AGROTECHNIQUES IN INDIAN SARSAPARILLA

(*Hemidesmus indicus* [Linn] R. Br)

By

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THESIS

Submitted in partial fulfilment of the
requirement for the degree

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Faculty of Agriculture
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DECLARATION

I here by declare that this thesis entitled "Agrotechniques in Indian sarsaparilla (*Hemidesmus indicus* [Linn] R. Br.)" is a bonafide record of research work done by me during the course of research work and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other university or society.

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Certified that the thesis entitled " Agrotechniques in Indian sarsaparilla (*Hemidesmus indicus* [Linn] R. Br) " is a record of the research work done independently by **Mrs. K.C. SHINA** (95-11-12) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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We, the undersigned members of the Advisory Committee of Mrs. K.C. SHINA (95-11-12), a candidate for the degree of Master of Science in Agriculture with major in Agronomy, agree that, the thesis entitled "Agrotechniques in Indian sarsaparilla (*Hemidesmus indicus* [Linn] R. Br.)" may be submitted by Mrs. K.C. SHINA, in partial fulfilment of the requirement for the degree.

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Dedicated to

fond memories

of my father

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

11. Interaction effect of spacing × *FYM* and stages of harvest on K uptake by the plant

12. Interaction effect of spacing × *FYM* and stages of harvest on soil available N after experiment

13. Interaction effect of spacing × *FYM* and stages of harvest on soil available P_2O_5 after experiment

14. Interaction effect of spacing × *FYM* and stages of harvest on soil available K_2O after experiment

15. Interaction effect of spacing × *FYM* and stages of harvest on soil organic carbon content after experiment

16. Effect of spacing × *FYM* and stages of harvest on Essential oil content in *Hemidesmus indicus*

17. Effect of spacing × *FYM* and stages of harvest on Oil yield in *Hemidesmus indicus*

18. Effect of spacing × *FYM* and stages of harvest on Water soluble extract in *Hemidesmus indicus*

19. Effect of spacing × *FYM* and stages of harvest on Alcohol soluble extract in *Hemidesmus indicus*

LIST OF APPENDICES

INTRODUCTION

INTRODUCTION

Ancient Indian knowledge on medicinal plants was wide and comprehensive. A good number of medicinal plants are found mentioned in the ancient classical Ayurvedic texts. The destruction and degradation of natural habitats of medicinal plants have led to diminished supply of these valuable raw materials. The poor availability has also resulted in adulteration of raw drug. One of the effective ways to check the use of adulterants is to cultivate the much needed drug plants.

Hemidesmus indicus [Linn.] R. Br. belonging to the family Asclepiadacea is renowned for its pharmacological properties Known as Sariva in Sanskrit, the plant is popular as Naruninti or Nannari in our vernacular language. The plant is a slender, laticiferous, twining shrub occurring over the greater part of India. The tuberous root is dark brown, silvery white, tortuous with transversely cracked and longitudinally fissured bark.

The root forms the official part which is reported to possess cooling and blood purifying action and is hence used to make refreshing drinks. The root preparations are used for relief in skin diseases, fever, thirst, chronic rheumatism, anaemia etc. (Warrier *et al.*, 1995). Average annual requirement of fresh roots of *Hemidesmus indicus* for the ayurvedic drug manufacturers is about 52,000 kg and the whole demand is met by collection from natural forests. The market price of fresh root is Rs. 45 per kg.

Roots contain 0.225 per cent essential oil containing 2 hydroxy - 4 - methoxy benzaldehyde as the major component (CSIR., 1959). The drug forms the main component in commercial ayurvedic preparations like saribadyasavam, pindathailam, vidaryadileham, jatyadighrtam etc. The enormous uses and the high demand have created enthusiasm among the farmers for taking up the cultivation of this plant. Domestication and standardisation of agrotechniques deserves utmost importance at this juncture. The present state of our knowledge is scanty especially on optimum spacing, standard stage of harvest and nutrition of *Hemidesmus indicus* so as to increase the yield and quality of produce. In view of this the present study was taken up with the following objectives:

1. To standardise the planting material.
2. To arrive at optimum spacing for getting maximum yield.
3. To work out optimum stage of harvest of *Hemidesmus indicus* so as to get highest yield of good quality.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Hemidesmus indicus commonly known as 'NarunInti' is a well known ayurvedic drug since ancient times. Average annual requirement of dry roots of *Hemidesmus indicus* for the ayurvedic drug manufacturers is about 26, 500 kg and the whole demand is met by collection from natural forests. The plant is not reported to be cultivated any where. Since literature available on cultivation aspects of this crop is scanty, information available on all the medicinal plants are reviewed in this chapter.

2.1 **Methods of Propagation**

2.1.1 **Seed**

Seed germination is the capacity of seeds to give rise to normal sprouts within a definite period, fixed for each crop under optimum conditions. The percentage of germination is the numerical ratio of normally germinated seeds to the total number taken for germination.

Badhwar *et al.* (1957 and 1963) recommended propagation of sarpagandhi (*Rauvolfia serpentina*) by seeds for better economic yield and observed 25 - 50 per cent germination. The seed rate recommended is @ 5.5 kg ha^{-1}. On an average irrigated two year old plantation yielded 2200 kg and a three year old plantation 3300 kg air dried roots per hectare. Sahu (1979) found that yield contributing characters like length, diameter and weight of fresh and air dried roots were higher from seed propagated plants.

In *Potentilla erecta* Kozlowski (1981) reported that seed germination was found to be 95 per cent. The plants grew well but slowly and disease free and obtained a maximum rhizome yield in the fourth year of planting (2500 kg ha^{-1}). Devi *et al.* (1982) reported that fresh seeds are used for viable propagation of *Rauvolfia serpentina* compared to stem or root cuttings.

Hegde (1988) reported that in periwinkle (*Catharanthus roseus*), plants propagated through cuttings flowered 3 - 4 months earlier than that raised from seeds. For dry matter production plants should be propagated through seeds and for seed production through cuttings. Plants propagated through cuttings showed slightly increased plant height, branches per plant and stem diameter. Where as the productivity in terms of root, leaf and stem was not affected by the method of propagation. He also found that the method of propagation did not show any influence on harvest index. Root shoot ratio was considerably lower in plants propagated through cuttings than those raised from seeds.

Mitra and Kushari (1989) compared the germination and seedling survival of two cultivars of *Solanum khasianum.* They found that scarification of seeds with 10 per cent nitric acid improved germination and seedling survival in Gandi which had heavier seeds with higher glycoside content than S - S type cultivar of *Solanum khasianum.*

2.1.1.1 **Seedling**

Meera (1994) rated seedlings as the best planting material in adapathiyan (*Holostemma annulare)* for realising maximum yield of fresh as well as dry roots. Among the five propagules, seedlings showed the highest field establishment of 91.7 per cent followed by root stumps (87.5 per cent), root cuttings (84.7 per cent) and vine cuttings (83.3 per cent). Seedlings recorded highest value in terms of length of vine, diameter of vine, inter nodal length and number of branches. She also found that the seedlings recorded higher root yield and yield contributing factors like root length and root volume, where as root diameter remained unaffected by the type of planting material used. The fresh and dry root yield of seedlings were 3.49 and 1.19 t ha^{-1}, respectively.

2.1.1 **Vegetative means**

Vegetative or asexual propagation is adopted to produce plants identical in genotype with the source plant. New plants are regenerated from stem, leaf or root.

Sahu (1969) reported that in *Rauvolfia serpentina,* 5 cm of the root with a portion of the stem above the collar planted in May - June in irrigated fields gave 90 - 92 per cent success. Peppermint, propagated by rooted sprouts picked from after crop peppermint fields, has been found to improve large scale growing, instead of propagation by tillers (Foldesi and Havas., 1979). Khaskhas (*Vetiveria zizanioides*) propagated through slips with roots was found to be successful in the black soil of Pune, for increasing root yield (Karnick, 1979). Sandal wood (*Santalum album*) propagated through root suckers and side grafting techniques were found to be promising (Husain *et al.*, 1982).

In *Hemidesmus indicus,* Philip *et al.* (1991) reported that the root cuttings of 10 cm length having a girth of 1.3 to 1.8 cm at the centre can be used for vegetative propagation. The stem cuttings failed to root even with the applications of 10, 20 and 30 ppm of IAA, IBA and NAA, respectively.

Legha and Sharma (1993) reported that in liquorice (*Glycyrrhiza glabra*) cuttings of under ground stem or root of 15 - 25 cm, possessing 2 - 3 eye buds are found better for getting higher yield.

Sudhadevi (1992) observed that the root cuttings of tree turmeric (*Coscinium fenestratum*) recorded sprouting of 70 per cent, but no rooting was observed.

In *Dioscorea floribunda* crown portions of the tubers as planting material produced highest dry matter compared to medium and tip portions under Bangalore condition (Hegde and Randhawa, 1982). They also reported that the percentage of dry matter distribution into different parts was not affected by planting material. Rajagopalan (1983) reported that in kacholam (*Kaempferia galanga*) planting of mother rhizomes were found to be superior to that by finger rhizomes for producing maximum fresh and dry rhizome yields. Oleoresin yield was also high when mother rhizomes were planted. Philip (1984) reported that in turmeric (*Curcuma longa*) halves of mother rhizomes of 35 - 44 g weight is the best planting material for getting higher yield of cured produce as well as for the higher yield of curcumin. Krishnan (1995) observed that in *Dioscorea floribunda* optimum crop growth is obtained when tuber pieces of 50 - 70 g were used.

In *Inula japonica* the simplest method of propagation is by planting orthotropic shoots in the Moscow region and Soviet Far East (Novoselceva *et al.*, 1970). Nambiar *et al.* (1977) observed that two noded cuttings of

Panniyur - 1 variety of pepper was the best propagating material resulting in maximum rooting and field establishment. In *Mentha Citrata*, stem cuttings could be used for large scale cultivation (Arumugan and Kumar, 1980). They also concluded that at least one leaf is required on the stem cutting for successful rooting in *Mentha citrata.*

Vadivel *et al.* (1981) recommended hard wood cuttings for successful vegetative propagation in cinnamon. Zelenina (1981) reported that rhizome cuttings are superior to root cuttings for the propagation of *Podophyllum pelatum*. Hegde (1983) observed that in Black Pepper (*Piper nigrum*), the three noded cuttings, rooted better than one or two noded cuttings in Panniyur -1 variety.

Gauniyal *et al.* (1988) suggested that stem cuttings of 6 - 7 cm with two buds is the best suited propagule of *Rauvolfia serpentina* and that hard wood cuttings performed better than soft wood cuttings. Seong *et al.*(1989) obtained 90 - 100 per cent rooting by using cuttings in *Gymnostemma pentaphyllum.*

In chethikoduveli (*Plumbago rosea*), Subha (1990) didnot observe any significant difference between two noded and three noded cuttings in terms of root yield as well as root characters.

Shi *et al.* (1990) compared the survival rate of *Artemisia rutifolia* and *A. transiliansis* by using cuttings and found that *A. rutifolia* and *A. transiliansis* had a mean survival rate of 69.4 per cent and 60 per cent, respectively.

In *Rosa damascena* Farooqi *et al.* (1994) reported that the basal woody cuttings treated with IBA at 300 ppm recorded the highest rooting per cent (46.2), more number of roots (57.3), higher fresh (0.53 mg) and dry weight (0.07 mg). This treatment also had better shoot growth and survival of cuttings. Shinji *et al.* (1994) reported that in *Polygonum multiflorum,* rate of rooting was highest when planted with cuttings. Balu and Algesaboopathi (1995) observed that in *Andrographis lineata*, the percentage of establishment was highest (67.0) with stem cuttings.

Singh and Singh (1980) found that *Dioscorea floribunda* can be effectively propagated by air and ground layering. Rema and Krishnamoorthy (1994) obtained 87 per cent success in clove when it was vegetatively propagated by grafting.

2.2 Spacing

In any crop, there should be optimum plant population in the field for realising maximum economic yields. If the plant population is very low or very high it will have an adverse effect on the yield of the crop.

2.2.1 Biometric characters

Goren *et al.* (1981) reported that in hops (*Humulus lupulus*) a spacing of 125 × 150 cm was found to be optimum for producing higher shoot and bud development. In Arabian jasmine (*Jasminum sambac*) Lekskul (1982) recommended 0.75 × 1 m spacing for inducing free flowering habit and producing higher flower yield. Laszlo and Gyongyi (1982) found that for best growth of *Carum carvi* the optimum stand density should be 110.7 plants / m^2. Joseph (1983) found that in channakoova (*Costus speciosus*) when planted at a spacing of 75 × 75 cm enhanced the vegetative growth of the plants as indicated by the maximum number of tillers, number of leaves and leaf area per plant.

Singh and Dadlani (1988) made an elaborate study on the growth and flowering in *Rosa damascena* and reported that the plant height, plant spread, number of shoots per plant, number of flowers per plant and weight of flowers per plant was found to be optimum at a spacing of 75 × 75 cm. In *Plumbago rosea,* Subha (1990) observed that the height of plant increased with decrease in spacing., whereas the spread of plant increased with increase in spacing.

Maximum height of 76.5 cm was obtained at a spacing of 50 × 15 cm.

In palmarosa the tiller and leaf number increased to a sizeable extent by planting at a spacing of 30 × 15 cm (Maheshwari *et al.*, 1991). In tube rose (*Polianthes tuberosa)* Bhattacharjee *et al.* (1994) reported that planting of bulbs at a spacing of 25 × 20 cm is best for increasing vegetative growth, flowering and bulb formation.

2.2.2 **Yield attributes**

According to Sharma and Singh (1979) the herb and oil yield of peppermint was found to be higher at a row spacing of 60 cm. Clark and Menary (1979) compared the oil yield obtained from peppermint by lower and higher density of planting. The oil yield obtained from higher density of planting (30 and 40 plants m^{-2}) continued to increase even at a menthol content of 50 per cent.

Herbage and oil yield of java citronella showed a linear increase due to increase in the levels of plant population (Bommegowda *et al.*, 1980). In *Dioscorea floribunda,* Rao *et al.* (1981) recommended a spacing of 45 × 30 cm for a one year crop and 60 × 45 cm for two year crop for getting highest tuber yield and diosgenin content.

Nandi and Chatterjee (1981) reported that the total herbage yield of senna was found to be optimum at a spacing of 30 × 30 cm. Hazarika *et al.* (1981) compared the herb and oil yields of palmarosa with respect to different spacing combinations and found that maximum herb (12,852 kg ha^{-1}) and oil (70.69 kg ha^{-1}) yield was obtained at a spacing of 40 × 40 cm. In chicory, Pappiah and Muthuswami (1981) reported that closest spacing is better for producing higher tuber yield.

In turmeric, Ponnuswamy and Muthuswamy (1981) recommended a spacing of 45 × 20 cm for getting higher yield. Ghosh *et al.* (1981) observed that in black cumin a spacing of 20 cm between rows produced maximum yield of 697.77 kg ha^{-1}. In caraway, Laszlo and Gyongi (1982) obtained highest yield at a planting density of 105 - 120 plants m^{-2}.

In senna an optimum spacing of 45 × 30 cm was found to be better for producing highest yield (Pareek *et al.*, 1983). Joseph (1983) reported that in *Costus speciosus* higher rhizome and diosgenin yield was obtained when planted at a spacing of 50 × 50 cm. Singh *et al.* (1983) observed that in lemongrass, the herb and oil yield was maximum at a plant population of 1,11,000 plants per hectare.

Singh *et al.* (1983) found that an optimum row spacing of 20 cm produced maximum seed and oil yield in coriander (*Coriandrum sativum*). In *Valeriana wallichii* a spacing of 50×45 cm was found to be optimum for producing highest dry root yield and maximum essential oil. The dry root yield and essential oil content obtained in this case was 30.9 g per plant and 1.183 per cent, respectively at three years of plant age (Shah and Gupta, 1983).

Rao *et al.* (1984) obtained highest biomass and essential oil yields in bergamont mint by planting at 45 cm row spacing. In palmarosa, Rao *et al.* (1985) recommended a spacing of 30×30 cm and 45×30 cm and application of 240 kg N per hectare per year for getting higher essential oil yield. Mircea (1987) reported a row spacing of 62.5 cm for getting highest yield of *Tagetes patula*. The seed rate recommended was @ 4 kg ha^{-1}.

In sage (*Salvia officinalis*) Tabara *et al.* (1987) found that an increase of row spacing from 62.4 to 75 cm resulted in an average yield decrease by 13 per cent. Gaur and Sharma (1987) reported that inter and intra row spacings had no effect on increasing seed and latex yield in *Opium poppy*. Ahmed and Rahman (1987) compared seed size and spacing on the yield of turmeric and found that medium sized (11 - 20 g) seed at a closer spacing of 15 cm apart is the best for producing maximum yield. In *Ocimum gratissimum* var.

clocimum, fresh and dry weight of plant increased with decrease in plant population density (Balyan *et al.*, 1988).

Ahmed *et al.* (1988) observed that in ginger (*Zingiber officinale*) maximum yield of 13.4 t ha^{-1} was obtained with a narrow spacing of 15 cm. Rao *et al.* (1988) recommended a spacing of 60 × 45 cm for getting highest herb and oil yield of 11.2 kg ha^{-1} at a row spacing of 30 cm.

According to Kamwar and Saimbhi (1989) the highest seed yield in fenugreek was obtained with a row spacing of 20 cm and seed rate used in this case was 37.5 kg ha^{-1}. Bordia *et al.* (1995) recommended row distance of 30 × 15 cm for obtaining commercial yield in *Chlorophytum sp.* Subha (1990) reported that in *Plumbago rosea* the highest root yield was obtained with the closest spacing of 50 × 15 cm, whereas the per plant root yield was highest under wider spacing of 50 × 45 cm. In palmarosa, Maheshwari *et al.* (1991) obtained highest herbage and oil yield when planted at a spacing of 30 × 15 cm.

Badiyala and Panwar (1992) suggested that the highest grain yield of kalazira was obtained at a row spacing of 35 cm over narrow spacings of 25 and 15 cm. In *Mentha viridis* a spacing of 30 cm between rows is found effective for producing highest herbage and oil yields (Chinnabhai *et al.*, 1992). Bhati (1992) reported that maximum seed yield and harvest index of cumin is assoicated with a row spacing of 22.5 cm.

Chatterjee *et al.* (1995) observed a spacing of 10 × 10 cm for increasing the yield in *Cepaelis ipecacuanha.* In long pepper (*Piper longum*), Viswanathan (1995) found that spacing of 60 × 60 cm produced higher yield. Sheela (1996) recommended 50 × 50 cm spacing in *Piper longum* for getting better growth and yield during the first year of growth whereas Ayisha (1997) obtained the highest cumulative yield and yield attributing characters at a wider spacing of 60 × 60 cm in the second and third year of growth.

