	9.40	79.03	80.70
$F_5 - N_{60}P_{40}K_{20}$ + 5 t FYM/ha	92.07	93.58	17.77	18.41	9.53	9.90	82.35	83.99
S. Ed. (±)	3.93	3.85	0.34	0.33	0.43	0.48	3.75	3.99
C. D. (5%)	8.03	7.85	0.70	0.67	0.89	0.98	7.66	8.16
Interaction (S x F)								
S. Ed. (±)	6.81	6.66	0.59	0.57	0.75	0.83	6.50	6.92
C. D. (5%)	NS	NS	NS	NS	NS	NS	NS	NS

FYM = Farmyard manure, NS = Non significant

All the fertilizer management practices significantly increased the leaf area over control at all the stages of growth. Though highest leaf area was found associated with incorporation of F_5- $N_{60}P_{40}K_{20}$ + 5 t FYM/ha producing leaf area of 2.22 and 2.27 cm^2 at vegetative stage; 2.23 and 2.97 cm2 at flowering stage; 2.21 and 2.25 cm2 at maturity during both the years respectively, however, it remained *at par* with the treatments F_3- $N_{90}P_{50}K_{30}$, F_4- 10 t FYM/ha and F_2- $N_{60}P_{40}K_{20}$, but recorded significant superiority over F_1 - $N_{30}P_{20}K_{10}$.

Similar trend was also observed due to nutrient treatment on ground cover, where all nutrient treatments produced marked superiority over control at all the growth stages. At vegetative stages the treatment F_5– $N_{60}P_{40}K_{20}$ + 5 t FYM/ha, F_4– 10 t FYM/ha and F_3– $N_{90}P_{60}K_{30}$ had similar ground cover but were superior to the other two equally effective treatments *i. e.* F_2 – $N_{60}P_{40}K_{20}$ and F_1 – $N_{30}P_{20}K_{10}$. At flowering and maturity stages, the treatments F_5– $N_{60}P_{40}K_{20}$ + 5 t FYM/ha, F_4– 10 t FYM/ha, F_3– $N_{90}P_{60}K_{30}$ and F_2 – $N_{60}P_{40}K_{20}$ resulted similar ground cover but were proved superior to F_1 – $N_{30}P_{20}K_{10}$. The largest ground cover 11.41; 11.30; 22.09; 22.18 and 24.32; 25.33 cm^2 was recorded due to the treatment F_5– $N_{60}P_{40}K_{20}$ + 5 t FYM/ha in both the years and all growth stages respectively.

The interaction effect between spacing and nutrient management treatments was found non significant on leaf area and ground cover.

4.1.1.11 Leaf area index

Perusal of the data on leaf area index (LAI) (Table 4.1.13 and graphically in Fig. 4.7 and Fig. 4.8) revealed that all the spacing treatments remained statistically *at par* at vegetative. However at flowering and maturity stages the wider spacing 30 x 30 cm produced highest LAI (25.76 and 26.09; 22.97 and 22.07 in 2005-06 and 2006-07 at both the stages respectively) though it remained almost *at par* with 25 x 25 cm spacing (25.01 and 25.28; 22.45 and 21.59) but recorded marked superiority to closer spacing 20 x 20 cm.

Nutrient application brought about significant improvement on this attribute over control. Among the nutrient application treatments, F_5– $N_{60}P_{40}K_{20}$ + 5 t FYM/ha recorded the highest LAI at all the stages *i.e.* (14.28 and 14.83) at vegetative stage, (27.41 and 28.03) at flowering stage and (24.31 and 24.22) at maturity stage in both the years of cultivation, and observed to be statistically similar to the treatments F_4– 10 t FYM/ha, F_3– $N_{90}P_{60}K_{30}$ and F_2 – $N_{60}P_{40}K_{20}$. All these fourtreatments proved

Table 4.1.10 Effect of spacing and various sources and rates of nutrients on dry matter production/plant (%) at different growth stages

Treatments	Vegetative stage		Flowering stage		Maturity stage	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Spacing						
S_1 - 20 cm x 20 cm	9.75	9.96	12.99	13.25	13.67	13.34
S_2 - 25 cm x 25 cm	9.94	10.23	14.28	14.54	14.97	15.14
S_3 - 30 cm x 30 cm	10.60	10.89	14.19	14.42	15.06	15.18
S. Ed. (±)	0.64	0.64	0.37	0.37	0.45	0.38
C. D. (5%)	NS	NS	1.04	1.05	1.26	1.07
Doses of nutrients						
F_0 – $N_0P_0K_0$	8.54	8.71	10.89	11.64	11.70	11.71
F_1 – $N_{30}P_{20}K_{10}$	9.39	9.68	13.64	13.85	14.57	14.45
F_2 – $N_{60}P_{40}K_{20}$	10.06	10.37	13.55	13.67	14.27	14.15
F_3 – $N_{90}P_{60}K_{30}$	11.28	11.54	15.29	15.41	15.94	15.87
F_4 – 10 t FYM/ha	10.03	10.25	13.69	13.80	14.22	14.41
F_5 – $N_{60}P_{40}K_{20}$ + 5 t FYM/ha	11.28	11.62	15.89	16.06	16.70	16.74
S. Ed. (±)	0.25	0.26	0.49	0.48	0.43	0.44
C. D. (5%)	0.51	0.53	1.00	0.98	0.89	0.90
Interaction (S x F)						
S. Ed. (±)	0.44	0.46	0.85	0.84	0.76	0.77
C. D. (5%)	NS	NS	NS	NS	NS	NS

FYM = Farmyard manure, NS = Non significant

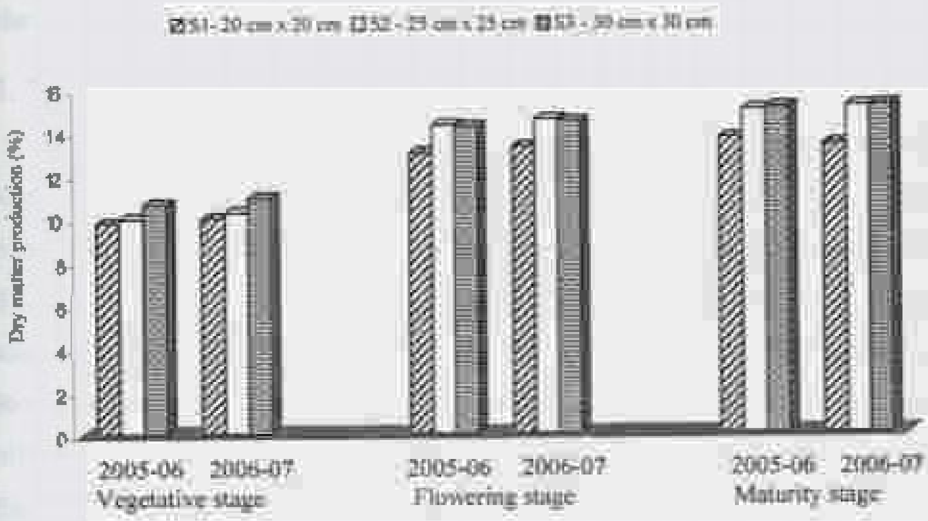

Fig. 4.5 Effect of spacing on dry matter production at different growth stages

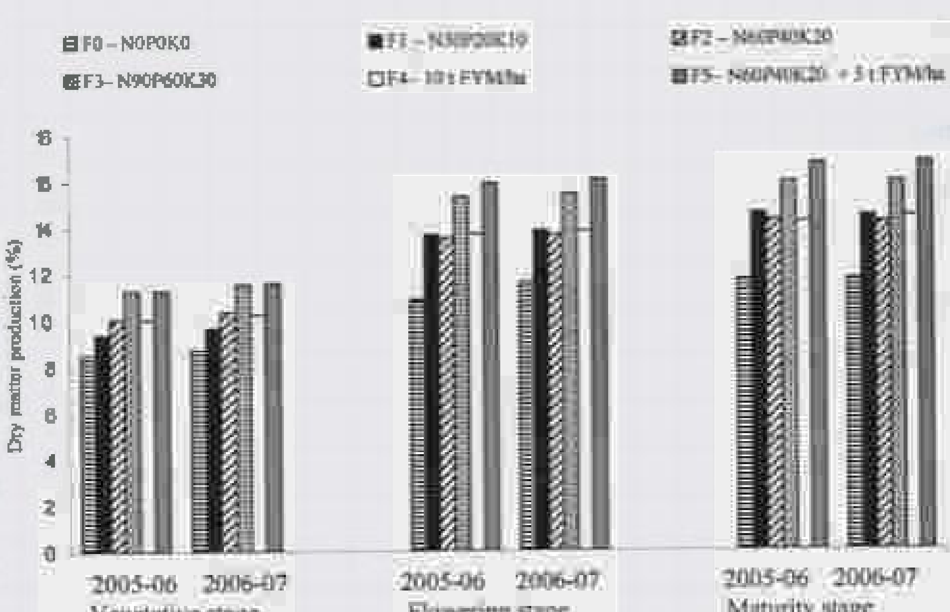

Fig. 4.6 Effect of sources and rates of nutrient on dry matter production at different growth stages

superior to the treatment $F_1 - N_{30}P_{20}K_{10}$ at all the growth stages.

The interaction effect of spacing and fertilizer on leaf area index was found statistically *at par* at all the growth stages irrespective of year of cultivation.

4.1.2 Yield (q/ha)

The data (Table 4.1.14) on fresh and dry herb yield (q/ha) revealed that the spacing of 25 x 25 cm and 30 x 30 cm remained equally effective on yield. The maximum fresh herb yield of 187.60 and 188.57 q/ha and dry herb yield 28.37 and 28.82 q/ha were recorded due to 25 x 25 cm spacing followed by 30 x 30 cm spacing producing 186.22 and 187.27; 28.29 and 28.67 q/ha in both the years 2005-06 and 2006-07 respectively. Notwithstanding these two treatments established their significant superiority over closer spacing 20 x 20 cm. The pattern of yield produced is diagrammatically represented by Fig. 4.9 and Fig. 4.10.

Incorporation of fertilizer with or without organic sources proved much effective in increasing the fresh and dry herb yields during both the years over control. The treatments $F_5 - N_{60}P_{40}K_{20}$ + 5 t FYM/ha, $F_3 - N_{90}P_{60}K_{30}$, F_4 – 10 t FYM/ha and $F_2 - N_{60}P_{40}K_{20}$ though remained equally effective in producing fresh herb yield but recorded their superiority over $F_1 - N_{30}P_{20}K_{10}$. Regarding dry herb yield, it was noted that the treatment $F_5 - N_{60}P_{40}K_{20}$+ 5 t FYM/ha (32.93 and 33.20 q/ha) and $F_3 - N_{90}P_{60}K_{30}$(31.25 and 31.38 q/ha) remained *on par* but proved superior to the treatments F_4– 10 t FYM/ha, $F_2 - N_{60}P_{40}K_{20}$ and $F_1 - N_{30}P_{20}K_{10}$. These later three treatments were statistically *at par*.

The interaction effect of both spacing and nutrient management treatments on fresh and dry herb yield was found to be non significant in both the years of cultivation.

4.1.3 Nutrient content of plant

4.1.3.1 Total nitrogen, phosphorus and potash content of plant(%)

The data on nutrient content in plant (Table 4.1.15) revealed that there was no significant variation in content of nitrogen, phosphorus and potash due to the various spacing treatments. However, highest nitrogen content (1.70 and 1.79%), phosphorus content (0.44 and 0.46%) and potash content (1.57 and 1.61%) were recorded at 25 x 25 cm spacing during 2005-06 and 2006-07 respectively.

Table 4.1.11 Effect of spacing and various sources and rates of nutrients on leaf area (cm^2) at different growth stages

Treatments	Vegetative stage		Flowering stage		Maturity stage	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Spacing						
S_1- 20 cm x 20 cm	2.01	2.04	2.00	2.45	2.01	2.04
S_2 - 25 cm x 25 cm	2.05	2.10	2.12	2.57	2.14	2.14
S_3 - 30 cm x 30 cm	2.04	2.07	2.10	2.83	2.08	2.14
S. Ed. (±)	0.08	0.08	0.08	0.11	0.08	0.08
C. D. (5%)	NS	NS	NS	NS	NS	NS
Doses of nutrients						
$F_0 - N_0P_0K_0$	1.66	1.68	1.69	2.04	1.69	1.73
$F_1 - N_{30}P_{20}K_{10}$	1.93	1.92	1.97	2.43	1.96	2.00
$F_2 - N_{60}P_{40}K_{20}$	2.10	2.14	2.15	2.70	2.14	2.19
F_3- $N_{90}P_{60}K_{30}$	2.13	2.18	2.19	2.72	2.25	2.23
F_4- 10 t FYM/ha	2.18	2.24	2.22	2.85	2.21	2.25
F_5- $N_{60}P_{40}K_{20}$ + 5 t FYM/ha	2.22	2.27	2.23	2.97	2.21	2.25
S. Ed. (±)	0.07	0.08	0.07	0.13	0.07	0.07
C. D. (5%)	0.15	0.17	0.15	0.26	0.15	0.15
Interaction (S x F)						
S. Ed. (±)	0.13	0.15	0.13	0.22	0.13	0.13
C. D. (5%)	NS	NS	NS	NS	NS	NS

FYM = Farmyard manure, NS = Non significant

Table 4.1.12 Effect of spacing and various sources and rates of nutrients on ground cover (cm^2) at different growth stages

Treatments	Vegetative stage		Flowering stage		Maturity stage	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Spacing						
S_1- 20 cm x 20 cm	10.15	10.10	19.06	1.38.90	21.47	21.94
S_2- 25 cm x 25 cm	10.63	10.65	20.41	20.77	22.82	23.73
S_3- 30 cm x 30 cm	10.84	10.82	20.96	21.27	23.40	24.16
S. Ed. (±)	0.16	0.17	0.44	0.53	0.46	0.42
C. D. (5%)	0.44	0.47	1.24	1.48	1.29	1.16
Doses of nutrients						
$F_0 - N_0P_0K_0$	8.73	8.73	15.04	15.18	17.32	18.18
$F_1 - N_{30}P_{20}K_{10}$	10.09	10.15	19.06	19.23	21.53	21.73
$F_2 - N_{60}P_{40}K_{20}$	10.54	10.47	21.29	21.88	23.50	24.54
$F_3 - N_{90}P_{60}K_{30}$	11.01	11.01	21.48	21.38	24.25	24.91
F_4 – 10 t FYM/ha	11.46	11.37	21.82	22.02	24.46	24.98
$F_5 - N_{60}P_{40}K_{20}$ + 5 t FYM/ha	11.41	11.30	22.09	22.18	24.32	25.33
S. Ed. (±)	0.22	0.21	0.18	0.47	0.50	0.52
C. D. (5%)	0.45	0.43	0.98	0.96	1.03	1.06
Interaction (S x F)						
S. Ed. (±)	0.38	0.37	0.83	0.82	0.88	0.90
C. D. (5%)	NS	NS	NS	NS	NS	NS

FYM = Farmyard manure, NS = Non significant

Regarding the effect of different sources of nutrients with varying doses on nutrient content in plant *Eclipta prostrata*, it was observed that all the nutrient treatments proved statistically superior to control. Among the nutrient management treatments F_3– $N_{90}P_{60}K_{30}$, F_4– 10 t FYM/ha and F_5– $N_{60}P_{40}K_{20}$ + 5 t FYM/ha were statistically similar but superior to the treatment F_1 – $N_{30}P_{20}K_{10}$ and F_2 – $N_{60}P_{40}K_{20}$, whereas F_1 and F_2 were also proved similar. The treatment F_5– $N_{60}P_{40}K_{20}$ + 5 t FYM/ha recorded the highest nitrogen (1.97 and 2.05%), phosphorus (0.50 and 0.51%) and potash content (1.70 and 1.74%) in both the years respectively, followed by the treatment F_4– 10 t FYM/ha (nitrogen: 1.90 and 1.97%, phosphorus: 0.49 and 0.50%, potash: 1.67 and 1.70%) whereas the treatment control recorded the lowest nitrogen, phosphorus and potash content.

The interaction effect of spacing and fertilizers was found *at par* on nutrient content in plant of *E. prostrata* L in both the years.

4.1.3.2 Organic carbon content in plant of *E. prostrata* (%)

The data on organic carbon content (Table 4.1.15) revealed that all the spacing treatments remained statistically *at par* on organic carbon content (%) in plant of *E. prostrata* in both the years.

Regarding nutrient management treatments, it was observed that all the nutrient applied treatments were statistically superior to control. Among the nutrient applied treatments, F_5– $N_{60}P_{40}K_{20}$ + 5 t FYM/ha recorded the maximum organic carbon (42.91 and 43.11%) followed by F_4– 10 t FYM/ha (42.37 and 42.77%) in both the years respectively. Both these two treatments remained statistically *at par* but proved superior to the other three nutrient treatments (F_1, F_2 and F_3).

The interaction effect of both spacing and nutrients showed that all combinations failed to bring any significant difference on organic carbon content.

4.1.3.3 Nitrogen, phosphorus and potash uptake (Kg/ha)

Regarding N, P and K uptake (Kg/ha) by the plant (Table 4.1.16), the treatments S_2 -25 x 25 cm and S_3 - 30 x 30 cm found statistically similar but superior to the treatment 20 x 20 cm. The treatment 25 x 25 cm recorded the highest uptake of nitrogen (49.72 and 53.07 kg/ha), phosphorus (12.95 and 13.31 kg/ha) and potash (45.43 and 46.35 kg/ha) in both the years respectively and the lowest was recorded in the treatment 20 x 20cm (41.21 and 43.56, 11.27 and 11.66, 39.64 and 40.67 Kg/ha N,

Table 4.1.13 Effect of spacing and various sources and rates of nutrients on leaf area index (LAI) at different growth stages

Treatments	Vegetative stage		Flowering stage		Maturity stage	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Spacing						
S_1 - 20 cm x 20 cm	11.71	12.47	22.61	22.37	19.70	19.90
S_2 - 25 cm x 25 cm	12.98	13.60	25.01	25.28	22.45	21.59
S_3 - 30 cm x 30 cm	13.21	13.55	25.76	26.09	22.97	22.07
S. Ed. (±)	0.68	0.64	0.85	0.49	0.97	0.51
C. D. (5%)	NS	NS	NS	NS	2.70	1.42
Doses of nutrients						
F_0 – $N_0P_0K_0$	8.91	9.37	17.81	18.45	16.11	14.76
F_1 – $N_{30}P_{20}K_{10}$	11.52	11.68	21.24	21.69	18.79	17.59
F_2 – $N_{60}P_{40}K_{20}$	13.71	14.38	25.96	25.43	23.10	22.70
F_3 – $N_{90}P_{60}K_{30}$	13.58	14.33	26.81	25.88	24.01	23.30
F_4 – 10 t FYM/ha	13.82	14.66	27.55	27.99	23.93	24.54
F_5 – $N_{60}P_{40}K_{20}$ + 5 t FYM/ha	14.28	14.83	27.41	28.03	24.31	24.22
S. Ed. (±)	0.90	0.87	1.45	1.52	1.10	1.35
C. D. (5%)	1.845	1.78	2.96	3.12	2.25	2.77
Interaction (S x F)						
S. Ed. (±)	1.57	1.51	2.52	3.88	1.91	2.35
C. D. (5%)	NS	NS	NS	NS	NS	NS

FYM = Farmyard manure, NS = Non significant

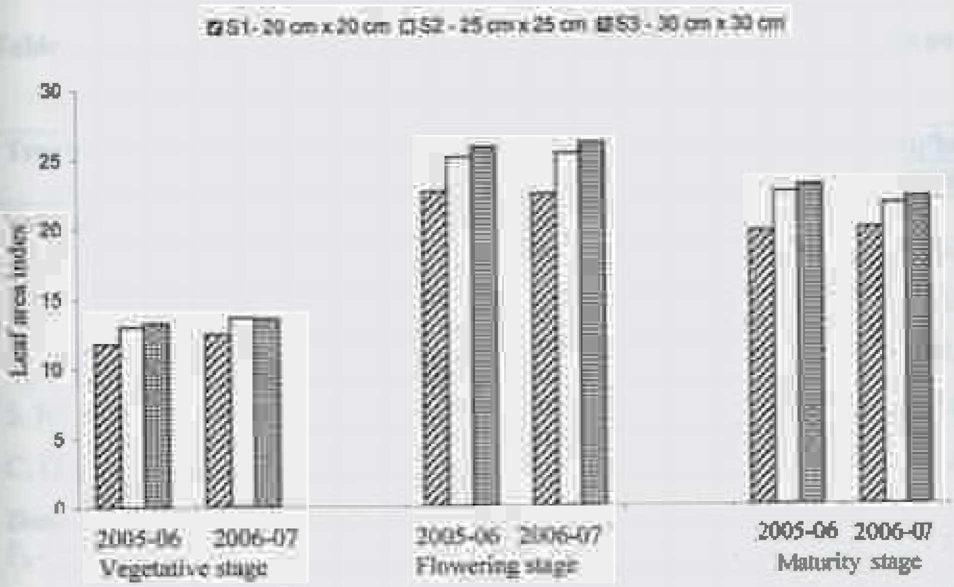

Fig. 4.7 Effect of spacing on leaf area index at different growth stages

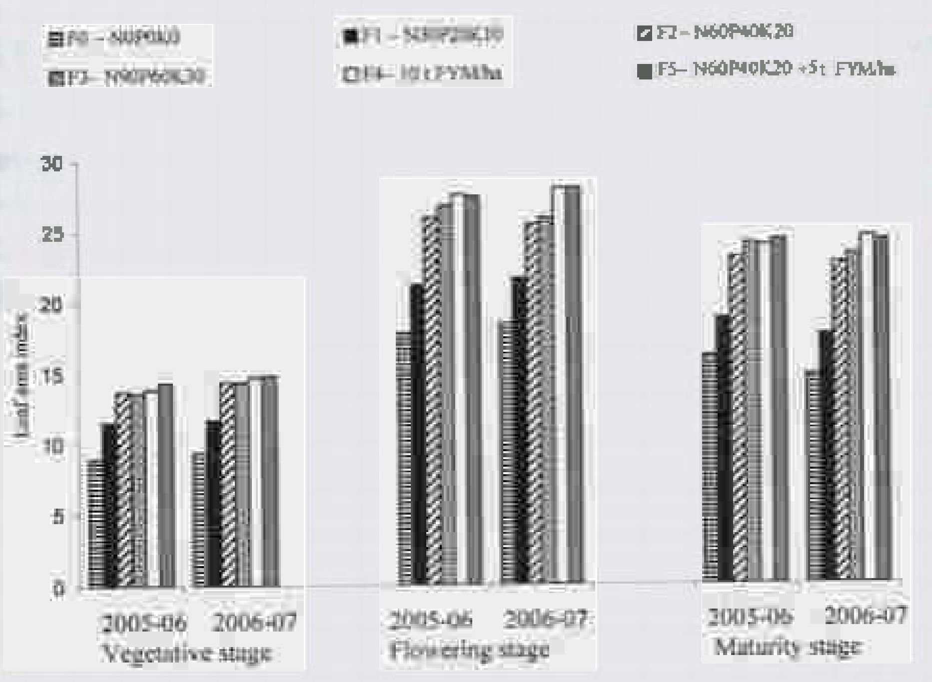

Fig. 4.8 Effect of sources and rates of nutrient on leaf area index at different growth stages

Table 4.1.14 Effect of spacing and various sources and rates of nutrients on fresh and dry yield (q/ha) at maturity stage

Treatments	Fresh yield (q/ha)		Dry yield (q/ha)	
	2005-06	2006-07	2005-06	2006-07
Spacing				
S_1- 20 cm x 20 cm	182.78	183.80	25.14	24.71
S_2-25cmx25cm	187.60	188.57	28.37	28.82
S_3-30cmx30cm	186.22	187.27	28.29	28.67
S. Ed.(±)	1.17	1.18	0.80	0.65
C. D. (5%)	3.25	3.29	2.22	1.82
Doses of nutrients				
F_0– $N_0P_0K_0$	148.08	148.91	17.31	17.44
F_1 – $N_{30}P_{20}K_{10}$	184.14	185.18	26.84	26.77
F_2– $N_{60}P_{40}K_{20}$	193.47	194.47	27.62	27.51
F_3– $N_{90}P_{60}K_{30}$	195.90	197.00	31.25	31.38
F_4–10 t FYM/ha	194.52	195.58	27.65	28.19
F_5– $N_{60}P_{40}K_{20}$ + 5 t FYM/ha	197.08	198.13	32.93	33.20
S. Ed.(±)	1.97	1.94	0.88	0.91
C. D. (5%)	4.02	3.97	1.80	186
Interaction (S x F)				
S. Ed.(±)	3.41	3.38	1.53	1.58
C. D. (5%)	NS	NS	NS	NS

FYM = Farmyard manure, NS – Non significant

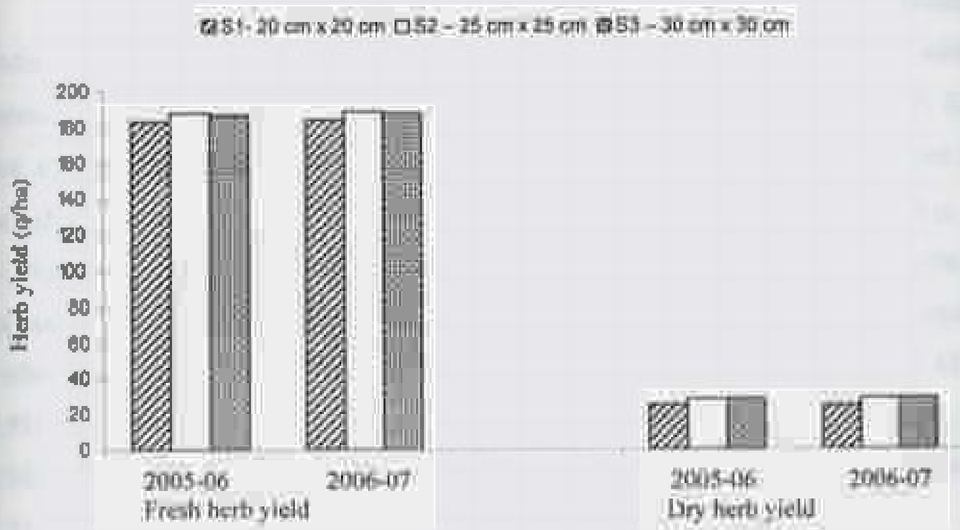

Fig. 4.9 Effect of spacing on herb yield (q/ha)

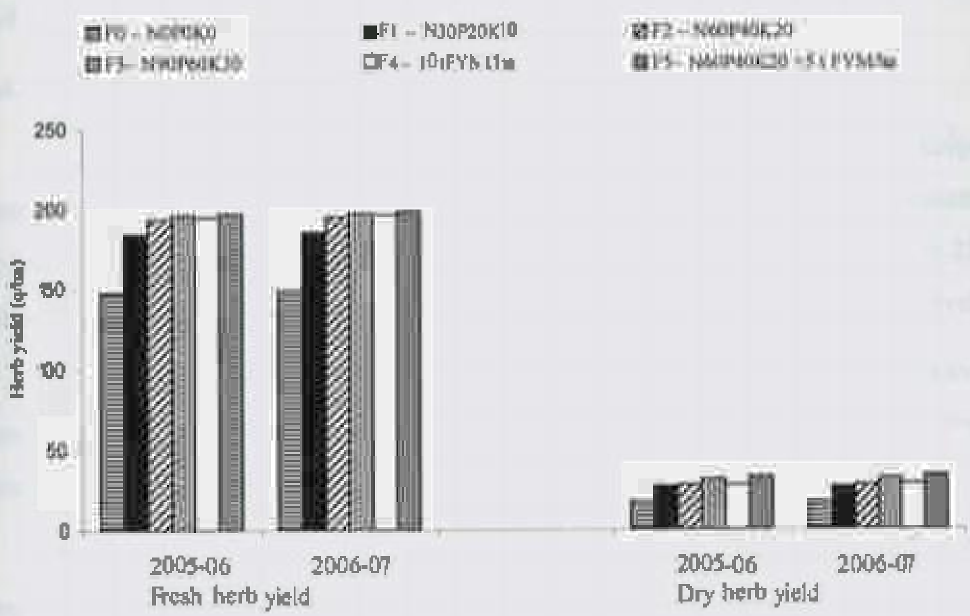

Fig. 4.10 Effect of sources and doses of nutrient on herb yield (q/ha)

P and K respectively) in both the years of 2005-06 and 2006-07.

On the other hand all different nutrient treatments significantly increased the uptake of N, P and K over no nutrient applied treatment. Among the nutrient treatments, F_5– $N_{60}P_{40}K_{20}$ + 5 t FYM/ha brought about highest uptake of N, P, K but were statistically *at par* with F4 – 10 t FYM/ha on N uptake. The treatment F_3 – $N_{90}P_{60}K_{30}$ was also proved superior on N uptake to the treatment F_2 – $N_{60}P_{40}K_{20}$ and F_1 – $N_{30}P_{20}K_{10}$, where F_2 and F_1 recorded *at par*. The treatment F_4– 10 t FYM/ha also resulted into superior uptake of P and K than F_3– $N_{90}P_{60}K_{30}$ but they proved superior to other nutrient treatments. The highest uptake of N (65.28 and 68.46), P (16.45 and 16.91) and K (56.13 and 57.38) was recorded under the treatment F_5– $N_{60}P_{40}K_{20}$ + 5 t FYM/ha followed by F_4 -10 t FYM/ha(59.74 and 61.71, 15.47and 15.84, 52.24 and 53.21 kg/ha N, P and K) in both the years 2005-06 and 2006-07 respectively.

Combination effect of spacing and nutrient management treatments proved that all the treatment combinations failed to bring any significant variation on N, P and K uptake.

4.1.4 Quality parameters

4.1.4.1 Total Alkaloid Content (%)

The data of Table 4.1.17 revealed that the total alkaloid content (%) of *Eclipta prostrata* L failed to show marked variation due to three different spacing treatments. The total alkaloid content was 0.27 and 0.28 % in 20 x 20 cm, 0.28 and 0.28% in 25 x 25 cm and 0.28 and 0.28% in 30 x 30 cm treatment during both the years respectively.

All the nutrient treatments proved statistical superiority on total alkaloid content of the plant over control. However, the effectivity of all the nutrient management treatments proved equal on alkaloid content.

In the interaction effect of spacing and nutrient management treatment it was found that all the combination treatments were *at par* on alkaloid content.

4.1.4.2 Total Alkaloid yield (Kg/ha)

The total alkaloid yield (Table 4.1.17) could not show marked variation due to wider spacing of 30x 30 cm and 25x 25 cm treatments but proved superior to the closest spacing 20 x 20 cm. The treatment 30x 30 cm spacing recorded the maximum

Table 4.1.15 Effect of spacing and various sources and rates of nutrients on nitrogen, phosphorus, potash and organic carbon content (%)

Treatments	Nitrogen content (%)		Phosphorus content (%)		Potash content (%)		Organic carbon content (%)	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Spacing								
S_1 - 20 x 20 cm	1.59	1.71	0.44	0.45	1.55	1.59	39.79	40.09
S_2 - 25 x 25 cm	1.70	1.79	0.44	0.46	1.57	1.61	39.81	40.11
S_3 - 30 x 30 cm	1.65	1.71	0.44	0.45	1.56	1.60	39.81	40.06
S. Ed. (±)	0.03	0.05	0.01	0.01	0.02	0.02	0.31	0.30
C. D. (5%)	NS	NS	NS	NS	NS	NS	NS	NS
Doses of nutrients								
F_0 – $N_0P_0K_0$	1 .26	1.34	0.37	0.38	1.29	1.33	36.05	36.30
F_1 – $N_{30}P_{20}K_{10}$	1.43	1.53	0.40	0.41	1.50	1.54	38.86	39.22
F_2 – $N_{60}P_{40}K_{20}$	1.48	1.63	0.41	0.42	1.56	1.59	39.16	39.44
F_3 – $N_{90}P_{60}K_{30}$	1.84	1.92	0.48	0.49	1.65	1.69	39.47	39.69
F_4 – 10 t FYM/ha	1.90	1.97	0.49	0.50	1.67	1.70	42.37	42.77
F_5 – $N_{60}P_{40}K_{20}$ + 5 t FYM/ha	1.97	2.05	0.50	0.51	1.70	1.74	42.91	43.11
S. Ed. (±)	0.06	0.07	0.01	0.01	0.02	0.03	0.37	0.32
C. D. (5%)	0.13	0.14	0.02	0.02	0.05	0.06	0.76	0.66
Interaction (SxF)								
S. Ed. (±)	0.11	0.12	0.02	0.02	0.05	0.05	0.64	0.56
C. D. (5%)	NS	NS	NS	NS	NS	NS	NS	NS

FYM = Farmyard manure, NS = Non significant

alkaloid yield (8.22 and 8.12 kg/ha in both the years respectively) followed by 25 x 25 cm (8.18 and 8.12 kg/ha). Both these two treatments were *at par* but showed their superiority over 20 x 20 cm (7.01 and 7.18 kg/ha). The pattern of alkaloid yield was graphically represented by Fig. 4.11 and Fig. 4.12.

All the nutrient applied treatments produced statistically superior alkaloid yield over control. Among the nutrient treatments, F_5– $N_{60}P_{40}K_{20}$ + 5 t FYM/ha produced the maximum alkaloid yield (9.79 and 9.77 kg/ha in 2005-06 and 2006-07 respectively) which was recorded statistically similar to the treatment F_4– 10 t FYM/ha but superior to the other nutrient applied treatments *i.e.* F_3– $N_{90}P_{60}K_{30}$, F_2 – $N_{60}P_{40}K_{20}$ and F_1 – $N_{30}P_{20}K_{10}$. The later three treatments also remained statistically similar in both the years.

The interaction effect of both the spacing and fertilizer proved non significant on the yield of total alkaloid and its content.

4.1.4.3 Sugar content (%)

Data on sugar content presented in Table 4.1.18 revealed no significant variation on account of three spacing treatments on total sugar as well as reducing sugar and non-reducing sugar content (%) in plant during both the year of experimentation.

Regarding fertility management practices once again they showed their marked superiority over control treatment (F_0) in increasing total sugar and reducing sugar. However, the content of non reducing sugar remained unaffected by all nutrient treatments including control. Maximum non reducing sugar was found associated with F_4– 10 t FYM/ha treatment (1.39 and 1.38% in both the years respectively) followed by the treatment F_5– $N_{60}P_{40}K_{20}$ + 5 t FYM/ha (1.36 and 1.35%). The treatment 10 t FYM/ha recorded the highest total sugar (6.82 and 6.88% in both the years respectively) and remained statistically *at par* with the treatment $N_{60}P_{40}K_{20}$ + 5 t FYM/ha (6.79 and 6.86%). Both these two treatments were found superior to the other three (F_1 – $N_{30}P_{20}K_{10}$, F_2 – $N_{60}P_{40}K_{20}$ and F_3– $N_{90}P_{60}K_{30}$) treatments which were statistically similar among themselves. All the five nutrient applied treatments were statistically *at par* on reducing sugar content but proved superior to control.

All the treatment combinations statistically proved non significant on total sugar content including reducing and non reducing sugar in both the years.

Table 4.1.16 Effect of spacing and various sources and rates of nutrients on nitrogen, phosphorus and potash uptake (kg/ha)

Treatments	Nitrogen uptake (Kg/ha)		Phosphorus uptake (Kg/ha)		Potash uptake (Kg/ha)	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Spacing						
S_1 - 20 cm x 20 cm	41.21	43.56	11.27	11.66	39.64	40.67
S_2 - 25 cm x 25 cm	49.72	53.07	12.95	13.31	45.43	46.35
S_3 - 30 cm x 30 cm	47.95	50.35	12.74	13.12	44.96	46.13
S. Ed. (±)	2.43	2.45	0.22	0.57	1.24	1.28
C. D. (5%)	6.76	6.81	0.61	1.49	3.45	3.56
Doses of nutrients						
$F_0 - N_0P_0K_0$	21.87	23.51	6.41	6.67	22.37	23.19
$F_1 - N_{30}P_{20}K_{10}$	38.69	41.20	10.75	11.17	40.48	41.58
$F_2 - N_{60}P_{40}K_{20}$	41.17	44.81	11.34	11.82	43.05	44.12
$F_3 - N_{90}P_{60}K_{30}$	50.98	54.26	13.50	13.77	45.79	46.81
F_4 – 10 t FYM/ha	59.74	61.71	15.47	15.84	52.24	53.21
$F_5 - N_{60}P_{40}K_{20}$ + 5 t FYM/ha	65.28	68.46	16.45	16.91	56.13	57.38
S. Ed. (±)	2.75	2.64	0.42	0.48	1.73	1.77
C. D. (5%)	5.62	5.39	0.87	0.99	3.53	3.61
Interaction (S x F)						
S. Ed. (±)	4.76	4.57	0.74	0.84	3.00	3.06
C. D. (5%)	NS	NS	NS	NS	NS	NS

FYM = Farmyard manure, NS = Non significant

Table 4.1.17 Effect of spacing and various sources and rates of nutrients on total alkaloid content (%) and total alkaloid yield (kg/ha)

Treatments	Total alkaloid content (%)		Total alkaloid yield (Kg/ha)	
	2005-06	2006-07	2005-06	2006-07
Spacing				
S_1-20cmx20cm	0.27	0.28	7.01	7.18
S_2-25cmx25cm	0.28	0.28	8.18	8.12
S_3-30cmx30cm	0.28	0.28	8.22	8.11
S. Ed.(±)	0.01	0.01	0.31	0.28
C. D. (5%)	NS	NS	0.87	0.77
Doses of nutrients				
F_0–$N_0P_0K_0$	0.24	0.24	4.29	4.24
F_1–$N_{30}P_{20}K_{10}$	0.27	0.28	7.33	7.72
F_2– $N_{60}P_{40}K_{20}$	0.29	0.29	8.03	8.00
F_3– $N_{90}P_{60}K_{30}$	0.29	0.29	8.09	8.07
F_4– 10 t FYM/ha	0.29	0.28	9.29	9.01
F_5– $N_{60}P_{40}K_{20}$ + 5 t FYM/ha	0.29	0.29	9.79	9.77
S. Ed.(±)	0.01	0.01	0.46	0.36
C. D. (5%)	0.02	0.02	0.95	0.74
Interaction (S x F)				
S. Ed.(±)	0.02	0.01	0.80	0.63
C. D. (5%)	NS	NS	NS	NS

FYM = Farmyard manure, NS= Non significant

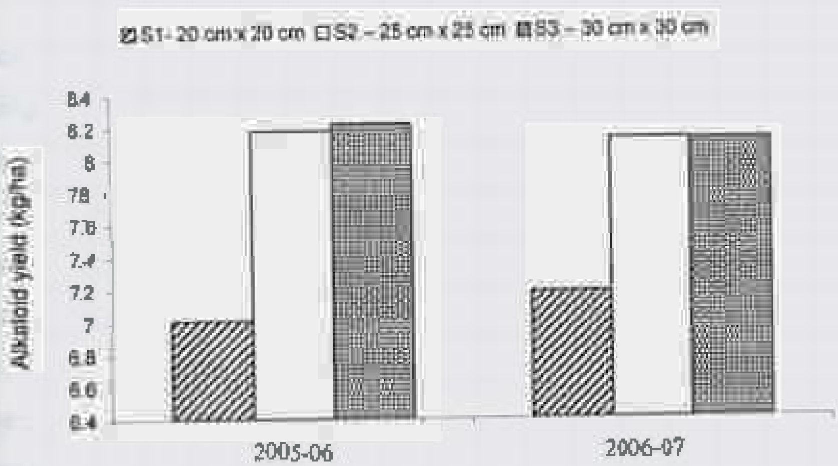

Fig. 4.11 Effect of spacing on alkaloid yield (Kg/ha)

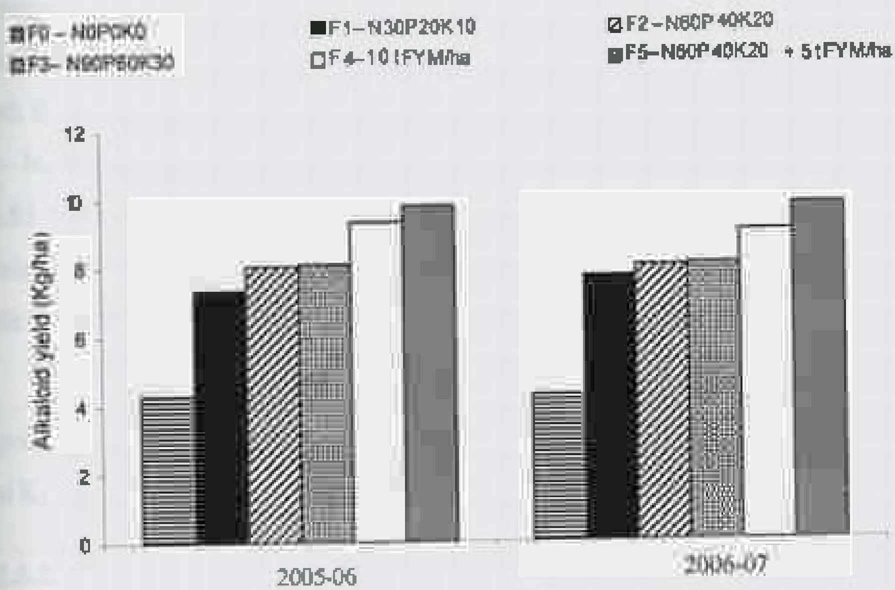

Fig. 4.12 Effect of sources and rates of nutrient on alkaloid yield (kg/ha)

4.1.5 Soil parameters

4.1.5.1 Available Soil Nitrogen, Phosphorus, Potash (Kg/ha)

The data (Table 4.1.19) on available residual nitrogen in soil (Kg/ha) after harvesting of crop revealed marked variation on this attribute due to different spacing. Spacing of 20 x 20 cm resulted into maximum available N in soil (280.03 and 276.02 kg/ha respectively in both the years) however, it remained *at par* with 30 x 30 cm (279.06 and 275.59 Kg/ha) but proved superior to 25 x 25 cm (277.89 and 274.03 Kg/ha). Residual availability of P_2O_5 and K_2O remained unaffected by spacing treatments and showed almost equally effective. However, spacing of 30 x 30 cm recorded the maximum available P_2O_5 (27.74 and 27.74 kg/ha) whereas 20 x 20 cm showed maximum available K_2O (80.12 and 76.13 Kg/ha) in both the years respectively.

Nutrient applied treatments significantly increased the residual fertility in terms of available N, P_2O_5, K_2O and proved superior to control after each harvest. The treatment F_4– 10 t FYM/ha recorded the maximum available nitrogen (288.21 and 284.47) and available K_2O (83.02 and 78.89) Kg/ha in both the years respectively and remained statistically *at par* with the treatment F_5– $N_{60}P_{40}K_{20}$ + 5 t FYM/ha (available N: 287.35 and 283.84 kg/ha and available K_2O 82.67 and 78.55 Kg/ha in both the years respectively). Available P_2O_5 however was recorded maximum due to F_5– $N_{60}P_{40}K_{20}$ + 5t FYM/ha (31.20 and 27.04 Kg/ha) F_4– 10 t FYM/ha (30.75 and 26.83 Kg/ha) respectively in both the years. These two treatments *i.e.* F_5 and F_4 statistically proved superior to the other three nutrient treatments (F_3, F_2 and F_1) in both the years, however the treatments F_3, F_2 and F_1 remained *on par*.

The interaction effect of both the spacing and fertilizer treatment revealed no significant differences among different treatment combinations on available N, P_2O_5 and K_2O in soil after harvesting of the crop.

4.1.5.2 Organic Carbon Content (%) in soil

The data on soil organic carbon content (Table 4.1.19) revealed no significant variation due to various plant spacing on soil organic carbon content. However, spacing 20 x 20 cm produced higher soil organic carbon (0.69 % and 0.67 % in both the years 2005-06 and 2006-07 respectively).

Content of soil organic carbon significantly increased due to all nutrient management practices over control. Application of F_4 - 10 t FYM/ha and F_5 - $N_{60}P_{40}K_{20}$ + 5 t FYM/ha though remained statistically *at par* but proved superior to F_1- $N_{30}P_{20}K_{10}$, F_2- $N_{60}P_{40}K_{20}$ and F_3- $N_{90}P_{60}K_{30}$. Similarly the treatments F_1, F_2 and F_3 proved equally effective. The treatment F_4– 10 t FYM/ha recorded highest soil organic carbon content (0.72 and 0.70%) followed by the treatment F_5– $N_{60}P_{40}K_{20}$ +5 t FYM/ha (0.72 and 0.69%) in both the years respectively. The lowest soil organic carbon was recorded under control *i.e.* F_0– $N_0P_0K_0$with 0.64 and 0.63% respectively in both the years.

The interaction effect of both the spacing and nutrient management treatments failed to produce significant variation on soil organic carbon content.

4.1.6 Economic indices

The economic indices (pooled data of2005-06 and 2006-07) were presented in the Table 4.1.20. From the Table it is revealed that the total cost in the trial increased with successive decrease in spacing. The maximum total cost of Rs. 9,099/ha was recorded due to 20 x 20 cm spacing followed by 25 x 25 cm spacing (Rs. 8,989/ha). The highest gross income (Rs. 28,595/ha) and net income (Rs. 19,606/ha) was recorded in the treatment S_2 – 25 x 25 cm followed by the treatment S_3 – 30 x 30 cm (Rs. 28,480/ha and Rs.19,601/ha as gross income and net income respectively). The highest benefit cost ratio (2.21 :1) was noted in the treatment S_3– 30 x 30 cm followed by the treatment S_2– 25 x 25 cm (2.18: 1).

Regarding nutrient management treatments the highest cost (Rs. 9,981/ha) was observed in the treatment F_3– $N_{90}P_{60}K_{30}$ followed by the treatment F_5– $N_{60}P_{40}K_{20}$+ 5 t FYM/ha (Rs. 9,539/ha). The highest gross income (Rs. 33,605/ha) and net income (Rs. 23,526/ha) were recorded under the treatment F_5– $N_{60}P_{40}K_{20}$ + 5 t FYM/ha followed by the treatment F_3- $N_{90}P_{60}K_{30}$ (Rs. 31,315/ha and Rs. 21,334/ha as gross and net income respectively). The maximum benefit : cost ratio (2.47: 1) was recorded due to the treatment F_5– $N_{60}P_{40}K_{20}$+ 5 t FYM/ha followed by the treatment F_4– 10 t FYM/ha (2.44: 1).

Table 4.1.18 Effect of spacing and various sources and rates of nutrients on total sugar, reducing sugar and Non-reducing content (%)

Treatments	Total sugar content (%)		Reducing sugar content (%)		Non-reducing sugar (%)	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Spacing						
S_1 - 20 cm x 20 cm	6.39	6.61	5.20	5.42	1.19	1.19
S_2 - 25 cm x 25 cm	6.67	6.67	5.39	5.39	1.28	1.28
S_3 - 30 cm x 30 cm	6.65	6.65	5.46	5.46	1.19	1.19
S. Ed. (±)	0.05	0.06	0.06	0.06	0.09	0.09
C. D. (5%)	NS	NS	NS	NS	NS	NS
Doses of nutrients						
$F_0 - N_0P_0K_0$	6.15	6.20	5.12	5.19	1.04	1.01
$F_1 - N_{30}P_{20}K_{10}$	6.49	6.57	5.34	5.40	1.16	1.18
$F_2 - N_{60}P_{40}K_{20}$	6.54	6.62	5.41	5.49	1.13	1.13
$F_3 - N_{90}P_{60}K_{30}$	6.66	6.74	5.42	5.49	1.24	1.25
F_4 - 10 t FYM/ha	6.82	6.88	5.43	5.50	1.39	1.38
$F_5 - N_{60}P_{40}K_{20}$ + 5 t FYM/ha	6.79	6.86	5.42	5.50	1.36	1.35
S. Ed. (±)	0.09	0.09	0.08	0.08	0.13	0.13
C. D. (5%)	0.19	0.20	0.17	0.17	NS	NS
Interaction (S x F)						
S. Ed. (±)	0.16	0.17	0.14	0.14	0.23	0.23
C. D. (5%)	NS	NS	NS	NS	NS	NS

FYM = Farmyard manure, NS = Non significant

Table 4.1.19 Effect of spacing and various sources and rates of nutrients on available soil N, P_2O_5, K_2O (kg/ha) and organic carbon content (%)

Treatments	Available N		Available P_2O_5		Available K_2O		Organic carbon	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Spacing								
S_1 - 20 x 20 cm	280.03	276.02	27.63	23.83	80.12	76.13	0.69	0.67
S_2 - 25 x 25 cm	277.89	274.03	27.49	23.47	79.96	75.82	0.68	0.67
S_3 - 30 x 30 cm	279.06	275.59	27.74	23.98	79.15	75.14	0.68	0.67
S. Ed. (±)	0.36	0.53	0.12	0.19	0.481	0.53	0.01	0.01
C. D. (5%)	1.01	1.48	NS	NS	NS	NS	NS	NS
Doses of nutrient								
$F_0 - N_0P_0K_0$	263.68	259.81	18.69	15.44	74.40	70.44	0.64	0.63
$F_1 - N_{30}P_{20}K_{10}$	277.58	273.83	27.86	23.98	79.02	75.18	0.68	0.66
$F_2 - N_{60}P_{40}K_{20}$	277.87	273.88	28.53	24.68	79.51	75.32	0.67	0.66
$F_3 - N_{90}P_{60}K_{30}$	279.25	275.44	28.70	24.59	79.85	75.80	0.68	0.67
F_4 – 10 t FYM/ha	288.21	284.47	30.75	26.83	83.02	78.89	0.72	0.70
$F_5 - N_{60}P_{40}K_{20}$ + 5 t FYM/ha	287.35	283.84	31.20	27.04	82.67	78.55	0.72	0.69
S. Ed. (±)	0.82	0.88	0.41	0.51	0.36	0.36	0.01	0.01
C. D. (5%)	1.69	1.81	0.84	1.05	0.73	0.75	0.01	0.01
Interaction (SxF)								
S. Ed. (±)	1.43	1.53	0.71	0.89	0.62	0.63	0.01	0.01
C. D. (5%)	NS	NS	NS	NS	NS	NS	NS	NS

FYM = Farmyard manure, NS = Non significant

Table 4.1.20 Effect of spacing and various sources and rates of nutrients on economic indices

Treatment	Total cost (Rs/ha)	Gross income (Rs/ha)	Net income (Rs/ha)	Benefit : Cost ratio
Spacing				
S_1- 20 x 20 cm	9099	24925	15826	1.74
S_2-25x25cm	8989	28595	19606	2.18
S_3-30x30cm	8879	28480	19601	2.21
Doses of nutrients				
F_0- $N_0P_0K_0$	7005	17375	10370	1.48
F_1 - $N_{30}P_{20}K_{10}$	7997	26805	18808	2.35
F_2-$N_{60}P_{40}K_{20}$	8989	27565	18576	2.07
F_3- $N_{90}P_{60}K_{30}$	9981	31315	21334	2.14
F_4-10 t FYM/ha	8105	27920	19815	2.44
F_5-$N_{60}P_{40}K_{20}$ + 5 t FYM/ha	9539	33065	23526	2.47

4.2 Date of transplanting and harvesting stage trial

4.2.1 Growth

Effectivity of experimental variables *i.e.* different date of transplanting and harvesting stage of *Eclipta prostata* L. was measured in terms of plant height, number of primary and secondary branches, diameter of main stem and branches, number of leaves and leaf area index, number of roots and root length, and dry matter production during both the years 2005-06 and 2006-07.

4.2.1.1 Plant height (cm)

Data on plant height (cm) presented in Table 4.2.1 revealed significant effect of date of transplanting. Transplanting of *Eclipta prostata* L. seedlings on 15th June produced tallest and statistically superior plant height (43.10 and 46.56 cm during both the years respectively) as compared to other transplanting times, closely followed by the 15th May transplanting (38.88 and 40.25 cm). Transplanting on 15th May also proved superior to 15th April and 15th July. Effect of later two remained statistically *at par*. The pattern of increase in plant height due to these two variables are graphically represented in Fig. 4.13 and Fig. 4.14.

Late harvesting of crop coinciding maturity stage produced tallest and superior plant height (46.96 and 51.37 cm) in both the years respectively as against harvesting at flowering and vegetative stages. The shortest plant height was recorded due to harvesting at vegetative stage (22.46 and 23.73 cm). Accordingly harvesting at 50 % flowering stage (40.38 and 43.52 cm) remained statistically superior to harvesting at vegetative stage.

The interaction effect of transplanting times and harvesting stages was found statistically similar on plant height.

4.2.1.2 Primary branches

Different dates of transplanting brought about significant variation in the production of primary branches (Table 4.2.1). The 15th June transplanting treatment recorded the maximum number of primary branches/plant (15.15 and 17.37 in 2005-06 and 2006-07 respectively) and proved statistically superior to other transplanting dates. Similarly 15th May and 15th July transplanting treatments were equally effective but showed their superiority over 15th April transplanting in production of primary branches.

Varying date of harvesting also proved marked variation in the production of primary branches. Harvesting of crop at maturity stage produced maximum number of primary branches *i.e.* 14.23 and 16.37 respectively during first and second year but remained statistically *at par* with the harvesting at 50% flowering stage but both the stages proved markedly superior to harvesting at vegetative stage producing lowest number of primary branches (5.67 and 6.24) in respective years.

The interaction effect of time of transplanting and harvesting stage failed to bring any significant differences on production of number of primary branches per plant in both the years 2005-06 and 2006-07.

4.2.1.3 Secondary branches

Perusal of Table 4.2.1 exhibited highest number of secondary branches (24.44 and 26.08) per plant when planted on 15th June during 2005-06 and 2006-07 respectively and proved superior to 15th May transplanting (19.93 and 19.07). Production of secondary branches/plant markedly decreased due to very early and too late transplanting on 15th April (10.09 and 13.65) and 15th July treatment (12.40 and 15.16) during both the years respectively. Whereas 15th April and 15th July transplanting remained statistically *at par*.

Data further revealed that harvesting at maturity stage recorded the maximum number of secondary branches (24.56 and 26.82 respectively in both the years) but remained *at par* with harvesting at 50 per cent flowering stage (19.69 and 23.59). However, it proved superior to H_1 – harvesting at vegetative stage (4.39 and 5.07 in first and second year respectively).

The interaction between transplanting time and harvesting stage was non significant on production of secondary branches.

4.2.1.4 Stem and branch diameter (mm)

Scanning of the data (Table 4.2.2) pertaining to stem and branch diameter revealed that 15th June transplanting treatment recorded the highest value of stem diameter (4.72 and 5.91mm) during both the years respectively and proved statistically superior to the other treatments followed by ST_2 - 15th May transplanting (4.55 and 5.26 mm). Similarly, 15th June transplanting recorded the maximum value ofbranch diameter (2.20 and 2.30 mm) during 2005-06 and 2006-07 respectively and remained statistically similar to 15th May transplanting, however, proved superior to

Table 4.2.1 Effect of transplanting time and harvesting stages on plant height (cm); number of primary and Secondary branches/plant

Treatments	Plant height (cm)		Primary branches/plant		Secondary branches/plant	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Transplanting time						
ST_1- 15th April	31.70	34.40	8.62	10.39	10.09	13.65
ST_2- 15th May	38.88	40.25	10.10	11.76	17.93	19.07
ST_3- 15th June	43.10	46.56	15.15	17.37	24.44	26.08
ST_4- 15th July	32.72	36.96	9.97	11.57	12.40	15.16
S. Ed. (±)	0.45	0.54	0.52	0.29	1.23	1.10
C. D. (5%)	1.12	1.32	1.26	0.72	3.02	2.70
Harvesting stages						
H_1 – Vegetative stage	22.46	23.73	5.67	6.24	4.39	5.07
H_2 - 50 % Flowering stage	40.38	43.52	12.98	15.87	19.69	23.59
H_3 – Maturity stage	46.96	51.37	14.23	16.37	24.56	26.82
S. Ed. (±)	1.74	1.91	0.72	0.70	2.43	2.18
C. D. (5%)	3.70	4.05	1.54	1.48	5.15	4.63
Interaction (ST x H)						
S. Ed. (±)	3.49	3.82	1.45	1.73	7.58	4.37
C. D. (5%)	NS	NS	NS	NS	NS	NS

NS = Non significant

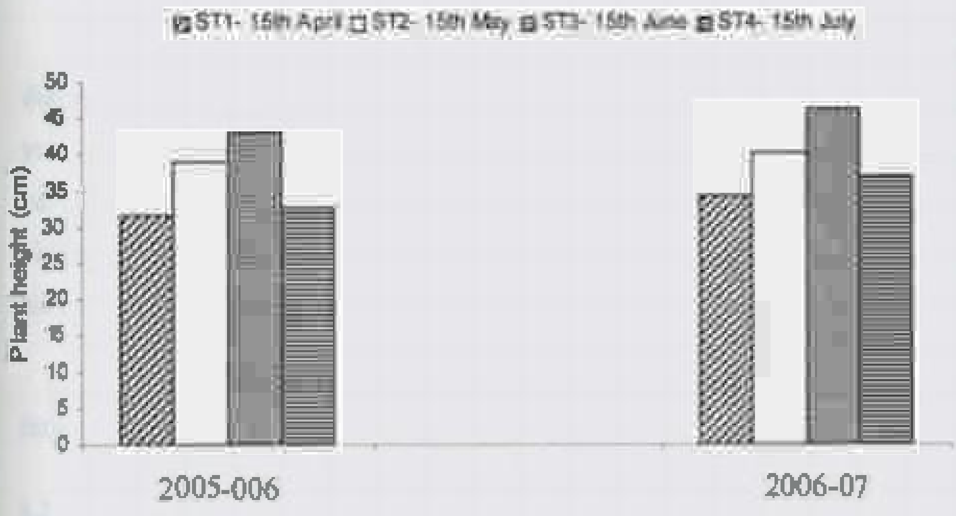

Fig 4.13 Effect of transplanting time on plant height (cm)

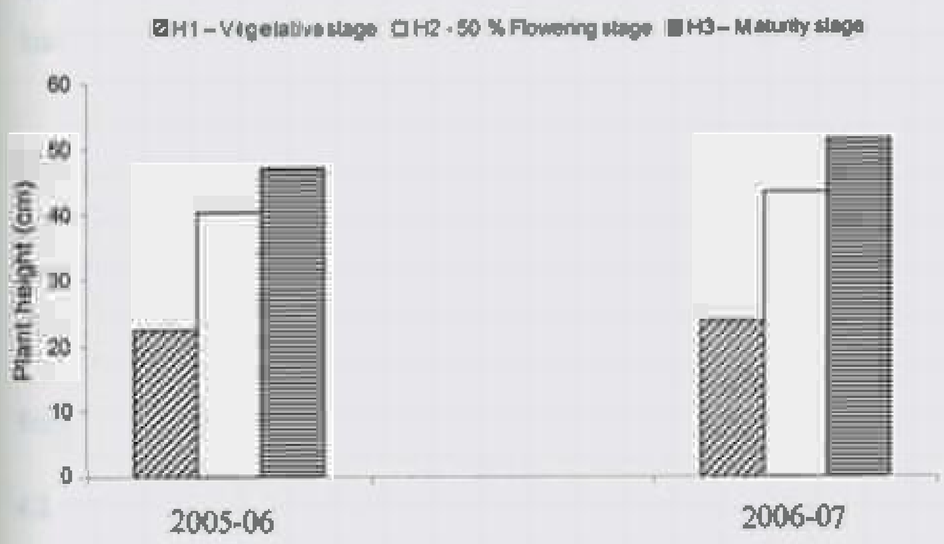

Fig 4.14 Effect of harvesting stages on plant height (cm)

15th April and 15th July transplanting treatments. These 15th April and 15th July transplanting remained statistically *at par* but failed to bring significant increase in stem and branch diameter during both the years of cultivation.

Harvesting of *Eclipta prostrata* at maturity stage recorded the highest stem diameter (5.30 and 5.82 mm) as well as branch diameter (2.19 and 2.24 mm) in the year 2005-06 and 2006-07 respectively, but remained statistically *on par* with harvesting at 50% flowering stage (5.14, 5.73 and 2.23, 2.33 mm stem and branch diameter in both the years respectively). However, they proved markedly superior to harvesting at vegetative stage.

All the treatment combinations of transplanting times and harvesting stages failed to bring any significant variations on stem diameter and branch diameter.

4.2.1.5 Number of leaves

Production of leaves varied significantly due to varying dates of transplanting. From the data (Table 4.2.2), it was observed that ST_3 – 15th June transplanting resulted into the production of maximum number of leaves per plant (169.96 and 179.27 in the year 2005-06 and 2006-07 respectively), and proved markedly superior to the other treatments, followed by ST_2 – 15th May transplanting (141.39 and 144.98). Transplanting on 15th July and 15th April showed the lowest production of leaves but remained *at par*.

Data further revealed that harvesting at 50 % flowering stage, recorded the highest production of number of leaves 187.35 and 195.52 in both the years respectively and remained statistically superior to harvesting at maturity stage. The lowest leaf number (57.42 and 63.91) was recorded due to harvesting at vegetative stage.

The interaction effect of time of transplanting and harvesting stages were found non significant in production of leaves number.