2.2.3 **Secondary metabolites**

Plant secondary metabolites are compounds present in plants which are believed to have no role in the basic life processes, but have secondary non essential role (Mizrahi, 1988).

Rao *et al.* (1981) reported that for getting highest diosgenin content of medicinal yam a spacing of 45 × 30 cm is to be adopted for a one year crop. In senna, the total sennoside content of the plant was maximum when planted at a spacing of 60 × 60 cm and minimum in 30 × 30 cm. The sennoside content per plant was shown to be most pronounced when planted at 90 × 60 cm spacing (Nandi and Chatterjee, 1981). Hatakeyama (1981) found that in opium poppy (*Papaver somniferum*) better morphine yield per unit area was obtained when the plants were more densely planted.

In *Solanum viarum* spacing of 90 × 150 cm gave optimum yield (84 kg ha^{-1}) of solasodine (Patil and Laloraya, 1981). Hazarika *et al.* (1981) obtained maximum geraniol content in palmarosa at 40 × 60 cm spacing. Laszlo and Gyongyi (1982) obtained lower content of volatile oil from crops harvested from dense stand of caraway.

Singh *et al.* (1983) obtained highest citral content of lemon grass under a maximum population of 1,11,000 plants per hectare. In palmarosa planting densities of 14.81 and 22.22 plants m^{-2} produced essential oil of good quality with low amount of terpenes and geranyl acetate but higher amount of free geraniol (Pareek *et al.*, 1983).

In flos adonis (*Adonis automnalis*) El - Gengaihi *et al.* (1981) observed that spacing had no effect on cardiac glycoside percentage. In *Coriandrum sativum* spacing didnot affect quality of oil (Singh *et al.*, 1983).

Joseph (1983) obtained highest diosgenin yield in *Costus speciosus* at a higher density planting (50 × 50 cm) as compared to planting it either at 60 × 60 cm or 75 × 75 cm. Shah and Gupta (1983) reported that a spacing of 50 × 45 cm gave maximum essential oil content (1.18per cent) in *Valeriana wallichii*.

Singh *et al.* (1989) reported that in japanese mint the essential oil yield was highest at the closest spacing of 30 × 10 cm, whereas spacing had no appreciable effect on menthone and menthol content.

Subha (1990) obtained highest plumbagin yield of 4.29 kg ha^{-1} at a spacing of 50 × 15 cm in *Plumbago rosea* whereas the highest per plant yield of plumbagin (0.11 g) was obtained from a wide spacing of 50 × 45 cm. In chamomile, Gowda *et al.* (1991) obtained highest essential oil yield at a spacing of 30 × 20 cm.

Rao *et al.* (1984) observed that essential oil concentration was not affected by spacing in bergamont mint.

2.3 Stage of harvest

Optimum stage of harvest for a crop is an important management practice to be adopted for getting highest yield and good quality of produce.

2.3.1 **Yield attributes**

Nybe (1978) obtained the maximum yield of green ginger when harvested at 180 days after planting. He also observed that the drying percentage continued to increase with the maturity of the crop and maximum drying percentage was obtained during the last stage of harvest i.e. at 270 days after planting.

Patil and Borse (1979) reported that harvesting of turmeric at the stage of eight and a half months after planting gave the highest yield of turmeric. They also found that increase in the curing percentage was observed as the period of harvesting was enhanced. In java citronella, five herbage cuts were possible in 26 months and an oil yield of 655 kg was obtained from a hectare (Bommegowda and Krishnamoorthy, 1979). Prasad and Saxena (1980) reported that the accumulation of dry matter was maximum at the time of harvest of first and second cuttings in peppermint (*Mentha piperita*).

Pareek *et al.* (1981) obtained maximum oil yield in palmarosa (*Cymbopogon martinii* var *motia*) at the commencement of flowering. They also observed that the total herbage yield was higher when harvested at the early seed formation stage. In *Eucalyptus citriodora* Nair *et al.* (1983) reported that the optimum time for getting maximum yield of oil was middle of

May for the pre - monsoon harvest of leaves and middle of November for the Post monsoon harvest.

Chandra and Singh (1983) found that in field mint (*Mentha arvensis*), the highest oil yield and best quality of oil were obtained by harvesting the crop at 135 days after sowing. In *Kaempferia galanga,* Rajagopalan (1983) reported that six month old crop gave maximum yield of fresh rhizome. But the dry rhizome yield was maximum in seven month old crop. He also reported that fresh and dry rhizome yield per hectare and drying percentage were significantly influenced by planting time, harvesting time and propagation method.

Joseph (1983) obtained maximum dry rhizome yield and diosgenin content in *Costus speciosus* at nine months after planting. By delaying the harvest to 12 months after planting, the dry matter percentage decreased together with low rhizome yield and diosgenin content. In cinnamon (*Cinnamomum zeylanicum*) Thomas *et al.* (1987) obtained maximum leaf oil with superior quality when two harvests were taken per year, one in May and another in November.

White *et al.* (1987) reported that in pepper the best yield of high quality oil was obtained in late January - early February when the inflorescence on the main stem was in 10 - 20 per cent bloom. Hegde (1988) found that in *Catharanthus roseus* the highest rate of drymatter production was obtained between 150 and 210 days after transplanting.

Chinnamma (1985) found that in palmarosa herbage yield in the first year, second year and total yield for the two years were significanly influenced by different intervals of harvest and the minimum value was recorded by 65 days cutting interval in both the years. Geetha and Thomas (1988) reported that the optimum stage of harvest of jamrosa comes out to be 60 days. Kuriakose (1989) observed that in palmarosa maximum grass and oil yield was obtained when harvested at 90 days interval.

Bakshi *et al.* (1991) found that in hops after the cone formation, third and fourth weeks are the optimum period for harvesting of hop flowers in varieties late cluster, comet, Golden cluster, Hybrid - 2 and Talisman for the production of dry matter, oils and alpha acids. Late cluster is more stable amongst all the varieties. Gill and Randhawa (1992) recommended that to get maximum herb and oil yields of French basil, the crop may be transplanted from March 25 to May 10 under North Indian condition and should be harvested at complete flowering stage.

Meera (1994) observed that yield as well as soluble carbobhydrate content of adapathiyan (*Holostemma annulare)* increased with advancing stage of maturity and it was maximum at 18 months stage. The vine length showed a progressive increase with increase in the duration of crop. The number of leaves, total leaf area per plant, fresh and dry weight of stem and leaf first showed an increasing trend upto 12 months and there after decreased. Maximum fresh (4.14 t ha^{-1}) and dry root yield (1.56 t ha^{-1}) was obtained when the crop was harvested at 18 months stage. Maximum driage and harvest index also was noticed when harvested at this stage.

Nigam and Kandalkar (1995) recommended the harvesting of *Withania somnifera* 150 to 170 days after sowing for getting maximum root yield. Legha *et al.* (1995) reported that the crop should be harvested at 2½ - 3 years for getting higher yield in *Glycyrrhiza glabra.* In periwinkle, the crop should be harvested six months after planting for getting maximum root yield and optimum alkaloid content (Krishnan, 1995). In *piper longum* Viswanathan (1995) observed that the maximum yield of 1000 kg ha^{-1} was obtained in third year of planting. In *Rauvolfia serpentina*, Trivedi (1995) reported that 18 month old crop gave maximum root yield. Ayisha (1997) found that the peak bearing stage in *Piper longum* was at 17 months stage after which there was a drastic reduction in yield.

2.3.2 **Secondary metabolites**

Nybe (1978) observed that oleoresin and oil content was maximum at 165 days after planting and minimum at 270 days in four types of ginger viz, Rio - de - janeiro, Maran, Kuruppampady and Wayanad Local. Gigliano (1980) reported that in capsules of *Papaver bracteatum,* the alkaloid thebaine content reached its maximum value 5 - 10 days after anthesis and after wards it decreased very quickly reaching the lowest value at 25 - 30 days after anthesis. Kaith (1981) observed that in *Carum bulbocastanum* plant, the flavour score and the essential oil content was 14.16 and 8.75 during 90 per cent seed setting stage and decreased to 6.42 and 6.25 respectively on 50 per cent maturity and 6.00 in both cases on complete maturity. Thus for culinary and medicinal purposes, the crop should be harvested at 90 per cent seed setting. According to Nair *et al.* (1983) different times of harvest had no effect on the physico - chemical properties of oil of *Eucalyptus citriodora.*

Joseph (1983) observed a steady decrease in the percentage of diosgenin with delay in harvest, the maximum being during the sixth month (November) and minimum during the twelth month (May). Lammerink *et al.*

(1989) recommended the optimum harvest period in Lavandin from mid to late flowering for obtaining higher percentage of 1,8 - cineole, linalool and camphor or borneol. In Hungarian peppermint an early cut in mid - August and a final cut in October gave high yields of high quality essential oil containing 2 per cent pulegone (Bouverat - Bernier, 1989).

Chandra *et al.* (1992) observed no marked differences in the total geraniol content of jamrosa grass with respect to various dates of harvest.

Leela and Angadi (1994) compared the laevomenthol, menthone and neomenthol content of peppermint obtained during different times of harvest, viz, April, July and October. Their study revealed that essential oil content and menthol were highest and menthone content of oil was minimum when harvested in July. Meera (1994) revealed that in adapathiyan the free amino acids were not affected by stages of harvest where as soluble carbohydrate content was highest when harvested at 18 months stage.

2.4 **Organic manuring**

Application of organic manures is one of the important management practices for increasing yield and quality.

Kultunov (1984) reported that in garlic, application of farm yard manure

(FYM) @ 40 t ha^{-1} resulted in the highest yield of bulbs suitable for long term storage. In pepper, cattle manure @10 t ha^{-1} was found to be the most viable treatment compared to goat or chicken manure (Adiyoga, 1987). Chairani (1987) reported that in *Costus speciosus* the best growth was obtained by soaking 2 - node stem cuttings in 15 per cent solution of cow urine.

According to Balashanmugham *et al.* (1989) the optimum dose of FYM for producing highest yield in turmeric was found to be 25.0 t ha^{-1}. The fresh rhizome yield obtained in this case was 32,370 kg ha^{-1}. Maheshwari *et al.* (1991) observed that in palmarosa FYM @ 15 t ha^{-1} gave higher biomass and oil yield. But the application of FYM did not affected the geraniol content. In rainfed niger Ram *et al.* (1992) found that application of FYM resulted in 65 per cent increase in seed yield as compared to that in the control.

Viswanathan (1995) reported that FYM @ 20 t ha^{-1} is required for satisfactory growth of *Piper longum*. Legha *et al.* (1995) observed that FYM @ 15 t ha^{-1} for getting maximum root and leaf yield in *Catharanthus roseus.* He also suggested green manuring as an alternative for FYM application and is found to be beneficial in *Catharanthus roseus*. Bordia *et al.* (1995) found that in *Chlorophytum sp.*, FYM @ 10 - 15 t ha^{-1} provide good nutrient status to the substratum for supporting healthy growth of plant. Trivedi (1995) reported that

FYM @ 20 - 25 t ha^{-1} would give good response in *Rauvolfia serpentina*. In *Cephaelis ipecacuanha*, soil suitably enriched with leaf mould and cowdung produces fleshy roots and improves yield (Chatterjee *et al.*, 1995).

In *Piper longum* Sheela (1996) and Ayisha (1997) recommended the application of FYM @ 20 t ha^{-1} for the best growth in terms of fresh and dry spike yield.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present study was undertaken at the College of Horticulture, Vellanikkara, Trichur, Kerala during March 1996 to March 1997. The experimental site is located at 10° 31′ N latitude and 76° 13′ E longitude at an elevation of about 40.3 m above mean sea level.

The materials used and the methodology adopted are discussed in this chapter. The site is characterised by heavy rains during June - September (South - East Monsoon) and October - November (North - East Monsoon) months followed by a summer season from March to May.The meteorological data for the experimental period are presented in Appendix I and Fig. I.

Weather during the crop growth period was favourable for the satisfactory performance of the crop. During the period of investigation a total rainfall of 2239.8 mm was received in 105 rainy days. The mean maximum and mean minimum temperature during the period ranged from 28.8°C to 36.4°C and 21.8°C to 25.2°C, respectively. The mean sunshine hours during the period of experimentation ranged from 2.7 to 9.6 with a mean relative humidity of 73.5 per cent.

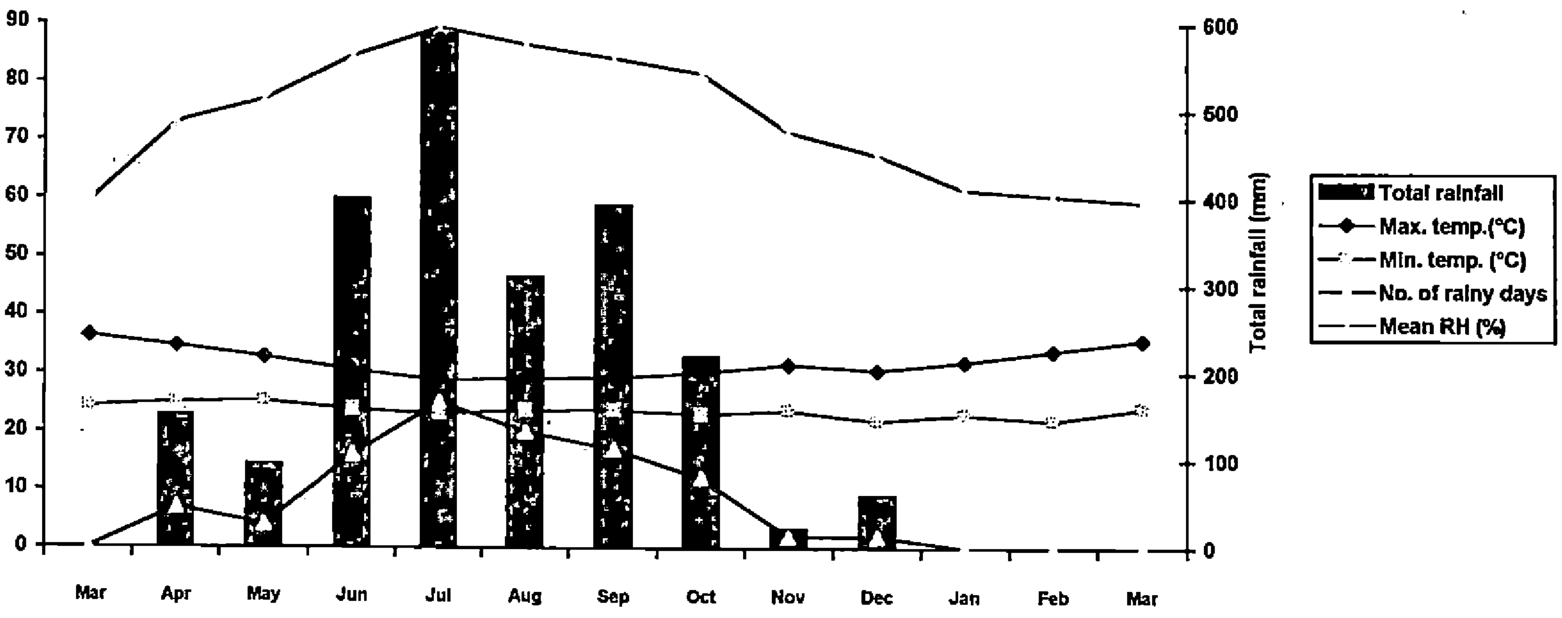


Fig. 1 Meteorological data (monthly mean) at Vellanikkara, Trichur for the period of March 1996 to March 1997

The soil of the experimental site was a deep well drained sandy clay loam. The data on the physical and chemical properties of the soil are given in Table 1.

Table 1. Physico-chemical properties of the soil of the experimental site.

Sl. No.	Particulars	Value	Method employed
A.	Mechanical Composition	(per cent)	
	Coarse sand	26.0	Robinson's international pipette method (Piper, 1942)
	Fine sand	23.1	
	Silt	21.2	
	Clay	29.7	
	Texture: Sandy clay loam		
B.	Chemical composition	(kg ha^{-1})	
	Total Nitrogen	0.072 per cent	Microkjeldhal method (Jackson, 1958)
	Available Nitrogen	250.88	Alkaline permanganate method (Jackson, 1958)
	Available P_2O_5	15.86	Bray - I extract- Ascorbic acid blue colour method. (Watanabe and Olsen, 1965)
	Available K_2O	177.32	Neutral normal ammonium acetate extract. Flame photometry. (Jackson, 1958)
	Organic Carbon	0.83 per cent	Walkley - Black method. (Jackson, 1958)
	Soil p^H	4.9	1:2.5 soil water ratio. p^H meter (Jackson, 1958)

3.1 Preparation of planting materials and nursery

Four types of planting materials were adapted for the nursery screening.

i) Three noded vine cuttings planted vertically.

ii) Five centimetre long main root cuttings and planted vertically with 1cm portion remaining above ground level.

iii) Five centimetre long main root cuttings and planted horizontally at 2 cm below the soil surface

iv) Five centimetre long root stumps consisting of 2.5 cm shoot and 2.5 cm root portion.

The planting materials for the nursery studies were collected locally from Vellanikkara during March 1996. For preparing vine cuttings actively grówing plants were collected and three noded cuttings were prepared. Root stumps of 5 cm were prepared by retaining 2.5 cm root and 2.5 cm shoot portion above the collar region. Main root cuttings of 5 cm were planted in two ways - horizontally, 2 cm below the soil surface forming one treatment and the other vertically so that 1 cm of it remain above the soil level.

These materias were planted in pots of size 1.2′× 1.2′ × 2′, filled with potting mixture (sand, soil and farm yard manure in 1:1:1 ratio) and kept under partial shade and irrigated frequently at least twice daily to avoid desiccation. The nursery studies lasted for two months.

The propagules raised were screened based on the initial establishment and growth observations and the best planting material was found out and used for field experimentation.

3.2 **Field experiment**

3.2.1 **Experimental details**

The field trial was laid out in split plot design with three replications. Main plot treatments included combinations of 3 levels of manuring and 3 plant densities and the subplot treatments consisted of 4 stages of harvest. The details of the treatment combination are given below.

A. **Main plot treatments: Nine**

Treatment	**FYM (t ha^{-1})**	**Spacing (cm)**
T_1	0	10 × 10
T_2	0	15 × 15
T_3	0	20 × 20
T_4	5	10 × 10
T_5	5	15 × 15

T_6	5	20 × 20
T_7	10	10 × 10
T_8	10	15 × 15
T_9	10	20 × 20

B. **Sub plot treatments: Four times of harvesting**

K_1 - Harvesting at five months after planting (MAP).