4.2.1.6 Number of root and root length (cm)

Data on number of roots/plant and length of roots (cm) are presented in Table-4.2.3. Examination of data showed that 15th June transplanting produced maximum rootnumber/plant (50.97 and 54.26) as well as root length (15.15 and 16.89 cm) during both the years. It proved markedly superior to the other dates of transplanting

Table 4.2.2 Effect of transplanting time and harvesting stages on stem diameter, branch diameter (mm) and number of leaves/plant

Treatments	Stem diameter (mm)		Branch diameter (mm)		Number of leaves/plant	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Transplanting time						
ST_1- 15th April	4.39	4.58	1.66	1.76	112.42	122.62
ST_2- 15th May	4.55	5.26	2.01	2.12	141.39	144.98
ST_3- 15th June	4.72	5.91	2.20	2.30	169.96	179.27
ST_4- 15th July	4.39	4.46	1.78	1.87	121.79	132.39
S. Ed. (±)	0.05	0.25	0.08	0.07	7.25	3.99
C. D. (5%)	0.14	0.63	0.20	0.17	17.74	9.76
Harvesting stages						
H_1 – Vegetative stage	3.10	3.61	1.32	1.47	57.42	63.91
H_2 - 50 % Flowering stage	5.14	5.73	2.23	2.33	187.35	195.52
H_3 – Maturity stage	5.30	5.82	2.19	2.24	164.40	175.02
S. Ed. (±)	0.08	0.199	0.13	0.12	7.61	6.91
C. D. (5%)	0.17	0.42	0.28	0.26	16.13	14.65
Interaction (ST x H)						
S. Ed. (±)	0.16	0.43	0.27	0.24	15.21	13.82
C. D. (5%)	NS	NS	NS	NS	NS	NS

N S = Non significant

in respect of number of roots but remained *at par* with 15th May transplanting in case of root length. The lowest root number and root length were recorded at 15th July closely followed by 15th April transplanting, though later two were statistically *at par*.

Again harvesting at maturity stage produced maximum number of roots/plant (50.74 and 55.43) along with longer root length (15.32 and 17.98 cm) respectively during both the years. However, harvesting at 50 % flowering stage (root number- 48.09 and 54.79; root length- 14.41 and 16.00 cm) proved equally effective. Both these two treatments remained superior to harvesting at vegetative stage (root number-31.09 and 31.13; root length- 11.89 and 12.16 cm).

The treatment combinations of sowing time and harvesting stage revealed that there was no significant effect on number of roots per plant and root length of *E. Prostrata* L.

4.2.1.7 Dry matter production

The data on dry matter production (Table 4.2.4) revealed that transplanting on 15th June produced the maximum fresh weight/plant (31.93 and 33.01 g), dry weight/plant (8.85 and 9.48 g) as well as dry matter production (25.65 and 26.46) in 2005-06 and 2006-07 respectively, and established its superiority over other treatments followed by transplanting on 15th May (fresh weight 26.96 and 28.57; dry weight 6.76 and 7.57; dry matter production 23.26 and 24.40 respectively in both the years). Transplanting the crop on 15th July and 15th April resulted into the lowest values of these parameters and remained statistically *at par* in their effectivity in respect of fresh weight, dry weight and dry matter production. The graphical representation of dry matter production is presented in the Fig. 4.15 and Fig. 4.16.

Similarly harvesting at 50 % flowering stage recorded the maximum fresh weight/plant (36.71 and 38.68 g), dry weight/plant (9.92 and 10.99 g) and dry matter production (26.26 and 27.8) respectively in both the years and proved statistically superior to other harvesting stages. Concurrently harvesting at maturity stage proved next best producing fresh weight: 28.33 and 29.73 g, dry weight: 6.42 and 7.15 g and dry matter production- 22.24 and 23.66 respectively in both the year. The lowest value of fresh weight (10.65 and 11.72 g), dry weight (1.88 and 2.14 g) and dry matter production (17.52 and 18.25) were recorded in case of harvesting the crop at vegetative stage.

Table 4.2.3 Effect of transplanting time and harvesting stages on number of root/plant and rootlength (cm)

Treatments	Number of root/plant		Root length (cm)	
	2005-06	2006-07	2005-06	2006-07
Transplanting time				
ST_1- 15th April	36.69	40.30	12.45	14.19
ST_2- 15th May	45.32	49.38	14.89	16.70
ST_3- 15th June	50.97	54.26	15.15	16.89
ST_4- 15th July	40.24	44.53	12.99	13.74
S. Ed. (±)	1.83	1.96	0.29	0.24
C. D. (5%)	4.48	4.79	0.72	0.59
Harvesting stages				
H_1 – Vegetative stage	31.09	31.13	11.89	12.16
H_2 – 50 % Flowering stage	48.09	54.79	14.41	16.00
H_3 – Maturity stage	50.74	55.43	15.32	17.98
S. Ed. (±)	3.32	3.31	1.16	1.10
C. D. (5%)	7.05	7.01	2.46	2.34
Interaction (ST x H)				
S. Ed. (±)	6.65	6.62	2.32	2.21
C. D. (5%)	NS	NS	NS	NS

NS = Non significant

The interaction effect of time of transplanting and harvesting stage failed to produce significant variation on these parameters in either year.

4.2.1.8 Leaf area, ground cover and total leaf area (cm^2)

The data on leaf area (Table 4.2.5) clearly showed no significant variation due to different time of transplanting and harvesting stages of *Eclipta prostrata* L. during both the years of cultivation. However, in respect of ground cover and total leaf area (Table 4.2.5) significant variations were observed. Transplanting on 15th June brought about highest ground cover (27.95 and 29.88 cm^2) and total leaf area (358.31 and 444.00 cm^2) in 2005-06 and 2006-07 respectively, and proved statistically superior to the other treatments followed by 15th May transplanting (ground cover- 23.34 and 24.93 cm^2; total leaf area- 290.32 and 330.31 cm^2 in both the years respectively). The treatments 15th April and 15th July transplanting resulted the lowest ground cover and total leaf area and their effectivity remained statistically similar.

Harvesting of crop at various stages showed no marked variation on individual leaf area. Notwithstanding H_2- harvesting at 50 % flowering stage recorded relatively higher ground cover (25.92 and 29.12 cm^2 in both the yearsrespectively) closely followed by harvesting at maturity (24.85, 27.23 cm^2) but both these two stages proved statistical superiority over harvesting at vegetative stage. On the other hand harvesting at 50% flowering stage proved statistically superior in total leaf area (390.59 and 455.73 cm^2 in both the years respectively) followed by harvesting at maturity stage (336.44 and 391.10 cm^2). The lowest total leaf area (108.68 and 138.66 cm^2) was observed at vegetative stage.

The treatment combinations of transplanting time and harvesting stage revealed that there was no significant difference due to their combination on leaf area/leaf, total leaf area and ground cover/plant.

4.2.1.9 Leaf area Index (LAI)

Data on LAI (Table 4.2.5) exhibited significant variation due to different dates of transplanting during both the years. Crop transplanted on 15th June recorded highest leaf area index 12.35 and 14.26 in both the years respectively. However, it remained *at par* with 15th May transplanting (12.00 and 13.66), but proved markedly superior to 15th April and 15th July transplanting treatments. The later two dates of transplanting proved equally effective.

Table 4.2.4 Effect of transplanting time and harvesting stages on fresh weight/plant (g), dry weight/plant (g) and dry matter production (%)

Treatments	Fresh weight/plant (g)		Dry weight/plant (g)		Dry matter production (%)	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Transplanting time						
ST_1- 15th April	19.23	21.39	3.96	4.86	19.53	21.48
ST_2- 15th May	26.96	28.57	6.76	7.56	23.26	24.40
ST_3- 15th June	31.93	33.01	8.85	9.48	25.65	26.46
ST_4- 15th July	22.82	23.86	4.71	5.14	19.58	20.59
S. Ed. (±)	1.47	1.05	0.32	0.14	0.24	0.52
C. D. (5%)	3.61	2.56	0.79	0.34	0.60	1.28
Harvesting stages						
H_1 – Vegetative stage	10.65	11.72	1.88	2.14	17.52	18.25
H_2 – 50 % Flowering stage	36.71	38.68	9.91	10.99	26.26	27.80
H_3 – Maturity stage	28.33	29.73	6.42	7.15	22.24	23.66
S. Ed. (±)	1.61	1.57	0.75	0.78	0.68	1.10
C. D. (5%)	3.41	3.33	1.60	1.65	1.44	2.33
Interaction (ST x H)						
S. Ed. (±)	3.21	3.13	1.51	1.55	1.36	2.20
C. D. (5%)	NS	NS	NS	NS	NS	NS

N S = Non significant

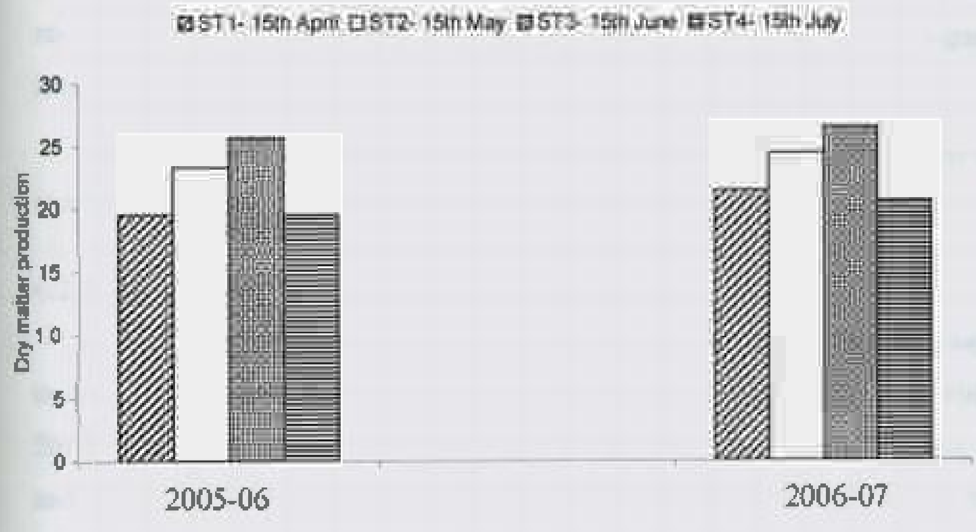

Fig 4.15 Effect of transplanting time on dry matter production (%)

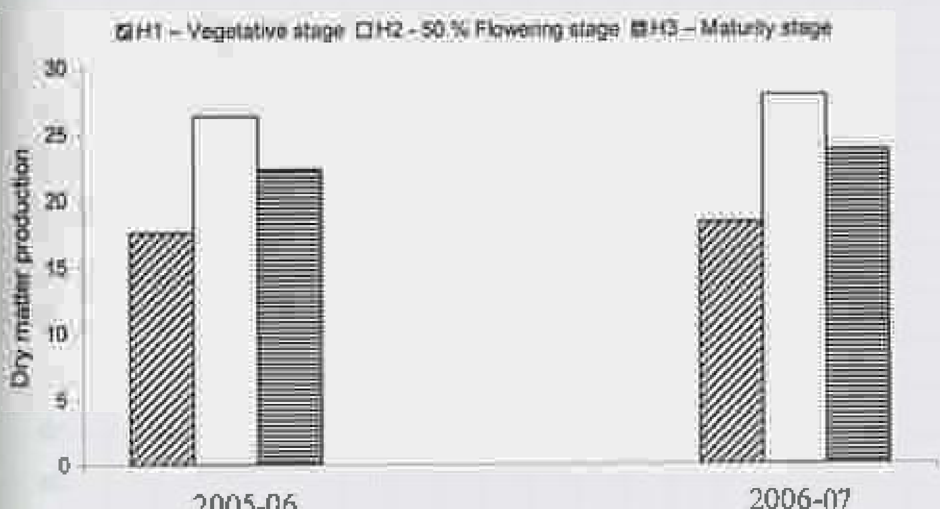

Fig 4.16 Effect of harvesting stages on dry matter production (%)

Harvesting of crop at 50 % flowering stage produced maximum leaf area index (15.38 and 15.73), though it was found at *par* with harvesting at maturity stage (13.46 and 14.58), but showed statistical superiority over harvesting at vegetative stage (6.81 and 8.86). The effect of transplanting dates and harvesting stages on leaf area index is diagrammatically represented in Fig. 4.17 and Fig. 4.18.

Leaf area index could not show marked variation due to interaction effect of transplanting dates and harvesting stages.

4.2.2 Yield (q/ha)

Perusal of data on yield (Table 4.2.6) clearly showed that earlier as well as late transplanting proved detrimental on yield. Maximum fresh herb yield (196.94 and 201.30 q/ha) as well as dry herb yield (52.07 and 55.05) respectively during 2005-06 and 2006-07 were recorded due to transplanting of crop on 15th June (Fig. 4.19) and proved statistically superior to other transplanting dales. Next in order of performance in increasing herb yield was 15th May transplanting (fresh yield -184.06 and 188.41q/ha, dry yield- 43.55 and 46.87 q/ha in both the years respectively). No significant improvement in the production of fresh and dry herb yield could be established due to transplanting the crop on 15th July and 15th April and they remained equally effective.

Harvesting the crop at different growth stages produced significant variation on yield (Fig. 4.20) of fresh and dry herb. Harvesting at 50 % flowering stage recorded the maximum fresh herb yield (203.82 and 208.11 q/ha) as well as dry herb yield (54.00 and 58.31 q/ha) respectively in first and second year of cultivation and proved significantly superior to other harvesting stages. Concurrently harvesting at maturity stage produced comparable fresh herb yield (191.23 and 194.81 q/ha) and dry herb yield (42.90 and 46.42 q/ha) respectively in both the years, establishing its marked superiority overothers. Lowest fresh herb yield (152.66 and 156.63 q/ha) and dry herb yield (26.73 and 28.60 q/ha) were recorded due to harvesting at vegetative stage during both the years respectively.

The interaction effect of transplanting times and harvesting stages remained statistically similar on fresh and dry herb yield irrespective of years of cultivation.

Table 4.2.5 Effect of transplanting time and harvesting stages on leaf area (cm^2), ground cover (cm^2), total leaf area(cm^2) and leaf area index (LAI)

Treatments	Leaf area (cm^2)		Ground cover (cm^2)		Total leaf area (cm^2)		Leaf area index	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Transplanting time								
ST_1- 15th April	1.96	2.08	18.48	20.27	226.07	259.47	11.48	12.18
ST_2- 15th May	2.04	2.29	23.34	24.93	290.32	330.31	12.00	13.66
ST_3- 15th June	2.06	2.30	27.95	29.88	358.31	444.00	12.35	14.26
ST_4- 15th July	1.94	2.09	19.97	22.46	239.59	280.22	11.71	12.13
S. Ed. (±)	0.06	0.08	0.96	0.95	16.52	13.55	0.35	0.58
C. D. (5%)	NS	NS	2.34	2.34	40.41	33.16	0.87	1.42
Harvesting stages								
H_1 – Vegetative stage	1.90	2.15	16.53	16.81	108.68	138.66	6.81	8.86
H_2 – 50 % Flowering stage	2.07	2.25	25.92	29.12	390.59	455.73	15.38	15.73
H_3 – Maturity stage	2.03	2.18	24.85	27.23	336.44	391.10	13.46	14.58
S. Ed. (±)	0.07	0.07	1.76	1.47	19.98	24.03	1.12	1.02
C. D. (5%)	NS	NS	3.74	3.11	42.36	50.94	2.38	2.15
Interaction (ST x H)								
S. Ed. (±)	0.14	0.15	3.53	2.93	39.96	48.06	2.24	2.03
C. D. (5%)	NS	NS	NS	NS	NS	NS	NS	NS

N S = Non significant

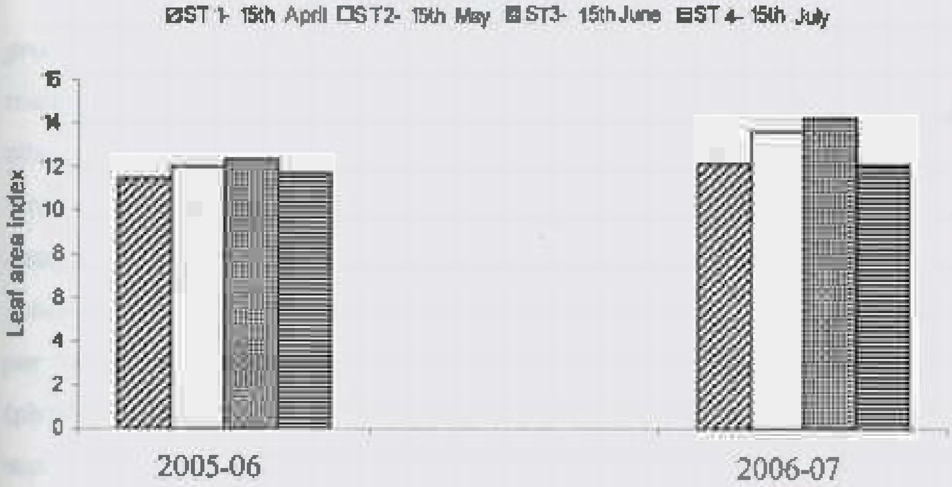

Fig 4.17 Effect of transplanting time on Leaf area index

Fig 4.18 Effect of harvesting stages on Leaf area index

4.2.3 Nutrient content of plant

4.2.3.1 Total nitrogen, phosphorus and potash content of plant

Significant improvement in the content of N, P and K in plant of *Eclipta prostrata* L. was recorded due to transplanting of seedlings on 15th June which proved marked superior (Table 4.2.7) to the other transplanting dates, producing highest plant nitrogen content of 1.35 % and 1.39% during both the years respectively. The other three dates of transplanting remained *at par* pertaining to N content. Similarly 15th June transplanting produced highest plant phosphorus (0.41% and 0.42%) and plant potash (1.41 % and 1.45 %) in both the years. However, it was found statistically *at par* with the treatment 15th May transplanting seedlings in case of P and K (phosphorus-0.40 and 0.40, potash 1.38 and 1.43 in both the years respectively) but superior to the other two, *i.e.* 15th April and 15th July transplanting seedlings.

On study of harvesting stages, it was revealed that harvesting of crop at 50 % flowering stage produced highest value of plant nitrogen content (1.50 % and 1.54 %), plant phosphorus (0.46 % and 0.46 %) and plant potash (1.48 % and 1.52 %) in 2005-06 and 2006-07 respectively and proved statistically superior to the other treatments closely followed by harvesting at maturity stage (plant nitrogen 1.23 and 1.27%, phosphorus- 0.37 and 0.38%, potash -1.41% and 1.45% in both the years respectively). The lowest value of these parameters was recorded due to harvesting of crop at vegetative stages.

The interaction effect between transplanting time and harvesting stage showed that all the treatment combinations remained statistically non significant pertaining to nitrogen, phosphorus and potash content of plant.

4.2.3.2 Organic carbon content of plant (%)

The treatment transplanting of seedling on 15th June brought about highest organic carbon content in plant (40.16 and 40.47 %) followed by 15th May transplanting seedling (39.50 and 39.77 %) and recorded its marked superiority over other two treatments (Table 4.2.7). Transplanting on 15th July as well as 15th April proved almost equal in respect of organic carbon content of plant.

Harvesting of crop at 50 % flowering stage recorded the maximum value of plant organic carbon (42.18 and 42.43 %) respectively during both the years and proved statistically superior to harvesting at maturity stage (39.33 and 39.60 %). The

Table 4.2.6 Effect of transplanting time and harvesting stages on fresh and dry herb yield (q/ha)

Treatments	Fresh herb yield (q/ha)		Dry herb yield (q/ha)	
	2005-06	2006-07	2005-06	2006-07
Transplanting time				
ST_1-15th April	173.19	177.02	34.20	38.43
ST_2- 15th May	184.06	188.41	43.55	46.87
ST_3-15th June	196.94	201.30	52.07	55.05
ST_4- 15th July	176.10	179.34	35.01	37.43
S. Ed. (±)	1.91	1.82	0.62	0.96
C. D. (5%)	4.68	4.46	1.51	2.34
Harvesting stages				
H_1 – Vegetative stage	152.66	156.63	26.73	28.60
H_2 – 50% Flowering stage	203.82	208.11	54.00	58.31
H_3 – Maturity stage	191.23	194.81	42.90	46.42
S. Ed. (±)	5.06	5.05	2.50	3.03
C. D. (5%)	10.72	10.70	5.30	6.42
Interaction (ST x H)				
S. Ed.(±)	10.12	10.09	5.00	6.06
C. D. (5%)	NS	NS	NS	NS

NS = Non significant

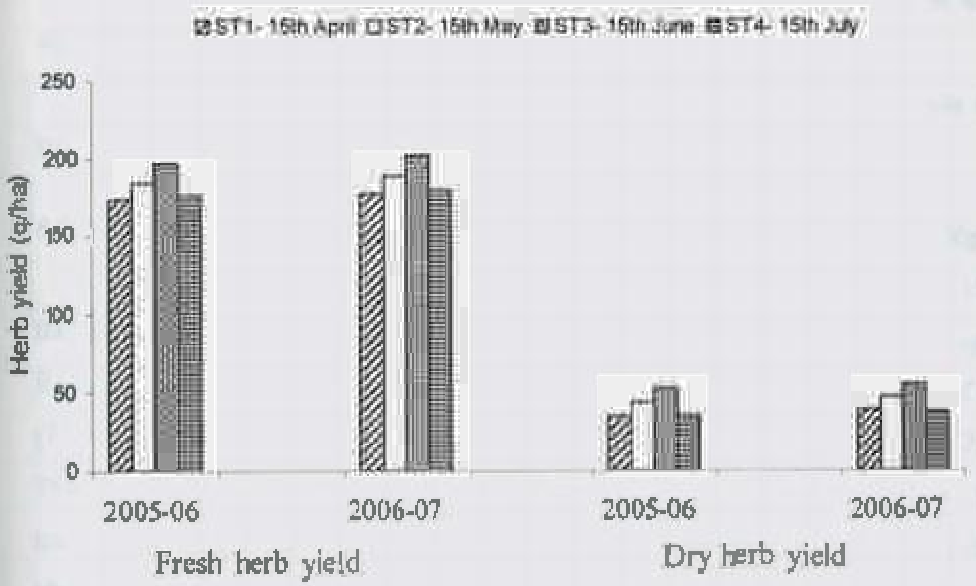

Fig 4.19 Effect of transplanting time on fresh and dried herb yield (q/ha)

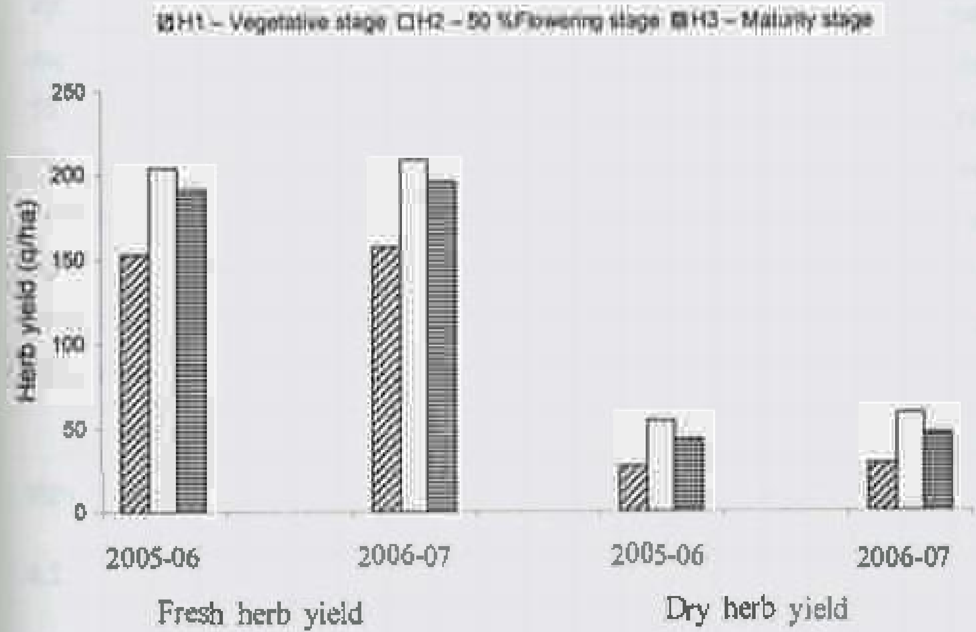

Fig 4.20 Effect of harvesting stages on fresh and dried herb yield (q/ha)

lowest value of organic carbon was found associated with harvesting at vegetative stage.

The plant organic carbon remained unchanged due to interaction effect of transplanting time and harvesting stage.

4.2.3.3 Uptake of nitrogen, phosphorus and potash by plant from soil (Kg/ha)

The data of Table 4.2.8 revealed statistical superiority of 15th June transplanting seedlings in increasing nitrogen, phosphorus and potash uptake by *Eclipta prostrata* irrespective of year of cultivation. The highest uptake of nitrogen (73.40 and 79.68 kg/ha), phosphorus (22.47 and 22.78 kg/ha) and potash (76.05 and 78.29 kg/ha) respectively during 2005-06 and 2006-07 were recorded due to 15th June transplanting followed by 15th May transplanting (Nitrogen -57.39 and 64.05 kg/ha, phosphorus- 18.03 and 18.29 kg/ha and potash- 61.59 and 63.71 kg/ha). The treatment 15th April and 15th July transplanting treatments remained statistically *at par* in nitrogen, phosphorus and potash uptake from soil.

Harvesting at 50 % flowering stage recorded the highest nitrogen uptake (81.69 and 90.54 Kg/ha), phosphorus uptake (25.08and 25.42 kg/ha) and potash uptake (80.77 and 83.07 kg/ha) in both the years respectively and proved statistically superior to the other treatments followed by harvesting at maturity stage (nitrogen - 53.35 and 59.32 kg/ha, phosphorus -16.20 and 16.44 kg/ha and potash – 60.81 and 62.62 kg/ha). The lowest uptake of nutrients was recorded in the treatment harvesting at vegetative stage with nitrogen 29.51 and 32.99 kg/ha, phosphorus- 9.56 and 9.74 kg/ha and potash-32.71 and 34.05 kg/ha respectively in both the years. The variation of uptake of N, P and K due to different transplanting times and harvesting stages are diagramatically represented by Fig. 4.21 and Fig. 4.22.

The interaction effect of transplanting times and harvesting stages produced no significant effect on nitrogen, phosphorus and potash uptake by the plant.

4.2.4 Quality aspect

4.2.4. 1 Total alkaloid content (%)

The results on total alkaloid content(%) revealed ineffectivity of four different seedling transplanting times on total alkaloid content during both the years of cultivation (Table 4.2.9).

Table 4.2.7 Effect of transplanting time and harvesting stages on nitrogen, phosphorus, potash and organic carbon content (%)

Treatments	Nitrogen content (%)		Phosphorus content (%)		Potash content (%)		Organic carbon (%)	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Transplanting time								
ST_1- 15th April	1.24	1.27	0.38	0.39	1.35	1.39	38.66	38.94
ST_2- 15th May	1.27	1.32	0.40	0.40	1.38	1.43	39.50	39.77
ST_3- 15th June	1.35	1.39	0.41	0.42	1.41	1.45	40.16	40.47
ST_4- 15th July	1.24	1.29	0.38	0.39	1.34	1.39	38.47	38.72
S. Ed. (±)	0.02	0.02	0.01	0.01	0.01	0.01	0.11	0.09
C. D. (5%)	0.04	0.05	0.01	0.01	0.03	0.04	0.27	0.24
Harvesting stages								
H_1 – Vegetative stage	1.10	1.15	0.35	0.36	1.22	1.27	36.08	36.39
H_2 – 50 % Flowering stage	1.50	1.54	0.46	0.46	1.48	1.52	42.18	42.43
H_3 – Maturity stage	1.23	1.27	0.37	0.38	1.41	1.45	39.33	39.60
S. Ed. (±)	0.02	0.01	0.01	0.01	0.02	0.01	0.22	0.24
C. D. (5%)	0.05	0.04	0.01	0.01	0.04	0.04	0.46	0.51
Interaction (ST x H)								
S. Ed. (±)	0.04	0.03	0.01	0.01	0.04	0.03	0.44	0.48
C. D. (5%)	NS	NS	NS	NS	NS	NS	NS	NS

N S = Non significant

Table 4.2.8 Effect of transplanting time and harvesting stages on nitrogen, phosphorus and potash uptake (kg/ha)

Treatments	Nitrogen uptake		Phosphorus uptake		Potash uptake	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Transplanting time						
ST_1- 15th April	43.48	50.26	13.44	13.69	46.91	48.23
ST_2- 15th May	57.39	64.05	18.03	18.29	61.59	63.71
ST_3- 15th June	73.40	79.68	22.47	22.78	76.05	78.29
ST_4- 15th July	45.15	49.81	13.85	14.03	47.84	49.42
S. Ed. (±)	1.08	1.60	0.30	0.31	1.48	1.66
C. D. (5%)	2.65	3.92	0.74	0.76	3.61	4.06
Harvesting stages						
H_1 – Vegetative stage	29.51	32.99	9.56	9.74	32.71	34.05
H_2 - 50 % Flowering stage	81.69	90.54	25.08	25.42	80.77	83.07
H_3 – Maturity stage	53.35	59.32	16.20	16.44	60.81	62.62
S. Ed. (±)	4.72	5.26	1.36	1.39	4.49	4.57
C. D. (5%)	10.00	11.15	2.89	2.95	9.52	9.69
Interaction (ST x H)						
S. Ed. (±)	9.44	10.52	2.72	2.78	8.98	9.14
C. D. (5%)	NS	NS	NS	NS	NS	NS

N S = Non significant

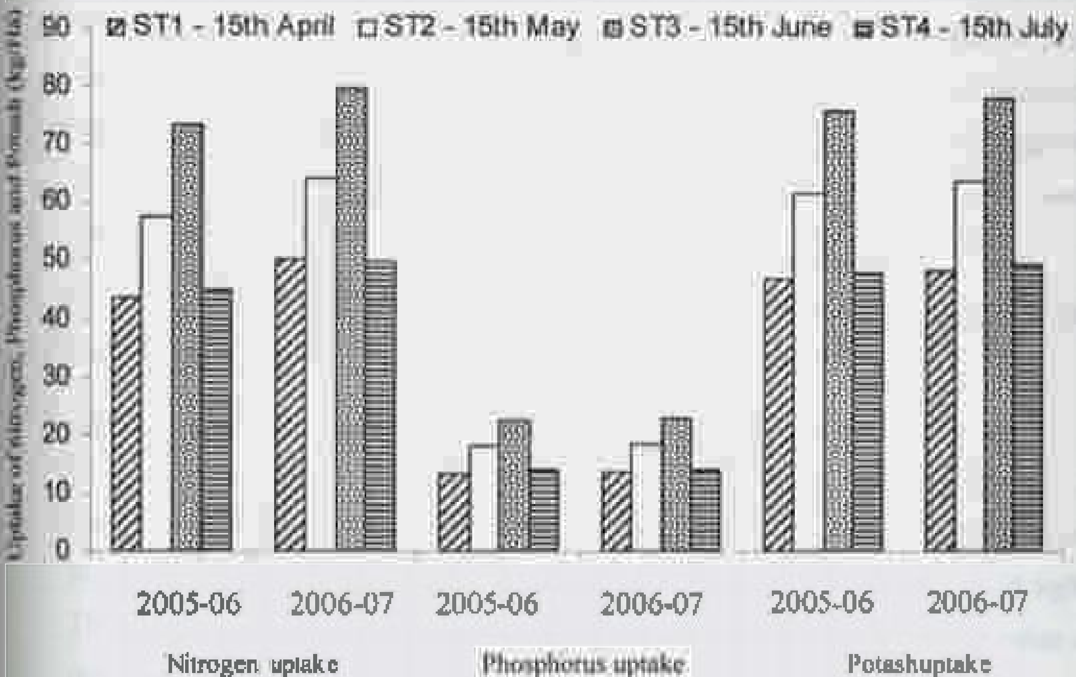

Fig 4.21 Effect of transplanting time on uptake N, P and K (kg/ha)

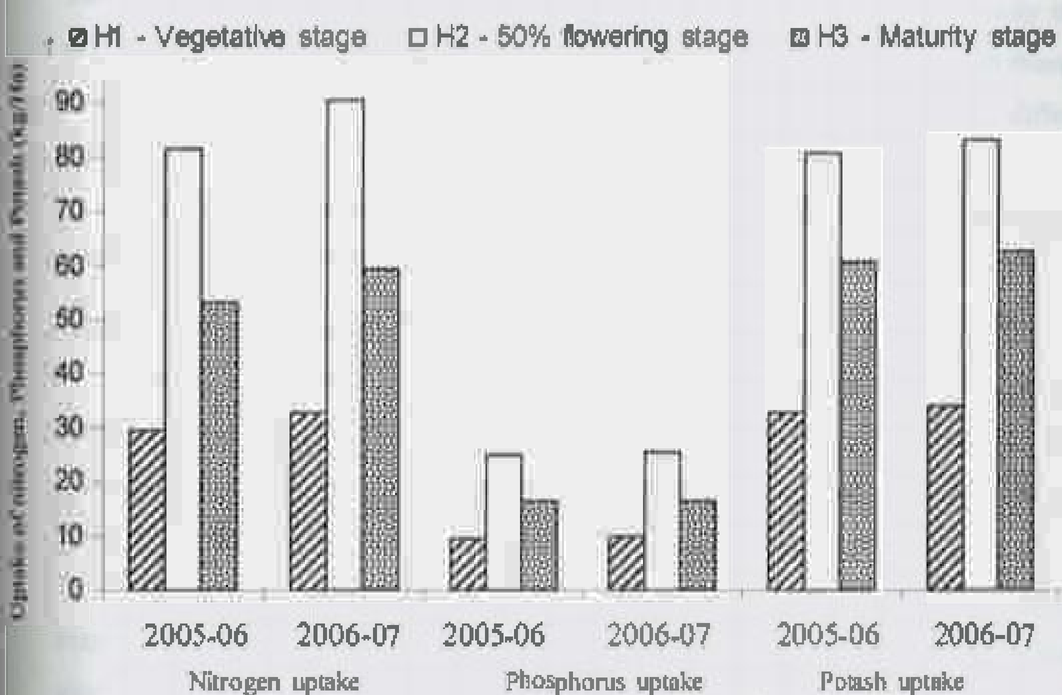

Fig 4.22 Effect of harvesting stages on uptake N, P and K (kg/ha)

Variation in harvesting stages produced significant effect on alkaloid content. Harvesting of crop at 50 % flowering stage recorded the highest total alkaloid content (0.32 and 0.31 % in 2005-06 and 2006-07 respectively) which proved statistically superior to the other treatments, closely followed by harvesting at maturity stage (0.27 and 0.27 %). The lowest value on total alkaloid content was recorded in case of harvesting at vegetative stage (0.12 and 0.11 % in both the year respectively).

All the interaction combinations of transplanting times and harvesting stages were found statistically non significant on total alkaloid content.

4.2.4. 2 Total alkaloid yield (Kg/ha)

The total alkaloid yield (Kg/ha) was recorded highest (Table 4.2.9) under 15th June transplanting treatment (14.16 and 13.49 kg/ha), which was statistically superior to the other treatments followed by 15th May transplanting (11.62 and 11.28 kg/ha). The 15th April and 15th July transplanting treatments resulted into lowest value and remained statistically similar in respect of total alkaloid yield (Fig. 4.23).

Harvesting of *Eclipta prostrata* at 50 % flowering stage showed the highest alkaloid yield (17.67 kg/ha and 16.90 kg/ha in both the years respectively) and proved statistically superior to the other treatments followed by harvesting at maturity stage (11.95 and 11.74 kg/ha). The lowest alkaloid yield (3.08 and 3.01 kg/ha) was recorded due to harvesting at vegetative stage. Pattern of alkaloid yield affected by different harvesting stages is diagrammatically represented by Fig. 4.24.

The interaction effect of transplanting time and harvesting stage proved ineffective on total alkaloid yield.

4.2.4.3 Total sugar, reducing sugar and non-reducing sugar content (%)

The data (Table 4.2.10) revealed no significant variation due to different transplanting treatments of *Eclipta prostrata* L. on total sugar and non-reducing sugar content(%). However, 15th June transplanting seedlings produced the highest total sugar (6.69 and 6.75%). Similarly non-reducing sugar content was highest on 15th April transplanting seedlings (1.75 and 1.48 % during 2005-06 and 2006-07 respectively). The treatment ST_2 – 15th May and ST_3- 15th June remained statistically similar on reducing sugar, whereas both showed higher value than other two treatments *i.e.* ST_1- 15th April and ST_4-15th July. The highest reducing sugar was recorded due to transplanting on 15th May (5.22 and 5.35%) followed by transplanting on 15th June (5.17 and 5.31%) respectively in both the years.

Table 4.2.9 Effect of transplanting time and harvesting stages on total alkaloid content (%) and total alkaloid yield (kg/ha)

Treatments	Total alkaloid (%)		Alkaloid yield (Kg/ha)	
	2005-06	2006-07	2005-06	2006-07
Transplanting time				
ST_1- 15th April	0.23	0.23	8.69	8.68
ST_2- 15th May	0.24	0.23	11.62	11.28
ST_3- 15th June	0.24	0.23	14.16	13.49
ST_4- 15th July	0.23	0.23	9.12	8.75
S. Ed. (±)	0.01	0.01	0.22	0.27
C. D. (5%)	NS	NS	0.55	0.68
Harvesting stages				
H_1 – Vegetative stage	0.11	0.11	3.08	3.01
H_2 - 50 % Flowering stage	0.32	0.31	17.67	16.90
H_3 – Maturity stage	0.27	0.27	11.95	11.74
S. Ed. (±)	0.01	0.01	0.95	0.84
C. D. (5%)	0.02	0.01	2.01	1.79
Interaction (ST x H)				
S. Ed. (±)	0.01	0.01	1.90	1.69
C. D. (5%)	NS	NS	NS	NS

N S = Non significant

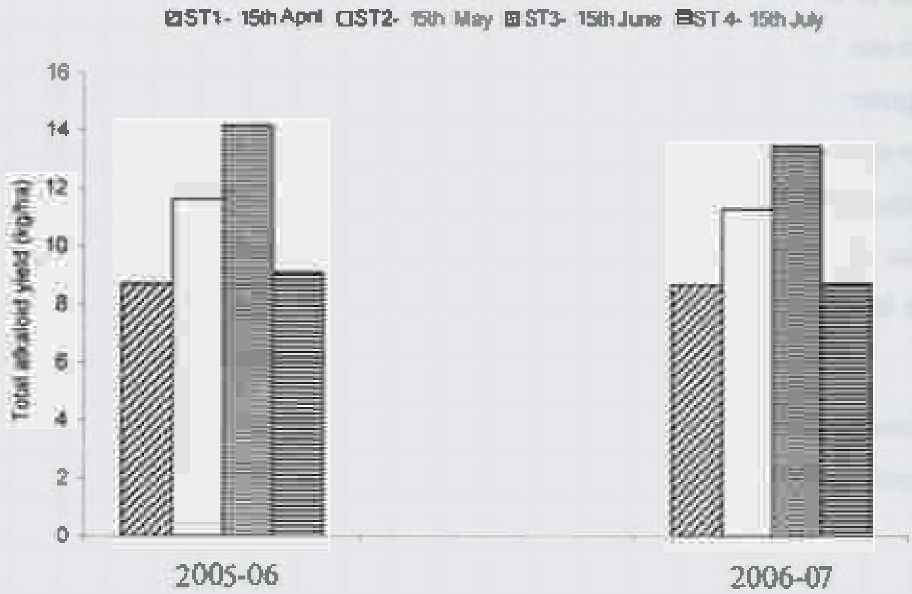

Fig 4.23 Effect of transplanting time on total alkaloid yield (kg/ha)

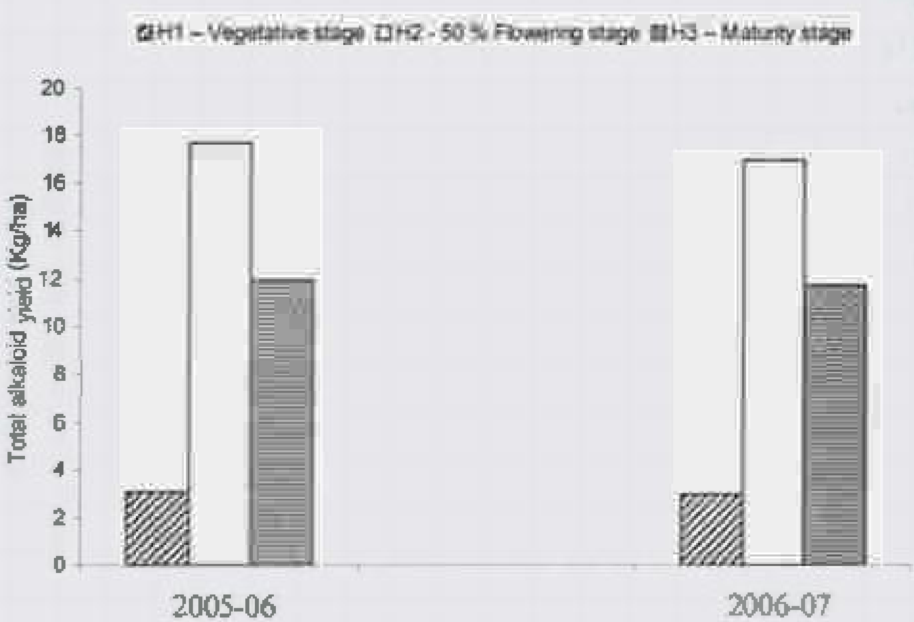

Fig 4.24 Effect of harvesting stage on alkaloid yield (Kg/ha)

Among the different harvesting stage treatments, harvesting at 50 % flowering stage recorded the maximum total sugar content (7.65 and 7.69%) and non-reducing sugar (2.06 and 1.89%), and proved statistically superior to other harvesting stages followed by harvesting at maturity stage (total sugar- 6.68 and 6.60 %, non-reducing sugar – 1.86 and 1.62% during both the year respectively). Regarding reducing sugar harvesting at 50 % flowering stage produced the highest values (5.58 and 5.80) establishing superiority to other treatments *i.e.* harvesting at vegetative and maturity stage, where last two stages were statistically similar.

It was also observed that all the treatment combinations of transplanting time and harvesting stage failed to bring any significant differences on these parameters.

4.2.5 Soil parameters

4.2.5. 1 Available Soil Nitrogen, Phosphorus, Potash (Kg/ha)

Available soil N, P_2O_5 and K_2O (kg/ha) produced due to 15th April and 15th May transplanting though remained statistically similar but proved superior to other transplanting dates irrespective of year of cultivation (Table 4.2.11). It was also observed that 15th May transplanting produced statistically higher soil N, P_2O_5 and K_2O than 15th June transplanting seedling. The highest available soil N (281.31 and 278.40) was recorded under ST_1 - 15th April transplanting, whereas highest available soil P_2O_5 (26.30 and 23.17) and K_2O (71.52 and 68.52) were observed due to 15th July transplanting. The lowest value of N, P_2O_5 and K_2O were recoded due to 15th June transplanting (N- 261.95 and 259.36, P_2O_5- 21.77 and 18.99, K_2O- 55.07 and 53.06 kg/ha) respectively in 2005-06 and 2006-07.

Data on harvesting stages showed lower values of soil N, P_2O_5 and K_2O due to harvesting at 50% flowering and maturity stages in comparison to harvesting at vegetative stage. Maximum residual soil N (292.59 and 289.45) and K_2O (79.26 and 76.28 in both the years respectively) were recorded due to harvesting at vegetative stage and proved superior to harvesting at 50% flowering and maturity stages, whereas later two remained *at par* in respect of N and K_2O. Notwithstanding, harvesting at vegetative stage resulted into highest available soil P_2O_5 (27.97 and 24.79 kg/ha) followed by harvesting at maturity stages (23.82 and 20.77) in both the years respectively and proved superior to harvesting at 50% flowering stages.

Table 4.2.10 Effect of transplanting time and harvesting stages on total, reducing and non-reducing sugar content (%)

Treatments	Total Sugar content (%)		Reducing sugar (%)		Non-reducing sugar (%)	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Transplanting time						
ST_1- 15th April	6.56	6.56	4.817	5.08	1.75	1.48
ST_2- 15th May	6.68	6.68	5.22	5.35	1.46	1.33
ST_3- 15th June	6.69	6.75	5.17	5.31	1.51	1.43
ST_4- 15th July	6.58	6.51	4.99	5.17	1.58	1.34
S. Ed. (±)	0.04	0.07	0.08	0.07	0.08	0.10
C. D. (5%)	NS	NS	0.21	0.19	NS	NS
Harvesting stages						
H_1 – Vegetative stage	5.55	5.58	4.74	4.91	0.81	0.67
H_2 - 50 % Flowering stage	7.65	7.69	5.58	5.80	2.06	1.89
H_3 – Maturity stage	6.68	6.60	4.82	4.98	1.86	1.62
S. Ed. (±)	0.03	0.03	0.09	0.07	0.09	0.06
C. D. (5%)	0.07	0.07	0.19	0.14	0.20	0.13
Interaction (ST x H)						
S. Ed. (±)	0.07	0.07	0.18	0.14	0.19	0.12
C. D. (5%)	NS	NS	NS	NS	NS	NS

N S = Non significant

The interaction effect of transplanting time and harvesting stage showed no significant variation on soil N, P_2O_5 and K_2O in either year.

4.2.5.2 Organic Carbon content (%)

Regarding soil organic carbon content, all the four different times of transplanting remained statistically similar in their effectivity (Table 4.2.11).

Harvesting at vegetative stage recorded the maximum soil organic carbon content (0.68 and 0.68%) in both the years respectively and proved superior to H_2-harvesting at 50% flowering stage and H_3- harvesting at maturity stage. The later two (H_2 and H_3) also remained *on par.*

All treatment combinations of transplanting times and harvesting stages failed to bring any significant differences on content of soil organic carbon.

4.2.6 Economics of the experiment

The average value of both the years on economic indices *viz.* total cost, gross income, net income and benefit cost-ratio of different transplanting times and harvesting stagesare presented in Table 4.2.12. The data revealed that the total cost (Rs. 8,985/ha) remained almost similar irrespective of treatments. However, ST_3-15th June transplanting produced the highest gross income (Rs. 53,560/ha), net income (Rs. 44,575/ha) and benefit-cost ratios (4.96: l) followed by the treatment ST_2- 15th May transplanting producing Rs. 45,210/ha, Rs. 36,225/ha and 4.03:l; gross income, net income and benefit-cost ratio respectively.

Harvesting at 50 % flowering stage resulted the highest gross income (Rs. 56, 155/ha), net income (Rs. 47,170/ha) and benefit cost ratio (5.25: 1) followed by the treatment H_3-harvesting at maturity stage, whereas harvesting at vegetative stage resulted the lowest values on economic indices.

Table 4.2.11 Effect of transplanting time and harvesting stages on available soil N, P_2O_5, K_2O (kg/ha) and soil organic carbon (%)

Treatments	Available soil N		Available soil P_2O_5		Available soil K_2O		Soil organic carbon	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Transplanting time								
ST_1 - 15th April	281.31	278.40	26.28	23.13	70.33	67.54	0.67	0.66
ST_2 - 15th May	270.46	267.54	22.99	20.09	60.90	58.41	0.67	0.66
ST_3 - 15th June	261.95	259.36	21.77	18.99	55.07	53.06	0.67	0.66
ST_4 - 15th July	280.01	276.85	26.30	23.17	71.52	68.52	0.67	0.66
S. Ed. (±)	4.55	4.43	0.11	0.22	1.98	1.94	0.01	0.01
C. D. (5%)	11.13	10.83	0.28	0.53	4.84	4.74	NS	NS
Harvesting stages								
H_1 – Vegetative stage	292.59	289.45	27.97	24.79	79.26	76.28	0.68	0.68
H_2 – 50 % Flowering stage	258.69	256.03	21.21	18.47	55.38	53.17	0.66	0.65
H_3 – Maturity stage	269.01	266.13	23.82	20.77	58.72	56.20	0.66	0.65
S. Ed. (±)	5.29	5.14	0.70	0.68	4.07	3.91	0.01	0.01
C. D. (5%)	11.21	10.90	1.48	1.44	8.63	8.29	0.01	0.01
Interaction (ST x H)								
S. Ed. (±)	10.85	10.28	1.39	1.36	8.14	7.82	0.01	0.01
C. D. (5%)	NS	NS	NS	NS	NS	NS	NS	NS

N S = Non significant

Table 4.2.12 Effect of transplanting time and harvesting stages on total cost gross income, net income and benefit : cost ratio

Treatments	Total cost (Rs./ha)	Gross income (Rs/ha)	Net income (Rs/ha)	Benefit: Cost ratio
Transplanting time				
ST_1- 15th April	8985	36315	27330	3.04
ST_2-15th May	8985	45210	36225	4.03
ST_3- 15th June	8985	53560	44575	4.96
ST_4- 15th July	8985	36220	27235	3.03
Harvesting stages				
H_1 – Vegetative stage	8985	27665	18680	2.08
H_2– 50 % Flowering stage	8985	56155	47170	5.25
H_3– Maturity stage	8985	44660	35675	3.97

CHAPTER–V

DISCUSSION

DISCUSSION

Findings of the present investigation entitled "Development of Agrotechnologies for Domestication and Quality Aspect of Bhringaraj (*Eclipta prostrata* L.)" carried out under two field experiments have been described in details on the basis of statistical significance in the preceding chapter of experimental findings. An effort has been made in this chapter to explain the possible causes of variations brought about by different experimental variables on the basis of scientific facts to draw the valid conclusions well supported by earlier reports pertaining to effect of spacing and nutrient management and dates of transplanting and harvesting stages on growth, herb yield and quality of *Eclipta prostrata* L., so as to optimize the various agronomic requirements related to spacing and nutrient management practices and standardize the time of transplanting and harvesting stages for proper growth and development, yield and quality of *Eclipta prostrata* L.

5.1 Effect of spacing and nutrient management

5.1.1 Effect on Growth

(a) Spacing

The plant height and number of leaves per plant of Bhringaraj were significantly affected by different spacing treatments. The wider spacing 30 x 30 cm and 25 x 25 cm recorded the longest plant height than the closest spacing 20 x 20 cm, which indicated that the wider spacing provides more light for photosynthesis and less competition for nutrients, water and space. Maurya (2005) and Bhattacharjee *et al.* (1979) also reported the superior growth characteristics in wider spaced crop cultivation. Closer spacing might have created severe competition among plants for nutrients, moisture and light, resulting in poor plant growth and development. This result supported the findings of Bhati (1988) on Fenugreek cultivation and Singh *et al.* (1995) on garlic cultivation.

Number of primary and secondary branches per plant, stem and branch diameter, number of roots and root length were found associated with wider spacing (30 x 30 cm and 25 x 25 cm) of *Eclipta prostrata* L. cultivation than the closer spacing which indicated better availability and absorption of biological resources like solar radiation, light intensity, soil nutrient, water, *etc.* in wider spacing. These results confirmed the findings of Singh *et al.* (1999) and Gnanavel and Kathiresan (2006) on *Mentha arvensis* cultivation. All the spacing treatments remained statistically similar in case of secondary branch, stem and branch diameter, number of roots and root length at vegetative stage. This might be due to lack of shortage of soil nutrients and less competition for different inputs up to the vegetative stage of Bhringaraj, which fails to bring any significant differences among the spacing treatments.

(b) Sources and doses of nutrients

All the nutrient management practices irrespective of sources and doses proved instrumental in increasing the growth and yield characters *viz.* plant height, number of primary and secondary branches, stem and branch diameter, number of leaves and roots, root length, number of flowers and heads, dry matter production, leaf area index, fresh herb yield and dry herb yield, *etc.* over control, indicating better availability and utilization of plant nutrients in nutrient applied plots. Balakumbahan *et al.* (2005) also reported the superior growth and yield characters through nutrient management against control.

Among the nutrient management treatments, the plant height, number of leaves, number of roots and root length were recorded maximum due to application of $N_{60}P_{40}K_{20}$ + 5 t FYM/ha. Though it remained statistically similar to the treatment F_4- 10 t FYM/ha, F_3-N90P60 K_{30} and F_2- $N_{60}P_{40}K_{20}$, but superior to the treatment F1- $N_{30}P_{20}K_{10}$ irrespective of growth stages, which indicated that relatively higher doses of N, P and K either through application of farmyard manure alone or integration of organic and inorganic fertilizer showed positive effect on plant height, number of leaves and root per plant. It could be attributed to the fact that after proper decomposition and mineralization, the farmyard manure supplied adequate quantity of available nutrient along with higher doses of fertilizer directly to the plant and also had solubulizing effect on fixed form of nutrients in soil. Such observation was also made by Singh and Ramesh (2002) and Sinha *et al.* (1981).

Relatively higher doses of fertilizer application at the rate of $N_{90}P_{60}K_{30}$, integrated treatment $N_{60}P_{40}K_{20}$ + 5 t FYM/ha or FYM alone applied treatment (10 t FYM/ha) resulted higher number of primary and secondary branches per plant and stem and branch diameter. The increase in number of primary and secondary branches may be attributed due to enhanced vegetative growth, increased cell division and meristematic cell elongation in auxiliary buds which in turn trigged the various activities and increased the supply of photosynthates under adequate nutrient availability. As a result increased lateral growth is found to occur due to arrest of apical dominance (Torry, 1950). The response of FYM application alone or in combination with inorganic fertilizer can be attributed due to better nutrient availability, proper absorption and assimilation in addition to favorable effect on physical and biological properties of soil resulting in increased stem and branch diameter. Such favorable effect of FYM alone or in combination with NPK and higher doses of nutrients had been reported earlier by different workers in various medicinal plants *viz.* Kedia and Kasera (2006) on *Phyllanthus fraternus*, Chaughan and Nautiyal (2005) on *Nardostachys jatamansi*, Shrivastava and Jha (2002) on *Andrographis paniculata* and Harinkhede *et al.* (2001) on *Plumbago zeylanica* cultivation.

5.1.2 Effect on dry matter production

(a) Spacing

The dry matter production per plant of *Eclipta prostrata* L. gradually increased with every increase in spacing from 25 x 25 cm to 30 x 30 cm than the closest spacing (20 x 20 cm) at all the growth stages except the vegetative stage. At vegetative stage, all the spacing treatments remained statistically similar in dry matter production. At this stage competition of required inputs remained very less due to low rate of growth and development. Accumulation of dry weight is directly related to fresh weight production. Marked increase in fresh weight might be attributed due to enhanced vegetative growth induced by availability of more nutrients, light and water to the plant at wider spacing. Plants with luxuriant growth brought about increase dry weight of plant, proportionately and resulted into more dry matter production at flowering and maturity stage. Patidar *et al.* (1990) also reported the similar trend of results.

(b) Sources and doses of nutrients

The data on dry matter production revealed that the integrated use of organic manure and inorganic fertilizer ($N_{60}P_{40}K_{20}$ + 5 t FYM/ha) and highest dose of N, P and K ($N_{90}P_{60}$ K_{30}) produced maximum dry matter. Concurrently it was followed by FYM alone (10 t FYM/ha) and $N_{60}P_{40}K_{20}$ treatment. The increased dry matter production due to integrated treatment with higher doses of nutrient not only increased availability of N, P, K and other micronutrients but instrumental in making available from farmyard manure in proper amount. Higher availability of essential nutrients produced luxuriant growth with increased photosynthesis and translocation of photosynthates to required site and thus increased the dry matter content. The significant effect of nutrient management on dry matter production was also reported by Balakumbahan *et al.* (2005) on *Phyllanthus amarus* and Singh and Kewalanand (1981) in *Mentha citrate* cultivation.

5.1.3 Effect on leaf area index

(a) Spacing

Though the individual leaf area was not significantly influenced by different spacing treatments yet the wider spacing treatment found associated with higher leaf area index than closer spacing in *Eclipta prostrata* L. cultivation. The increased leaf area index in wider spacing treatment might be due to prolific sprouting and stimulated growth of auxillary shoots and better population dynamics providing more room for canopy coverage. The significant increase in leaf area index due to higher spacing was also reported by Gnanavel and Kathiresan (2006) on *Coleus aromaticus* cultivation.

(b) Sources and doses of nutrients

Relatively higher doses of N, P, K applied either through FYM alone or in combination with inorganic fertilizer treatment produced significantly more leaf area and leaf area index than the lowest rate of N, P and K ($N_{30}P_{20}K_{10}$) at all the growth stages of *Eclipta prostrata* L. Increase availability of adequate nutrients under higher rate of fertilizer incorporation may be attributed as the main factor for production of higher primary and secondary branches and leading to increased production of leaves as well as leaf area index at higher doses of nutrient applied treatments irrespective of sources. This confirmed the findings of Sinclair (1990).

5.1.4 Effect on flowers and heads

(a) Spacing

The number of flowers at flowering stage and heads at maturity stage was found statistically higher under wider spacing than closer spacing, which might be due to superior performance of vegetative characters in wider spacing of bhringaraj cultivation. This result is also in conformity with the findings of Singh and Chauhan (2001).

(b) Sources and doses of nutrients

Production of flowers and heads coinciding flowering and heading stage markedly increased due to incorporation of higher rates of N, P and K either through fertilizer or integrated with organic manure over low rates of applications. Adequate amount of available nutrients through out the plant growth period without any nutrient stress brought about proper growth and development of plant in respect of plant height, number of branches, high leaf area index and thus proved responsible for higher production of number of flowers and heads per plant. The significant effect of nutrient management treatment on number of flower and head has been reported by Kavitha and Vadivel (2006) and Sudheendra *et al.* (1993a.) on *Mucuna pruriens* and celery cultivation respectively.

5.1.5 Effect on herb yield

(a) Spacing

The fresh and dry herb yield per hectare gradually increased with increase in spacing. The 30 x 30 cm and 25 x 25 cm spacing treatment resulted superior fresh and dry herb yield to the closest spacing 20 x 20 cm, mainly because of proper vegetative growth and development as well as reproduction and yield contributing characters under wider spacing. The better availability of resources like solar radiation, light intensity, soil nutrient, water, etc. under wider spacing treatments increased the growth and yield components and ultimately herb yield of *Eclipta prostrata*. The increase in yield due to wider spacing was earlier reported by Singh *et al.* (2002 a) on vetiver cultivation, Sarma and Kanjilal, (2000) on patchouli and Gosh *et al.* (2008) on elephant foot yam cultivation.

(b) Sources and doses of nutrients

Increasing rates of nutrient incorporation proved instrumental in increasing herb yield. All the nutrient applied treatments irrespective of sources produced higher fresh herb yield, most probably due to superior growth and development of plants under higher doses of nutrient application. It is well established that nitrogen is a main constituent of chlorophyll and involved in various important metabolic activities like photosynthesis and protein synthesis bringing about increased vegetative growth along with fresh yield production at higher nutrient concentration (Potti and Arora, 1986). Higher doses of phosphorus played key role in root development, energy transformation and many other metabolic processes of plants. Its ample availability at successive growth stages perhaps resulted in greater synthesis and translocation of photosynthates (Tisdale *et al.*, 1995). Adequate availability of photosynthates as well as energy conservation is one well known factors directly related to higher biomass yield of crop (Hedge and Srinivas, 1989). Similar trend of results were also obtained by Yadav *et al.* (2003) and Rai *et al.* (2002).

Similar to fresh weight production, dry herb yield also markedly increased due to increasing rate of nutrient application. Application of $N_{60}P_{40}K_{20}$+5 t FYM/ha and $N_{90}P_{60}K_{30}$ produced the highest dry herb yield over all other nutrient treatments. Integrated nutrient management proved much effective than fertilizer alone in increasing higher dry matter production. Addition of organic manure lower downed the soil bulk density, improved soil aggregation and aeration by adding organic amendments and various humic fractions (Kadalli *et al.* 2000) which increased the soil microbial and enzymatic activity due to combination of farmyard manure with inorganic fertilizer (Mukharjee *et al.*, 2000). Rahman *et al.* (2003) also reported the significant increase in dry herb yield due to improved nutrient management practices on *Mentha arvensis* cultivation.

5.1.6 Effect on nutrient content in plant

(a) Spacing

The results of experiment showed that nitrogen, phosphorus, potash and organic carbon content in *Eclipta prostrata* failed to show marked variation irrespective of different spacing treatments mainly because of lack of over crowding and minimum competition for nutrients.

(b) Sources of nutrients

All the nutrient management treatments irrespective of sources markedly increased the content of nitrogen, phosphorus, potash and organic carbon content in plant over control. This might be attributed to better availability of plant nutrients in soil and their better utilization by the crop. However, integrated nutrient management showed better effectivity over fertilizer alone. Among the different nutrient management treatments, incorporation of $N_{60}P_{40}K_{20}$ + 5 t FYM/ha, 10 t FYM/ha and $N_{90}P_{60}K_{30}$ induced improvement on N, P and K content in *Eclipta prostrata* over $N_{60}P_{40}K_{20}$ and $N_{30}P_{20}K_{10}$. Under low soil fertility increased level of applied nutrient through organic or inorganic sources resulted in increased absorption of elements by plant, which in turn resulted in higher concentration of N, P and K in plant biomass. Meenakshi *et al.* (2001) also reported the similar trend of results.

Regarding plant organic carbon content,it was observed that FYM application either alone or in combination with inorganic fertilizer, recorded the highest organic carbon content over all chemical fertilizer applied treatments, probably due to addition of more carbonaceous materials through application of FYM in soil.

5.1.7 Effect on nutrient uptake by plant

(a) Spacing

Uptake of nitrogen, phosphorus and potash markedly increased at 25 x 25 cm spacing followed by 30 x 30 cm. Lower spacing of 20 x 20 cm proved least effective. With increased plant population in closer spacing,growth and development of plant reduced, causing relatively low nutrient uptake. Relative increase in plant population due to 25 x 25 cm spacing than 30 x 30 cm increased the herb yield and thus resulted into higher nitrogen, phosphorus and potash uptake from soil. This finding is also in conformity with the findings of Kandiannan and Chandaragiri (2008).