K_2 - Harvesting at six months after planting

K_3 - Harvesting at seven months after planting

K_4 - Harvesting at eight months after planting

The lay out of the experiment is presented in Fig.2.

3.2.2 **Land preparation and planting**

The area was cleared off weeds and ploughed well to bring the soil to a fine tilth and then levelled. Raised beds of 1.8 m × 1.2 m size and with a height of 15 cm were formed with an inter channel of 15 cm between the beds. Farm yard manure was applied at the required rate for each plot and incorporated into the soil prior to planting. The root cuttings were planted as per the treatments during July 1996.

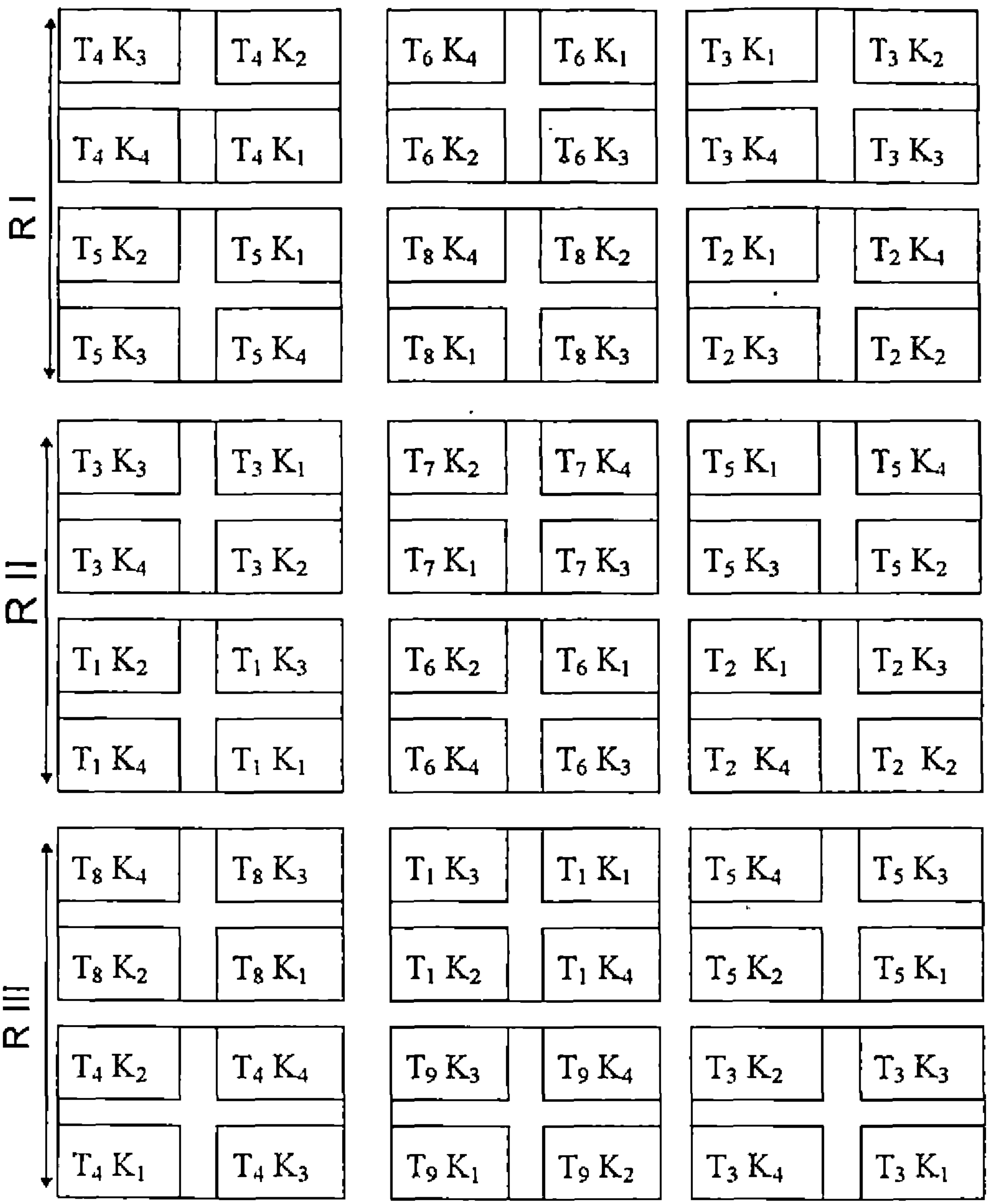
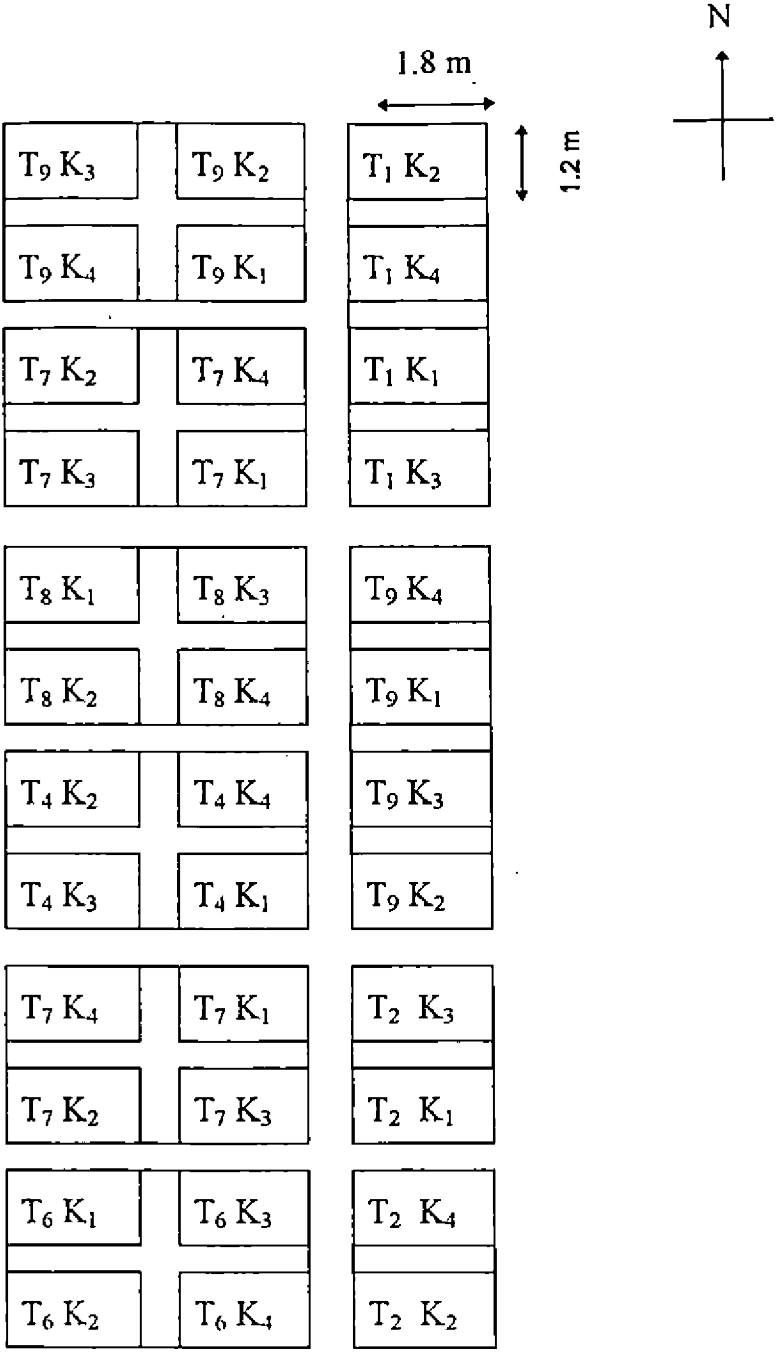


Fig 2. Plan of Lay out


N
1.8 m
1.2 m
T9 K3
T9 K2
T1 K2
T9 K4
T9 K1
T1 K4
T7 K2
T7 K4
T1 K1
T7 K3
T7 K1
T1 K3
T8 K1
T8 K3
T9 K4
T8 K2
T8 K4
T9 K1
T4 K2
T4 K4
T9 K3
T4 K3
T4 K1
T9 K2
T7 K4
T7 K1
T2 K3
T7 K2
T7 K3
T2 K1
T6 K1
T6 K3
T2 K4
T6 K2
T6 K4
T2 K2

Contd.

Spacing × FYM	FYM (t ha^{-1})	Spacing (cm)
T_1	0	10 × 10
T_2	0	15 × 15
T_3	0	20 × 20
T_4	5	10 × 10
T_5	5	15 × 15
T_6	5	20 × 20
T_7	10	10 × 10
T_8	10	15 × 15
T_9	10	20 × 20

Stages of harvest

K_1	Five month stage
K_2	Six month stage
K_3	Seven month stage
K_4	Eight month stage

3.2.3 **Crop management**

The plots were cleared off weeds twice in the season and earthing up was also carried out. Fertilizers were not applied in the experimental field. The details of manual operations taken up in the experimental field have been presented in Table 2.

Table 2. Details of cultural operations

Date	**Operation**
2-7-96	Land preparation - weeding & ploughing
4-7-96	Layout & preparation of beds
5-7-96	Application of FYM
7-7-96 to 9-7-96	Planting
24-7-96	Gapfilling
28-8-96 to 2-9-96	First weeding
10-9-96	Earthing up
4-11-96 to 7-11-96	Second weeding
24-12-96	Harvesting at 5 MAP
24-1-97	Harvesting at 6 MAP
24-2-97	Harvesting at 7 MAP
24-3-97	Harvesting at 8 MAP

3.3 Observations

a. Nursery studies

1. Days to sprout and sprouting percentage
2. Length and girth of shoot (cm)
3. Length and girth of root (cm)
4. Number of leaves

b. Field experiment

3.3.1 Percentage of field establishment

The number of plants established in the field was counted separately for each treatment and the percentage establishment was worked out as follows,

$$\frac{No.of\ cuttings\ germinated}{No.of\ cuttings\ planted} \times 100$$

3.3.2 Pre - harvest observations

Ten plants in each of the experimental plots were selected at random for recording the observations on various biometric characters at monthly intervals.

3.3.2.1 Plant height

Height of the plant was measured from the ground level to the tip of the terminal bud. The mean value was worked out and expressed as plant height in centimetres.

3.3.2.2 **Number of branches per plant**

The total number of branches in each of the plants were counted, the average worked out and expressed as the number of branches per plant.

3.3.2.3 **Number of leaves per plant**

The number of leaves present in each of the plants were recorded at monthly intervals and the mean per plant was worked out and expressed as the number of leaves per plant.

3.3.2.4 **Leaf area per plant**

To estimate leaf area, 200 leaves of *Hemidesmus indicus* were collected and the actual leaf area of each of the leaves was found out graphically. The length and breadth of individual leaves were also recorded. Regression equations were derived from the data based on the leaf length, leaf breadth and length × breadth relationship with the actual leaf area. The best fitting regression equation was obtained using length and length × breadth with the actual leaf area. i.e.

$Y = -0.3523 + 0.20021\ L + 0.49054\ LB$ ($R^2 = 0.7983$). Where Y is the leaf area (cm^2) L = leaf length (cm), LB = length × breadth (cm^2) of the individual leaf.

3.3.2.5 **Observations on flowering**

Days to first flower appearance, the number of inflorescence per plant and the number of flowers per inflorescence on which flowering occurred were counted.

3.3.3 **Post harvest Observations**

As per the treatments, harvesting was carried out at four stages, five months, six months, seven months and eight months after planting. The ten observational plants were dug out separately taking care to collect the entire roots and cleaned in water to remove the adhering soil particles.

3.3.3.1 **Length of root**

The total length of the root was measured from the base to the tip of the root in centimetres separately for each observational plant and the mean was worked out and expressed as the length of the root .

3.3.3.2 **Diameter of the main root**

Diameter of the main root of each observational plant was measured using a non - elastic twine, the length of which was measured in centimetres and the mean worked out and expressed as the diameter of the root.

3.3.3.3 **Number of roots per plant**

The total number of roots for each observational plant was also recorded and the mean of which was expressed as number of roots per plant.

3.3.3.4 **Fresh weight of aerial parts (stem and leaf)**

Fresh weight of stem and leaf were recorded separately for each observational plant and the average worked out and expressed as fresh herbage yield in grams per plant.

3.3.3.5 **Fresh weight of roots**

After cleaning the roots, fresh root weight of the observational plants were recorded and the mean value was worked out and expressed as the fresh weight of root in grams per plant.

3.3.3.6 **Dry weight of aerial parts (stem and leaf)**

The stem and leaf samples after recording the fresh weight were dried in the oven kept at 70°C for 24 - 48 hours until constant weight and the mean worked out and expressed as dry weight of herbage in grams per plant.

3.3.3.7 **Dry weight of roots**

The root samples were oven dried at 70°C for 24 - 48 hours until a constant weight is obtained. The mean per plant was worked out and expressed as dry weight of roots in grams per plant.

3.3.3.8 **Dry matter yield**

The dry weight of aerial and root portion in each of the treatments were added separately and expressed as total dry matter yield in kg ha^{-1}

3.3.3.9 **Harvest index**

Harvest index was worked out using the formula, Harvest index =

$$\frac{Economic\ yield}{Biological\ yield} = \frac{Oven\ dry\ root\ yield}{Oven\ dry\ weight\ of\ herbage + Oven\ dry\ weight\ of\ root}$$

3.3.4 **Net plot yield**

From the net plot area all the plants were harvested and the aerial and root portion were weighed separately and expressed as herbage yield (kg ha^{-1}) and root yield (kg ha^{-1}).

3.5 Quality attributes / parameters

3.5.1 Essential oil content

Essential oil content in *Hemidesmus indicus* was estimated by steam distillation of fresh roots using clevenger apparatus. For this 40 g of fresh root sample was first mashed and taken in a 500 ml round bottomed distillation flask to which 100 ml of distilled water was added. The contents were distilled for 3½ - 4 hours until the oil level remained constant and the volume of oil collected was noted and expressed as per cent on volume by weight basis.

3.5.2 Essential oil yield

From the oil content and the fresh root yield, the oil yield was worked out and expressed in litres per hectare.

3.5.3 Alcohol soluble extract

Soxhlet extraction method was adopted for the determination of the alcohol soluble extract of air dried roots of *Hemidesmus indicus* (Lees, 1975). For this 10.0g of finely powdered air dried roots of *Hemidesmus indicus* was accurately transfered to a filter paper to hold the sample and the weight of the sample together with filter paper was recorded. The sample packet was then kept in the extraction tube of Soxhlet apparatus, which in turn of is connected to a condenser. The extraction tube is connected to a round bottomed flask of 125 ml. Methanol was used as the solvent, of which was poured through the sample in the tube in to the flask. Extraction of the sample was carried out for eight hours without interruption in a water bath maintained at 80°c. The temperature of water bath was regulated in such a way that the solvent which volatilizes condensed and drops continuously upon the sample without any appreciable loss. At the end of the extraction period, the sample in the extraction tube turned colourless, and the sample packet was removed from the extractor. The Soxhlet flask was dismantled and allowed to cool. The solvent was evaporated on a water bath kept at 90°C. The Soxhlet flask along with the residue was weighed. The residue left in the Soxhlet flask after the complete evaporation of the solvent was weighed to get the alcohol soluble extract which was expressed as a percentage on dry weight basis.

Total alcohol soluble extract in g = wt of Soxhlet flask along with residue (g) - wt. of empty Soxhlet flask (g)

$$\text{Total alcohol soluble extract (per cent)} = \frac{wt.of\ residue\,(g)}{\begin{array}{c} wt.of\ dried\ sample \\ used\ for\ extraction\,(g) \end{array}} \times 100$$

3.5.4 Water soluble extract

Fresh root samples of *Hemidesmus indicus* were used for the estimation of water soluble extract using specific gravity method (Ranganna, 1977). For this 10.0g of fresh root sample was made into a paste using a mortar and pestle. 50ml of distilled water was added to this and centrifuged for 20 minutes. The supernatant liquid which contained the water soluble material, was decanted and the specific gravity of which was determined using a specific gravity bottle.

$$\text{Specific gravity} = \frac{\textit{Weight of extract}}{\textit{Weight of an equal volume of water}}$$

The specific gravity values thus obtained were then converted into the corresponding total soluble salt values from the Tables which shows the relation between specific gravity and grams of sugar per litre (Ranganna, 1977).

3.6 Chemical analysis

3.6.1 Plant analysis

The oven dried plant samples were powdered and stored properly for carrying out chemical analysis. The nitrogen, Phosphorus and potassium contents of these samples were estimated.

3.6.2 Total Nitrogen

Total nitrogen content of the plant sample was determined by microkjeldhal digestion and distillation method (Jackson, 1958).

3.6.3 Total Phosphorus

The plant samples were digested using diacid mixture (HNO_3 $HClO_4$ in the ratio of 2:1) and the contents were made upto 50 ml. The P content was estimated in the diacid digest by vanado molybdo phosphoric yellow colour method in HNO_3 system (Jackson, 1958)

3.6.4 Total Potassium

The potassium content of plant sample was determined in the diacid digest using Emission Spectroscopy using EEL Flame photometer (Jackson, 1958).

3.6.5 Total plant uptake

Nitrogen, phosphorus and potassium uptake by the crop at different stages of harvest were computed from their respective chemical concentration and dry matter production and expressed in kg ha^{-1}

3.6.5.1 Nitrogen uptake

The N uptake by the above ground-portion (leaf + stem) and root portion were found out separately by the following equation.

Root or shoot N uptake (kg ha^{-1})

$$= \frac{N\,content \times Dry\,matter\,yield\,of\,root\,or\,shoot\,(kg ha^{-1})}{100}$$

Total plant N uptake (kg ha^{-1}) = N uptake by root + N uptake by shoot (leaf + stem)

3.6.5.2 Phosphorus uptake

The P uptake by the above ground portion (leaf + stem) and root portion were estimated individually from the respective P concentration as follows.

Root or Shoot P uptake (kg ha^{-1})

$$= \frac{P\,content\,(per\,cent) \times Dry\,matter\,yield\,(kg\,ha^{-1})}{100}$$

Total plant P uptake (kg ha^{-1})

= P uptake by root (kg ha^{-1}) + P uptake by shoot (kg ha^{-1}).

3.6.5.3 **Potassium uptake**

The K uptake by the shoot in above ground portion (leaf + stem) and root portion were estimated separately from the K concentration and the respective dry matter yield.

Root or Shoot K uptake (kg ha^{-1})

$$= \frac{K\,content\,(per\,cent) \times Dry\,matter\,yield\,(kg\,ha^{-1})}{100}$$

Total plant K uptake (kg ha^{-1}) = K uptake by root (kg ha^{-1})

+ K uptake by shoot (kg ha^{-1})

3.6.6 **Soil**

The soil samples collected after the experiment, were air dried and sieved through a 2 mm screen.