(b) Sources of nutrients

On the basis of equal amount of nutrient applied through organic source as well as integrated with fertilizers proved much effective in increasing the uptake of N, P and K. Accordingly application of $N_{60}P_{40}K_{20}$+ 5 t FYM/ha as well as 10 t FYM/ha showed marked increase in uptake of nitrogen over other treatments. Similarly $N_{60}P_{40}K_{20}$+ 5 t FYM/ha showed highest uptake of phosphorus and potash followed by 10 t FYM/ha and $N_{90}P_{60}K_{30}$. Higher nitrogen uptake resulted in integrated treatment due to stimulated microbial activity and improved root growth on account of favourable soil physico-chemical properties created by farm yard manure (Anandswarup *et al.*, 1998). Phosphorus uptake was increased under this treatment because organic manure reduced the capacity of soil mineral to fix phosphorus and increased its availability due to its release from organic sources. Increase in uptake of nutrient might be the outcome of increased availability of nutrients to plants in addition to decomposition of farmyard manure. These results are in conformity with the findings of Pratibha and Konwar (2005), Sadanandan and Hamza (1998) and Kattimani *et al*. (2001) who reported the increase in nutrient content and their uptake on indigo, turmeric and japanese mint cultivation, respectively.

5.1.8 Effect on quality parameters

5.1.8.1 Effect on alkaloid content and alkaloid yield

(a) Spacing

All spacing failed to cause marked variation on total alkaloid content of *Eclipta prostrata* L. All spacing *i.e.* 20 x 20 cm, 25 x 25 cm and 30 x 30 cm remained *on par* to each other. However, total alkaloid yield increased under wider spacing 25 x 25 cm and 30 x 30 cm as compared to the closest spacing 20 x 20 cm. This might be due to higher dry herb yield in wider spacing, which confirms the findings of Patel *et al.* (2003) on ashwagandha cultivation.

(b) Sources of nutrients

All the nutrient management treatments proved superior in respect of alkaloid content and total alkaloid yield of *Eclipta prostrata* L. to control. Among the nutrient management treatments, the alkaloid content did not vary significantly either due to organic or inorganic fertilizer alone, or in combination indicating their ineffectivity on alkaloid content. No significant effect of fertilizer or integrated nutrient management on alkaloid content was also reported by Balakumbahan *et al*. (2005) and Puttanna *et al.* (2006) on *Phyllanthus amarus* and *Centella asiatica* cultivation respectively. Though the nutrient management treatments proved *at par* effect on their alkaloid content but the treatment $N_{60}P_{40}K_{20}$ + 5 t FYM/ha and 10 t FYM/ha recorded the highest alkaloid yield followed by $N_{90}P_{60}K_{30}$ and $N_{60}P_{40}K_{20}$. This might be due to superior dry herb yield under FYM alone or in combination to fertilizer application plots. This confirmed the findings of Jana and Varghese (1996). Organic or inorganic sources of nutrient were found equally efficient not only in higher crop production but also in respect of quality parameters which help to get higher market price (Sanwal *et al*., 2007).

5.1.8.2 Effect on sugar content

(a) Spacing

The data on total sugar, reducing and non reducing sugar content of *Eclipta prostrata* L. revealed that all the spacing treatments failed to bring any significant differences among themselves. This finding is in line with the findings of Sarma and Kanjilal (2000).

(b) Sources of nutrients

All the nutrient management treatments recorded superior result on total sugar and reducing sugar content in *Eclipta prostrata* L. over control, indicating positive effect of fertilizer and FYM on sugar content. Notwithstanding, all the treatments remained statistically *at par* on non-reducing sugar content. FYM application treatments either alone @ 10 t FYM/ha or in combination with fertilizer @ 5 t FYM/ha with $N_{60}P_{40}K_{20}$ recorded statistically higher total sugar content than only fertilizer application treatments irrespective of doses. This might be due to presence of other micro nutrients in FYM including carbon, which is an important component of sugar, played important role in increasing total sugar content. All the nutrient management treatments showed the similar result on reducing sugar content.

5.1.9 Effect on Soil Parameters

5.1.9.1 Effect on available soil nitrogen, phosphorus and potash

(a) Spacing

The result of the experiment showed higher available soil nitrogen both in the closest and widest spacing treatments than medium spacing of 25 x 25 cm which might be due to more uptake of soil nitrogen in this treatment. On the other hand, the value on available P_2O_5 and K_2O revealed that all the spacing remained statistically *at par* and failed to produce any significant differences.

(b) Sources of nutrients

Soil parameters *viz.* available soil nitrogen, phosphorus and potash increased at all nutrient management treatments irrespective of sources over control, mainly due to better availability of plant nutrients in soil through application of fertilizer or FYM. Puttanna *et al.* (2006) also reported the similar results on soil parameters due to nutrient management treatment over control after harvesting of *Centella asiatica*.

Application of FYM either alone or in combination with NPK resulted in the highest available nitrogen in soil, which proved superior to other inorganic fertilizer treatments. It might be due to application of organics alone or in combination with inorganic which after subsequent decomposition resulted in gradual build up in available nitrogen on account of direct addition of nitrogen. Presence of organic sources increased the multiplication of soil microorganism which proved advantageous in mineralization of organically bound nitrogen to inorganic form (Mathur, 1997). Application of organic manure also favoured the retention and accumulation of exchangeable cations in soil exchange complex. Inorganic fertilization could not contribute much in the build-up of available nutrient pool of soil because of their poor retention capacity.

It was also recorded that application of organics showed higher availability of phosphorous and potassium over direct addition through inorganic sources. This might be due to the fact that the organic materials form a cover on sesquioxides, reducing the phosphate fixing capacity of soil and solubilization of insoluble phosphorus fractions resulting into release of more available phosphorus. Higher availability of potash in soil due to organic could be ascribed to addition of potash to the available pool of soil, besides reduction in potash fixation and release of potash due to interaction of organic matter and clay (Sanwal *et al.*, 2007).

5.1.9.2 Effect on soil organic carbon content

(a) Spacing

The results showed no significant effect on soil organic carbon content due to different spacing treatments. Content of soil organic carbon remained almost same in all the three spacing.

(b) Sources of nutrients

All the sources of nutrient irrespective of various rates, recorded marked variation on soil organic carbon content over control. Increasing rates of nutrients increased the content of soil organic carbon which is mainly due to better availability and higher amount of organic components in soil through application of fertilizer or FYM. Incorporation of organic sources *i.e.* FYM either alone or in combination with fertilizer produced higher soil organic carbon content in comparison to inorganic fertilizer alone. This might be due to addition of more carbonaceous materials in soil through farmyard manure. Gupta *et al.* (1999) and Kalita and Deka (2001) also reported significant increase in organic carbon content of soil due to application of different organic sources of nutrient in comparison to chemical fertilizer.

5.1.10 Effect on Economic indices

(a) Spacing

The closest spacing (20 x 20 cm) recorded the highest cost of cultivation which might be due to increase in labour cost for transplanting and other intercultural operations, as more number of seedlings were uprooted and transplanted. In the widest spacing treatment (30 x 30 cm), low cultivation cost was recorded due to low labour cost. The maximum gross income and net income was recorded in the treatment 25 x 25 cm spacing, which might be due to more dry herb yield in this treatment. Though 25 x 25 cm spacing recorded the highest gross and net income but it failed to show the highest benefit-cost ratio. The treatment 30 x 30 cm spacing recorded the highest benefit-cost ratio which might be due to relatively lower labour required coupled with almost similar net income associated with this treatment.

(b) Sources of nutrients

The results on economic attributes revealed that increased doses of inorganic fertilizer treatments recorded the highest cost of cultivation which might be due to higher price of chemical fertilizers. The integration of NPK and FYM treatment (F_5– $N_{60}P_{40}K_{20}$ + 5 t FYM/ha) recorded the maximum gross return and net income followed by the highest dose of NPK applied treatment (F_3– $N_{90}P_{60}K_{30}$). Statistically higher dry herb yield in these two treatments is responsible for maximum gross return and net income. The treatment F_5– $N_{60}P_{40}K_{20}$ + 5 t FYM/ha recorded the maximum benefit-cost ratio followed by the treatment FYM 10t/ha, which might have more dry herb yield and relatively low cost of cultivation.

5. 2 Effect of transplanting time and harvesting stage

5.2.1 Effect on growth

(a) Transplanting time

Planting on 15th June brought about significant improvement in all growth attributes *viz.* plant height, primary branches and secondary branches, stem diameter, leaf number and number of roots per plant during both the years over other times of transplanting closely followed by 15th May transplanting, which also recorded significant superiority over 15th July and 15th April transplanting. Better performance of crop due to 15th June transplanting may be attributed due to favourable climatic conditions and equitable distribution of other parameters throughout the growth period. These results are in congruity with the findings of Bhatt *et al.* (2007), Maurya (1990), Sharma and Prasad (1990) and Mahajan *et al.* (1979). The 15th June and 15th May transplanting treatments were *at par* on branch diameter and root length but proved statistical superiority over 15th July and 15th April transplanting. The climate required pertaining to branch diameter and root length probably remained similar, which resulted *at par branch* diameter and root length in June and May transplanting (Kandiannan and Chandaragiri, 2008).

(b) Harvesting stage

Different stages of crop harvesting also showed marked effect on various growth attributes. It was observed that the growth parameters like plant height and number of primary braches proved superior when harvested at maturity stage followed by harvesting at 50 % flowering stage. But, both showed their significant superiority over harvesting at vegetative stage. Notwithstanding, harvesting at maturity stage as well as 50 % flowering stage proved similar on production of number of secondary branches, stem and branch diameter, number of roots and root length but proved superior to harvesting at vegetative stage. The increase in growth parameters due to harvesting at 50 % flowering and maturity stages might be due to well-known fact of continuous increase habit of growth of crop up to the maturity stage. Accordingly harvesting at 50% flowering stage recorded the highest number of leaves followed by harvesting at maturity stage. This might be due to senescence of leaves at maturity stage, coupled with initiation of complete leaves at 50% flowering stage than vegetative stage.

5.2.2 Effect on dry matter production

(a) Transplanting Time

The highest dry matter production of plant was recorded due to 15th June transplanting in both the years 2005-06 and 2006-07 and proved statistical superiority over other transplanting treatments followed by 15th May. 15th June transplanting produced highest dry matter producing attributes *viz.* fresh weight and dry weight of plant, which is responsible for increased dry matter production in this treatment. This result confirmed the findings of Agarwal *et al.* (2004) and Kahar *et al.* (1991).

(b) Harvesting stage

Harvesting at 50 % flowering stage recorded the highest fresh weight, dry weight and dry matter production per plant and proved superior to the other harvesting treatments. The peak growth and development of plant with highest accumulation of plant nutrients and other chemical constituents at 50% flowering stage might be responsible for highest dry matter production in the same stage. Singh *et al.* (2004) also reported the superior results on dry matter production at flowering stage on Indian basil cultivation.

5.2.3 Effect on leaf area index

(a) Transplanting Time

Regarding individual leaf area, all the treatments irrespective of transplanting time showed statistically similar values, which indicated no effect of different transplanting times on individual leaf area. However, the highest leaf area index was recorded under ST_3- 15th June and ST_2- 15th May transplanting treatments, which were superior in comparison to other two transplanting treatments. On account of this fact more number of leaves and total leaf area in May and June transplanting plots were produced. The findings of Solanki and Shaktawat (1999) are also in the same line.

(b) Harvesting stage

All the harvesting stages produced almost similar individual leaf area thus showed their ineffectivity on leaf size. However, maximum total leaf area and highest ground cover were recorded in the treatment H_2- harvesting at 50 % flowering stage which proved superior to other treatments followed by H_3 – harvesting at maturity stage. Full crop growth with maximum number of leaves at 50 % flowering stage was responsible for increase in total leaf area and ground cover. Similarly the highest leaf area index was observed due to harvesting at 50 % flowering stage that was *at par* with harvesting at maturity stage but proved superior to harvesting at vegetative stage. Though individual leaf area was similar at all harvesting stages but leaf area index increased at 50% flowering stage which might be due to highest total leaf area.

5.2.4 Effect on herb yield

(a) Transplanting Time

Transplanting of seedlings on 15th June recorded the highest fresh and dry herb yield and proved statistical superiority over other transplanting times followed by 15th May transplanting in both the successive years. Superior results of almost all the growth and yield attributing parameters due to 15th June transplanting might be responsible for highest fresh and dry herb yield in the same treatment. Prevalence of favourable weather conditions in June transplanting coupled with higher temperature as well as hotter and drier climatic condition with heavy and even distribution of rain during the growth period might have helped to increase growth and development and ultimately herb yield. Similar trend of results were also reported by Singh *et al.* (2002 b.) and Randhawa *et al.* (1994) on green onion and french basil cultivation respectively.

(b) Harvesting stage

Harvesting at 50 % flowering stage recorded the maximum fresh and dry herb yield followed by harvesting at maturity stage and both proved statistically superior to harvesting at vegetative stage. Almost all the growth characteristics of the plants *viz.* number of leaves, active stems and branches, higher leaf area index and dry matter production were associated with harvesting at 50 % flowering stage. Thus induced the highest fresh and dry herb yield in this treatment than early and delay harvesting stages. The significant increase in herb yield at 50 % flowering stage was also reported by many scientists (Sharma *et al.*, 2002; Gupta and Shahi, 1999 and Pareek *et al.*, 1980).

5.2.5 Effect on nutrient content in plant

(a) Transplanting Time

It was observed that nitrogen, phosphorus, potash and organic carbon content in *Eclipta prostrata* L. were recorded highest due to 15th June transplanting followed by 15th May and proved superior to 15th July and 15th April transplanting. As the growth and development and production of photosynthates was more in 15th June transplanting treatment, therefore, it leads to uptake more nutrients from soil and more concentration of plant nutrients were more in this treatment. This finding is in the same line with the findings of Kandiannan and Chandaragiri (2008).

(b) Harvesting stage

Different harvesting stages showed significant effect on nitrogen, phosphorus, potash and plant organic carbon content in plant. The highest plant nitrogen, phosphorus, potash and organic carbon content were recorded due to harvesting at 50 % flowering stage. Absorption of more plant nutrients in this stage might be responsible for increased nutrient content in plant. Moreover, the accumulation of these plant nutrients and other chemical constituents were more inside the plant at 50% flowering stage than maturity or vegetative stage. The significant increase of plant nutrients at 50 per cent flowering stage were also reported by many other scientists (Pratibha and Konwar, 2005 and Ram *et al*. 2002).

5.2.6 Effect on nutrient uptake from soil

(a) Transplanting Time

The uptake of nitrogen, phosphorus and potash by plant was recorded more due to 15th June transplanting followed by 15th May. All the growth parameters were found superior in 15th June transplanting treatment, indicating more need of nutrients to fulfill their requirement for more growth and development. Therefore, it leads to uptake more nutrients from soil. Kandiannan and Chandaragiri (2008) also reported similar tend of result.

(b) Harvesting stage

Harvesting at 50 % flowering stage recorded significantly more uptake of nitrogen, phosphorus and potash from soil. Due to maximum growth characteristics associated with 50 % harvesting stage coupled with higher leaf area index and more dry matter production increased the uptake of more nutrients to fulfill the need of maximum nutrient requirement whereas, at vegetative and maturity stage the nutrient requirement remained low. Pareek *et al.* (1980) reported significant increase in uptake of nitrogen, phosphorus and potash from soil at flowering stage of crop.

5.2.7 Effect on quality parameters

5.2.7. 1 Effect on alkaloid content and alkaloid yield

(a) Transplanting Time

All the treatments irrespective of different transplanting times failed to bring significant variations on percentage of total alkaloid content of *Eclipta prostrata*, indicating no effect of transplanting time on alkaloid concentration. Sarma and Kanjilal (2000) also reported no significant effect of different sowing times on alkaloid concentration on patchouli cultivation. Though all treatments were similar in alkaloid content but 15th June transplanting proved superior result on alkaloid yield followed by 15th May transplanting. Production of superior dry herb yield in this treatment was responsible for higher alkaloid yield. This is in conformity with the findings of Minami *et al.* (1997) and Reda *et al.* (1978). The influences of environmental factors on herb and quality aspects of medicinal and aromatic plants were also well documented earlier (Singh *et al.*, 1991; Burbott and Loomis, 1967).

(b) Harvesting stage

The alkaloid content in *Eclipta prostrata* was significantly influenced by different harvesting stages. Harvesting at 50 % flowering stage produced the highest alkaloid content that might be due to presence of more nitrogen, carbon and other chemical constituents at this stage, which are important components of alkaloid. Diversion of photosynthates to seed formation and fall of older leaves in absence of energy support due to the mobilization of photosynthates from lower leaves to meristamatic parts were responsible for lower alkaloid content at maturity stage. This result is in conformity with findings of Sharma *et al.* (2002), who reported significant higher content of alkaloid at flowering stage. As no alkaloid synthesis was held in leaves upto one month of age coupled with variation in alkaloid content with age in different plant parts proved lower alkaloid content at vegetative stage (Pachori, 1995).

Similarly, harvesting at 50 % flowering stage proved statistical superiority on alkaloid yield over other stages. Maximum alkaloid content along with production of highest dry herb yield at 50 % flowering stage was responsible for increased alkaloid yield in this stage. Baraiya *et al.* (2005) also reported significant increase of alkaloid yield with increasing age of plant up to flowering stage.

5.2.7. 2 Effect on sugar content

(a) Transplanting Time

All the transplanting times showed similar results on total sugar and non-reducing sugar content. However, 15th June and 15th May transplanting proved statistical superiority on reducing sugar over 15th July and 15th April transplanting. This may be due to production of more photosynthates in June transplanting plant.

(b) Harvesting stage

Harvesting at 50 % flowering stage recorded the highest total sugar, reducing sugar and non reducing sugar and proved statistical superiority over other harvesting stages. Production of more plant organic carbon which is an important component of carbohydrate along with production of more photosyntates and dry herb yield due to harvesting at 50% flowering stage might be the possible reasons for higher sugar content at this stage. Moreover, fall of carbohydrate after flowering stage due to ageing of the leaf and depletion of the endogenous growth substances of the plant were responsible for lower sugar content at maturity stage. Increased carbohydrate production from one stage to another up to flowering stage and then gradual fall of carbohydrate concentration in crop were recorded by Saimbhi and Nandapuri (1981), Singh *et al.* (1973) and Davlin (1975).

5.2.8 Effect on Soil properties

5.2.8.1 Effect on available soil nitrogen, phosphorous and potash

(a) Transplanting Time

Highest available soil nitrogen, phosphorus and potash were recorded due to 15^{th} April transplanting proved statistically *at par* with 15^{th} July but both these two were superior over 15^{th} June and 15^{th} May transplanting. Less uptake of primary nutrients *viz.* N, P and K on 15^{th} April and 15^{th} July transplanted plots might be the possible reason for higher availability of these attributes in soil after harvesting of crop.

(b) Harvesting stage

Harvesting of crop at different stages showed significant effect on available soil nutrients. Harvesting at vegetative stage showed highest available soil nitrogen, phosphorus and potash than other harvesting stages. The crop was harvested after 33-35 DAT in harvesting at vegetative stage, whereas another one and two months required for harvesting at 50% flowering and maturity stages respectively, therefore, uptake of different plant nutrients reduced and resulted into more available nitrogen, phosphorus and potash in soil due to harvesting of crop at vegetative stage.

5.2.8.2 Effect on soil organic carbon

(a) Transplanting Time

All the transplanting times showed statistically similar organic carbon content in soil after harvesting of crop which indicates no effect of different transplanting times on soil organic carbon content.

(b) Harvesting stage

The treatment H_1- harvesting at vegetative stage showed maximum soil organic carbon than harvesting at 50% flowering and maturity stages. This might be due to less uptake of organic carbon from soil for shorter growth period in harvesting at vegetative stage as compared to other two stages.

5.2.9 Economic indices

(a) Transplanting Time

Total cost of cultivation was similar in all the transplanting treatments, which might be due to involvement of equal input, labours and management practices. However, 15th June transplanting recorded the maximum gross return, net benefit and benefit cost ratio. Production of highest dry herb yield is responsible for higher economics in this treatment.

(b) Harvesting stage

Similar cost of cultivation was recorded irrespective of harvesting treatments, which might be due to involvement of equal inputs, labours and management practices. Though all the treatments were similar in total cost of cultivation but harvesting at 50 % flowering stage produced highest gross income, net benefit and benefit cost ratio. More production of dry herb yield in this treatment is responsible for higher economics as compared to harvesting at maturity and vegetative stage.

CHAPTER–VI

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

The investigation entitled "Development of Agrotechnologies for Domestication and Quality Aspect of Bhringaraj (*Eclipta prostrata* L.)" was carried out at the Research-cum-Experimental Farm, Department of Forestry, North Eastern Regional Institute of Science and Technology (NERIST), Nirjuli, Arunachal Pradesh during 2005-06 and 2006-07 to domesticate an important medicinal wild herb Bhringaraj (*Eclipta prostrata* L.) by developing its cultivation techniques mainly the optimum spacing, doses of nutrients with varying sources, time of transplanting and the optimum harvesting stage. To study the effect of different spacing, sources of nutrient with varying doses, transplanting time and different harvesting stages on growth and development, herb yield and quality aspect of Bhringaraj, two field experiments were conducted under split plot design with three replications. To find out the optimum spacing and doses of nutrient from various sources, the first experiment was laid out with three different spacings *viz.* S_1- 20 x 20 cm, S_2- 25 x 25 cm and S_3- 30 x 30 cm between row to row and plant to plant respectively considering as main plot and six different doses of nutrients *viz.* F_0 – $N_0P_0K_0$, F_1–$N_{30}P_{20}K_{10}$, F_2 – $N_{60}P_{40}K_{20}$, F_3– $N_{90}P_{60}K_{30}$, F_4– 10 t FYM/ha and F_5– $N_{60}P_{40}K_{20}$+ 5 t FYM/ha assigned to sub plot with total 18 treatment combinations and 54 number of plots.

The second experiment was conducted to find out the suitable time of transplanting and harvesting stages of *Eclipta prostrata* L, taking transplanting time as main factor with four different transplanting times *viz.* ST_1-15th April, ST_2-15th May, ST_3-15th June and ST_4-15th July transplanting treatments and harvesting stage as sub factor with three different harvesting stages *viz.* H_1- Vegetative stage, H_2-50 % flowering stage and H_3- Maturity stage with total of 12 treatment combinations and 36 plots.

The effect of different treatments of both the experiments on various parameters were recorded for the studies and summarized under the following heads.

I. Effect of spacing

A. Growth and herb yield

1. The different spacing treatments proved their significant effects on growth and yield attributes. Comparatively wider spacing significantly increased the growth characters of *Eclipta prostrata* L than closer spacing in both the year of cultivation. The treatment 30 x 30 cm and 25 x 25 cm spacing recorded statistically similar plant height, number of primary branches, number of leaves at all the three growth stages *viz.* vegetative, flowering and maturity stage, which recorded statistically superior to 20 x 20 cm spacing. Regarding number of secondary branches per plant, stem and branch diameter, number of root and root length, the treatments 30 x 30 cm and 25 x 25 cm spacing though remained *at par* but proved statistically superior to the closest spacing 20 x 20 cm at flowering and maturity stages. Whereas, at vegetative stage all the three spacing treatments were statistically *at par* on these attributes.
2. Comparatively wider spacing resulted into superior reproductive characters than closer spacing. The treatments 25 x 25 cm and 30 x 30 cm produced maximum number of flowers and heads at flowering and maturity stage respectively than the closest spacing of 20 x 20 cm.
3. Wider spacing recorded the highest dry matter production including fresh weight and dry weight per plant of *Eclipta prostrata* L than closer spacing. The treatments 30 x 30 cm and 25 x 25 cm spacing proved statistical superiority on fresh weight, dry weight and dry matter production over the closest spacing 20 x 20 cm at flowering and maturity stage. But at vegetative stage all the spacing treatments showed their similarity on these attributes.
4. All the spacing treatments showed statistical similarity on individual leaf area at all the three growth stages. However, wider spacing *i.e.* 30 x 30 cm and 25 x 25 cm recorded superior leaf area index to the closest spacing 20 x 20 cm at maturity and 50 % flowering stage. But at vegetative stage, among the different spacing treatments no significant variations could be established.
5. Comparatively wider spacing recorded higher fresh and dry herb yield than closer spacing. The treatments 25 x 25 cm and 30 x 30 cm spacing showed statistical similarity but proved superior in fresh and dry herb yield to the spacing 20 x 20 cm.

B. Nutrient content and its uptake

1. All the spacing treatments showed statistically similar on major nutrient content of *Eclipta prostrata* L. Nitrogen, phosphorus, potash and organic carbon content of plant proved statistically *at par* irrespective of different spacing.
2. Comparatively wider spacing resulted more uptake of major nutrients by plant from soil than closer spacing. The nitrogen, phosphorus and potash uptake remained similar in 25 x 25 cm and 30 x 30 cm spacing but proved superior to the closest spacing 20 x 20 cm.

C. Quality parameters

1. All the treatments pertaining to different spacing *viz.* 30 x 30 cm, 25 x 25 cm and 20 x 20 cm recorded statistically similar total alkaloid content in *Eclipta prostrata* L.
2. Regarding total alkaloid yield, relatively wider spacing produced more alkaloid yield than closer spacing. Though the treatments 30 x 30 cm and 25 x 25 cm spacing remained *at par* but proved statistical superiority over 20 x 20 cm spacing.
3. All the spacing treatments produced similar sugar content. The spacing 30 x 30 cm, 25 x 25 cm and 20 x 20 cm were statistically *at par* in production of total sugar, reducing sugar and non-reducing sugar.

D. Soil parameters

1. The widest (30 x 30 cm) and closest (20 x 20 cm) spacing produced statistically superior results on higher available soil nitrogen after harvesting of crop than medium (25 x 25 cm) spacing.
2. All the spacing treatments viz. 30 x 30 cm, 25 x 25 cm and 20 x 20 cm proved statistically similar in available phosphorus, potash and organic carbon content in soil after harvesting of crop.

E. Economics

1. The closest spacing 20 x 20 cm recorded the highest cost of cultivation (Rs. 9,099/ha) than relatively wider spacing followed by 25 x 25 cm (Rs. 8,989/ha). The lowest cost of cultivation (Rs. 8,879/ha) was recorded under the spacing 30 x 30 cm.

2. The highest gross income (Rs. 28,595/ha) was recorded due to 25 x 25 cm spacing, which was close to 30 x 30 cm spacing (Rs. 28,480/ha) and the lowest (Rs. 24,925/ha) was recorded in the closest spacing 20 x 20 cm.
3. The spacing 25 x 25 cm produced the maximum net return (Rs. 19,606/ha) which was very close to 30 x 30 cm spacing (Rs. 19,601/ha). The highest benefit cost ratio (2.21:1) was recorded in the treatment 30 x 30 cm spacing followed by 25 x 25 cm (2.18:1). The spacing 20 x 20 cm recorded the lowest values of all the economic indices.

II. Effect of nutrient management treatments

A. Growth and herb yield

1. All the nutrient application treatments irrespective of different sources and doses proved statistical superiority on growth characteristics over control *i.e.* no nutrient applied treatment at all the growth stages *viz.* vegetative, flowering and maturity stage in both the year 2005-06 and 2006-07.
2. Among the nutrient applied treatments, integration of FYM and chemical fertilizer, FYM alone and highest doses of fertilizer ($N_{90}P_{60}K_{30}$) treatments recorded the tallest plant height than lower doses of fertilizer at all the growth stages of *Eclipta prostrata* L. The treatments $N_{60}P_{40}K_{20}$ + 5 t FYM/ha, 10 t FYM/ha and $N_{90}P_{60}K_{30}$ remained statistically similar but proved superior on growth characteristics *viz.* number of primary and secondary branches, stem and branch diameter, number of leaves, number of roots and root length at flowering and maturity stages than other low fertilizer applied treatment *i.e.* $N_{60}P_{40}K_{20}$ and $N_{30}P_{20}K_{10}$. On the other hand at vegetative stage, the treatment $N_{90}P_{60}K_{30}$ and $N_{60}P_{40}K_{20}$ + 5 t FYM/ha recorded the highest primary branches, $N_{60}P_{40}K_{20}$ + 5 t FYM/ha and 10 t FYM/ha recorded the maximum secondary branches, $N_{60}P_{40}K_{20}$ + 5 t FYM/ha, 10 t FYM/ha and $N_{90}P_{60}K_{30}$ treatments produced highest stem diameter and number of leaves.
3. In case of reproductive characters, the treatment $N_{60}P_{40}K_{20}$+ 5 t FYM/ha, 10 t FYM/ha and $N_{90}P_{60}K_{30}$ though produced statistical similarity on number of flowers and heads at flowering and maturity stages respectively but proved statistical superiority over lower doses of fertilizer application treatments *viz.* $N_{60}P_{40}K_{20}$ and $N_{30}P_{20}K_{10}$.

4. Integration of $N_{60}P_{40}K_{20}$ + 5 t FYM/ha and highest doses of fertilizer ($N_{90}P_{60}K_{30}$) produced statistically similar dry matter and proved superior to other nutrient applied treatments at all the growth stages of the crop.
5. Incorporation of 5 t FYM/ha along with $N_{60}P_{40}K_{20}$ though produced highest leaf area and leaf area index but proved statistical similarity with other nutrient management treatment excluding $N_{30}P_{20}K_{10}$.
6. All the nutrient management treatments except $N_{30}P_{20}K_{10}$ produced statistically similar but proved superior in fresh herb yield over control. Notwithstanding, $N_{60}P_{40}K_{20}$+ 5 t FYM/ha and $N_{90}P_{60}K_{30}$ recorded statistically *at par* dry herb yield but produced superior results over $N_{60}P_{40}K_{20}$ and $N_{30}P_{20}K_{10}$ and only FYM applied treatment.

B. Nutrient content and its uptake

1. Major nutrient content *viz.* nitrogen, phosphorus, potash and organic carbon of *Eclipta prostrata* L. and uptake were recorded statistically superior in all the nutrient applied treatments over control.
2. The organic sources of nutrient either alone (10 t FYM/ha) or in combination with inorganic fertilizer ($N_{60}P_{40}K_{20}$ + 5 t FYM/ha) and the highest dose of fertilizer ($N_{90}P_{60}K_{30}$) showed higher nitrogen, phosphorus and potash content over lower doses of fertilizer application *viz.* $N_{60}P_{40}K_{20}$and $N_{30}P_{20}K_{10}$.
3. In case of plant organic carbon content, FYM applied treatments either alone or in combination with inorganic fertilizer was similar but proved superior to other chemical fertilizer applied treatments irrespective of doses.
4. Regarding uptake of plant nutrients the treatments $N_{60}P_{40}K_{20}$ + 5 t FYM/ha and 10 t FYM/ha produced statistically *at par* on nitrogen uptake from soil but proved superior to other nutrient applied treatments followed by $N_{90}P_{60}K_{30}$. On the other hand, plant phosphorus and potash uptake were highest in integrated treatment *i.e.* $N_{60}P_{40}K_{20}$ + 5 t FYM/ha and proved superior to the other nutrient applied treatments followed by 10 t FYM/ha.