3.6.6.1 **Available Nitrogen**

Available nitrogen in soil was determined by alkaline permanganate method (Subbaiah and Asija, 1956). For this 10g of air dried powdered soil sample was mixed with 100 ml each of 0.32 per cent $KMnO_4$ and 2.5 per cent

NaOH. 20 ml of distilled water was also added. A small amount of wax was added to the content to prevent frothing during distillation. Nitrogen evolved was collected in 10 ml of 4 per cent boric acid containing mixed indicator and the ammonia evolved was neutralized by titrating against 0.01 N H_2SO_4. From the titre value, the available N in the soil was estimated and expressed in kg ha^{-1}.

3.6.6.2 **Available Phosphorus**

Available P in the soil was extracted by using Bray - I extractant and the P content was determined by ascorbic acid blue colour method (Watanabe and Olsen, 1965) using spectronic - 20 spectrophotometer. For this five gram air dried 2 mm sieved soil sample was mixed with 50 ml of Bray I (0.03 N NH_4F + 0.025 N HCl solution). The contents were shaken for five minutes and filtered using Whatman No. 42 filter paper. To 5ml of aliquot, 4ml of the reagent (12g ammonium molybdate + 0.291g antimony potassium tartarate + 5 N H_2SO_4 + 1.056 g ascorbic acid) was added and made upto 25 ml. The colour intensity was read in Spectronic 20 and the P content in soil was estimated and expressed as kg P_2O_5 ha^{-1}.

3.6.6.3 **Available Potassium**

Available K in the soil was extracted by neutral normal ammonium acetate and was estimated using EEL flame photometer (Jackson, 1958). For this 10g soil was mixed with 50ml neutral ammonium acetate. The contents were shaken for 5 minutes and then filtered using whatman No. 42 filter paper. A 5ml of the aliquot was diluted to 25ml with distilled water and the K content in soil was determined using flame photometer and expressed as kg K_2O ha^{-1} .

3.6.6.4 **Organic carbon**

Organic carbon content in the soil was determined using Walkley and Black titration method (Jackson, 1958). For this one gram of finely ground soil was mixed with 10 ml of 1 N $K_2Cr_2O_7$ and 20 ml conc. H_2SO_4 and shaken for a minute. After keeping the contents for half an hour, the reaction was arrested by adding 200 ml of distilled water. The contents were then titrated against 0.5 N ferrous sulphate using 1 ml ferroin as indicator. From the titre value, the organic carbon content of the soil was determined and expressed in per cent.

3.7 **Economics of cultivation**

The economics of cultivation of *Hemidesmus indicus* was estimated and expressed on per hectare basis.

3.8 **Statistical analysis**

The data were statistically analysed for analysis of variance as per the procedure outlined by Panse and Sukhatme (1978).

RESULTS

RESULTS

The results of the investigations on Agrotechniques in Indian sarsaparilla (*Hemidesmus indicus* [Linn.] R. Br) are presented in this chapter.

4.1 Nursery studies

Screening of plant parts to be used as planting material was carried out to select the best material as a propagule for conducting the field trial. The results of the nursery studies are presented in the Table 3.

4.1.1 Days to sprout and sprouting percentage

The influence of planting material on germination and establishment of *Hemidesmus indicus* is given in Table 3. Excepting vine cuttings, all the planting materials sprouted within one week of planting. The vine cuttings failed to sprout even after three weeks of planting.

Maximum establishment was noticed in main root cuttings planted vertically (60 per cent). The treatments main root cuttings planted horizontally and the root stumps were similar in terms of field establishment.

4.1.2 Length and girth of shoot

The length of shoot formed varied between the planting materials used (Table 3). At seven week stage, shoot length ranged from 5.4 to 10.8 cm and the main root cuttings planted vertically recorded the maximum length.

At seven week stage shoot girth varied between 0.2 and 0.4 cm. The treatments main root cutting planted vertically had thicker shoots. The main root cuttings planted horizontally recorded lower values in terms of shoot girth and shoot length.

4.1.3 **Number of leaves**

At seven week stage, the number of leaves produced on a plant ranged from 4.8 to 6.5 and as in the case of shoot length and shoot girth, the treatment main root cuttings planted vertically recorded the maximum value followed by the treatment root stump.

4.1.4 **Length and girth of root**

At seven week stage, the treatment main root cutting planted vertically had the longest roots (14 cm). The main root cuttings planted horizontally ranked second in this character.

The root girth was similar (0.2 cm) in these treatments whereas root stumps produced thinner roots.

Table 3. Effect of various plant parts as propagule in *Hemidesmus indicus* on the biometric characters of the plant

Treatments	Days to sprout	Sprouting Per cent	Shoot length (cm)	Shoot girth (cm)	No. of leaves per plant	Root length (cm)	Root girth (cm)
Main root cuttings (5 cm) planted vertically	6	60	10.8	0.4	6.5	14	0.2
Main root cuttings (5 cm) planted horizontally	6	40	5.4	0.2	4.8	12	0.2
Root stumps (5 cm)	5	40	6.4	0.3	5.3	10.5	0.1
Vine cuttings planted vertically (5 cm)	---	---	---	---	---	---	---

The results of the nursery studies revealed that vertically planted main root cuttings of 5 cm length is the ideal planting material in *Hemidesmus indicus* and the field experiment was conducted with this.

4.2 **Field experiment**

Observations on field establishment (Table not presented) revealed that 84 - 88 per cent of the 5 cm long main root cuttings planted vertically established within the first week of planting. Observations of biometric and yield characters were recorded, the results of which are presented here.

4.2.1 **Biometric Characters**

4.2.1.1 **Height of plant**

The influence of spacing × FYM and stages of harvests on plant height in *Hemidesmus indicus* are presented in Table 4.

The treatment spacing × FYM significantly influenced the height of plants. The data revealed that in all the three spacings viz., 10 × 10 cm, 15 × 15 cm and 20 × 20 cm, application of FYM resulted in a significant increase in plant height and the plant height increased with increasing level of FYM. The plots receiving FYM @ 10 t ha^{-1} had the tallest plants.

Table 4. Effect of spacing × FYM and stage of harvest on plant height (cm) in *Hemidesmus indicus*

Treatments	Stage of the plant (months after planting)						
	2	3	4	5	6	7	8*
A. Spacing × FYM							
T_1	12.9	16.0	16.9	17.9	18.4	21.9	22.5
T_2	16.9	19.1	20.1	21.4	22.3	24.6	25.1
T_3	14.9	17.5	18.6	19.8	20.9	26.3	26.6
T_4	19.4	25.1	26.0	27.1	29.9	34.6	38.2
T_5	25.6	28.0	28.6	29.7	32.9	37.2	39.7
T_6	18.3	21.4	21.2	22.6	24.4	27.1	29.2
T_7	29.4	36.8	32.5	34.3	36.1	36.0	41.2
T_8	29.1	32.0	31.6	32.9	33.6	38.4	41.3
T_9	21.9	25.5	25.1	25.6	27.6	32.1	35.0
SEm ±	2.7	3.1	2. 9	2. 9	3. 3	4. 9	4.7
CD (0.05)	8. 2	9. 2	8. 6	8. 6	10.0	14.6	14.0
B. Stage of harvest							
K_1	21.3	24.2	24.1	25.5	---	---	---
K_2	20.5	24.7	24.5	25.4	26.9	---	---
K_3	20.8	24.5	24.6	26.1	27.4	29.2	---
K_4	21.1	25.0	24.9	25.9	27.7	32.6	---
SEm ±	1. 2	1.1	1.1	1.1	1.2	0. 8	---
CD (0.05)	NS	NS	NS	NS	NS	2. 2	---
C. Interaction	NS	NS	NS	NS	NS	NS	---

* Analysed in RBD

Excepting seven month stage, stage of the plant did not influence the plant height in *Hemidesmus indicus*. Also the treatment combinations did not affect the height of plants in *Hemidesmus indicus*.

4.2.1.2 **Number of leaves per plant**

The treatment spacing × FYM influenced significantly the number of leaves produced on a plant (Tables 5a to 5c). Irrespective of the varying plant densities, application of FYM @ 10 t ha $^{-1}$ recorded the maximum number of leaves per plant followed by the treatment FYM @ 5 t ha $^{-1}$.

The different stages of harvest did not affect the rate of leaf production in *Hemidesmus indicus*.

The interaction effect of treatments was significant at five and seven month stages. At four month stage, the leaf number per plant varied from 15.6 to 45.0 and the treatment receiving FYM @ 10 t ha $^{-1}$ planted at 10 × 10 cm spacing and harvested at six month stage recorded the maximum value. At five month stage, also the same treatment recorded the maximum number of leaves per plant (45.8). At seven month stage, the treatment receiving FYM @ 10 t ha $^{-1}$ and planted at 10 × 10 cm spacing recorded the highest value of 44.4 (Tables 5b and 5c).

Table 5a. Effect of spacing × FYM and stage of harvest on leaf number per plant in *Hemidesmus indicus*

Treatments	Stage of the plant (months after planting)						
	2	3	4	5	6	7	8*
A. Spacing × FYM							
T_1	12.3	15.2	17.7	18.9	21.1	24.4	25.3
T_2	14.8	17.6	19.7	21.1	23.6	25.5	22.7
T_3	14.1	16.8	19.1	21.3	22.3	25.0	20.9
T_4	18.6	22.2	24.9	26.1	27.7	29.3	26.6
T_5	23.0	28.9	30.8	31.7	34.1	38.1	37.6
T_6	19.9	22.1	24.8	26.9	29.2	29.9	25.2
T_7	26.0	37.4	39.1	40.1	42.6	41.9	35.0
T_8	27.9	33.4	35.8	36.7	39.1	38.3	33.6
T_9	21.8	27.0	33.9	35.4	36.5	33.8	32.6
SEm ±	1.7	1. 9	1. 3	1. 2	1.4	1. 6	1.7
CD (0.05)	5. 2	5. 6	4. 0	3.7	4. 2	4.7	5. 2
B. Stage of harvest							
K_1	20.7	23.8	26.4	28.3	---	---	---
K_2	19.4	25.1	28.5	30.0	30.9	---	---
K_3	19.4	24.4	26.8	28.3	30.0	31.2	---
K_4	19.8	24.8	27.5	28.7	31.1	32.4	---
SEm ±	0.87	0.97	0.69	0.66	0.57	0.60	---
CD (0.05)	NS	NS	NS	NS	NS	NS	---
C. Interaction	NS	NS	sig	sig	NS	sig	---

* Analysed in RBD

Table 5b. Interaction effect of treatments on the leaf number per plant in *Hemidesmus indicus* at five month stage

Treatments	K_1	K_2	K_3	K_4
T_1	17.9	16.4	16.7	24.7
T_2	21.4	21.0	21.4	20.5
T_3	22.7	19.2	24.4	18.7
T_4	24.9	26.1	25.8	27.7
T_5	28.4	27.5	33.6	37.3
T_6	29.7	28.0	25.3	24.6
T_7	36.2	45.8	40.9	37.6
T_8	34.7	41.4	36.1	34.8
T_9	38.4	40.5	30.7	32.1
SEm ±	1.9			
CD (0.05)	5.6			

Table 5c. Interaction effect of treatments on the leaf number per plant in *Hemidesmus indicus* at seven month stage

Treatments	K_3	K_4
T_1	19.9	28.8
T_2	24.4	26.6
T_3	27.2	22.9
T_4	28.3	30.3
T_5	35.5	40.6
T_6	31.7	28.1
T_7	44.4	39.4
T_8	39.2	37.5
T_9	30.2	37.4
SEm ±	1.79	
CD (0.05)	5.08	

4.2.1.3 **Number of branches per plant**

The influence of various treatments on the number of branches per plant in *Hemidesmus indicus* are presented in Table 6a. The data showed that the treatment spacing × FYM significantly influenced the number of branches. Irrespective of the planting density, and the growth stages, the treatments receiving FYM @ 10 t ha^{-1} recorded the maximum value which was significantly superior to that in all the other treatments.

The influence of stages of harvests on the number of branches was significant only at four and seven month stages and the values ranged from 0.8 to 1.0 at four months stage and from 2.4 to 2.7 at seven month stage.

The interaction effect of the treatments on the character was found to be significant at sixth and seventh month stages (Tables 6b and 6c). Irrespective of spacings the treatments receiving FYM @ 10 t ha^{-1} and plants at the eight month stage recorded the highest value of 2.9.

4.2.1.4 **Leaf area per plant**

The influence of various treatments on the leaf area of *Hemidesmus indicus* are presented in Table 7a.

Table 6a. Effect of spacing × FYM & stage of harvest on the number of branches per plant in *Hemidesmus indicus*

Treatments	Stage of the plant (months after planting)						
	2	3	4	5	6	7	8*
A. Spacing × FYM							
T_1	0.5	0.7	0.8	1.1	1.2	2.4	2.6
T_2	0.4	0.6	0.7	1.1	1.2	2.4	2.5
T_3	0.6	0.7	0.8	1.1	1.3	2.2	2.4
T_4	0.6	0.7	0.9	1.1	1.2	2.5	2.7
T_5	0.6	0.7	0.8	1.1	1.2	2.6	2.7
T_6	0.7	0.8	1.0	1.2	1.4	2.4	2.6
T_7	0.7	0.9	1.0	1.2	1.3	2.7	2.9
T_8	0.8	0.9	1.0	1.2	1.5	2.8	2.8
T_9	0.8	0.9	1.0	1.2	1.4	2.8	2.9
SEm ±	0.06	0.06	0.04	0.04	0.04	0.06	0.07
CD (0.05)	0.19	0.16	0.13	0.13	0.11	0.19	0.21
B. Stage of harvest							
K_1	0.6	0.8	0.9	1.1	---	---	---
K_2	0.6	0.8	0.8	1.1	1.3	---	---
K_3	0.6	0.8	0.9	1.1	1.3	2.4	---
K_4	0.6	0.8	1.0	1.2	1.3	2.7	---
SEm ±	0.03	0.02	0.03	0.03	0.17	0.01	---
CD (0.05)	NS	NS	0.08	NS	NS	0.03	---
C. Interaction	NS	NS	NS	NS	sig	sig	---

* Analysed in RBD

Table 6b. Interaction effect of treatments on the number of branches per plant in *Hemidesmus indicus* at six month stage

Treatments	K_2	K_3	K_4
T_1	1.2	1.2	1.2
T_2	1.3	1.2	1.2
T_3	1.2	1.2	1.3
T_4	1.2	1.3	1.2
T_5	1.4	1.1	1.2
T_6	1.5	1.4	1.4
T_7	1.4	1.2	1.4
T_8	1.4	1.5	1.5
T_9	1.4	1.4	1.5
SEm ±	0.05		
CD (0.05)	0.15		

Table 6c. Interaction effect of treatments on the number of branches per plant in *Hemidesmus indicus* at seven month stage

Treatments	K_3	K_4
T_1	2.2	2.5
T_2	2.3	2.4
T_3	2.0	2.4
T_4	2.3	2.7
T_5	2.4	2.8
T_6	2.2	2.7
T_7	2.4	2.9
T_8	2.6	2.9
T_9	2.7	2.9
SEm ±	0.04	
CD (0.05)	0.12	

Table 7a. Effect of spacing × FYM and stages of harvest on the leaf area per plant in *Hemidesmus indicus*

Treatments	Stage of the plant (months after planting)						
	2	3	4	5	6	7	8*
A. Spacing × FYM							
T_1	17.6	21.8	33.2	52.3	58.5	144.2	147.5
T_2	21.2	25.2	37.0	58.2	65.3	155.4	143.0
T_3	20.2	24.0	35.8	58.7	61.8	152.7	127.7
T_4	26.6	31.3	46.7	72.2	78.6	190.5	186.0
T_5	32.6	41.4	57.7	87.5	97.4	236.6	216.3
T_6	29.2	31.7	46.6	74.2	86.4	177.8	148.1
T_7	36.9	53.0	73.4	110.9	118.5	260.0	238.7
T_8	39.7	46.4	67.0	101.4	105.2	240.8	225.7
T_9	31.2	38.6	63.7	97.7	103.3	239.1	211.7
SEm ±	2.42	2.71	2.5	3.41	3.56	4.37	3.86
CD (0.05)	7.25	8.11	7.51	10.21	10.68	13.11	8.18
B. Stage of harvest							
K_1	29.6	33.2	49.5	78.1	---	---	---
K_2	27.8	35.7	53.4	81.6	85.7	---	---
K_3	27.8	34.9	50.3	78.2	81.8	188.5	---
K_4	28.3	35.5	51.7	79.1	90.9	210.9	---
SEm ±	1.28	1.42	1.29	1.82	1.41	2.18	---
CD (0.05)	NS	NS	NS	NS	4.0	6.18	---
C. Interaction	NS	NS	NS	sig	sig	sig	---

* Analysed in RBD

The data showed that the treatment spacing × FYM significantly influenced the leaf area per plant. Irrespective of the planting density, the plots receiving higher rate of FYM (10 t ha^{-1}) recorded the maximum leaf area.

The stage of the crop significantly affected the leaf area at sixth and seventh month stages. At six month stage the values ranged from 81.8 to 90.9 cm^2 and at seven month stage values ranged from 188.5 to 210.9 cm^2.

The interaction effect of the various treatments on the leaf area per plant was significant at five, six and seven month stages (Tables 7b to 7d). At five month stage, the treatment receiving FYM @ 10 t ha^{-1} with 10 × 10 cm spacing (T_7 K_2) recorded the maximum value which was significantly superior to that in the other treatments, and the leaf area per plant ranged from 45.4 to 126.3 cm^2. At six month stage also the treatment T_7 K_2 recorded the highest value and the values ranged from 48.8 to 129.5. At seven month stage the treatment T_5 K_4 recorded the highest value where the leaf area per plant. ranged from 116.8 to 264.9 cm^2.