C. Quality parameters

1. All the nutrient applied treatments recorded statistically superior total alkaloid content of plant, alkaloid yield and sugar content than control in both the cultivation years.

2. Among the nutrient applied treatments irrespective of sources and doses, no significant variations were recoded on total alkaloid content.
3. Regarding total alkaloid yield, FYM applied treatments either alone or in combination with fertilizer (10 t FYM/ha and $N_{60}P_{40}K_{20}$ + 5 t FYM/ha) showed maximum effectivity and superior result than other fertilizer applied treatments irrespective of doses.
4. The maximum total sugar was observed in the treatments $N_{60}P_{40}K_{20}$ + 5 t FYM/ha and 10 t FYM/ha, which were statistically similar but superior to the other chemical fertilizer application treatments *viz.* $N_{90}P_{60}K_{30}$, $N_{60}P_{40}K_{20}$ and $N_{30}P_{20}K_{10}$. All the nutrient applied treatments were statistically *at par* on reducing sugar content, while non-reducing sugar remained unaffected by all the treatments including control.

D. Soil parameters

1. All the nutrient management treatments were superior in soil parameters *viz.* available soil nitrogen, phosphorus, potash and soil organic carbon content over control *i.e.* no nutrient applied treatment after harvesting of the crop.
2. Among the nutrient management treatments, FYM applied treatments either alone (10 t FYM/ha) or in combination with chemical fertilizer ($N_{60}P_{40}K_{20}$ + 5 t FYM/ha) though remained similar on all soil parameters but both proved superior to other fertilizer applied treatments ($N_{90}P_{60}K_{30}$, $N_{60}P_{40}K_{20}$ and $N_{30}P_{20}K_{10}$).

E. Economics

1. The treatment $N_{90}P_{60}K_{30}$ recorded the highest cost of cultivation (Rs. 9,981/ha) followed by $N_{60}P_{40}K_{20}$ + 5 t FYM/ha (Rs. 9,539/ha) and the lowest cost of cultivation (Rs. 7,005/ha) was recorded in control treatment.
2. The highest gross income (Rs. 33,065/ha) and net income (Rs. 23,526/ha) was recorded due to $N_{60}P_{40}K_{20}$ + 5 t FYM/ha followed by $N_{90}P_{60}K_{30}$ (Gross income : Rs. 31,315/ha and net income: Rs. 21,334/ha)
3. Regarding per rupee investment $N_{60}P_{40}K_{20}$ + 5 t FYM/ha recorded the highest benefit-cost ratio (2.47:1) followed by 10 t FYM/ha as 2.44: 1 and the lowest per rupee investment 1.48: 1 was recorded in control ($N_0P_0K_0$).

III. Transplanting time

A. Growth and herb yield

1. The maximum growth characteristics *viz.* plant height, secondary branches, stem diameter, number of leaves and number of roots were recorded statistically superior due to 15th June transplanting followed by 15th May. 15th April and 15th July treatments were statistically similar and showed lowest values on these growth characters. Regarding number of primary branches 15th June transplanting recorded superior results followed by the 15th May and 15th April transplanting, where the later two showed statistically *at par* but proved superior to 15th July transplanting. 15th June and 15th May transplanting treatments produced statistically similar branch diameter and root length but proved superior to 15th July and 15th April transplanting.
2. The treatment 15th June transplanting recorded maximum and statistically superior fresh weight, dry weight and dry matter production per plant followed by 15th May transplanting. The treatments 15th April and 15th July transplanting were statistically similar on these attributes.
3. All the transplanting times of *Eclipta prostrata* produced no significant effect on individual leaf area. Regarding total leaf area and ground cover per plant 15th June transplanting proved superior to other time of transplanting followed by 15th May. Notwithstanding, 15th June and 15th May transplanting proved statistically *at par* on leaf area index but proved superior over other two similar treatments *viz.* 15th April and 15th July.
4. Regarding fresh and dry herb yield, 15th June transplanting treatment produced the highest and superior result over other transplanting times followed by 15th May transplanting. The other two treatments *viz.* 15th April and 15th July were statistically *at par* and produced lowest fresh and dry herb yield.

B. Nutrient content and its uptake

1. Nitrogen content of *Eclipta prostrata* L. recorded maximum on 15th June transplanting and proved superior to the other times of transplanting, where the remaining three treatments were statistically *at par*.
2. Regarding phosphorous and potash content, 15th June and 15th May transplanting treatments though remained similar but proved statistically superior to 15th July and 15th April transplanting treatments.

3. Plant organic carbon content was found maximum due to 15th June transplanting which was superior to other treatments followed by 15th May transplanting. 15th April and 15th July transplanting treatments were statistically similar and proved lower in organic carbon content.
4. Regarding uptake of nitrogen, phosphorus and potash from soil, the maximum uptake of nutrients were recorded due to 15th June transplanting and proved statistically superior to the other treatments followed by 15th May transplanting. The 15th April and 15th July transplanting treatments were found *at par* on these attributes.

C. Quality parameters

1. Different transplanting times failed to produce significant increase on total alkaloid content in plant during both the years.
2. The maximum total alkaloid yield was recorded on 15th June transplanting treatment followed by 15th May transplanting and proved superior to the treatments 15th July and 15th April transplanting.
3. All the transplanting treatments showed no variations on total sugar and non-reducing sugar content of *Eclipta prostrata* L.
4. Though 15th May and 15th June transplanting produced statistically *at par* reducing sugar, but proved superior to 15th July and 15th April transplanting, where the later two treatments were statically similar.

D. Soil parameters

1. After harvesting of crop the residual soil nitrogen, phosphorus and potash were found statistically similar due to 15th April and 15th July transplanting and showed statistical superiority over other treatments followed by 15th May transplanting treatment.
2. Regarding soil organic carbon content, all the treatments irrespective of transplanting time were statistically similar.

E. Economics

1. Total cost of cultivation (Rs. 8,985/ha) was similar in all the transplanting time treatments.
2. The maximum gross income (Rs. 53,560/ha), net income (Rs. 44,575/ha) and per rupee investment (4.96) were recorded due to 15th June transplanting

treatment followed by 15th May (Rs. 45,210/ha, Rs 36,225/ha and 4.03:1 as gross income, net income and benefit cost ratio, respectively).

IV. Harvesting stage

A. Growth and herb yield

1. Harvesting at maturity stage recorded the tallest plant height, maximum number of primary branches per plant and proved superior to the other harvesting stages followed by harvesting at 50 % flowering stage. The highest number of leaves was recorded due to harvesting at 50 % flowering stage which was superior to the other harvesting stages followed by harvesting at maturity stage. Though harvesting at 50 % flowering and maturity stages remained same on stem and branch diameter, number of secondary branches, number of roots and root length, but proved superior to harvesting at vegetative stage.
2. Harvesting at 50 % flowering stage produced maximum fresh weight, dry weight and dry matter production and proved statistically superior to the other treatments followed by harvesting at maturity stage.
3. All the harvesting stage treatments failed to bring significant variations on individual leaf area. Regarding total leaf area and ground cover per plant, harvesting at 50 % flowering stage recorded the superior results followed by harvesting at maturity stage. On the other hand, harvesting at 50 % flowering and maturity stages produced similar results on leaf area index but proved superior to harvesting at vegetative stage.
4. Harvesting at 50 % flowering stage recorded the highest fresh and dry herb yield and proved superior to the other harvesting stages followed by harvesting at maturity stage. The lowest fresh and dry herb yield was recorded due to harvesting at vegetative stage.

B. Nutrient content and its uptake

1. The major nutrient content of plant viz. nitrogen, phosphorous, potash and organic carbon were found maximum due to harvesting at 50 % flowering stage and proved superior to the other treatments followed by harvesting at maturity stage.

2. Harvesting at 50 % flowering stage recorded the highest and superior nitrogen, phosphorous and potash uptake from soil than other treatments followed by harvesting at maturity stage treatment.

C. Quality parameters

1. The treatment, harvesting at 50 % flowering stage recorded the maximum alkaloid content of *Eclipta prostrata* L and total alkaloid yield and proved superior to other harvesting stages followed by harvesting at maturity stage. The lowest alkaloid content and alkaloid yield was recorded due to harvesting at vegetative stage.
2. Regarding total and non reducing sugar content, the treatment harvesting at 50 % flowering stage recorded superior results followed by harvesting at maturity stage.
3. Harvesting at 50 % flowering stage recorded the superior result on reducing sugar content than other two statistically similar treatments *viz*. harvesting at maturity stage and vegetative stage.

D. Soil parameters

1. Regarding residual soil parameters *viz.* available soil nitrogen, potash and organic carbon, harvesting at vegetative stage showed the highest values on these parameters and proved superior to other harvesting stages. The treatments, harvesting at 50 % flowering stage and maturity stage remained statistically similar.
2. Harvesting at vegetative stage recorded maximum available soil phosphorus and proved statistically superior to other treatments followed by harvesting at maturity stage. The lowest available phosphorous was recorded due to harvesting at 50 % flowering stage.

E. Economics

1. Total cost of cultivation was similar (Rs. 8,985/ha) at all the harvesting stage treatments.
2. The maximum gross income (Rs. 56,155/ha), net income (Rs. 47,170/ha) and per rupee investment (5.25) was recorded due to harvesting at 50 % flowering stage followed by harvesting at maturity stage (gross income Rs. 44,660/ha, net income Rs. 35,675/ha. and per rupee investment 3.97).

CONCLUSION

The following conclusions may be drawn from the results of the investigations.

1. Cultivation of *Eclipta prostrata* L. at the spacing of 25 x 25 cm and 30 x 30 cm produced similar fresh and dry herb yield along with higher alkaloid yield, although from per rupee investment point of view the 30 x 30 cm spacing proved optimum for cultivation. In the areas where labour is available and cheap, the spacing 25 x 25 cm may be considered the most effective for commercial cultivation of the herb since gross income and net income is found highest in this treatment.
2. From the nutrient management point of view integration of organic sources of nutrients along with inorganic fertilizer @ 5 t/ha farmyard manure and 60:40:20 kg/ha N:P:K respectively proved the best in increasing herb yield, quality and economics.
3. Transplanting of seedlings in the mid June was found to be the optimum time for cultivation of *Eclipta prostrata* L. for higher herb and alkaloid yield along with more gross and net income and better return on per rupee investment.
4. 50 per cent flowering stage proved the best stage for harvesting of *Eclipta prostrata* L. and produced highest herb and alkaloid yield with better quality and more return from its cultivation.

CHAPTER – VII

BIBLIOGRAPHY

BIBLIOGRAPHY

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APPENDICES

Monthly weather parameters during the experimentation period 2005-06

Month	Temperature (°C)		Rain fall (mm)	Relative humidity (%)	Bright sun shine hour
	Minimum	Maximum			
Jan'05	21.0	11.0	54.0	75	102.24
Feb'05	22.6	15.0	100.8	77	60.30
March'05	23.0	18.0	213.3	81	28.36
April'05	26.6	19.9	154.8	80	110.48
May'05	27.9	21.5	357.4	84	89.54
June'05	30.9	25.2	399.0	85	106.36
July'05	31.1	25.7	505.2	86	113.24
Aug'05	30.5	26.1	760.2	76	165.24
Sep'05	30.8	21.6	90.8	81	150.48
Oct'05	32.5	24.8	218.8	76	165.24
Nov'05	26.7	15.9	19.6	72	163.00
Dec'05	24.8	10.1	6.0	68	183.12

APPENDIX-II

Monthly weather parameters during the experimentation period 2006

Month	Temperature (°C)		Rain fall (mm)	Relative humidity(%)	Bright sun shine hour
	Minimum	Maximum			
Jan'06	23.0	10.2	19.4	72	165.54
Feb'06	23.8	15.1	233.4	80	100.54
March'06	27.0	16.9	37.8	71	180.36
April'06	28.0	20.6	204.8	78	127.30
May'06	33.2	23.8	375.2	75	166.36
June'06	30.8	25.3	881.0	86	83.24
July'06	33.3	27.0	515.6	80	121.48
Aug'06	33.5	26.0	211.8	77	196.54
Sep'06	31.5	24.4	201.3	79	130.18
Oct'06	30.2	20.4	100.9	74	186.06
Nov'06	25.6	15.6	102.8	77	114.18
Dec'06	23.4	11.3	24.4	77	157.48

Important cultural practices in first experiment during 2005-06 and 2006-07

Sl. No.	Particulars of operation	Date of Operation	
		2005-06	2006-07
01	Preparation of nursery bed and application of well decomposed FYM	26.04.05 to 28.04.05	24.04.06 27.04.06
02	Final nursery bed preparation and sowing of seed	06.05.05	05.05.06
03	Weeding in the nursery bed	15.05.05 & 25.05.05	1305.06 & 24.05.06
04	Main field preparation	30.04.05	28.04.06
05	Final land preparation	26.05.05	26.05.06
06	Lay out of plots in the main field	28.05.05 & 29.05.05	27.05.06 & 28.05.06
07	Application of well decomposed farmyard manure (as per treatment)	29.05.05	28.05.06
08	Basal application fertilizer (as per treatment)	04.06.05	04.06.06
09	Transplanting of seedlings	05.06.05	05.06.06
10	Application of malathion dust surrounding the seedling	11.06.05	10.06.06
11	Gapfitlingofseedlings	14.0605	13.06.06
12	First weeding	25.06.05	24.06.06
13	Second weeding	18.07.05	18.07.06
14	Top dressing of urea as per treatment	21.07.05	21.07.06
15	Application of fungicide (Bavistin)	25.07.05	--
16	Harvesting	16.0805 & 17.0805	15.08.06 & 16.08.06

Important cultural practices on 15th April transplanting treatment

Sl. No.	Particulars of operation	Date of Operation	
		2005-06	2006-07
01	Preparation of nursery bed and application of well decomposed FYM	28.02.05	26.02.06
02	Final nursery bed preparation and sowing of seed	14.03.05	15.03.06
03	Main field preparation	01.03.05	28.02.06
04	Final land preparation	06.04.05	08.04.06
05	Lay out of plots in the main field	08.04.05 & 09.04.05	09.04.06 & 10.04.06
06	Basal application of fertilizer	14.04.05	14.04.06
07	Transplanting of seedlings	15.04.05	15.04.06
08	Application of malathion dust surrounding the seedling	19.04.05	18.04.06
09	Gap filling of seedlings	21.04.05	21.04.06
10	First weeding	03.05.05	05.05.06
11	Second weeding	26.05.05	28.05.06
12	Application of fungicide (Bavistin)	02.06.05	-------
13	Harvesting at vegetative stage (H_1)	19.05.05	20.05.06
14	Harvesting at 50 % flowering stage (H_2)	09.06.05	09.06.06
15	Harvesting at maturity stage (H_3)	30.06.05	02.07.06

Important cultural practices on 15th May transplanting treatment

Sl. No.	Particulars of operation	Date of Operation	
		2005-06	2006-07
01	Preparation of nursery bed and application of well decomposed FYM	26.03.05	25.03.06
02	Final nursery bed preparation and sowing of seed	14.04.05	14.04.06
03	Main field preparation	01.03.05	28.02.06
04	Lay out of plots in the main field	08.04.05 & 09.04.05	09.04.06 & 10.04.06
05	Final land preparation	07.05.05	08.05.06
06	Basal application of fertilizer	14.05.05	14.05.06
07	Transplanting of seedlings	15.05.05	15.05.06
08	Application of malathion dust surrounding the seedling	18.05.05	17.05.06
09	Gap filling of seedlings	21.05.05	20.05.06
10	First weeding	08.06.05	10.05.06
11	Second weeding	30.06.05	29.06.06
12	Harvesting at vegetative stage (H_1)	20.06.05	19.06.06
13	Harvesting at 50 % flowering stage (H_2)	10.07.05	11.07.06
14	Harvesting at maturity stage (H_3)	02.08.05	02.08.06

Important cultural practices on 15th June transplanting treatment

Sl. No.	Particulars of operation	Date of Operation	
		2005-06	2006-07
01	Preparation of nursery bed and application of well decomposed FYM	01.05.05	02.05.06
02	Final nursery bed preparation and sowing of seed	15.05.05	15.05.06
03	Main field preparation	01.03.05	28.02.06
04	Lay out of plots in the main field	08.04.05 & 09.04.05	09.04.06 & 10.04.06
05	Final land preparation	06.06.05	08.06.06
06	Basal application of fertilizer	14.06.05	14.06.06
07	Transplanting of seedlings	15.06.05	15.06.06
08	Application of malathion dust surrounding the seedling	18.06.05	17.06.06
09	Gap filling of seedlings	22.06.05	21.06.06
10	First weeding	06.07.05	07.07.06
11	Second weeding	28.07.05	29.07.06
12	Harvesting at vegetative stage (H_1)	19.07.05	20.07.06
13	Harvesting at 50 % flowering stage (H_2)	08.08.05	09.08.06
14	Harvesting at maturity stage (H_3)	01.09.05	31.08.06

Important cultural practices on 15th July transplanting treatment

Sl. No.	Particulars of operation	Date of Operation	
		2005-06	2006-07
01	Preparation of nursery bed and application of well decomposed FYM	03.06.05	05.06.06
02	Final nursery bed preparation and sowing of seed	14.06.05	15.06.06
03	Main field preparation	01.03.05	28.02.06
04	Lay out of plots in the main field	08.04.05 & 09.04.05	09.04.06 & 10.04.06
05	Final land preparation	06.07.05	08.07.06
06	Basal application of fertilizer	14.07.05	14.07.06
07	Uprooting and transplanting of seedlings	15.07.05	15.07.06
08	Application of malathion dust surrounding the seedling	19.07.05	17.07.06
09	Gap filling of seedlings	21.07.05	22.07.06
10	First weeding	07.08.05	09.08.06
11	Second weeding	28.08.05	29.08.06
12	Harvesting at vegetative stage (H_1)	19.08.05	19.08.06
13	Harvesting at 50 % flowering stage (H_2)	10.09.05	09.09.06
14	Harvesting at maturity stage (H_3)	30.09.05	30.09.06

APPENDIX-VIII

Cost of cultivation in details for spacing and sources of nutrients with varying doses (first) experiment

1. Common cost for all the experiments

Item		Unit/quantity	Rs./ha
A. Raising of seedlings			
a.	Nursery bed preparation	3 man days	165.00
b.	FYM	1 thela	40.00
c.	Seed collection and seed sowing	3 man days	110.00
d.	Uprooting of seedlings	3 man days	165.00
B. Main field preparation and input			
a.	Land preparation (Ploughing, harrowing leveling etc.		1000.00
b.	Fertilizer application	2 man days	110.00
c.	Gap filling	2 man days	110.00
d.	Weeding (Two times)	20 man days	1100.00
e.	Top dressing	2 man days	110.00
f.	Irrigation	4 man days	220.00
g.	Cost of plant protection chemicals		350.00
h.	Application of insecticides	3 man days	165.00
i.	Harvesting and transportation	18 man days	990.00
j.	Cleaning	10 man days	550.00
k.	Drying and begging	6 man days	330.00
l.	Miscellaneous expenditure		500.00
		Total (A+ B)	**6015.00**

Contd ....

2. i. Cost of fertilizer and FYM according to treatment

Treatment	Urea (Kg/ha)		SSP (Kg/ha)		MOP (Kg/ha)		FYM (t/ha)		Sum total (Rs./ha)
	Quantity	Price	Quantity	Price	Quantity	Price	Quantity	Price	
$F_0 - N_0P_0K_0$	0	0	0	0	0	0	0	0	0
$F_1 - N_{30}P_{20}K_{10}$	65.21	358.65	125.00	500.00	16.66	133.28	0	0	991.93
$F_2 - N_{60}P_{40}K_{20}$	130.43	717.37	250.00	1000.00	33.33	266.64	0	0	1984.01
$F_3 - N_{90}P_{60}K_{30}$	95.65	1076.08	375.00	1500.00	50.00	400.00	0	0	2976.00
F_4 – 10 t FYM/ha	0	0	0	0	0	0	10.00	1100.00	1100.00
$F_5 - N_{60}P_{40}K_{20}$ + 5 t FYM/ha	130.43	717.37	250.00	1000.00	33.33	266.64	5.00	550.00	2534.00

2. ii. Cost of transplanting

Treatment	Unit/quantity	Rs./ha
S_1 - 20 cm x 20 cm	20 Man days	1100.00
S_2 – 25 cm x 25 cm	18 Man days	990.00
S_3 – 30 cm x 30 cm	18 Man days	880.00

N.B.: Cost of input (Rs.) : Urea = 5.50/kg, SSP = 4.00/kg, MOP = 8.00/kg, FYM = 110.00/t. 1 man day = Rs. 55.00. Sale price of *Eclipta prostrata* Rs. 10.00/kg dry herb.

3. **Cost of cultivation in details for transplanting time and harvesting stage (Second) experiment**

Item		Unit/quantity	Rs/ha
A. Raising of seedlings			
a.	Nursery bed preparation	3 man days	165.00
b.	FYM	1 thela	40.00
c.	Seed collection and seed sowing	3 man days	110.00
d.	Uprooting of seedlings	3 man days	165.00
B. Main field preparation and input			
a.	Land preparation (Ploughing, harrowing leveling etc.		1000.00
b.	Fertilizers		
	i. Urea	130.43 kg	717.36
	ii. SSP	250.00 kg	1000.00
	iii. MOP	33.33	266.64
c.	Fertilizer application	2 man days	110.00
d.	Transplanting of seedlings	18 man days	990.00
c.	Gap filling	2 man days	110.00
d.	Weeding (Two times)	20 man days	1100.00
e.	Topdressing	2 man days	110.00
f.	Irrigation	4 man days	220.00
g.	Cost of plant protection (chemicals)		350.00
h.	Application of insecticides	3 man days	165.00
i.	Harvesting and transportation	18 man days	990.00
j.	Cleaning	10 man days	550.00
k.	Drying and begging	6 man days	330.00
l.	Miscellaneous expenditure		500.00
		Total (A+ B)	**8985.00**

NB: Cost of input (Rs.): Urea= 5.50/kg, SSP = 4.00/kg, MOP= 8.00/kg, FYM = 110.00/t, 1 man day= Rs. 55.00, Sale price of *Eclipta prostrata* Rs. 10.00/kg dry herb.

Analysis of variance (ANOVA) table for different parameters as affected by various treatments in 2005-06 and 2006-07 under spacing and sources of nutrient experiment.

Year →	2005-06					2006-07					
Source	**d.f.**	**S.S.**	**M.S.**	**F cal**	**F tab**	**Source**	**d.f.**	**S.S.**	**M.S.**	**F cal**	**F tab**
Plant height (cm) at vegetative stage											
Replication	2	3.29	1.64	4.54		Replication	2	0.94	0.47	1.15	
Spacing	2	14.10	7.05	19.48	6.94	Spacing	2	10.43	5.22	12.69	6.94
Error (A)	4	1.45	0.36			Error (A)	4	1.64	0.41		
Nutrient doses	5	464.86	92.97	45.87	2.53	Nutrient doses	5	479.03	95.81	38.87	2.53
Spacing x ND	10	20.06	2.01	0.99	2.18	Spacing x ND	10	23.34	2.33	0.95	2.18
Error (B)	30	60.80	2.03			Error (B)	30	73.95	2.47		
Plant height (cm) at flowering stage											
Replication	2	94.89	47.45	15.88		Replication	2	97.98	48.99	9.54	
Spacing	2	141.91	70.95	23.75	6.94	Spacing	2	153.34	76.67	14.93	6.94
Error (A)	4	11.95	2.99			Error (A)	4	20.54	5.13		
Nutrient doses	5	836.06	167.21	121.56	2.53	Nutrient doses	5	842.22	168.44	113.21	2.53
Spacing x ND	10	10.47	1.05	0.76	2.18	Spacing x ND	10	10.48	1.05	0.70	2.18
Error (B)	30	41.27	1.38			Error (B)	30	44.64	1.49		
Plant height (cm) at maturity stage											
Replication	2	97.86	48.93	16.94		Replication	2	138.59	69.29	28.55	
Spacing	2	255.49	127.75	44.22	6.94	Spacing	2	253.39	126.69	52.20	6.94
Error (A)	4	11.55	2.89			Error (A)	4	9.71	2.43		
Nutrient doses	5	843.98	168.80	107.85	2.53	Nutrient doses	5	850.73	170.15	130.39	2.53
Spacing x ND	10	15.96	1.60	1.02	2.18	Spacing x ND	10	14.77	1.48	1.13	2.18
Error (B)	30	46.95	1.57			Error (B)	30	39.15	1.30		

N D - Nutrient doses, d.f. - degree of freedom, S.S. - Sum of squares, MS - Mean squares, F cal - F calculated value, F tab - F tabulated value

Appendix - IX Cont....

Number of primary branches/plant at vegetative stage

Year →		2005-06						2006-07			
Source	d.f.	S.S.	M.S.	F cal	F tab	Source	d.f.	S.S.	M.S.	F cal	F tab
Replication	2	0.58	0.29	3.90		Replication	2	0.27	0.13	0.79	
Spacing	2	4.59	2.30	30.77	6.94	Spacing	2	6.14	3.07	18.22	6.94
Error (A)	4	0.30	0.07			Error (A)	4	0.67	0.17		
Nutrient doses	5	64.77	12.95	91.52	2.53	Nutrient doses	5	64.95	12.99	57.60	2.53
Spacing x ND	10	1.01	0.10	0.71	2.18	Spacing x ND	10	1.10	0.11	0.49	2.18
Error (B)	30	4.25	0.14			Error (B)	30	6.76	0.23		

Number of primary branches/plant at flowering stage

Source	d.f.	S.S.	M.S.	F cal	F tab	Source	d.f.	S.S.	M.S.	F cal	F tab
Replication	2	1.59	0.79	0.28		Replication	2	0.89	0.45	0.17	
Spacing	2	81.50	40.75	14.43	6.94	Spacing	2	78.96	39.48	15.44	6.94
Error (A)	4	11.30	2.82			Error (A)	4	10.23	2.56		
Nutrient doses	5	411.22	82.24	56.76	2.53	Nutrient doses	5	406.70	81.34	57.98	2.53
Spacing x ND	10	21.56	2.16	1.49	2.18	Spacing x ND	10	22.49	2.25	1.60	2.18
Error (B)	30	43.47	1.45			Error (B)	30	42.09	1.40		

Number of primary branches/plant at maturity stage

Source	d.f.	S.S.	M.S.	F cal	F tab	Source	d.f.	S.S.	M.S.	F cal	F tab
Replication	2	0.90	0.45	0.13		Replication	2	1.41	0.71	0.21	
Spacing	2	85.68	42.84	12.48	6.94	Spacing	2	88.15	44.07	12.90	6.94
Error (A)	4	13.73	3.43			Error (A)	4	13.67	3.42		
Nutrient doses	5	409.02	81.80	56.73	2.53	Nutrient doses	5	408.86	81.77	56.36	2.53
Spacing x ND	10	20.18	2.02	1.40	2.18	Spacing x ND	10	20.07	2.01	1.38	2.18
Error (B)	30	43.26	1.44			Error (B)	30	43.53	1.45		

Number of secondary branches/plant at vegetative stage

Source	d.f.	S.S.	M.S.	F cal	F tab	Source	d.f.	S.S.	M.S.	F cal	F tab
Replication	2	2.85	1.42	3.40		Replication	2	2.77	1.39	3.10	
Spacing	2	2.87	1.44	3.43	6.94	Spacing	2	2.77	1.39	3.11	6.94
Error (A)	4	1.68	0.42			Error (A)	4	1.79	0.45		
Nutrient doses	5	41.38	8.28	44.65	2.53	Nutrient doses	5	42.36	8.47	51.13	2.53
Spacing x ND	10	1.34	0.13	0.72	2.18	Spacing x ND	10	1.28	0.13	0.77	2.18
Error (B)	30	5.56	0.19			Error (B)	30	4.97	0.17		

N.D - Nutrient doses, d.f. - degree of freedom, S.S. - Sum of squares, MS – Mean squares, F cal - F calculated value, F tab - F tabulated value

Appendix - IX Cont….

Year →		2005-06						2006-07			
Source	d.f.	S.S.	M.S.	F cal	F tab	Source	d.f.	S.S.	M.S.	F cal	F tab
Number of secondary branches/plant at flowering stage											
Replication	2	8.25	4.13	0.18		Replication	2	8.22	4.11	0.58	
Spacing	2	193.66	96.83	13.51	6.94	Spacing	2	196.14	98.07	13.89	6.94
Error (A)	4	28.67	7.17			Error (A)	4	28.25	7.06		
Nutrient doses	5	686.01	137.20	82.54	2.53	Nutrient doses	5	680.06	136.01	84.01	2.53
Spacing x ND	10	19.92	1.99	1.20	2.18	Spacing x ND	10	19.91	1.99	1.23	2.18
Error (B)	30	49.87	1.66			Error (B)	30	48.57	1.62		
Number of secondary branches/plant at maturity stage											
Replication	2	49.42	24.71	4.57		Replication	2	46.43	23.21	3.93	
Spacing	2	203.90	101.95	18.86	6.94	Spacing	2	201.44	100.72	17.04	6.94
Error (A)	4	21.62	5.41			Error (A)	4	23.64	5.91		
Nutrient doses	5	678.70	135.74	84.68	2.53	Nutrient doses	5	692.85	138.57	73.99	2.53
Spacing x ND	10	17.77	1.78	1.11	2.18	Spacing x ND	10	24.23	2.42	1.29	2.18
Error (B)	30	48.09	1.60			Error (B)	30	56.18	1.87		
Stem diameter (mm) at vegetative stage											
Replication	2	0.20	0.10	3.64		Replication	2	0.25	0.12	0.75	
Spacing	2	0.18	0.09	3.36	6.94	Spacing	2	0.42	0.21	1.29	6.94
Error (A)	4	0.11	0.03			Error (A)	4	0.66	0.16		
Nutrient doses	5	6.16	1.23	44.88	2.53	Nutrient doses	5	8.99	1.80	39.65	2.53
Spacing x ND	10	0.49	0.04	1.41	2.18	Spacing x ND	10	0.79	0.08	1.74	2.18
Error (B)	30	0.82	0.03			Error (B)	30	1.36	0.05		
Stem diameter (mm) at flowering stage											
Replication	2	0.37	0.18	3.10		Replication	2	0.36	0.18	3.30	
Spacing	2	5.24	2.62	44.01	6.94	Spacing	2	5.34	2.67	48.78	6.94
Error (A)	4	0.24	0.06			Error (A)	4	0.22	0.05		
Nutrient doses	5	8.20	1.64	26.48	2.53	Nutrient doses	5	8.29	1.66	19.46	2.53
Spacing x ND	10	1.22	0.12	1.97	2.18	Spacing x ND	10	1.80	0.18	2.11	2.18
Error (B)	30	1.86	0.06			Error (B)	30	2.56	0.09		

N D - Nutrient doses, d.f. - degree of freedom, S.S. - Sum of squares, MS – Mean squares, F cal - F calculated value, F tab - F tabulated value

Appendix - IX Cont....

Stem diameter (mm) at maturity stage

Year →		2005-06						2006-07			
Source	d.f.	S.S.	M.S.	F cal	F tab	Source	d.f.	S.S.	M.S.	F cal	F tab
Replication	2	0.56	0.28	3.54		Replication	2	0.35	0.17	2.76	
Spacing	2	5.79	2.90	36.57	6.94	Spacing	2	5.15	2.58	40.92	6.94
Error (A)	4	0.32	0.08			Error (A)	4	0.25	0.06		
Nutrient doses	5	9.28	1.86	20.23	2.53	Nutrient doses	5	8.22	1.64	14.52	2.53
Spacing x ND	10	1.90	0.19	2.07	2.18	Spacing x ND	10	2.60	0.26	2.08	2.18
Error (B)	30	2.75	0.09			Error (B)	30	3.19	0.11		
Branch diameter (mm) at vegetative stage											
Replication	2	0.03	0.016	0.44		Replication	2	0.04	0.021	0.66	
Spacing	2	0.01	0.005	0.14	6.94	Spacing	2	0.01	0.007	0.24	6.94
Error (A)	4	0.14	0.036			Error (A)	4	0.13	0.031		
Nutrient doses	5	0.62	0.125	16.81	2.53	Nutrient doses	5	0.59	0.118	10.36	2.53
Spacing x ND	10	0.06	0.006	0.82	2.18	Spacing x ND	10	0.20	0.020	1.77	2.18
Error (B)	30	0.22	0.007			Error (B)	30	0.34	0.011		
Branch diameter (mm) at flowering stage											
Replication	2	0.04	0.02	0.16		Replication	2	0.04	0.02	0.16	
Spacing	2	2.93	1.47	12.93	6.94	Spacing	2	2.95	1.48	12.86	6.94
Error (A)	4	0.45	0.11			Error (A)	4	0.46	0.11		
Nutrient doses	5	4.47	0.89	30.49	2.53	Nutrient doses	5	4.47	0.89	25.63	2.53
Spacing x ND	10	0.25	0.03	0.87	2.18	Spacing x ND	10	0.42	0.04	1.20	2.18
Error (B)	30	0.88	0.03			Error (B)	30	1.05	0.03		
Branch diameter (mm) at maturity stage											
Replication	2	0.04	0.02	0.16		Replication	2	0.04	0.02	0.19	
Spacing	2	2.89	1.45	12.94	6.94	Spacing	2	2.96	1.48	13.68	6.94
Error (A)	4	0.45	0.11			Error (A)	4	0.43	0.11		
Nutrient doses	5	4.79	0.96	19.54	2.53	Nutrient doses	5	4.84	0.97	18.18	2.53
Spacing x ND	10	0.85	0.08	1.73	2.18	Spacing x ND	10	0.95	0.09	1.78	2.18
Error (B)	30	1.47	0.05			Error (B)	30	1.60	0.05		

N D - Nutrient doses, d.f. - degree of freedom, S.S. - Sum of squares, MS - Mean squares, F cal - F calculated value, F tab - F tabulated value

Appendix - IX Cont.…

Number of leaves/plant at vegetative stage											
Year →		**2005-06**						**2006-07**			
Source	**d.f.**	**S.S.**	**M.S.**	**F cal**	**F tab**	**Source**	**d.f.**	**S.S.**	**M.S.**	**F cal**	**F tab**
Replication	2	62.82	31.41	1.71		Replication	2	41.30	20.65	1.07	
Spacing	2	1162.75	581.37	31.70	6.94	Spacing	2	1047.77	523.89	27.20	6.94
Error (A)	4	73.36	18.34			Error (A)	4	77.05	19.26		
Nutrient doses	5	4920.66	984.13	13.09	2.53	Nutrient doses	5	4957.01	991.40	12.83	2.53
Spacing x ND	10	812.36	81.24	1.08	2.18	Spacing x ND	10	827.73	82.77	1.07	2.18
Error (B)	30	2256.13	75.20			Error (B)	30	2318.77	77.29		
Number of leaves/plant at flowering stage											
Replication	2	4268.48	2134.24	3.86		Replication	2	10977.69	5488.85	5.97	
Spacing	2	14585.60	7292.80	13.17	6.94	Spacing	2	25352.99	12676.50	13.80	6.94
Error (A)	4	2214.31	553.58			Error (A)	4	3675.14	918.79		
Nutrient doses	5	97043.30	19408.66	34.92	2.53	Nutrient doses	5	89798.13	17959.63	10.37	2.53
Spacing x ND	10	7797.39	779.74	1.40	.18	Spacing x ND	10	18045.71	1804.57	1.04	2.18
Error (B)	30	16671.84	555.73			Error (B)	30	51952.45	1731.75		
Number of leaves/plant at maturity stage											
Replication	2	1674.08	837.04	2.84		Replication	2	3971.15	1985.58	11.59	
Spacing	2	19465.91	9732.96	32.98	6.94	Spacing	2	10570.73	5285.37	30.84	6.94
Error (A)	4	1180.32	295.08			Error (A)	4	685.55	171.39		
Nutrient doses	5	78195.30	15639.06	27.56	2.53	Nutrient doses	5	110841.48	22168.30	36.39	2.53
Spacing x ND	10	4362.69	436.27	0.77	5.38	Spacing x ND	10	11754.56	1175.46	1.93	2.18
Error (B)	30	17026.42	567.55			Error (B)	30	18275.97	609.20		
Number of root/plant at vegetative stage											
Replication	2	160.59	80.30	3.09		Replication	2	154.25	77.13	2.88	
Spacing	2	240.84	120.42	4.63	6.94	Spacing	2	217.34	108.67	4.05	6.94
Error (A)	4	104.02	26.00			Error (A)	4	107.28	26.82		
Nutrient doses	5	4693.29	938.66	26.38	2.53	Nutrient doses	5	4745.20	949.04	22.24	2.53
Spacing x ND	10	673.03	67.30	1.89	2.18	Spacing x ND	10	884.15	88.42	2.07	2.18
Error (B)	30	1067.34	35.58			Error (B)	30	1280.13	42.67		

N D - Nutrient doses, d.f. - degree of freedom, S.S. - Sum of squares, MS – Mean squares, F cal - F calculated value, F tab - F tabulated value

Appendix - IX Cont....

Number of root/plant at flowering stage											
Year →		2005-06						2006-07			
Source	d.f.	S.S.	M.S.	F cal	F tab	Source	d.f.	S.S.	M.S.	F cal	F tab
Replication	2	87.23	43.61	6.96		Replication	2	88.23	44.12	7.25	
Spacing	2	773.86	386.93	61.77	6.94	Spacing	2	886.67	443.33	72.86	6.94
Error (A)	4	25.06	6.26			Error (A)	4	24.34	6.08		
Nutrient doses	5	2172.54	434.51	23.03	2.53	Nutrient doses	5	2163.38	432.68	19.90	2.53
Spacing x ND	10	162.63	16.26	0.86	2.18	Spacing x ND	10	254.69	25.47	1.17	2.18
Error (B)	30	565.97	18.87			Error (B)	30	652.29	21.74		
Number of root/plant at maturity stage											
Replication	2	81.91	40.96	2.69		Replication	2	81.34	40.67	2.69	
Spacing	2	626.05	313.03	20.57	6.94	Spacing	2	623.30	311.65	20.59	6.94
Error (A)	4	60.87	15.22			Error (A)	4	60.54	15.14		
Nutrient doses	5	2065.02	313.00	26.45	2.53	Nutrient doses	5	2070.50	414.10	22.83	2.53
Spacing x ND	10	160.34	16.03	1.03	2.18	Spacing x ND	10	249.03	24.90	1.37	2.18
Error (B)	30	468.37	15.61			Error (B)	30	544.24	18.14		
Root length (cm) at vegetative stage											
Replication	2	1.24	0.62	1.83		Replication	2	1.38	0.69	2.06	
Spacing	2	4.28	2.14	6.33	6.94	Spacing	2	4.01	2.00	5.96	6.94
Error (A)	4	1.35	0.34			Error (A)	4	1.34	0.34		
Nutrient doses	5	50.65	10.13	15.09	2.53	Nutrient doses	5	50.27	10.05	12.57	2.53
Spacing x ND	10	7.26	0.73	1.08	2.18	Spacing x ND	10	12.02	1.20	1.50	2.18
Error (B)	30	20.14	0.67			Error (B)	30	23.99	0.80		
Root length (cm) at flowering stage											
Replication	2	3.82	1.91	1.52		Replication	2	1.92	0.96	0.61	
Spacing	2	38.44	19.22	15.30	6.94	Spacing	2	50.21	25.11	16.05	6.94
Error (A)	4	5.02	1.26			Error (A)	4	6.26	1.56		
Nutrient doses	5	268.37	53.67	90.13	2.53	Nutrient doses	5	292.21	58.44	30.43	2.53
Spacing x ND	10	5.41	0.54	0.91	2.18	Spacing x ND	10	47.84	4.08	2.12	2.18
Error (B)	30	17.87	0.60			Error (B)	30	57.61	1.92		

N D - Nutrient doses, d.f. - degree of freedom, S.S. - Sum of squares, MS – Mean squares, F cal - F calculated value, F tab - F tabulated value

Appendix - IX Cont....

Root length (cm) at maturity stage											
Year →		**2005-06**						**2006-07**			
Source	**d.f.**	**S.S.**	**M.S.**	**F cal**	**F tab**	**Source**	**d.f.**	**S.S.**	**M.S.**	**F cal**	**F tab**
Replication	2	62.70	31.35	37.52		Replication	2	62.25	31.13	41.98	
Spacing	2	39.52	19.76	23.65	6.94	Spacing	2	41.31	20.66	27.86	6.94
Error (A)	4	3.34	0.84			Error (A)	4	2.97	0.74		
Nutrient doses	5	284.97	56.99	37.26	2.53	Nutrient doses	5	297.50	59.50	24.73	2.53
Spacing x ND	10	9.86	0.99	0.64	2.18	Spacing x ND	10	35.40	3.54	1.47	
Error (B)	30	45.89	1.53			Error (B)	30	72.16	2.41		
Number of flowers/plant at flowering stage											
Replication	2	650.17	325.09	2.08		Replication	2	643.45	321.73	1.81	
Spacing	2	12496.65	6248.33	40.04	6.94	Spacing	2	2506.78	1253.39	7.04	6.94
Error (A)	4	624.27	156.07			Error (A)	4	711.93	177.98		
Nutrient doses	5	12869.69	2573.94	37.01	2.53	Nutrient doses	5	13243.33	2648.67	39.80	2.53
Spacing x ND	10	1008.82	100.88	1.45	2.18	Spacing x ND	10	927.43	92.74	1.39	2.18
Error (B)	30	2086.33	69.54			Error (B)	30	1996.26	66.54		
Number of flowers/plant at maturity stage											
Replication	2	4.06	2.03	4.79		Replication	2	30.61	15.31	65.76	
Spacing	2	1.65	0.83	1.96	6.94	Spacing	2	1.50	0.75	3.23	6.94
Error (A)	4	1.69	0.42			Error (A)	4	0.93	0.23		
Nutrient doses	5	193.98	38.80	74.13	2.53	Nutrient doses	5	196.63	39.33	81.04	2.53
Spacing x ND	10	6.90	0.69	1.32	2.18	Spacing x ND	10	6.27	0.63	1.29	2.18
Error (B)	30	15.70	0.52			Error (B)	30	14.56	0.49		
Number of head/plant at flowering stage											
Replication	2	4.99	2.49	2.07		Replication	2	5.16	2.58	2.18	
Spacing	2	15.21	7.60	6.32	6.94	Spacing	2	15.81	7.91	6.67	6.94
Error (A)	4	4.82	1.20			Error (A)	4	4.74	1.19		
Nutrient doses	5	38.63	7.73	9.09	2.53	Nutrient doses	5	39.78	7.96	7.74	2.53
Spacing x ND	10	5.04	0.50	0.59	2.18	Spacing x ND	10	[illegible]	0.95	0.92	2.18
Error (B)	30	25.50	0.85			Error (B)	30	30.[illegible]	1.03		

N D - Nutrient doses, d.f. - degree of freedom, S.S. - Sum of squares, MS – Mean squares, F cal - F calculated value, F tab - F tabulated value

Appendix - IX Cont....

Year →		2005-06						2006-07			
Source	d.f.	S.S.	M.S.	F cal	F tab	Source	d.f.	S.S.	M.S.	F cal	F tab
Number of head/plantat maturity stage											
Replication	2	103.54	51.77	2.42		Replication	2	96.38	48.19	2.46	
Spacing	2	1005.10	502.55	23.49	6.94	Spacing	2	1113.88	556.94	28.41	6.94
Error (A)	4	85.56	21.39			Error (A)	4	78.41	19.60		
Nutrient doses	5	4771.23	954.25	15.06	2.53	Nutrient doses	5	4987.46	997.49	13.89	2.53
Spacing x ND	10	590.74	59.07	0.93	2.18	Spacing x ND	10	849.23	84.92	1.18	2.18
Error (B)	30	1900.65	63.36			Error (B)	30	2153.94	71.80		
Dry matter production (%) at vegetative stage											
Replication	2	11.72	5.86	1.56		Replication	2	13.62	6.81	1.82	
Spacing	2	7.25	3.63	0.97	6.94	Spacing	2	8.17	4.09	1.09	6.94
Error (A)	4	15.00	3.75			Error (A)	4	14.97	3.74		
Nutrient doses	5	51.51	10.30	35.98	2.53	Nutrient doses	5	55.57	11.11	35.44	2.53
Spacing x ND	10	1.61	0.16	0.56	2.18	Spacing x ND	10	2.00	0.20	0.64	2.18
Error (B)	30	8.59	0.29			Error (B)	30	9.41	0.31		
Dry matter production (%) at flowering stage											
Replication	2	8.52	4.26	3.33		Replication	2	13.63	6.82	5.26	
Spacing	2	18.83	9.41	7.36	6.94	Spacing	2	18.12	9.06	7.00	6.94
Error (A)	4	5.12	1.28			Error (A)	4	5.18	1.29		
Nutrient doses	5	136.43	27.29	25.20	2.53	Nutrient doses	5	107.31	21.46	20.40	2.53
Spacing x ND	10	11.18	1.12	1.03	2.18	Spacing x ND	10	13.72	1.37	1.30	2.18
Error (B)	30	32.49	1.08			Error (B)	30	31.56	1.05		
Dry matter production (%) at maturity stage											
Replication	2	9.20	4.60	2.48		Replication	2	8.20	4.10	3.04	
Spacing	2	39.69	19.84	10.68	6.94	Spacing	2	39.75	19.87	14.76	6.94
Error (A)	4	7.43	1.86			Error (A)	4	5.39	1.35		
Nutrient doses	5	133.91	26.78	31.29	2.53	Nutrient doses	5	133.02	26.60	30.12	2.53
Spacing x ND	10	10.51	1.05	1.23	2.18	Spacing x ND	10	9.75	0.97	1.10	2.18
Error (B)	30	25.68	0.86			Error (B)	30	26.49	0.88		

N D - Nutrient doses, d.f. - degree of freedom, S.S. - Sum of squares, MS – Mean squares, F cal - F calculated value, F tab - F tabulated value

Appendix - IX Cont....

Leaf area (cm^2) at vegetative stage

Year →	2005-06					2006-07					
Source	**d.f.**	**S.S.**	**M.S.**	**F cal**	**F tab**	**Source**	**d.f.**	**S.S.**	**M.S.**	**F cal**	**F tab**
Replication	2	0.29	0.15	2.31		Replication	2	0.25	0.13	2.21	
Spacing	2	0.02	0.01	0.18	6.94	Spacing	2	0.03	0.02	0.30	6.94
Error (A)	4	0.25	0.06			Error (A)	4	0.23	0.06		
Nutrient doses	5	1.92	0.38	15.82	2.53	Nutrient doses	5	2.29	0.46	13.30	2.53
Spacing x ND	10	0.19	0.02	0.78	2.18	Spacing x ND	10	0.51	0.05	1.48	2.18
Error (B)	30	0.73	0.02			Error (B)	30	1.03	0.03		
Leaf area (cm^2) at flowering stage											
Replication	2	0.28	0.14	2.06		Replication	2	1.73	0.87	8.13	
Spacing	2	0.14	0.07	1.06	6.94	Spacing	2	1.31	0.65	6.14	6.94
Error (A)	4	0.27	0.07			Error (A)	4	0.43	0.11		
Nutrient doses	5	2.05	0.41	15.64	2.53	Nutrient doses	5	5.05	1.01	13.34	2.53
Spacing x ND	10	0.25	0.03	0.97	2.18	Spacing x ND	10	0.54	0.05	0.72	2.18
Error (B)	30	0.78	0.03			Error (B)	30	2.27	0.08		
Leaf area (cm^2) at maturity stage											
Replication	2	0.23	0.11	1.77		Replication	2	0.25	0.12	1.89	
Spacing	2	0.17	0.09	1.33	6.94	Spacing	2	0.12	0.06	0.92	6.94
Error (A)	4	0.26	0.06			Error (A)	4	0.26	0.07		
Nutrient doses	5	2.04	0.41	15.50	2.53	Nutrient doses	5	1.91	0.38	14.62	2.53
Spacing x ND	10	0.22	0.02	0.84	2.18	Spacing x ND	10	0.24	0.02	0.93	2.18
Error (B)	30	0.79	0.03			Error (B)	30	0.79	0.03		
Ground cover (cm^2) at vegetative stage											
Replication	2	6.53	3.26	14.13		Replication	2	5.39	2.69	10.27	
Spacing	2	4.52	2.26	9.79	6.94	Spacing	2	5.21	2.60	9.92	6.94
Error (A)	4	0.92	0.23			Error (A)	4	1.05	0.26		
Nutrient doses	5	47.57	9.51	43.50	2.53	Nutrient doses	5	44.07	8.81	43.49	2.53
Spacing x ND	10	1.97	0.20	0.90	2.18	Spacing x ND	10	2.05	0.20	1.01	2.18
Error (B)	30	6.56	0.22			Error (B)	30	6.08	0.20		

N D - Nutrient doses, d.f. - degree of freedom, S.S. - Sum of squares, MS – Mean squares, F cal - F calculated value, F tab - F tabulated value

Appendix - IX Cont....

Year →		2005-06						2006-07			
Source	**d.f.**	**S.S.**	**M.S.**	**F cal**	**F tab**	**Source**	**d.f.**	**S.S.**	**M.S.**	**F cal**	**F tab**
Ground cover (cm^2) at flowering stage											
Replication	2	8.78	4.39	2.44		Replication	2	7.10	3.55	1.38	
Spacing	2	34.29	17.15	9.52	6.94	Spacing	2	56.15	28.08	10.95	6.94
Error (A)	4	7.20	1.80			Error (A)	4	10.25	2.56		
Nutrient doses	5	334.55	66.91	64.59	2.53	Nutrient doses	5	337.89	67.58	67.45	2.53
Spacing x ND	10	17.44	1.74	1.68	2.18	Spacing x ND	10	14.50	1.45	1.45	2.18
Error (B)	30	31.08	1.04			Error (B)	30	30.06	1.00		
Ground cover (cm^2) at maturity stage											
Replication	2	9.16	4.58	2.36		Replication	2	9.33	4.67	2.95	
Spacing	2	35.12	17.56	9.04	6.94	Spacing	2	49.89	24.94	15.76	6.94
Error (A)	4	7.77	1.94			Error (A)	4	6.33	1.58		
Nutrient doses	5	350.37	70.07	60.98	2.53	Nutrient doses	5	357.17	71.43	58.81	2.53
Spacing x ND	10	14.20	1.42	1.24	2.18	Spacing x ND	10	18.80	1.88	1.55	2.18
Error (B)	30	34.47	1.15			Error (B)	30	36.44	1.21		
Leaf area index at vegetative stage											
Replication	2	14.23	7.11	1.70		Replication	2	13.51	6.76	1.79	
Spacing	2	23.45	11.73	2.79	6.94	Spacing	2	14.81	7.40	1.96	6.94
Error (A)	4	16.79	4.20			Error (A)	4	15.08	3.77		
Nutrient doses	5	191.87	38.37	10.44	2.53	Nutrient doses	5	220.41	44.08	12.84	2.53
Spacing x ND	10	15.72	1.57	0.43	2.18	Spacing x ND	10	17.60	1.76	0.51	2.18
Error (B)	30	110.25	3.67			Error (B)	30	103.00	3.43		
Leaf area index at flowering stage											
Replication	2	209.78	104.89	5.36		Replication	2	335.37	167.68	8.49	
Spacing	2	97.52	48.76	2.49	6.94	Spacing	2	137.75	68.88	3.49	6.94
Error (A)	4	78.21	19.55			Error (A)	4	78.98	19.75		
Nutrient doses	5	725.62	145.12	15.27	2.53	Nutrient doses	5	646.09	129.22	5.71	2.53
Spacing x ND	10	146.93	14.69	1.55	2.18	Spacing x ND	10	204.58	20.46	0.90	2.18
Error (B)	30	285.21	9.51			Error (B)	30	678.87	22.63		

N D - Nutrient doses, d.f. - degree of freedom, S.S. - Sum of squares, MS – Mean squares, F cal - F calculated value, F tab - F tabulated value

Appendix - IX Cont....

Leaf area index at maturity stage

Year →		2005-06						2006-07			
Source	**d.f.**	**S.S.**	**M.S.**	**F cal**	**F tab**	**Source**	**d.f.**	**S.S.**	**M.S.**	**F cal**	**F tab**
Replication	2	95.82	47.91	5.61		Replication	2	120.89	60.44	3.39	
Spacing	2	110.81	55.41	6.49	6.94	Spacing	2	47.09	23.54	1.32	6.94
Error (A)	4	34.13	8.53			Error (A)	4	71.24	17.81		
Nutrient doses	5	529.03	105.81	19.31	2.53	Nutrient doses	5	733.54	146.71	17.68	2.53
Spacing x ND	10	46.78	4.68	0.85	2.18	Spacing x ND	10	164.55	16.45	1.98	2.18
Error (B)	30	164.40	5.48			Error (B)	30	248.88	8.30		
Fresh herb yield (q/ha) at maturity stage											
Replication	2	20.72	10.36	0.84		Replication	2	21.01	10.50	0.83	
Spacing	2	221.09	110.55	8.95	6.94	Spacing	2	218.91	109.45	8.63	6.94
Error (A)	4	49.42	12.36			Error (A)	4	50.70	12.68		
Nutrient doses	5	16102.56	3220.51	184.40	2.53	Nutrient doses	5	16255.54	3251.11	190.24	2.53
Spacing x ND	10	125.84	12.58	0.72	2.18	Spacing x ND	10	128.69	12.87	0.75	2.18
Error (B)	30	523.94	17.46			Error (B)	30	512.68	17.09		
Dry herb yield (q/ha) at maturity stage											
Replication	2	28.40	14.20	2.46		Replication	2	24.67	12.34	3.16	
Spacing	2	121.79	60.89	10.54	6.94	Spacing	2	195.35	97.67	25.05	6.94
Error (A)	4	23.11	5.78			Error (A)	4	15.60	3.90		
Nutrient doses	5	1327.92	265.58	75.17	2.53	Nutrient doses	5	1340.45	268.09	71.49	2.53
Spacing x ND	10	39.18	3.92	1.11	2.18	Spacing x ND	10	44.54	4.45	1.19	2.18
Error (B)	30	105.99	3.53			Error (B)	30	112.51	3.75		
Plant nitrogen content (%)											
Replication	2	0.0129	0.006	0.47		Replication	2	0.0251	0.013	0.56	
Spacing	2	0.1057	0.053	3.89	6.94	Spacing	2	0.0710	0.036	1.58	6.94
Error (A)	4	0.0543	0.014			Error (A)	4	0.0898	0.022		
Nutrient doses	5	3.8854	0.777	39.42	2.53	Nutrient doses	5	3.5890	0.718	32.58	2.53
Spacing x ND	10	0.1681	0.017	0.85	2.18	Spacing x ND	10	0.1729	0.017	0.78	2.18
Error (B)	30	0.5914	0.020			Error (B)	30	0.6609	0.022		

N D - Nutrient doses, d.f. - degree of freedom, S.S. - Sum of squares, MS – Mean squares, F cal - F calculated value, F tab - F tabulated value

Appendix - IX Cont....

Year →		2005-06						2006-07			
Source	d.f.	S.S.	M.S.	F cal	F tab	Source	d.f.	S.S.	M.S.	F cal	F tab
Plant phosphorous content (%)											
Replication	2	0.0001	0.00003	0.12		Replication	2	0.00001	0.00001	0.01	
Spacing	2	0.0007	0.00036	1.55	6.94	Spacing	2	0.00032	0.00016	0.27	6.94
Error (A)	4	0.0009	0.00023			Error (A)	4	0.00240	0.00060		
Nutrient doses	5	0.1460	0.02921	65.09	2.53	Nutrient doses	5	0.15492	0.02698	58.93	2.53
Spacing x ND	10	0.0056	0.00056	1.25	2.18	Spacing x ND	10	0.00143	0.00014	0.31	2.18
Error (B)	30	0.0135	0.00045			Error (B)	30	0.01374	0.00046		
Plant potash content (%)											
Replication	2	0.0235	0.012	1.97		Replication	2	0.0246	0.012	1.67	
Spacing	2	0.0050	0.002	0.42	6.94	Spacing	2	0.0034	0.002	0.23	6.94
Error (A)	4	0.0239	0.006			Error (A)	4	0.0295	0.007		
Nutrient doses	5	1.0461	0.209	55.77	2.53	Nutrient doses	5	0.9887	0.198	46.67	2.53
Spacing x ND	10	0.0110	0.001	0.29	2.18	Spacing x ND	10	0.0168	0.002	0.40	2.18
Error (B)	30	0.1125	0.004			Error (B)	30	0.1271	0.004		
Organic carbon content (%) in plant											
Replication	2	1.4614	0.731	0.815		Replication	2	1.836	0.918	1.130	
Spacing	2	0.0028	0.001	0.002	6.94	Spacing	2	0.016	0.008	0.010	6.94
Error (A)	4	3.5877	0.897			Error (A)	4	3.248	0.812		
Nutrient doses	5	285.0798	57.016	90.508	2.53	Nutrient doses	5	287.995	57.599	121.76	2.53
Spacing x ND	10	6.0936	0.609	0.967	2.18	Spacing x ND	10	3.775	0.378	0.798	2.18
Error (B)	30	18.8986	0.630			Error (B)	30	14.192	0.473		
Nitrogen uptake by plant (Kg/ha)											
Replication	2	60.725	30.36	0.57		Replication	2	148.32	74.16	1.37	
Spacing	2	727.391	363.70	7.81	6.94	Spacing	2	864.32	432.16	7.98	6.94
Error (A)	4	213.768	53.44			Error (A)	4	216.65	54.16		
Nutrient doses	5	11193.534	2238.71	65.65	2.53	Nutrient doses	5	11665.74	2333.15	74.24	2.53
Spacing x ND	10	315.297	31.53	0.92	2.18	Spacing x ND	10	199.49	19.95	0.63	2.18
Error (B)	30	1022.963	34.10			Error (B)	30	942.82	31.43		

N D - Nutrient doses, d.f. - degree of freedom, S.S. - Sum of squares, MS – Mean squares, F cal - F calculated value, F tab - F tabulated value

Appendix - IX Cont....

Year →		2005-06						2006-07			
Source	**d.f.**	**S.S.**	**M.S.**	**F cal**	**F tab**	**Source**	**d.f.**	**S.S.**	**M.S.**	**F cal**	**F tab**
Phosphorus uptake by plant (Kg/ha)											
Replication	2	5.58	2.79	6.24		Replication	2	6.79	3.40	1.14	
Spacing	2	29.95	14.98	33.30	6.94	Spacing	2	29.25	14.63	34.90	6.94
Error (A)	4	1.79	0.45			Error (A)	4	11.95	2.99		
Nutrient doses	5	600.98	120.20	145.87	2.53	Nutrient doses	5	613.92	122.78	114.37	2.53
Spacing x ND	10	10.96	1.10	1.33	2.18	Spacing x ND	10	9.48	0.95	0.88	2.18
Error (B)	30	24.72	0.82			Error (B)	30	32.21	1.07		
Potash uptake by plant (Kg/ha)											
Replication	2	56.15	28.08	2.01		Replication	2	71.30	35.65	2.41	
Spacing	2	372.12	186.06	13.32	6.94	Spacing	2	373.28	186.64	12.60	6.94
Error (A)	4	55.89	13.97			Error (A)	4	59.27	14.82		
Nutrient doses	5	6270.27	1254.05	92.85	2.53	Nutrient doses	5	6388.36	1277.67	90.55	2.53
Spacing x ND	10	120.07	12.01	0.89	2.18	Spacing x ND	10	119.76	11.98	0.85	2.18
Error (B)	30	405.19	13.51			Error (B)	30	423.32	14.11		
Alkaloid content in plant (%)											
Replication	2	0.0003	0.00017	1.073		Replication	2	0.0003	0.00016	0.774	
Spacing	2	0.0012	0.00059	3.754	6.94	Spacing	2	0.0000	0.00001	0.053	6.94
Error (A)	4	0.0006	0.00016			Error (A)	4	0.0008	0.00020		
Nutrient doses	5	0.0166	0.00332	5.492	2.53	Nutrient doses	5	0.0164	0.00328	7.182	2.53
Spacing x ND	10	0.0038	0.00038	0.634	2.18	Spacing x ND	10	0.0008	0.00008	0.166	2.18
Error (B)	30	0.0181	0.00060			Error (B)	30	0.0137	0.00046		
Total alkaloid yield (Kg/ha)											
Replication	2	2.0046	1.002	1.123		Replication	2	1.3476	0.674	0.953	
Spacing	2	17.0493	8.525	9.551	6.94	Spacing	2	10.5500	5.275	7.463	6.94
Error (A)	4	3.5703	0.893			Error (A)	4	2.8274	0.707		
Nutrient doses	5	169.5833	33.917	34.573	2.53	Nutrient doses	5	163.3932	32.679	53.915	2.53
Spacing x ND	10	8.8225	0.882	0.899	2.18	Spacing x ND	10	3.3543	0.335	0.553	2.18
Error (B)	30	29.4305	0.981			Error (B)	30	18.1835	0.606		

N D - Nutrient doses, d.f. - degree of freedom, S.S. - Sum of squares, MS – Mean squares, F cal - F calculated value, F tab - F tabulated value

Appendix - IX Cont....