4.2.1.5 **Leaf area index (LAI)**

The influence of various treatments on the leaf area index of *Hemidesmus indicus* are presented in the Table 8a. The data showed that the

Table 7b. Interaction effect of treatments on the leaf area per plant (cm^2) at five month stage in *Hemidesmus indicus*

Treatments	K_1	K_2	K_3	K_4
T_1	49.5	45.4	46.2	68.3
T_2	59.1	58.1	59.2	56.7
T_3	62.7	53.1	67.5	51.5
T_4	68.8	71.9	71.3	76.5
T_5	78.5	75.9	92.7	103.0
T_6	81.9	77.4	69.7	67.9
T_7	100.8	126.3	112.9	103.4
T_8	95.8	114.2	99.6	95.9
T_9	105.9	111.9	84.6	88.5
SEm ±	5.46			
CD (0.05)	15.48			

Table 7c. Interaction effect of treatments on the leaf area per plant (cm^2) at six month stage in *Hemidesmus indicus*

Treatments	K_2	K_3	K_4
T_1	48.8	49.0	77.5
T_2	62.3	63.5	70.0
T_3	56.4	70.1	58.9
T_4	74.7	75.1	86.0
T_5	79.5	94.7	118.0
T_6	83.5	84.5	91.4
T_7	129.5	117.5	108.5
T_8	120.0	92.9	102.8
T_9	116.1	88.5	105.4
SEM ±	4.23		
CD (0.05)	11.99		

Table 7d. Interaction effect of treatments on the leaf area per plant (cm^2) at seven month stage in *Hemidesmus indicus*

Treatments	K_3	K_4
T_1	116.8	171.7
T_2	142.8	168.1
T_3	159.2	146.2
T_4	165.6	215.3
T_5	208.2	264.9
T_6	189.8	165.9
T_7	260.2	259.7
T_8	230.2	251.3
T_9	223.2	255.0
SEm ±	6.53	
CD (0.05)	18.53	

Table 8a. Effect of spacing × FYM and stages of harvest on LAI in *Hemidesmus indicus*

Treatments	Stage of the plant (month after planting)						
	2	3	4	5	6	7	8*
A. Spacing × FYM							
T_1	0.2	0.21	0.33	0.52	0.58	1.44	1.47
T_2	0.09	0.11	0.16	0.26	0.29	0.69	0.63
T_3	0.05	0.06	0.09	0.15	0.19	0.38	0.32
T_4	0.26	0.31	0.47	0.72	0.78	1.9	1.85
T_5	0.15	0.18	0.26	0.39	0.43	1.05	0.96
T_6	0.07	0.07	0.11	0.18	0.21	0.44	0.37
T_7	0.37	0.53	0.73	1.10	1.18	2.59	2.39
T_8	0.18	0.21	0.30	0.45	0.47	1.07	1.00
T_9	0.07	0.09	0.16	0.24	0.25	0.60	0.53
SEm ±	0.02	0.02	0.01	0.02	0.03	0.02	0.02
CD (0.05)	0.06	0.06	0.06	0.07	0.08	0.07	0.08
B. Stage of harvest							
K_1	0.16	0.19	0.28	0.43	---	---	---
K_2	0.15	0.20	0.30	0.46	0.48	---	---
K_3	0.16	0.20	0.28	0.44	0.46	1.05	---
K_4	0.16	0.20	0.30	0.46	0.53	1.21	---
SEm ±	0.008	0.008	0.008	0.012	0.008	0.02	---
CD (0.05)	NS	NS	NS	NS	0.02	0.04	---
C. Interaction	NS	NS	sig	sig	sig	sig	---

* Analysed in RBD

treatment spacing × FYM significantly influenced the LAI. The crops planted at 10 × 10 cm spacing, where FYM @ 10 t ha^{-1} was applied, recorded the maximum LAI and those planted at 20 × 20 cm spacing without any FYM addition, the minimum LAI.

The stages of harvest significantly influenced the LAI at sixth and seventh month stages.

The interaction effect of the treatments was significant at four, five, six and seven MAP (Tables 8b to 8e). At four, five and six months stages, the treatment T_7 K_2 recorded the maximum LAI which was significantly superior to that of the other treatment combinations. At seven MAP, the LAI values ranged from 0.40 to 2.60 and the treatment T_7 K_3 recorded the maximum value. The treatment T_7K_4 was found to be on par with this.

4.2.1.6 **Flowering characters**

Flowering characteristics in *Hemidesmus indicus* were also recorded and the results are presented in the Table 9. Irrespective of the treatments, *Hemidesmus indicus* started flowering in February. The number of inflorescence per plant ranged from 3 - 4. On an average, there were 5.5

Table 8b. Interaction effect of treatments on LAI at five month stage in *Hemidesmus indicus*

Treatments	K_1	K_2	K_3	K_4
T_1	0.49	0.45	0.46	0.68
T_2	0.27	0.26	0.26	0.25
T_3	0.16	0.13	0.17	0.13
T_4	0.69	0.72	0.71	0.76
T_5	0.35	0.34	0.41	0.46
T_6	0.20	0.19	0.17	0.17
T_7	1.00	1.26	1.12	1.03
T_8	0.43	0.50	0.44	0.42
T_9	0.26	0.28	0.21	0.22
SEm ±	0.035			
CD (0.05)	0.098			

Table 8c. Interaction effect of treatments on LAI at six month stage in *Hemidesmus indicus*

Treatments	K_2	K_3	K_4
T_1	0.49	0.49	0.77
T_2	0.28	0.28	0.31
T_3	0.14	0.17	0.26
T_4	0.74	0.75	0.85
T_5	0.35	0.42	0.52
T_6	0.20	0.21	0.22
T_7	1.29	1.17	1.08
T_8	0.53	0.41	0.45
T_9	0.29	0.22	0.26
SEm ±	0.026		
CD (0.05)	0.074		

Table 8d. Interaction effect of treatments on LAI at seven month stage in *Hemidesmus indicus*

Treatments	K_3	K_4
T_1	1.16	1.71
T_2	0.63	0.74
T_3	0.40	0.37
T_4	1.65	2.15
T_5	0.92	1.17
T_6	0.47	0.41
T_7	2.60	2.57
T_8	1.02	1.11
T_9	0.55	0.64
SEm ±	0.046	
CD (0.05)	0.132	

Table 9. Observations on flowering characteristics in *Hemidesmus indicus*

Sl. No.	Characters	Range	Mean
1.	Days to first flowering	210 - 225	217.5
2.	Days to 50% flowering	250 - 260	255
3.	No. of inflorescence per plant	3 - 4	3.5
4.	No. of flowers per inflorescence	5 - 6	5.5
5.	Days from flower bud emergence to flower opening	6 - 7	6.5
6.	No. of days the flowers remained open	4 - 5	4.5
7.	Fruit / seed set	Nil	Nil

flowers in an inflorence. About six to seven days are required from flower bud emergence to flower opening. No seedset and fruit formation was noticed in the plant.

4.2.3 **Yield characters**

The effect of various treatments on the yield characters in *Hemidesmus indicus* are presented in Table 10a.

4.2.3.1 **Number of roots per plant**

The treatments spacing × FYM and stages of harvests had a significant influence on the number of roots per plant (Table 10a). In general, the application of 10 t ha $^{-1}$ FYM had a significant influence on the rate of root production in *Hemidesmus indicus*. Irrespective of the varying planting densities, application of FYM @ 10 t ha^{-1} recorded maximum number of roots per plant (3.0). Spacing did not affect the character very much. The treatment 20 × 20 cm spacing without any FYM application recorded the lowest number of roots per plant (2.5).

The number of roots was found to increase with the advancing age of plant. The plant harvested at 8 MAP recorded the highest number of roots per plant (3.2) followed by those harvested after 7 MAP (2.8). Five months old crop recorded the minimum number of roots (2.3).

The interaction effect of the treatments on the number of roots per plant was found to be significant (Table 10c) and the values ranged from 2.2 to 3.6. The treatments $T_8 K_4$ and $T_9 K_4$ was found to be significantly superior to all the other combinations. This was followed by the treatment $T_7 K_4$ (3.4) which was significantly lower than the above treatments.

4.2.3.2 **Length of root**

The influence of spacing × FYM and stages of harvest significantly influenced the length of root (Table 10a) in *Hemidesmus indicus*. The treatments receiving FYM @ 10 t ha^{-1} and planted at a spacing of 20 × 20 cm recorded the longest root (16.6 cm) and those at 10 × 10 cm spacing without any FYM application, the shortest roots (11.1 cm).

The different intervals of harvest exhibited significant influence on root length. The plants harvested after eight months, had the longest root (18.3 cm) followed by that in seven month old plants (14.3 cm). Five month old plants had the shortest roots (10.8 cm).

The interaction effect of treatments was found to be significant (Table 10d). The treatment receiving FYM @ 5 t ha^{-1} planted at a spacing of 15 × 15 cm and harvested at eight month stage was found to be superior (20.4 cm) to all the other treatments excepting $T_3 K_4$, $T_6 K_4$, $T_9 K_4$ and $T_8 K_4$. The treatment combination $T_1 K_1$ recorded the shortest root (8.4 cm).

4.2.3.3 **Girth of the main root**

The treatment spacing × FYM and stages of harvest significantly influenced the girth of main root in *Hemidesmus indicus* (Table 10a). Planting at 20 × 20 cm spacing and applying FYM @ 10 t ha^{-1} (T_9) resulted in the thickest roots (0.80 cm). The treatments 10 × 10 cm spacing without any FYM application recorded the thinnest roots (0.4 cm). Treatment T_9 was followed by T_5, T_6 and T_8 which significantly lower than T_9.

The girth of the main root was found to be increasing with increase in age of the plant. The plants harvested after eight months had thicker roots (0.8 cm) and five month old plants had thinner roots (0.4 cm).

The interaction effect of various treatments was not found to be significant.

4.2.3.4 **Root dry matter content**

The influence of spacing × FYM and stages of harvest on root dry matter content in *Hemidesmus indicus* are presented in the Table 10a. The treatments influenced the character significantly. Planting at 20 × 20 cm and applying FYM @ 5 t ha^{-1} (T_6) resulted in the maximum root dry matter content (36.0 per cent) and planting at 20 × 20 cm spacing without any FYM application recorded the lowest dry matter content (31.8 per cent) in roots. Treatments T_1, T_2, T_4, T_7 and T_8 was found to be on par with this.

Higher root dry matter content was obtained when the plants were harvested at six month stage (33.9 per cent) followed by that at eight month (33.4 per cent) stage.

The interaction effect of the various treatments was also found to significantly (Table 10b) affect the character. The values ranged from 29.1 per cent to 39.9 per cent and the treatments planted at 20 × 20 cm spacing with the application of FYM @ 5 t ha^{-1} and harvested at eight month stage (T_6 K_4) recorded highest value (39.9 per cent) and those planted at 20 × 20 cm spacing without any FYM application and harvested at five month after planting (T_3 K_1) recorded the lowest root dry matter content (29.1per cent). Treatments T_1 K_1, T_2 K_1, T_7 K_1, T_7 K_2, T_1 K_3, T_3 K_3, T_2 K_4 and T_3 K_4 was found to be on par with $T_3 K_1$.

4.2.3.5 **Fresh root yield per plant**

The influence of spacing × FYM and stages of harvest on fresh weight of root was found to be significant (Table 10a). Plants receiving FYM @ 10 t ha^{-1} and planted at a spacing of 20 × 20 cm resulted in the highest fresh root yield of 2.9 g per plant which was superior to that in the other treatments. Planting at a spacing of 15 × 15 cm along with the application of FYM @ 10 t ha^{-1} was found to be on par with this treatment. Planting at a spacing of 10 × 10 cm without any FYM application (T_1) recorded the lowest fresh root yield (1.7 g). T_4 was found to be on par with this treatment.

The fresh weight of root was found to increase with the age of plant. Harvesting the plants at eight months after planting resulted in maximum fresh root yield (2.8 g) and the lowest when harvested at five month stage (2.1 g).

The interaction between spacing × FYM and stages of harvest was not found to be significant.

4.2.3.6 **Dry root yield per plant**

The influence of spacing × FYM and stages of harvest on dry weight of root was found to be significant. (Table 10a); the trend being similar to those of fresh weight of roots. The maximum dry weight of 0.97 g was recorded by

Table 10a. Effect of spacing × FYM and stages of harvest on root characters at harvest in *Hemidesmus indicus*

Treatments	Root DM content per cent	No. of roots per plant	Length of root (cm)	Girth of root (cm)	Fresh wt. of root per plant (gm)	Dry wt. of root per plant (gm)
A. Spacing × FYM						
T_1	32.9	2.6	11.1	0.4	1.7	0.55
T_2	32.4	2.6	13.8	0.6	2.4	0.79
T_3	31.8	2.5	13.3	0.6	2.5	0.79
T_4	32.5	2.7	11.9	0.4	1.8	0.58
T_5	33.9	2.7	14.9	0.7	2.7	0.91
T_6	36.0	2.7	14.8	0.7	2.7	0.94
T_7	32.4	2.9	13.2	0.4	2.3	0.75
T_8	33.4	3	16.0	0.7	2.8	0.95
T_9	33.9	3	16.6	0.8	2.9	0.97
SEm ±	0.67	0.03	0.24	0.02	0.04	0.02
CD (0.05)	2.00	0.11	0.73	0.06	0.11	0.04
B. Stage of harvest						
K_1	32.8	2.3	10.8	0.4	2.1	0.68
K_2	33.9	2.6	12.4	0.6	2.3	0.77
K_3	32.8	2.8	14.3	0.6	2.5	0.82
K_4	33.4	3.2	18.3	0.8	2.8	0.94
SEm ±	0.45	0.02	0.14	0.01	0.02	0.01
CD (0.05)	NS	0.05	0.39	0.12	0.07	0.03
C. Interaction	sig	sig	sig	NS	NS	sig

Table 10c. Interaction effect of treatments on the number of roots per plant at harvest

Treatments	K_1	K_2	K_3	K_4
T_1	2.2	2.5	2.7	3.0
T_2	2.2	2.4	2.7	3.1
T_3	2.2	2.4	2.6	2.9
T_4	2.4	2.6	2.8	3.1
T_5	2.3	2.7	2.7	3.3
T_6	2.4	2.6	2.8	3.1
T_7	2.5	2.9	2.9	3.4
T_8	2.5	2.8	3.1	3.6
T_9	2.5	2.7	3.0	3.6
SEm ±	0.06			
CD (0.05)	0.16			

Table 10d. Interaction effect of treatments on the length of root per plant (cm)

Treatments	K_1	K_2	K_3	K_4
T_1	8.4	10.7	10.9	14.2
T_2	10.3	12.6	13.1	19.1
T_3	9.8	10.4	13.4	19.7
T_4	9.3	11.6	12.0	14.7
T_5	12.1	12.7	14.2	20.4
T_6	12.4	12.4	14.9	19.7
T_7	9.5	12.4	13.7	17.0
T_8	12.7	14.1	17.0	20.1
T_9	12.7	14.5	19.4	19.9
SEm ±	0.41			
CD (0.05)	1.17			

Table 10b. Interaction effect of treatments on root dry matter content in *Hemidesmus indicus*

Treatments	K_1	K_2	K_3	K_4
T_1	31.3	33.4	32.7	34.0
T_2	31.0	35.1	33.6	30.1
T_3	29.1	36.9	31.9	29.3
T_4	33.6	33.9	29.7	33.0
T_5	35.6	33.4	33.0	33.8
T_6	35.9	34.0	34.1	39.9
T_7	30.2	32.1	33.1	34.2
T_8	34.1	33.4	32.9	33.2
T_9	34.7	33.13	34.4	33.5
SEm ±	1.334			
CD (0.05)	3.785			

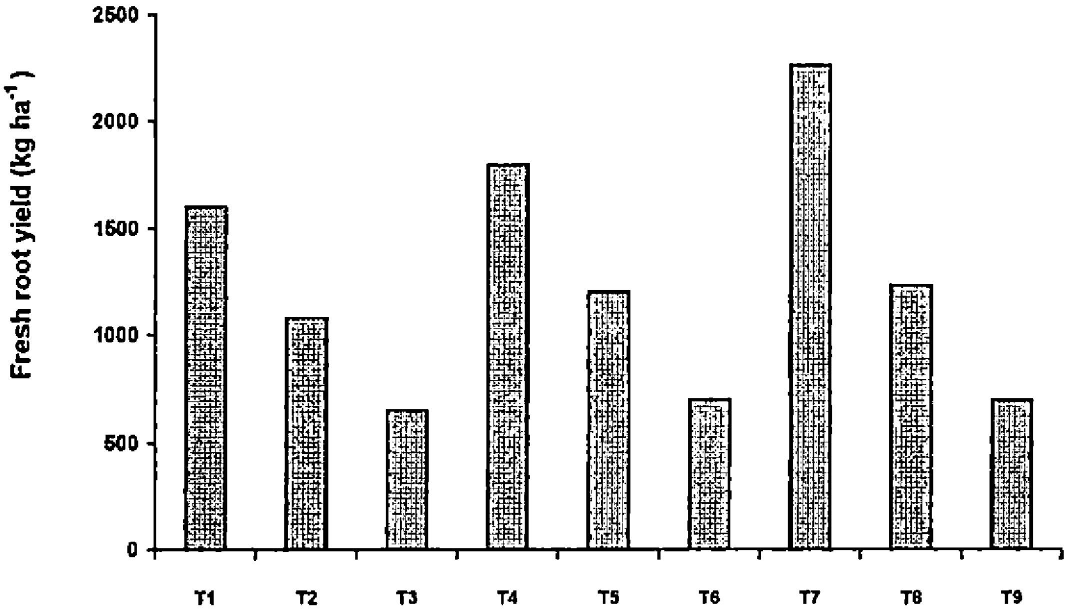
treatments receiving FYM @ 10 t ha $^{-1}$ planted at 20 × 20 cm spacing and the lowest value (0.55 g) in the plots with highest plant density without any FYM application.

The dry weight of root was also found to increase with the age of plant. Maximum dry weight of root per plant was recorded in plants harvested after eight months (0.94 g) and minimum in five month old plants (0.68 g).

The interaction between spacing × FYM and stages of harvest was found to be significant (Table 10e). The treatment combinations receiving FYM @ 5 t ha $^{-1}$ planted at 20 × 20 cm spacing and harvested at eight month stage ($T_6 K_4$) showed values significantly superior to that of the other treatment combinations.