Total sugar content (%) in plant

Year →	2005-06					2006-07					
Source	d.f.	S.S.	M.S.	F cal	F tab	Source	d.f.	S.S.	M.S.	F cal	F tab
Replication	2	0.0287	0.014	0.523		Replication	2	0.0339	0.017	0.517	
Spacing	2	0.8945	0.153	5.566	6.94	Spacing	2	0.0446	0.022	0.680	6.94
Error (A)	4	0.1099	0.027			Error (A)	4	0.1312	0.033		
Nutrient doses	5	2.6554	0.531	12.477	2.53	Nutrient doses	5	2.8567	0.571	13.161	2.53
Spacing x ND	10	0.4504	0.045	1.058	2.18	Spacing x ND	10	0.4096	0.041	0.944	2.18
Error (B)	30	1.2770	0.043			Error (B)	30	1.3024	0.043		

Reducing sugar content (%) in plant

Source	d.f.	S.S.	M.S.	F cal	F tab	Source	d.f.	S.S.	M.S.	F cal	F tab
Replication	2	0.0374	0.019	0.528		Replication	2	0.0419	0.021	0.601	
Spacing	2	0.6879	0.241	6.803	6.94	Spacing	2	0.0477	0.024	0.683	6.94
Error (A)	4	0.[illegible]417	0.035			Error (A)	4	0.1395	0.035		
Nutrient doses	5	0.6637	0.133	4.165	2.53	Nutrient doses	5	0.6874	0.137	4.296	2.53
Spacing x ND	10	0.2121	0.021	0.666	2.18	Spacing x ND	10	0.2095	0.021	0.655	2.18
Error (B)	30	0.9561	0.032			Error (B)	30	0.9600	0.032		

Non-reducing sugar content (%) in plant

Source	d.f.	S.S.	M.S.	F cal	F tab	Source	d.f.	S.S.	M.S.	F cal	F tab
Replication	2	0.0069	0.003	0.043		Replication	2	0.0034	0.002	0.020	
Spacing	2	0.0962	0.048	0.595	6.94	Spacing	2	0.1002	0.050	0.605	6.94
Error (A)	4	0.3235	0.081			Error (A)	4	0.3312	0.083		
Nutrient doses	5	0.8557	0.171	2.096	2.53	Nutrient doses	5	0.9088	0.182	2.202	2.53
Spacing x ND	10	0.[illegible]5045	0.050	0.618	2.18	Spacing x ND	10	0.4531	0.045	0.549	2.18
Error (B)	30	2.[illegible]4494	0.082			Error (B)	30	2.4764	0.083		

Available residual soil N (Kg/ha)

Source	d.f.	S.S.	M.S.	F cal	F tab	Source	d.f.	S.S.	M.S.	F cal	F tab
Replication	2	12.25	6.13	5.21		Replication	2	2.42	1.21	0.47	
Spacing	2	41.38	20.69	17.59	6.94	Spacing	2	39.75	19.87	7.77	6.94
Error (A)	4	4.71	1.18			Error (A)	4	10.24	2.56		
Nutrient doses	5	3531.88	706.38	228.49	2.53	Nutrient doses	5	3609.45	721.89	204.12	2.53
Spacing x ND	10	14.99	1.50	0.48	2.18	Spacing x ND	10	13.97	1.40	0.40	2.18
Error (B)	30	92.74	3.09			Error (B)	30	106.10	3.54		

N D - Nutrient doses, d.f. - degree of freedom, S.S. - Sum of squares, MS – Mean squares, F cal - F calculated value, F tab - F tabulated value

Appendix - IX Cont....

Available residual soil P_2O_5 (Kg/ha)											
Year →		2005-06						2006-07			
Source	d.f.	S.S.	M.S.	F cal	F tab	Source	d.f.	S.S.	M.S.	F cal	F tab
Replication	2	4.49	2.25	17.61		Replication	2	3.43	1.71	5.16	
Spacing	2	0.53	0.26	2.07	6.94	Spacing	2	2.45	1.22	3.68	6.94
Error (A)	4	0.51	0.13			Error (A)	4	1.33	0.33		
Nutrient doses	5	940.25	188.05	243.40	2.53	Nutrient doses	5	818.85	163.77	135.85	2.53
Spacing x ND	10	10.79	1.08	1.40	2.18	Spacing x ND	10	14.96	1.50	1.24	2.18
Error (B)	30	23.18	0.77			Error (B)	30	36.16	1.21		
Available residual soil K_2O (Kg/ha)											
Replication	2	2.49	1.25	0.60		Replication	2	2.35	1.17	0.46	
Spacing	2	9.69	4.85	2.33	6.94	Spacing	2	9.14	4.57	1.81	6.94
Error (A)	4	8.34	2.08			Error (A)	4	10.12	2.53		
Nutrient doses	5	435.98	87.20	148.39	2.53	Nutrient doses	5	417.85	83.57	136.64	2.53
Spacing x ND	10	6.49	0.65	1.10	2.18	Spacing x ND	10	6.26	0.63	1.02	2.18
Error (B)	30	17.63	0.59			Error (B)	30	18.35	0.61		
Soil organic carbon content (%)											
Replication	2	0.00002	0.00001	0.054		Replication	2	0.0002	0.00008	0.351	
Spacing	2	0.00047	0.00023	1.007	6.94	Spacing	2	0.0002	0.00012	0.547	6.94
Error (A)	4	0.00093	0.00023			Error (A)	4	0.0009	0.00023		
Nutrient doses	5	0.03642	0.00728	80.526	2.53	Nutrient doses	5	0.0316	0.00633	67.336	2.53
Spacing x ND	10	0.00087	0.00009	0.958	2.18	Spacing x ND	10	0.0008	0.00008	0.800	2.18
Error (B)	30	0.00271	0.00009			Error (B)	30	0.0028	0.00009		

N.D - Nutrient doses, d.f. - degree of freedom, S.S. - Sum of squares, MS – Mean squares, F cal - F calculated value, F tab - F tabulated value

Appendix – IX Cont....

Analysis of variance (ANOVA) table for different parameters as affected by various treatments in 2005-06 and 2006-07 under transplanting time and harvesting stages experiment

Year →		2005-06						2006-07			
Source	d.f.	S.S.	M.S.	F cal	F tab	Source	d.f.	S.S.	M.S.	F cal	F tab
Plant height (cm)											
Replication	2	1.39	0.69	0.74	5.14	Replication	2	0.95	0.47	0.36	5.14
T. T.	3	779.35	259.78	275.19	4.76	T. T.	3	745.82	248.61	188.26	4.76
Error (A)	6	5.66	0.94			Error (A)	6	7.92	1.32		
H. S.	2	3858.58	1929.29	105.50	3.63	H. S.	2	4868.95	2434.47	111.01	3.63
T. T. x H. S.	6	208.06	34.68	1.90	2.74	T. T. x H. S.	6	288.33	48.05	2.19	2.74
Error (B)	16	292.59	18.29			Error (B)	16	350.89	21.93		
Number of primary branches/plant											
Replication	2	11.00	5.50	4.58	5.14	Replication	2	7.69	3.85	9.69	5.14
T. T.	3	223.11	74.37	61.91	4.76	T. T.	3	255.56	85.19	214.60	4.76
Error (A)	6	7.21	1.20			Error (A)	6	2.38	0.40		
H. S.	2	513.42	256.71	81.02	3.63	H. S.	2	782.21	391.11	132.41	3.63
T. T. x H. S.	6	24.00	4.00	1.26	2.74	T. T. x H. S.	6	27.08	4.51	1.53	2.74
Error (B)	16	50.69	3.17			Error (B)	16	47.26	2.95		
Number of secondary branches/plant											
Replication	2	17.55	8.78	1.28	5.14	Replication	2	22.29	11.14	2.03	5.14
T. T.	3	1103.20	367.73	53.56	4.76	T. T.	3	832.10	277.37	50.40	4.76
Error (A)	6	41.19	6.87			Error (A)	6	33.02	5.50		
H. S.	2	2658.95	1329.47	37.46	3.63	H. S.	2	3305.67	1652.84	57.68	3.63
T. T. x H. S.	6	517.80	86.30	2.43	2.74	T. T. x H. S.	6	403.25	67.20	2.35	2.74
Error (B)	16	567.89	35.49			Error (B)	16	458.51	28.66		
Stem diameter (mm)											
Replication	2	0.25	0.12	8.31	5.14	Replication	2	0.04	0.02	0.07	5.14
T. T.	3	0.66	0.22	14.88	4.76	T. T.	3	12.21	4.07	13.56	4.76
Error (A)	6	0.09	0.01			Error (A)	6	1.80	0.30		
H. S.	2	35.98	17.99	432.17	3.63	H. S.	2	37.54	18.77	78.65	3.63
T. T. x H. S.	6	0.31	0.05	1.23	2.74	T. T. x H. S.	6	1.67	0.28	1.16	2.74
Error (B)	16	0.67	0.04			Error (B)	16	3.82	0.24		

T. T. = Transplanting time, H. S. = Harvesting stage, d.f. - degree of freedom, S.S. - Sum of squares, MS – Mean squares, F cal - F calculated value, F tab - F tabulated value

Appendix - IX Cont….

Branch diameter (mm)											
Year →		2005-06						2006-07			
Source	d.f.	S.S.	M.S.	F cal	F tab	Source	d.f.	S.S.	M.S.	F cal	F tab
Replication	2	0.05	0.02	0.74	5.14	Replication	2	0.02	0.01	0.44	5.14
T. T.	3	1.56	0.52	16.68	4.76	T. T.	3	1.57	0.52	23.47	4.76
Error (A)	6	0.19	0.03			Error (A)	6	0.13	0.02		
H. S.	2	6.26	3.13	28.42	3.63	H. S.	2	5.35	2.67	28.87	3.63
T. T. x H. S.	6	1.10	0.18	1.67	2.74	T. T. x H. S.	6	1.01	0.17	1.82	2.74
Error (B)	16	1.76	0.11			Error (B)	16	1.48	0.09		
Number of leaves/plant											
Replication	2	205.37	102.69	0.43	5.14	Replication	2	53.22	26.61	0.37	5.14
T. T.	3	17457.38	5819.13	24.62	4.76	T. T.	3	16504.41	5501.47	76.83	4.76
Error (A)	6	1418.33	236.39			Error (A)	6	429.64	71.61		
H. S.	2	115412.25	57706.12	166.17	3.63	H. S.	2	120339.82	60169.91	209.93	3.63
T. T. x H. S.	6	3875.08	645.85	1.86	2.74	T. T. x H. S.	6	4078.00	679.67	2.37	2.74
Error (B)	16	5556.27	347.27			Error (B)	16	4585.83	286.61		
Number of roots/plant											
Replication	2	49.92	24.96	1.66	5.14	Replication	2	18.85	9.43	0.55	5.14
T. T.	3	1043.89	347.96	23.12	4.76	T. T.	3	983.35	327.78	19.01	4.76
Error (A)	6	90.32	15.05			Error (A)	6	103.43	17.24		
H. S.	2	2729.06	1364.53	20.58	3.63	H. S.	2	4602.01	2301.01	35.03	3.63
T. T. x H. S.	6	798.02	133.00	2.01	2.74	T. T. x H. S.	6	911.82	151.97	2.31	2.74
Error (B)	16	1060.64	66.29			Error (B)	16	1050.95	65.68		
Root length (cm)											
Replication	2	2.38	1.19	3.07	5.14	Replication	2	4.47	2.23	8.446	5.14
T. T.	3	49.14	16.38	42.31	4.76	T. T.	3	73.313	24.44	92.406	4.76
Error (A)	6	2.32	0.39			Error (A)	6	1.587	0.26		
H. S.	2	75.53	37.76	4.67	3.63	H. S.	2	210.67	105.33	14.423	3.63
T. T. x H. S.	6	35.85	5.98	0.74	2.74	T. T. x H. S.	6	107.25	17.87	2.447	2.74
Error (B)	16	129.45	8.09			Error (B)	16	116.85	7.30		

T. T. = Transplanting time, H. S. = Harvesting stage, d.f. - degree of freedom, S.S. - Sum of squares, MS – Mean squares, F cal - F calculated value, F tab - F tabulated value

Appendix - IX Cont....

Fresh weight/plant (g)											
Year →		2005-06						2006-07			
Source	d.f.	S.S.	M.S.	F cal	F tab	Source	d.f.	S.S.	M.S.	F cal	F tab
Replication	2	14.27	7.14	30.23	5.14	Replication	2	14.92	7.46	12.39	5.14
T. T.	3	807.20	269.07	1139.8	4.76	T. T.	3	716.13	238.71	396.46	4.76
Error (A)	6	1.42	0.24			Error (A)	6	3.61	0.60		
H. S.	2	4246.93	2123.46	136.80	3.63	H. S.	2	4525.52	2262.76	153.12	3.63
T. T. x H. S.	6	245.15	40.86	2.63	2.74	T. T. x H. S.	6	217.84	36.31	2.46	2.74
Error (B)	16	248.35	15.52			Error (B)	16	236.45	14.78		
Dry weight/plant (g)											
Replication	2	1.21	0.61	13.16	5.14	Replication	2	1.26	0.63	7.12	5.14
T. T.	3	130.60	43.53	944.27	4.76	T. T.	3	128.62	42.87	486.14	4.76
Error (A)	6	0.28	0.05			Error (A)	6	0.53	0.09		
H. S.	2	389.56	194.78	56.36	3.63	H. S.	2	472.20	236.10	64.73	3.63
T. T. x H. S.	6	54.21	9.04	2.61	2.74	T. T. x H. S.	6	56.64	9.44	2.59	2.74
Error (B)	16	55.30	3.46			Error (B)	16	58.36	3.65		
Dry matter production (%)											
Replication	2	0.17	0.09	0.32	5.14	Replication	2	1.56	0.78	0.64	5.14
T. T.	3	242.15	80.72	301.33	4.76	T. T.	3	196.38	65.46	53.58	4.76
Error (A)	6	1.61	0.27			Error (A)	6	7.33	1.22		
H. S.	2	458.51	229.26	82.80	3.63	H. S.	2	550.16	275.08	37.89	3.63
T. T. x H. S	6	35.72	5.95	2.15	2.74	T. T. x H. S.	6	78.33	13.05	1.80	2.74
Error (B)	16	44.30	2.77			Error (B)	16	116.17	7.26		
Leaf area (cm^2)											
Replication	2	0.07	0.03	1.80	5.14	Replication	2	0.09	0.05	1.40	5.14
T. T.	3	0.09	0.03	1.62	4.76	T. T.	3	0.38	0.13	3.78	4.76
Error (A)	6	0.11	0.02			Error (A)	6	0.20	0.03		
H. S.	2	0.20	0.10	3.44	3.63	H. S.	2	0.06	0.03	0.87	3.63
T. T. x H. S.	6	0.05	0.01	0.29	2.74	T. T. x H. S.	6	0.11	0.02	0.52	2.74
Error (B)	16	0.47	0.03			Error (B)	16	0.58	0.04		

T. T. = Transplanting time, H. S. = Harvesting stage, d.f. - degree of freedom, S.S. - Sum of squares, MS – Mean squares, F cal - F calculated value, F tab - F tabulated value

Appendix - IX Cont....

Ground cover/plant (cm^2)											
Year →		2005-06						2006-07			
Source	d.f.	S.S.	M.S.	F cal	F tab	Source	d.f.	S.S.	M.S.	F cal	F tab
Replication	2	10.12	5.06	1.22	5.14	Replication	2	16.94	8.47	2.06	5.14
T. T.	3	476.14	158.71	38.41	4.76	T. T.	3	460.06	153.35	37.37	4.76
Error (A)	6	24.79	4.13			Error (A)	6	24.62	4.10		
H. S.	2	635.05	317.53	17.00	3.63	H. S.	2	1055.08	527.54	40.83	3.63
T. T. x H. S.	6	264.12	44.02	2.36	2.74	T. T. x H. S.	6	178.88	29.81	2.31	2.74
Error (B)	16	298.81	18.68			Error (B)	16	206.71	12.92		
Leaf area index											
Replication	2	22.28	11.14	4.75	5.14	Replication	2	13.27	6.64	3.18	5.14
T. T.	3	3.82	7.46	5.83	4.76	T. T.	3	31.14	10.38	4.97	4.76
Error (A)	6	30.45	1.28			Error (A)	6	12.52	2.09		
H. S.	2	485.49	242.74	32.22	3.63	H. S.	2	325.09	162.55	26.27	3.63
T. T. x H. S.	6	85.91	14.32	1.90	2.74	T. T. x H. S.	6	72.16	12.03	1.94	2.74
Error (B)	16	120.55	7.53			Error (B)	16	99.01	6.19		
Fresh herb yield (q/ha)											
Replication	2	355.15	177.57	10.79	5.14	Replication	2	383.88	191.94	12.82	5.14
T. T.	3	3045.99	1015.33	61.70	4.76	T. T.	3	3276.70	1092.23	72.93	4.76
Error (A)	6	98.74	16.46			Error (A)	6	89.86	14.98		
H. S.	2	17058.18	8529.09	55.56	3.63	H. S.	2	17142.43	8571.21	56.08	3.63
T. T. x H. S.	6	2251.52	375.25	2.44	2.74	T. T. x H. S.	6	2241.75	373.62	2.44	2.74
Error (B)	16	2456.05	153.50			Error (B)	16	2445.40	152.84		
Dry herb yield (q/ha)											
Replication	2	24.04	12.02	7.05	5.14	Replication	2	41.11	20.55	5.01	5.14
T. T.	3	1899.79	633.26	371.59	4.76	T. T.	3	1833.34	611.11	148.84	4.76
Error (A)	6	10.23	1.70			Error (A)	6	24.63	4.11		
H. S.	2	4514.38	2257.19	60.15	3.63	H. S.	2	5366.37	2683.19	48.76	3.63
T. T. x H. S.	6	561.50	93.58	2.49	2.74	T. T. x H. S.	6	774.28	129.05	2.35	2.74
Error (B)	16	600.44	37.53			Error (B)	16	880.48	55.03		

T. T. = Transplanting time, H. S. = Harvesting stage, d.f. - degree of freedom, S.S. - Sum of squares, MS – Mean squares, F cal - F calculated value, F tab - F tabulated value

Appendix - IX Cont....

Nitrogen content (%) in plant

Year →		2005-06						2006-07			
Source	d.f.	S.S.	M.S.	F cal	F tab	Source	d.f.	S.S.	M.S.	F cal	F tab
Replication	2	0.00914	0.0046	2.51	5.14	Replication	2	0.00431	0.0022	1.01	5.14
T. T.	3	0.06873	0.0229	12.60	4.76	T. T.	3	0.06896	0.0230	10.81	4.76
Error (A)	6	0.01091	0.0018			Error (A)	6	0.01276	0.0021		
H. S.	2	0.98234	0.4912	141.99	3.63	H. S.	2	0.95962	0.4798	223.75	3.63
T. T. x H. S.	6	0.01566	0.0026	0.75	2.74	T. T. x H. S.	6	0.00544	0.0009	0.42	2.74
Error (B)	16	0.05535	0.0035			Error (B)	16	0.03431	0.0021		
Phosphorus content (%) in plant											
Replication	2	0.00048	0.0002	1.88	5.14	Replication	2	0.00054	0.0003	1.81	5.14
T. T.	3	0.00622	0.0021	16.12	4.76	T. T.	3	0.00600	0.0020	13.45	4.76
Error (A)	6	0.00077	0.0001			Error (A)	6	0.00089	0.0001		
H. S.	2	0.07629	0.0381	194.68	3.63	H. S.	2	0.07608	0.0380	164.95	3.63
T. T. x H. S.	6	0.00232	0.0004	1.97	2.74	T. T. x H. S.	6	0.00265	0.0004	1.91	2.74
Error (B)	16	0.00314	0.0002			Error (B)	16	0.00369	0.0002		
Potash content (%) in plant											
Replication	2	0.00004	0.000019	0.02	5.14	Replication	2	0.00105	0.000525	0.81	5.14
T. T.	3	0.02781	0.009269	9.30	4.76	T. T.	3	0.03072	0.010241	7.95	4.76
Error (A)	6	0.00598	0.000997			Error (A)	6	0.00773	0.001288		
H. S.	2	0.43727	0.218636	87.61	3.63	H. S.	2	0.41015	0.205075	96.36	3.63
T. T. x H. S.	6	0.01835	0.003058	1.23	2.74	T. T. x H. S.	6	0.01589	0.002649	1.24	2.74
Error (B)	16	0.03993	0.002495			Error (B)	16	0.03405	0.002128		
Plant organic carbon content (%)											
Replication	2	0.253	0.127	2.21	5.14	Replication	2	0.292	0.146	3.32	5.14
T. T.	3	16.547	5.516	96.27	4.76	T. T.	3	17.408	5.803	131.93	4.76
Error (A)	6	0.344	0.057			Error (A)	6	0.264	0.044		
H. S.	2	223.878	111.939	380.68	3.63	H. S.	2	219.292	109.646	309.59	3.63
T. T. x H. S.	6	1.302	0.217	0.74	2.74	T. T. x H. S.	6	1.431	0.238	0.67	2.74
Error (B)	16	4.705	0.294			Error (B)	16	5.667	0.354		

T. T. = Transplanting time, H. S. = Harvesting stage, d.f. - degree of freedom, S.S. - Sum of squares, MS – Mean squares, F cal - F calculated value; F tab - F tabulated value

Appendix - IX Cont....

Year →	2005-06					2006-07					
Source	**d.f.**	**S.S.**	**M.S.**	**F cal**	**F tab**	**Source**	**d.f.**	**S.S.**	**M.S.**	**F cal**	**F tab**
Nitrogen uptake (Kg/ha) by plant											
Replication	2	8.13	4.07	0.77	5.14	Replication	2	37.13	18.56	1.61	5.14
T. T.	3	5165.34	1721.78	325.52	4.76	T. T.	3	5388.58	1796.19	155.56	4.76
Error (A)	6	31.74	5.29			Error (A)	6	69.28	11.55		
H. S.	2	16373.52	8186.76	61.27	3.63	H. S.	2	19923.46	9961.73	60.04	3.63
T. T. x H. S.	6	1946.68	324.45	2.43	2.74	T. T. x H. S.	6	2355.26	392.54	2.37	2.74
Error (B)	16	2137.98	133.62			Error (B)	16	2654.87	165.93		
Phosphorus uptake (Kg/ha) by plant											
Replication	2	7.39	3.69	9.03	5.14	Replication	2	7.35	3.67	8.57	5.14
T. T.	3	481.75	160.58	392.55	4.76	T. T.	3	492.03	164.01	382.75	4.76
Error (A)	6	2.45	0.41			Error (A)	6	2.57	0.43		
H. S.	2	1455.24	727.62	65.33	3.63	H. S.	2	1485.64	742.82	64.15	3.63
T. T. x H. S.	6	165.87	27.64	2.48	2.74	T. T. x H. S.	6	172.34	28.72	2.48	2.74
Error (B)	16	178.20	11.14			Error (B)	16	185.26	11.58		
Potash uptake (Kg/ha) by plant											
Replication	2	51.03	25.52	2.61	5.14	Replication	2	56.28	28.14	2.27	5.14
T. T.	3	5082.08	1694.03	173.01	4.76	T. T.	3	5389.30	1796.43	144.78	4.76
Error (A)	6	58.75	9.79			Error (A)	6	74.45	12.41		
H. S.	2	13988.14	6994.07	57.78	3.63	H. S.	2	14546.10	7273.05	57.98	3.63
T. T. x H. S.	6	1855.42	309.24	2.55	2.74	T. T. x H. S.	6	1921.75	320.29	2.55	2.74
Error (B)	16	1936.79	121.05			Error (B)	16	2006.88	125.43		
Total alkaloid content (%) in plant											
Replication	2	0.00048	0.00024	1.98	5.14	Replication	2	0.00019	0.00010	0.80	5.14
T. T.	3	0.00035	0.00012	0.95	4.76	T. T.	3	0.00033	0.00011	0.92	4.76
Error (A)	6	0.00073	0.00012			Error (A)	6	0.00073	0.00012		
H. S.	2	0.29648	0.14824	362.75	3.63	H. S.	2	0.27169	0.13585	926.56	3.63
T. T. x H. S.	6	0.00060	0.00010	0.24	2.74	T. T. x H. S.	6	0.00091	0.00015	1.03	2.74
Error (B)	16	0.00654	0.00041			Error (B)	16	0.00235	0.00015		

T. T. = Transplanting time, H. S. = Harvesting stage, d.f. - degree of freedom, S.S. - Sum of squares, MS – Mean squares, F cal - F calculated value, F tab - F tabulated value

Appendix - IX Cont....

Total alkaloid yield (kg/ha)											
Year →		2005-06						2006-07			
Source	d.f.	S.S.	M.S.	F cal	F tab	Source	d.f.	S.S.	M.S.	F cal	F tab
Replication	2	4.84	2.42	10.51	5.14	Replication	2	2.16	1.08	3.08	5.14
T. T.	3	172.85	57.62	250.43	4.76	T. T.	3	143.11	47.70	136.05	4.76
Error (A)	6	1.38	0.23			Error (A)	6	2.10	0.35		
H. S.	2	1296.97	648.49	119.44	3.63	H. S.	2	1183.51	591.76	138.05	3.63
T. T. x H. S.	6	71.93	11.99	2.21	2.74	T. T. x H. S.	6	65.53	10.92	2.55	2.74
Error (B)	16	86.87	5.43			Error (B)	16	68.58	4.29		
Total sugar content (%)											
Replication	2	0.006	0.003	0.28	5.14	Replication	2	0.004	0.002	0.07	5.14
T. T.	3	0.119	0.040	3.95	4.76	T. T.	3	0.317	0.106	3.92	4.76
Error (A)	6	0.060	0.010			Error (A)	6	0.162	0.027		
H. S.	2	26.556	13.278	1587.8	3.63	H. S.	2	26.806	13.403	1779.5	3.63
T. T. x H. S.	6	0.071	0.012	1.42	2.74	T. T. x H. S.	6	0.065	0.011	1.43	2.74
Error (B)	16	0.134	0.008			Error (B)	16	0.121	0.008		
Reducing sugar content (%)											
Replication	2	0.0516	0.026	0.74	5.14	Replication	2	0.0271	0.014	0.48	5.14
T. T.	3	0.9228	0.308	8.81	4.76	T. T.	3	0.4149	0.138	4.86	4.76
Error (A)	6	0.2096	0.035			Error (A)	6	0.1706	0.028		
H. S.	2	5.2016	2.601	50.04	3.63	H. S.	2	5.8805	2.940	99.73	3.63
T. T. x H. S.	6	0.3601	0.060	1.15	2.74	T. T. x H. S.	6	0.1697	0.028	0.96	2.74
Error (B)	16	0.8316	0.052			Error (B)	16	0.4717	0.029		
Non-reducing sugar content (%)											
Replication	2	0.0913	0.046	1.35	5.14	Replication	2	0.0172	0.009	0.18	5.14
T. T.	3	0.4179	0.139	4.13	4.76	T. T.	3	0.1399	0.047	0.97	4.76
Error (A)	6	0.2026	0.034			Error (A)	6	0.2894	0.048		
H. S.	2	10.8711	5.436	96.58	3.63	H. S.	2	9.8751	4.938	207.25	3.63
T. T. x H. S.	6	0.3454	0.058	1.02	2.74	T. T. x H. S.	6	0.1775	0.030	1.24	2.74
Error (B)	16	0.9005	0.056			Error (B)	16	0.3812	0.024		

T. T. = Transplanting time, H. S. = Harvesting stage, d.f. - degree of freedom, S.S. - Sum of squares, MS – Mean squares, F cal - F calculated value, F tab - F tabulated value

Appendix - IX Cont…

Available residual soil N (kg/ha)											
Year →		**2005-06**						**2006-07**			
Source	**d.f.**	**S.S.**	**M.S.**	**F cal**	**F tab**	**Source**	**d.f.**	**S.S.**	**M.S.**	**F cal**	**F tab**
Replication	2	469.94	234.97	2.53	5.14	Replication	2	456.34	228.17	2.59	5.14
T. T.	3	2213.55	737.85	7.93	4.76	T. T.	3	2120.93	706.98	8.01	4.76
Error (A)	6	558.34	93.06			Error (A)	6	529.33	88.22		
H. S.	2	7246.30	3623.15	21.58	3.63	H. S.	2	7047.20	3523.60	22.21	3.63
T. T. x H. S.	6	570.16	95.03	0.57	2.74	T. T. x H. S.	6	529.50	88.25	0.56	2.74
Error (B)	16	2686.34	167.90			Error (B)	16	2538.10	158.63		
Available residual soil P_2O_5 (kg/ha)											
Replication	2	2.18	1.09	18.94	5.14	Replication	2	2.25	1.12	5.30	5.14
T. T.	3	144.44	48.15	834.75	4.76	T. T.	3	122.82	40.94	192.85	4.76
Error (A)	6	0.35	0.06			Error (A)	6	1.27	0.21		
H. S.	2	278.97	139.48	47.57	3.63	H. S.	2	245.73	122.87	44.23	3.63
T. T. x H. S.	6	43.55	7.26	2.48	2.74	T. T. x H. S.	6	40.88	6.81	2.45	2.74
Error (B)	16	46.91	2.93			Error (B)	16	44.44	2.78		
Available residual soil K_2O (kg/ha)											
Replication	2	519.55	259.77	14.75	5.14	Replication	2	439.16	219.58	12.99	5.14
T. T.	3	1667.21	555.74	31.56	4.76	T. T.	3	1493.76	497.92	29.46	4.76
Error (A)	6	105.67	17.61			Error (A)	6	101.41	16.90		
H. S.	2	4010.01	2005.01	20.17	3.63	H. S.	2	3784.69	1892.34	20.60	3.63
T. T. x H. S.	6	946.15	157.69	1.59	2.74	T. T. x H. S.	6	858.82	143.14	1.56	2.74
Error (B)	16	1590.60	99.41			Error (B)	16	1469.66	91.85		
Soil organic carbon content											
Replication	2	0.00184	0.00092	34.24	5.14	Replication	2	0.00185	0.00092	43.43	5.14
T. T.	3	0.00010	0.00003	1.21	4.76	T. T.	3	0.00010	0.00003	1.52	4.76
Error (A)	6	0.00016	0.00003			Error (A)	6	0.00013	0.00002		
H. S.	2	0.00474	0.00237	6.86	3.63	H. S.	2	0.00507	0.00253	6.40	3.63
T. T. x H. S.	6	0.00539	0.00090	2.60	2.74	T. T. x H. S.	6	0.00604	0.00101	2.55	2.74
Error (B)	16	0.00553	0.00035			Error (B)	16	0.00633	0.00040		

T. T. = Transplanting time, H. S. = Harvesting stage, d.f. - degree of freedom, S.S. - Sum of squares, MS – Mean squares, F cal - F calculated value, F tab - F tabulated value