4.2.3.7 **Fresh root yield per hectare**

The influence of spacing × FYM and stages of harvest on the per hectare yield of fresh roots was found to be significant (Table 11a and Fig. 3). Plots receiving FYM @ 10 t ha $^{-1}$ at a spacing of 10 × 10 cm (T_7) recorded yields which was superior to that with all the other treatments. This treatment recorded the highest fresh root yield of 2255.9 kg ha $^{-1}$. The treatment receiving FYM @ 5 t ha $^{-1}$ and planted at 10 × 10 cm spacing recorded second in this



Spacing × *FYM*

Fig. 3 Effect of spacing ×*FYM* on fresh root yield in *Hemidesmus indicus*

Table 10e. Interaction effect of treatments on the dry weight of root per plant

Treatments	K_1	K_2	K_3	K_4
T_1	0.44	0.52	0.53	0.69
T_2	0.64	0.83	0.83	0.84
T_3	0.57	0.86	0.85	0.86
T_4	0.49	0.55	0.55	0.74
T_5	0.84	0.86	0.91	1.04
T_6	0.81	0.86	0.93	1.17
T_7	0.59	0.71	0.82	0.88
T_8	0.86	0.88	0.96	1.08
T_9	0.87	0.88	1.01	1.13
SEm ±	0.027			
CD (0.05)	0.077			

Table 11a. Effect of spacing × FYM and stage of harvest on yield characters in *Hemidesmus indicus*

Treatments	Fresh root yield (kg ha^{-1})	Dry root yield (kg ha^{-1})	Dry shoot yield (kg ha^{-1})	Dry matter yield (kg ha^{-1})	Harvest index
A. Spacing × FYM					
T_1	1660.2	546.7	1539.3	2086.0	0.26
T_2	1078.4	348.9	902.6	1251.5	0.29
T_3	651.2	210.1	542.9	753.0	0.27
T_4	1792.2	581.7	1608.3	2190.0	0.27
T_5	1196.7	405.2	1098.1	1503.3	0.27
T_6	700.2	251.1	649.4	900.5	0.28
T_7	2255.9	733.3	2025.0	2758.3	0.27
T_8	1224.1	407.8	1171.5	1579.2	0.26
T_9	695.4	235.2	706.9	942.1	0.25
SEm ±	37.66	12.01	31.24	40.51	0.004
CD (0.05)	112.89	35.99	93.63	121.42	NS
B. Stage of harvest					
K_1	1059.4	346.8	849.3	1196.1	0.29
K_2	1183.0	396.8	1095.7	1492.6	0.27
K_3	1336.8	435.4	1196.1	1631.5	0.27
K_4	1422.7	474.2	1411.7	1886.0	0.25
SEm ±	23.38	7.71	17.56	22.64	0.004
CD (0.05)	66.32	21.86	49.82	64.24	0.011
C. Interaction	sig	sig	sig	sig	sig

character (1792.2 kg ha^{-1}) and this was on par with T_7. Planting at 20 × 20 cm spacing without any FYM application resulted in the lowest fresh root yield of 651. 2 kg ha^{-1} (T_3). The treatments T_6 and T_9 were found to similar that of the treatment T_3.

The fresh root yield per hectare showed an increasing trend with the advancing age of the plant and it ranged form 1059.4 kg ha^{-1} at 5 MAP to 1422.7 kg ha^{-1} at 8 MAP.

The interaction between spacing × FYM and stages of harvest was also significant (Table 11b and Fig. 4). Treatments receiving FYM @ 10 t ha^{-1} at a spacing of 10 × 10 cm and harvested at eight months after planting recorded the highest fresh root yield of 2389.8 kg ha^{-1}. Planting at a wider spacing of 20 × 20 cm without any FYM application resulted in the lowest fresh root yield at five month stage (445.8 kg ha^{-1}).

4.2.3.8 **Dry root yield per hectare**

The influence of spacing × FYM and stages of harvest on the dry root yield per hectare was found to be significant (Table 11a). The treatments receiving FYM @ 10 t ha^{-1} along with a closer spacing of 10 × 10 cm resulted in the highest dry root yield of 733.3 kg ha^{-1}, followed by the treatment

Table 11b. Interaction effect of treatments on fresh root yield (kg ha^{-1}) in *Hemidesmus indicus*

Treatment	K_1	K_2	K_3	K_4
T_1	1400.1	1566.5	1633.4	2040.9
T_2	918.6	1052.4	1097.2	1245.5
T_3	445.8	583.3	841.7	734.1
T_4	1433.4	1633.2	1866.8	2235.4
T_5	1052.1	1140.8	1229.6	1364.4
T_6	566.8	633.4	858.4	742.4
T_7	1966.8	2200.1	2366.7	2389.8
T_8	1126.1	1170.5	1304.3	1295.6
T_9	625.0	666.7	733.4	756.6
SEm ±	70.14			
CD (0.05)	198.98			

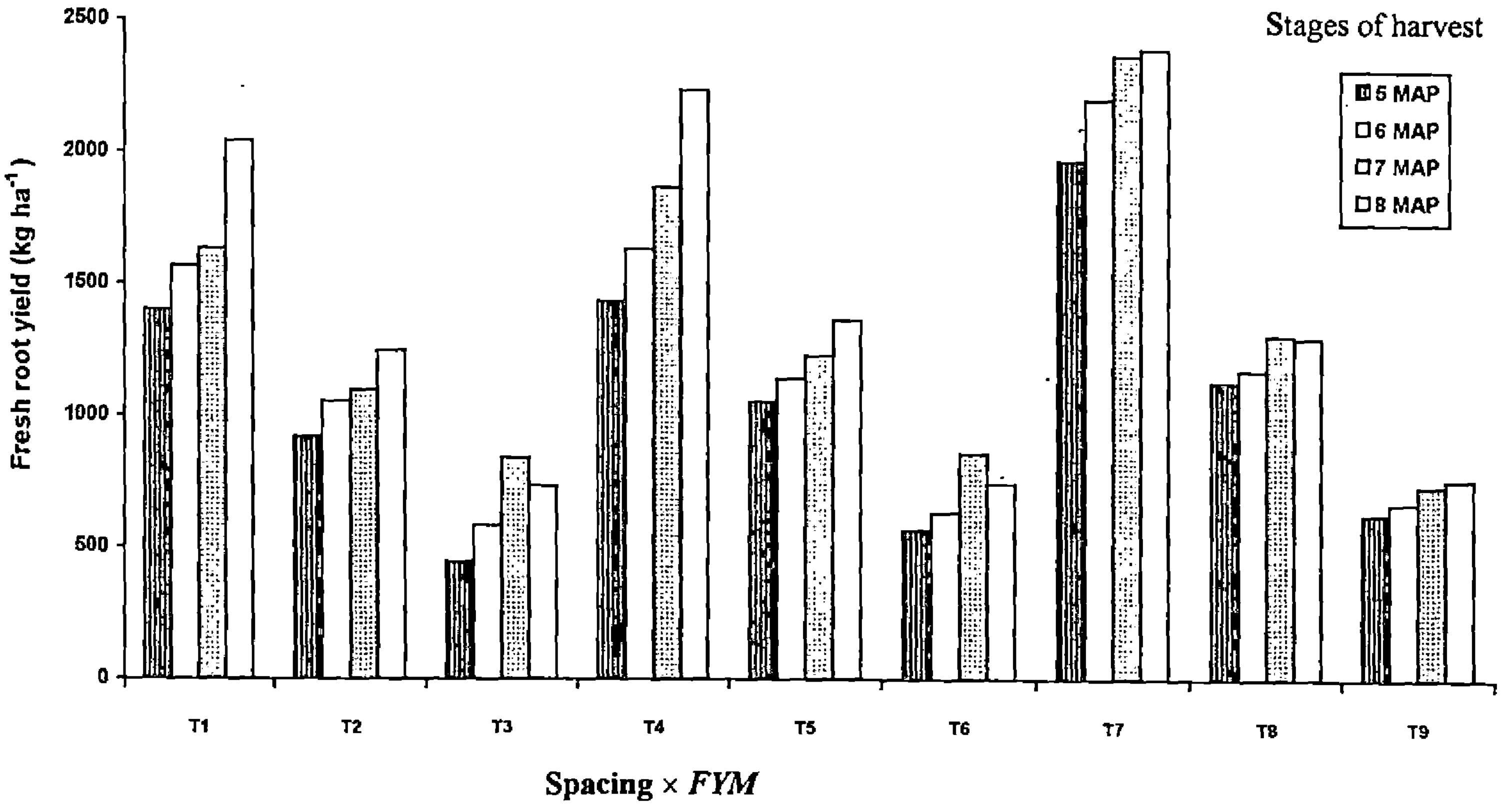


Fig. 4 Interaction effect of spacing × *FYM* and stages of harvest on fresh root yield

receiving FYM @ 5 t ha^{-1} and planted at a closer spacing of 10 × 10 cm ranked second in this character (581.7 kg ha^{-1}). Those planted at a spacing of 20 × 20 cm without any FYM application resulted in the lowest yield of 210.1 kg ha^{-1} (T_3). Treatments planted at 20 × 20 cm and FYM @ 10 t ha^{-1} (T_9) was found to be on par with this treatment.

The dry root yield per hectare showed an increasing trend with the advancing age of the plant. Highest dry root yield (474.2 kg ha^{-1}) was obtained in eight month old crop followed by that seven month stage plants (435.4 kg ha^{-1}). The lowest yield was obtained in five month old plants (346.8 kg ha^{-1}).

The interaction between spacing × FYM and stages of harvest was also significant (Table 11c and Fig. 5). The highest yield (816.7 kg ha^{-1}) was obtained in seventh and eighth month old plants in treatments receiving FYM @ 10 t ha^{-1} planted at a spacing of 10 × 10 cm and the lowest yield (143.3 kg ha^{-1}) was obtained in five month old crop planted at a spacing of 20 × 20 cm without any FYM application.

Table 11c. Interaction effect of treatments on dry root yield (kg ha^{-1})
Hemidesmus indicus

Treatments	K_1	K_2	K_3	K_4
T_1	436.7	523.3	533.3	693.3
T_2	284.5	368.9	368.9	373.3
T_3	143.3	215.0	266.9	215.0
T_4	486.7	550.0	553.3	736.7
T_5	373.3	380.7	405.9	460.7
T_6	203.3	215.0	293.6	292.5
T_7	593.3	706.7	816.7	816.7
T_8	383.7	391.1	428.1	428.1
T_9	216.7	220.8	251.7	251.7
SEm ±	23.12			
CD (0.05)	65.59			

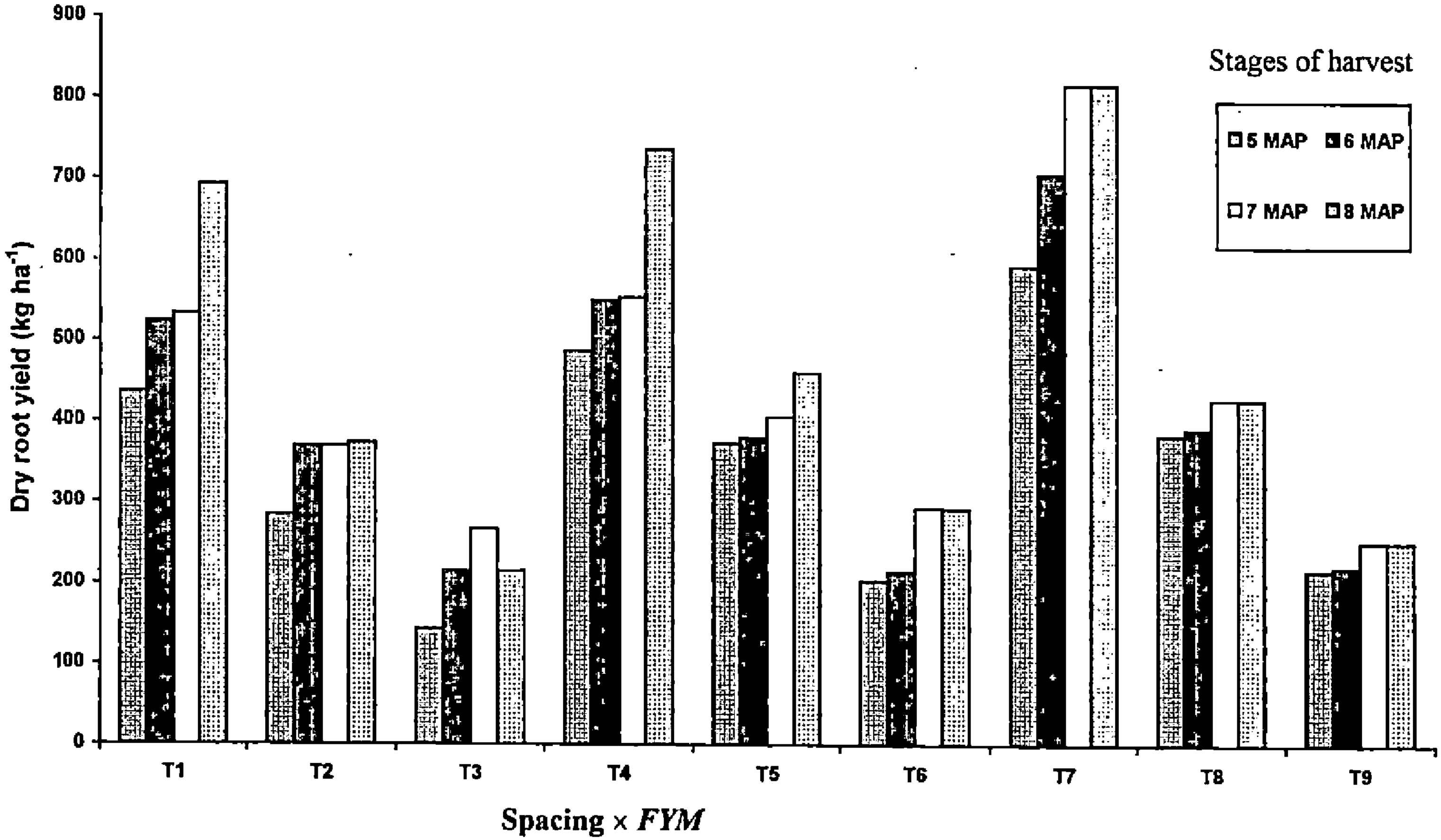


Fig.5 Interaction effect of spacing × *FYM* and stages of harvest on dry root yield

4.2.3.9 **Dry shoot yield per hectare**

The influence of spacing × FYM and stages of harvest on the per hectare yield of dry shoots was found to be significant (Table 11a). Plants receiving FYM @ 10 t ha^{-1} and planted at a spacing of 10 × 10 cm recorded the highest dry shoot yield (2025 kg ha^{-1}) followed by those receiving 5 t ha^{-1} FYM and planted at 10 × 10 cm spacing (1608.3 kg ha^{-1}) which was significantly lower than above treatment.. T_1 was found to be on par with this. As in the case of other yield characters, planting at 20 × 20 cm spacing without any FYM application resulted in the lowest dry shoot yield (542.9 kg ha^{-1}). Treatments planted at 20 × 20 cm spacing and receiving FYM @ 5 t ha^{-1} (T_6) was found to be par with this.

The dry shoot yield per hectare showed an increasing trend with the advancing age of the crop. Highest dry shoot yield (1411.7 kg ha^{-1}) was obtained from eight month old plants and lowest yield (849.3 kg ha^{-1}) was obtained from five month old plants.

The interaction between spacing × FYM and stages of harvest was also significant (Table 11d). The treatments receiving FYM @ 10 t ha^{-1} planted at

Table 11d. Interaction effect of treatments on dry shoot yield (kg ha^{-1}) in *Hemidesmus indicus*

Treatments	K_1	K_2	K_3	K_4
T_1	1203.3	1396.7	1543.3	2014.0
T_2	601.5	974.8	1003.0	1031.1
T_3	320.0	603.3	603.3	645.0
T_4	1266.7	1416.7	1546.7	2203.3
T_5	943.7	1053.3	1069.6	1325.9
T_6	560.8	618.3	616.7	801.7
T_7	1180.0	2076.7	2410.0	2433.3
T_8	958.5	1084.4	1219.3	1423.7
T_9	609.2	637.5	730.0	850.8
SEm ±	52.69			
CD (0.05)	149.48			

10 × 10 cm and harvested at eight month stage recorded highest dry shoot yield (2433.3 kg ha^{-1}) and lowest yield (320.0 kg ha^{-1}) was obtained in five month old crop planted at 20 × 20 cm spacing without any FYM application.

4.2.4 Total dry matter yield

The influence of spacing × FYM and stages of harvest on total dry matter yield was found to be significant (Table 11a and Fig. 6). Planting at 10 × 10 cm and applying FYM @ 10 t ha^{-1} resulted in highest total dry matter yield (2758.3 kg ha^{-1}). Treatments receiving FYM @ 5 t ha^{-1} and planted at 10 × 10 cm spacing (T_4) was significantly lower than this and treatment T_1 was found to be on par with T_4. Those planted at 20 × 20 cm spacing without any FYM application resulted in the lowest plant dry matter yield (753.0 kg ha^{-1}).

The plant dry matter yield was found to increase with increasing age of the plant. The plants harvested after eight month stage recorded higher dry matter yield (1886.0 kg ha^{-1}) and those harvested at five month stage had the minimum dry matter yield (1196.1 kg ha^{-1}).

The interaction effect of the treatments was also found to influence the character significantly (Table 11e and Fig. 7). Dense planting at 10 × 10 cm spacing along with the application of FYM @ 10 t ha^{-1} when harvested at eight

Table 11e. Interaction effect of treatments on dry matter yield (kg ha^{-1}) in *Hemidesmus indicus*

Treatments	K_1	K_2	K_3	K_4
T_1	1640.0	1920.0	2076.7	2707.3
T_2	885.9	1343.7	1371.8	1404.4
T_3	463.3	818.3	870.3	860.0
T_4	1753.3	1966.7	2100.0	2940.0
T_5	1317.0	1434.1	1475.5	1786.7
T_6	764.2	833.3	910.3	1094.2
T_7	1773.3	2783.3	3226.7	3250.0
T_8	1342.2	1475.5	1647.4	1851.8
T_9	825.8	858.3	981.7	1102.5
SEm ±	67.93			
CD (0.05)	192.71			

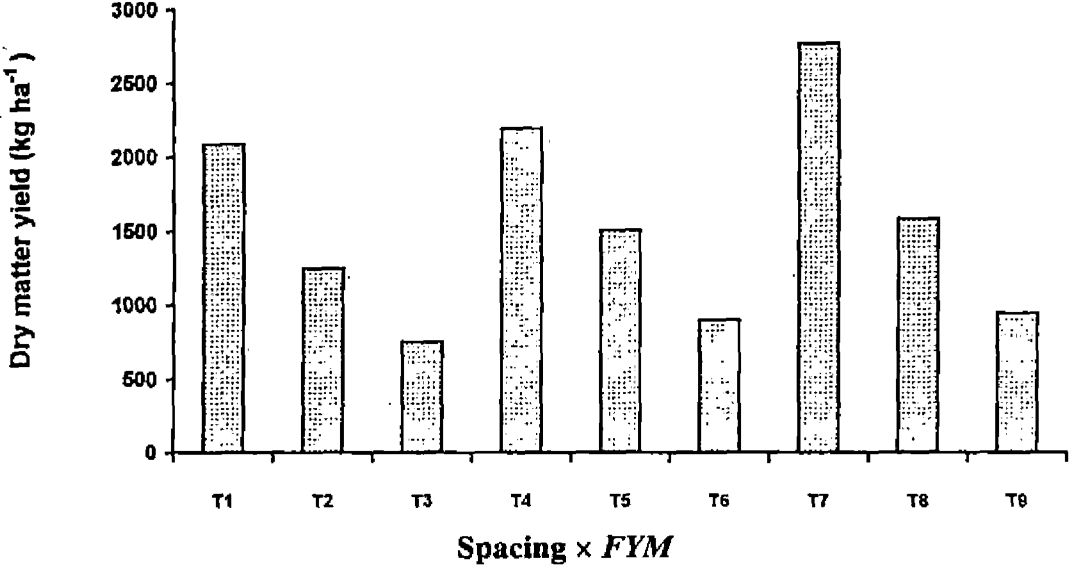


Fig. 6 Effect of spacing × *FYM* on total dry matter yield in *Hemidesmus indicus*

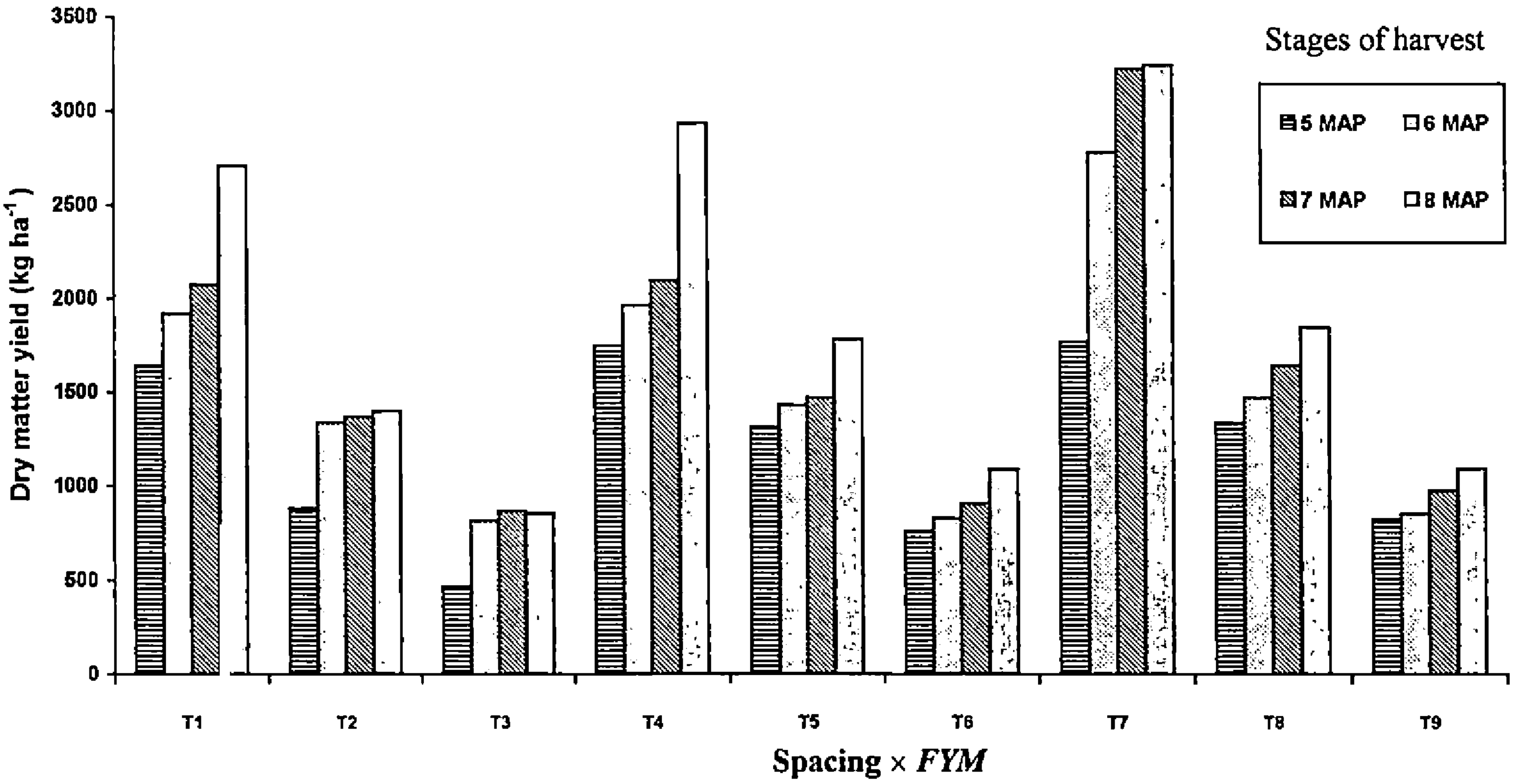


Fig.7 Interaction effect of spacing × *FYM* and stages of harvest on total dry matter yield

month stage recorded the highest dry matter yield (3250 kg ha^{-1}). This was closely followed by the treatment harvested at seven month stage (3226.7 kg ha^{-1}). The treatments 20 × 20 cm spacing without any FYM application and harvested at fifth month stage recorded the lowest plant dry matter yield of 463.3 kg ha^{-1}.

4.2.5 Harvest index

The influence of spacing × FYM and stages of harvest on harvest index in *Hemidesmus indicus* are presented in the Table 11a.

The data revealed that the treatments did not affect the harvest index in *Hemidesmus indicus*. But a definite trend was noticed. i.e., the harvest index was found to be decreasing with the increasing age of the plant. The maximum value was obtained for the five month old plants (0.29) and the minimum in the eight month old plants (0.25).

The interaction between spacing × FYM and the stages of harvest on harvest index in the crop was found to be significant (Table 11f and Fig. 8). The treatments T_2 K_1 and T_7 K_1 recorded 34 per cent harvest index where as the treatments T_8 K_4 and T_9 K_4 the lowest value of 23.0 per cent.

Table 11f. Interaction effect of treatments on harvest index in *Hemidesmus indicus*

Treatments	K_1	K_2	K_3	K_4
T_1	0.27	0.27	0.26	0.26
T_2	0.34	0.28	0.27	0.28
T_3	0.32	0.26	0.26	0.25
T_4	0.28	0.28	0.26	0.25
T_5	0.28	0.27	0.28	0.26
T_6	0.27	0.26	0.32	0.27
T_7	0.34	0.25	0.25	0.25
T_8	0.29	0.27	0.26	0.23
T_9	0.26	0.26	0.26	0.23
SEm ±	0.013			
CD (0.05)	0.036			

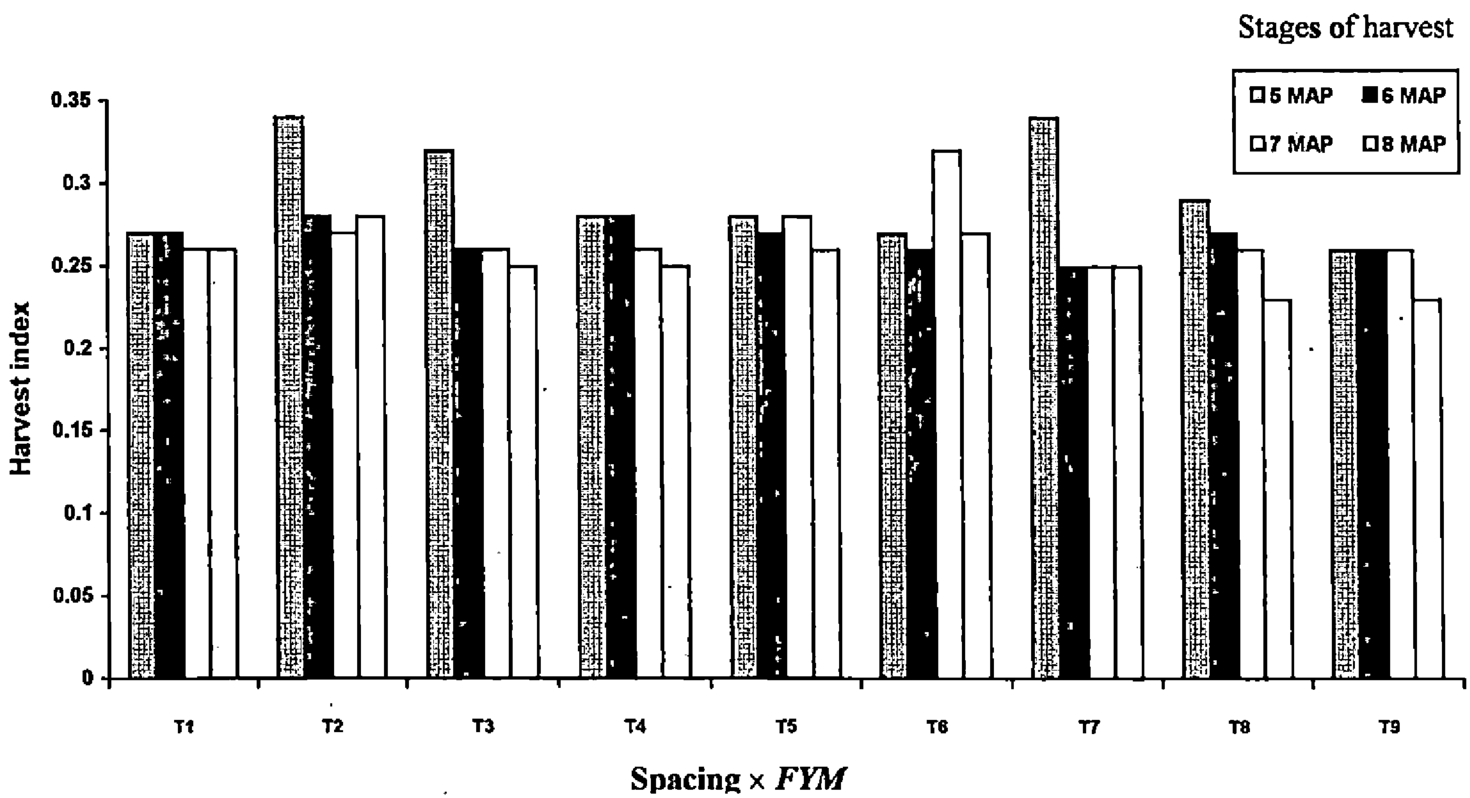


Fig. 8 Interaction effect of spacing × *FYM* and stages of harvest on harvest index

4.3 Content and uptake of nutrients

4.3.1 Nutrient content

a. Nitrogen

(i) Shoot

The treatments spacing × FYM and stages of harvest influenced the N content in the shoot significantly (Table 12a). Irrespective of spacing, increasing the levels of FYM resulted in higher N content in shoot. Planting at 10 × 10 cm spacing with an application of FYM @ 10 t ha $^{-1}$ resulted in highest N content in shoot (1.82 per cent). Treatment planted at 20 × 20 cm spacing and receiving FYM @ 10 t ha^{-1} (T_9) was found to be on par with this treatment. The treatments 10 × 10 cm spacing without any FYM application had the lowest N content in shoot (0.92 per cent).

The N content in the shoot was found to be increasing with increase in the age of the plant. Seven month old plants recorded the highest value (1.41 per cent) closely followed by eight month old plants (1.39 per cent) and the five month old plants recorded the lowest value of 1.2 per cent.

The interaction effect of various treatments was not found to influence the N content of shoots of *Hemidesmus indicus*.

(ii) **Root**

The treatments spacing × FYM and stages of harvest influenced the N content in root significantly (Table 12a).

The N content in root ranged form 0.70 per cent to 1.45 per cent. Application of FYM @ 10 t ha^{-1} and planting at 20 × 20 cm spacing (T_9), resulted in the highest concentration of N in roots of *Hemidesmus indicus* (1.45 per cent) and the treatments planted at 20 × 20 cm spacing without any FYM application, the lowest concentration of N in root (0.70 per cent). Treatment T_7 was found to be on par with T_9 and T_1 and T_2 was found to be on par with T_3.

With advancing age of plant, N content in the roots showed an increasing trend upto the seventh month (1.34 per cent) and then decreased. The lowest N concentration was noticed in the roots of five month old plants (0.69 per cent).

The interaction effect of various treatments was found to significantly influence the character (Table 12b). The N content of root ranged from 0.22 per cent to 1.92 per cent and the highest N concentration was noticed by the application of FYM @ 10 t ha^{-1} and planting at 20 × 20 cm spacing and

Table 12a. Effect of spacing × FYM and stages of harvest on the shoot and root NPK content in *Hemidesmus indicus*

Treatments	Shoot N per cent	Shoot P per cent	Shoot K per cent	Root N per cent	Root P per cent	Root K per cent
A. Spacing × FYM						
T_1	0.92	0.05	1.58	0.78	0.03	1.44
T_2	0.96	0.05	1.57	0.76	0.03	1.42
T_3	1.00	0.05	1.59	0.70	0.03	1.42
T_4	1.28	0.07	1.69	1.11	0.08	1.56
T_5	1.23	0.07	1.64	1.08	0.04	1.58
T_6	1.43	0.07	1.74	1.12	0.04	1.55
T_7	1.82	0.08	1.78	1.37	0.05	1.69
T_8	1.45	0.08	1.80	1.26	0.05	1.73
T_9	1.65	0.08	1.84	1.45	0.05	1.77
SEm ±	0.06	0.002	0.015	0.042	0.0118	0.021
CD (0.05)	0.179	0.007	0.045	0.125	NS	0.06
B. Stage of harvest						
K_1	1.20	0.07	1.68	0.69	0.04	1.56
K_2	1.22	0.07	1.71	1.08	0.04	1.58
K_3	1.41	0.06	1.70	1.34	0.04	1.57
K_4	1.39	0.06	1.69	1.19	0.06	1.58
SEm ±	0.036	0.0021	0.0114	0.0313	0.0019	0.01
CD (0.05)	0.103	NS	NS	0.088	NS	NS
C. Interaction	NS	sig	NS	sig	NS	NS

Table 12b. Interaction effect of treatments on the root N content in *Hemidesmus indicus*

Treatments	K_1	K_2	K_3	K_4
T_1	0.28	0.84	1.07	0.95
T_2	0.22	1.00	0.97	0.84
T_3	0.27	0.75	0.89	0.90
T_4	0.83	1.08	1.38	1.16
T_5	0.92	1.19	1.11	1.12
T_6	0.94	1.03	1.37	1.15
T_7	0.85	1.31	1.70	1.64
T_8	0.90	1.19	1.63	1.32
T_9	1.01	1.30	1.92	1.59
SEm ±	0.09			
CD (0.05)	0.188			

harvested at seventh month stage. Planting at 15 × 15 cm without the application of FYM and harvesting at five month stage resulted in the lowest N content.

b. **Phosphorus**

(i) **Shoot**

The treatment spacing × FYM influenced the P content of shoot significantly (Table 12a). Irrespective of spacing, the P content in shoot increased with increasing levels of FYM. The treatment receiving FYM @ 10 t ha^{-1} showed maximum concentration of P (0.08 per cent) and those treatments without any FYM application had the lowest shoot P content. (0.05per cent).

The P content of shoot was not found to be significantly influenced by stage of harvest.

The interaction effect of various treatments influenced the shoot P content significantly (Table 12c). The highest P content in shoot was obtained in treatments receiving FYM @ 5 t ha^{-1} planted at a spacing of 20 × 20 cm when harvested at eighth month stage (0.11 per cent) and lowest value was

Table 12c. Interaction effect of treatments on shoot P content in *Hemidesmus indicus*

Treatments	K_1	K_2	K_3	K_4
T_1	0.04	0.05	0.05	0.05
T_2	0.05	0.05	0.05	0.05
T_3	0.05	0.06	0.06	0.05
T_4	0.07	0.06	0.06	0.07
T_5	0.06	0.07	0.06	0.07
T_6	0.06	0.07	0.07	0.11
T_7	0.08	0.07	0.07	0.09
T_8	0.08	0.08	0.07	0.08
T_9	0.07	0.08	0.08	0.08
SEm ±	0.006			
CD (0.05)	0.018			

obtained in five month old plants planted at 10 × 10 cm spacing without any FYM application (0.04 per cent).

(ii) **Root**

The treatments spacing × FYM, stages of harvest and interaction effect was not found to influence the P content of roots of *Hemidesmus indicus* and the overall values ranged from 0.03 to 0.06 per cent .

c. **Potassium**

(i) **Shoot**

The treatment spacing × FYM influenced the K content of shoot significantly (Table 12a). The shoot K content ranged from 1.57 per cent to 1.84 per cent. The treatments where FYM @ 10 t ha^{-1} was applied and planted at a spacing of 20 × 20 cm recorded the highest K content and those planted at 15 × 15 cm spacing without any FYM application (T_2) the lowest K content. Treatments T_1 and T_3 was found to be on par with T_2 and T_8 was found to be on par with T_9.

Stages of harvest and interaction effect of various treatments did not affect the shoot K content in *Hemidesmus indicus*.

(ii) **Root**

The treatment spacing × FYM influenced the K content in root significantly (Table 12a). The root K content ranged from 1.42 per cent to 1.77 per cent. Planting at 20 × 20 cm wide and applying FYM @ 10 t ha^{-1} recorded the highest value. Those without any FYM application planted at medium and wider spacings of 15 × 15 cm and 20 × 20 cm recorded the lowest root K content.

The stages of harvest and the interaction effect of various treatments did not affect the root K content in *Hemidesmus indicus*.

4.3.2 **Nutrient uptake by plant**

a. **Nitrogen**

The treatments spacing × FYM and stages of harvest significantly influenced the N uptake by the crop (Table 13a and Fig. 9). Closest planting (very high density planting) along with the application of FYM @ 10 t ha^{-1} resulted in the maximum N uptake by the plant (47.7 kg ha^{-1}). The treatment receiving FYM @ 5 t ha^{-1} and planted at 10 × 10 cm spacing (T_4) ranked second in this character (27.5 kg ha^{-1}). Planting at 20 × 20 cm spacing without any FYM application resulted in the lowest N uptake (6.9 kg ha^{-1}).

Advancing the stage of harvest had been found to increase the N uptake by the plant. An eight month old crop removed the maximum quantity of N from the soil (26.2 kg ha^{-1}) and the five month old crop removed the minimum quantity (12.6 kg ha^{-1}).

The interaction effect of various treatments on N uptake by the plant was found to be significant (Table 13b and Fig. 10) and the values ranged from 4.0 kg ha^{-1} to 63.8 kg ha^{-1}. The treatments planted at 10 × 10 cm spacing along with the application of FYM @ 10 t ha^{-1} when harvested at eight month stage resulted in the maximum N uptake and the five month old plants planted at 20 × 20 cm spacing without any FYM application, the minimum value.

b. **Phosphorus**

The treatments spacing × FYM and the stages of harvest influenced the P uptake by the plant significantly (Table 13a and Fig. 9). The treatments receiving FYM @ 10 t ha^{-1} along with high density planting of 10 × 10 cm spacing resulted in the highest plant P uptake of 1.9 kg ha^{-1} and those without any FYM application and planted at a wider spacing of 20 × 20 cm resulted in the lowest P uptake (0.4 kg ha^{-1}).

Table 13a. Effect of spacing × FYM and stages of harvest in NPK uptake by plant in *Hemidesmus indicus*

Treatments	N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})
A. Spacing × FYM			
T_1	18.8	0.9	32.2
T_2	11.8	0.6	19.1
T_3	6.9	0.4	11.7
T_4	27.5	1.3	36.3
T_5	17.9	0.9	24.4
T_6	12.2	0.5	15.2
T_7	47.7	1.9	48.4
T_8	22.3	1.2	27.9
T_9	15.2	0.7	17.1
SEm ±	0.667	0.028	0.76
CD (0.05)	1.997	0.085	2.16
B. Stage of harvest			
K_1	12.6	0.74	19.8
K_2	18.2	0.91	25.0
K_3	23.1	0.95	27.1
K_4	26.2	1.09	31.30
SEm ±	0.636	0.034	0.39
CD (0.05)	1.804	0.096	1.10
C. Interaction	sig	NS	sig

Table 13b. Interaction effect of treatments on N uptake by plant (kg ha^{-1}) in *Hemidesmus indicus*

Treatments	K_1	K_2	K_3	K_4
T_1	10.8	17.1	20.5	26.8
T_2	6.1	13.5	13.8	13.8
T_3	4.0	6.8	8.0	9.0
T_4	19.0	22.3	28.5	40.4
T_5	14.7	17.2	17.0	22.8
T_6	8.7	10.0	14.3	15.8
T_7	24.8	44.8	57.5	63.8
T_8	14.7	19.6	29.3	25.4
T_9	10.9	12.6	19.0	18.3
SEm ±	1.908			
CD (0.05)	5.412			

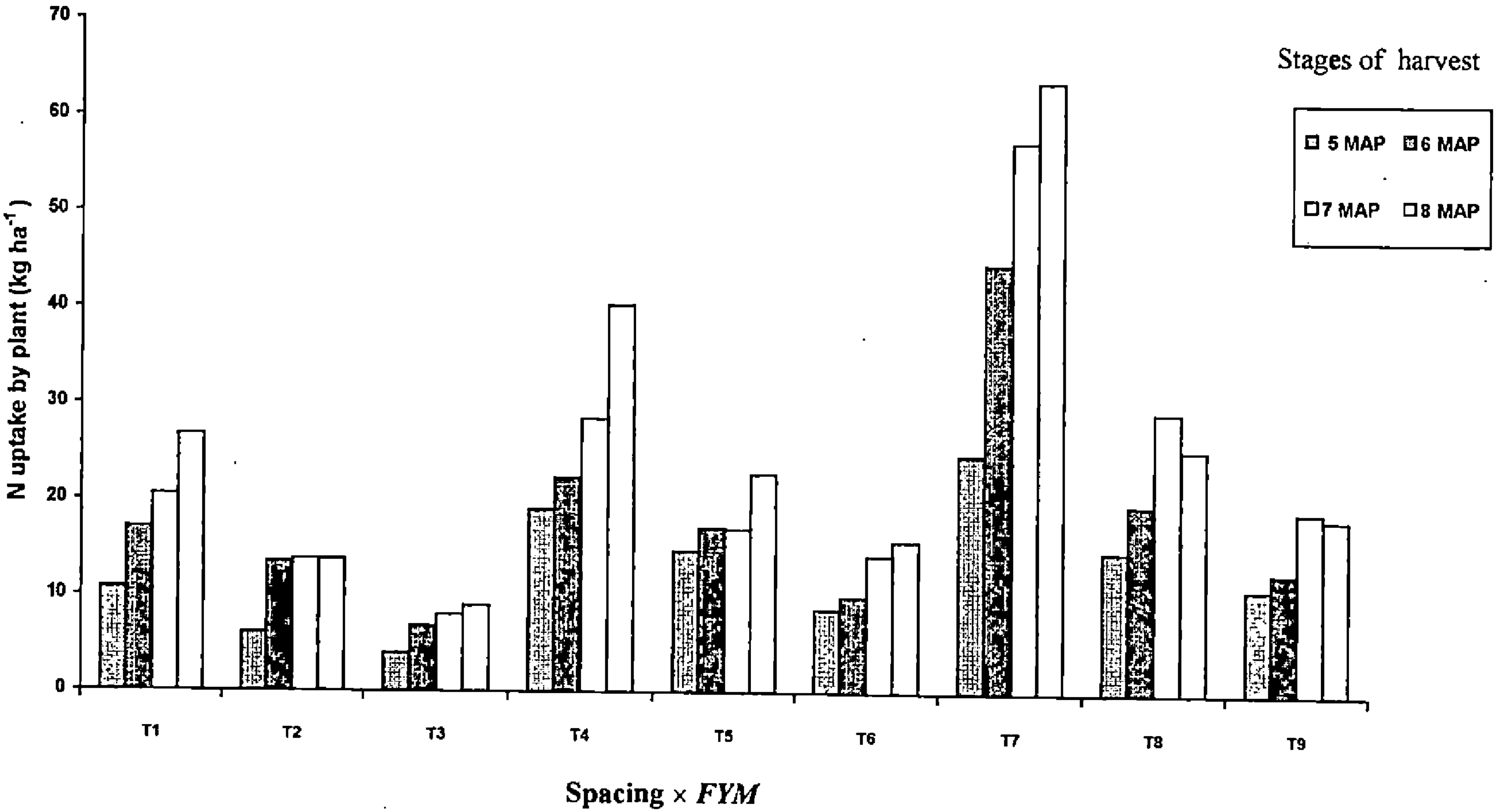


Fig.10 Interaction effect of spacing × *FYM* and stages of harvest on N uptake by the plant

The P uptake by the plant was found to be increasing with increasing the age of plant and it was highest in eight month old crop (1.09 kg ha^{-1}) and lowest in five month old crop (0.74 kg ha^{-1}).

The interaction effect of various treatments was not found to be significant.

c. **Potassium**

The treatment spacing × FYM and stages of harvest significantly influenced the K uptake by the plant (Table 13a and Fig. 9). The treatments receiving FYM @ 10 t ha^{-1} planted at 10 × 10 cm spacing resulted in the highest K uptake (48.4 kg ha^{-1}) and the treatment without any FYM application and planted at a wider spacing of 20 × 20 cm spacing, the lowest value (11.7 kg ha^{-1}).

The K uptake by the plant was found to be increasing with increase in the age of crop. The maximum value was obtained in eight month old crop (31.3 kg ha^{-1}) and the minimum value in five month old crop (19.8 kg ha^{-1}).

The interaction effect of various treatments on K uptake by the crop was found to be significant (Table 13c and Fig. 11). The treatments receiving FYM @ 10 t ha^{-1} and planted at 10 × 10 cm spacing and harvested at seven month

Table 13c. Interaction effect of treatments on K uptake by plant (kg ha^{-1}) in *Hemidesmus indicus*

Treatments	K_1	K_2	K_3	K_4
T_1	25.2	29.5	32.8	41.3
T_2	13.2	20.8	20.8	21.7
T_3	6.9	13.3	12.9	13.4
T_4	29.1	32.2	35.5	48.6
T_5	21.3	23.7	23.9	28.9
T_6	12.8	14.1	15.5	18.2
T_7	31.0	49.2	57.1	56.4
T_8	23.7	26.1	28.4	33.3
T_9	14.8	15.9	17.8	20.0
SEm ±	1.167			
CD (0.05)	2.34			

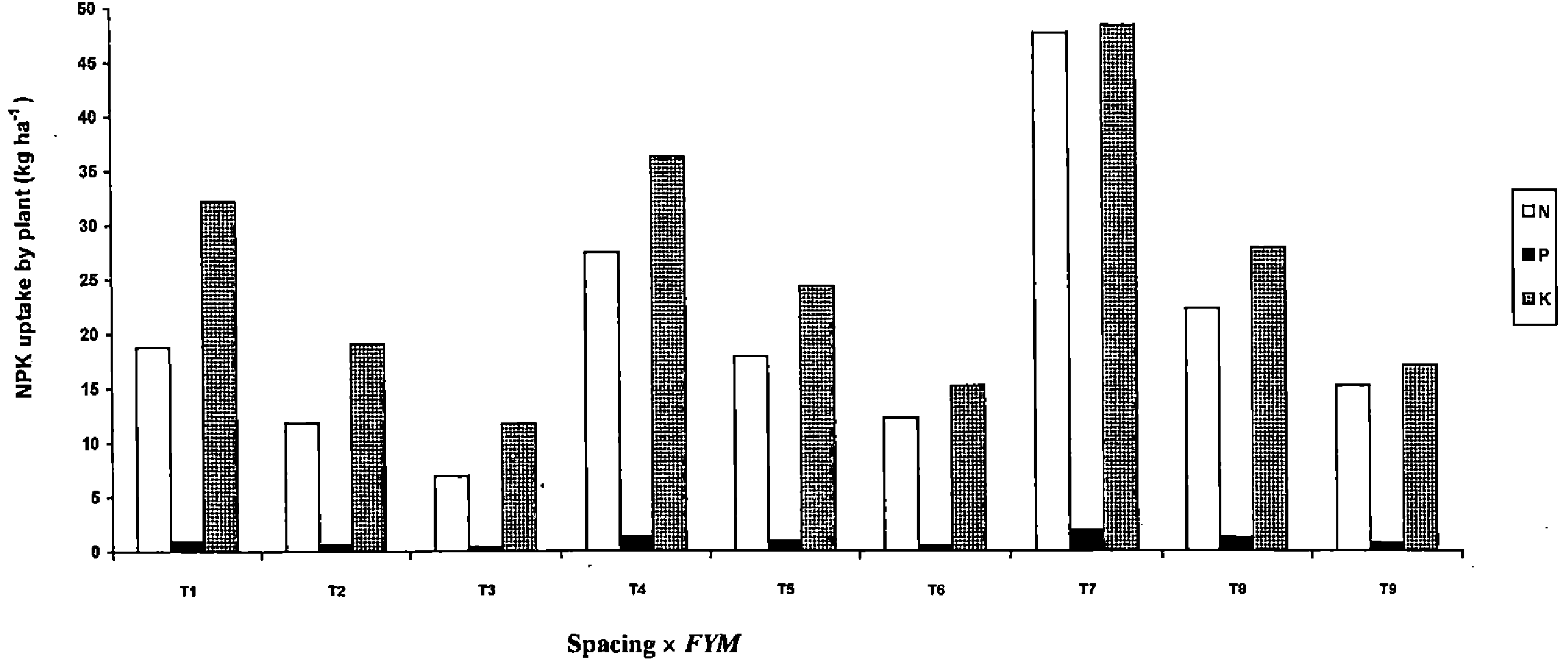


Fig .9 Effect of spacing × *FYM* on NPK uptake by plant

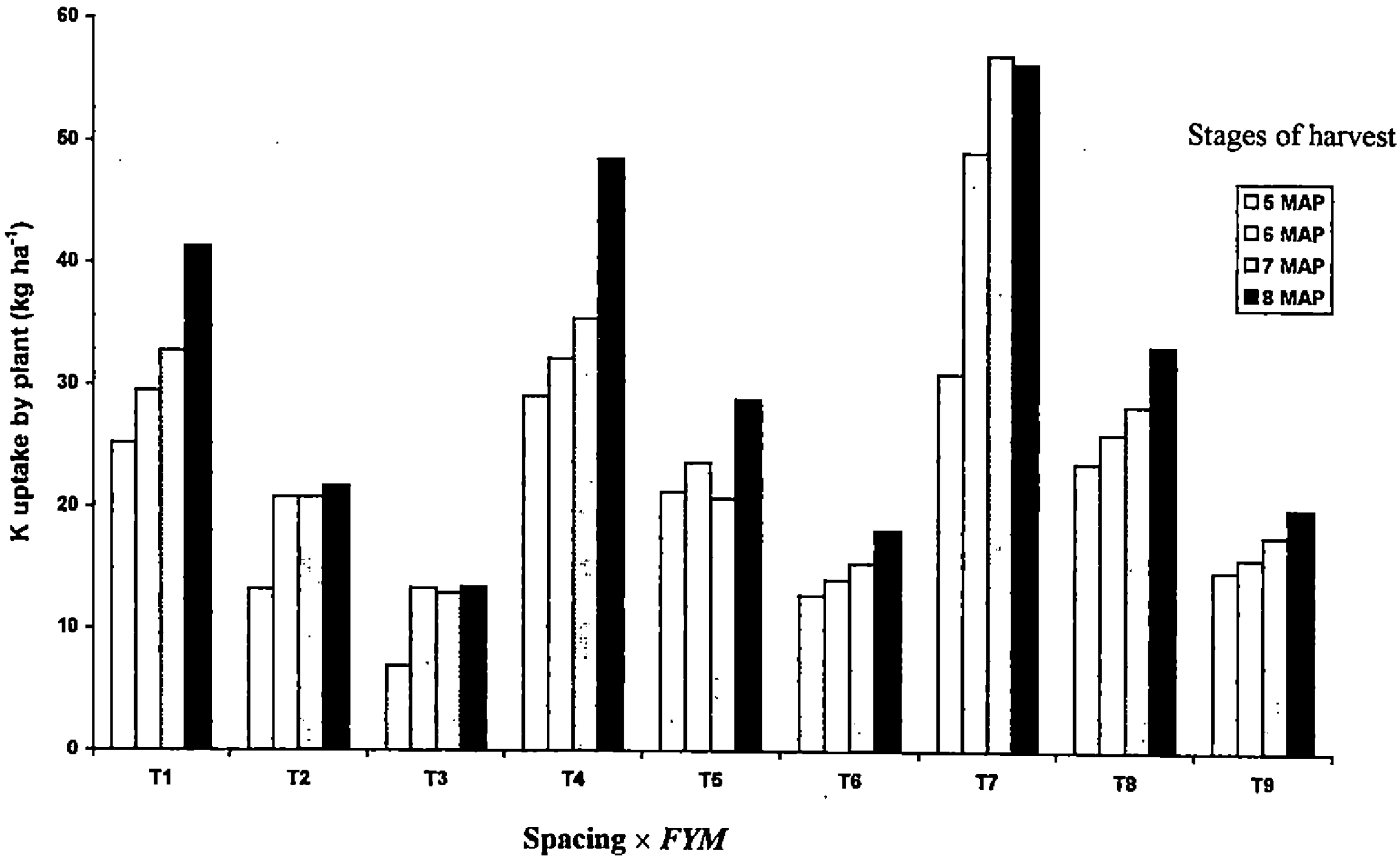


Fig. 11 Interaction effect of spacing × *FYM* and stages of harvest on K uptake by plant

stage ($T_7 K_3$) recorded the highest value of 57.1 kg ha^{-1}. The treatment without any FYM application planted at 20 × 20 cm and harvested at fifth month stage recorded the lowest value (6.9 kg ha^{-1}). The treatment receiving FYM @ 10 t ha^{-1} and planted at 10 × 10 cm spacing when harvested at eight month stage ($T_7 K_4$) was statistically similar to former i.e. $T_7 K_3$.

4.4 **Soil Analysis**

The influence of various treatments on the available N, available P_2O_5, available K_2O and Organic Carbon content of the soil after the experimentation are presented in the Table 14a.

4.4.1 **Available Nitrogen**

The treatments spacing × FYM and stages of harvest significantly influenced the available soil nitrogen in the soil after the experimentation. Irrespective of spacing, the available soil nitrogen was found to be highest in the treatments receiving FYM @ 10 t ha^{-1}. Planting at 20 × 20 cm spacing along with the application of FYM @ 10 t ha^{-1} resulted in higher amount of available N in the soil (371.4 kg ha^{-1}) which was significantly superior to that in the other treatments.

Harvesting at 5 MAP left higher amount of available soil N (312.2

kg ha^{-1}) as compared to that when harvested at 8 MAP (302.2 kg ha^{-1}).

Interaction effect of the various treatments on available soil N after experimentation was found to be significant (Table 14b and Fig. 12). The soil N content varied from 221.8 kg ha^{-1} to 410.1 kg ha^{-1}. The treatments planted at 20 × 20 cm spacing receiving FYM @ 10 t ha^{-1} and harvested at six month stage left the highest soil N and the treatments planted at 10 × 10 cm spacing without any FYM application and harvested at 6 MAP left the lowest N content in soil (221.8 kg ha^{-1}).

4.4.2 **Available P_2O_5**

The treatments spacing × FYM and stages of harvest significantly influenced the available P_2O_5 content of soil after the experiment (Table 14a). As in the case of available soil N content, irrespective of the spacing the available P_2O_5 content in the soil also increased with application of increased levels of FYM. The treatments receiving FYM @ 10 t ha^{-1} planted at 20 × 20 cm spacing left the maximum available P_2O_5 content in the soil (19.9 kg ha^{-1}). Treatments T_7 and T_8 was found to be on par with this. Those planted at 10 × 10 cm spacing without any FYM application left the minimum P_2O_5 content (15.4 kg ha^{-1}). Treatments T_2 and T_3 was found to be similar with this treatment.

Table 14a. Effect of spacing × FYM and stages of harvest on the soil NPK content and organic carbon after experimentation

Treatments	Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})	Organic carbon (per cent)
A. Spacing × FYM				
T_1	238.4	15.4	175.8	0.81
T_2	259.4	15.6	177.1	0.85
T_3	263.0	15.8	178.0	0.86
T_4	282.0	18.1	190.3	0.99
T_5	302.6	17.8	188.5	0.87
T_6	305.7	17.2	190.5	1.00
T_7	368.1	19.8	197.1	1.00
T_8	334.5	19.8	194.8	0.91
T_9	371.4	19.9	193.6	0.91
SEm ±	7.30	0.27	1.69	0.03
CD (0.05)	21.88	0.80	5.05	0.08
B. Stage of harvest				
K_1	312.2	16.9	182.9	0.97
K_2	311.9	17.4	185.6	0.96
K_3	284.8	18.4	192.3	0.97
K_4	302.2	18.1	188.5	0.75
SEm ±	4.80	0.17	0.90	0.02
CD (0.05)	13.63	0.49	2.55	0.05
C. Interaction	sig	sig	sig	sig

Table 14b. Interaction effect of treatments on soil available N after experimentation (kg ha^{-1})

Treatments	K_1	K_2	K_3	K_4
T_1	247.2	221.8	252.4	232.2
T_2	259.8	269.6	236.5	271.8
T_3	269.4	277.0	259.0	246.4
T_4	283.0	309.9	241.4	293.5
T_5	312.9	307.6	291.2	298.7
T_6	309.9	297.7	268.8	346.5
T_7	374.4	363.0	367.6	367.4
T_8	343.7	350.6	318.4	325.3
T_9	409.2	410.1	328.1	338.2
SEm ±	14.41			
CD (0.05)	40.88			

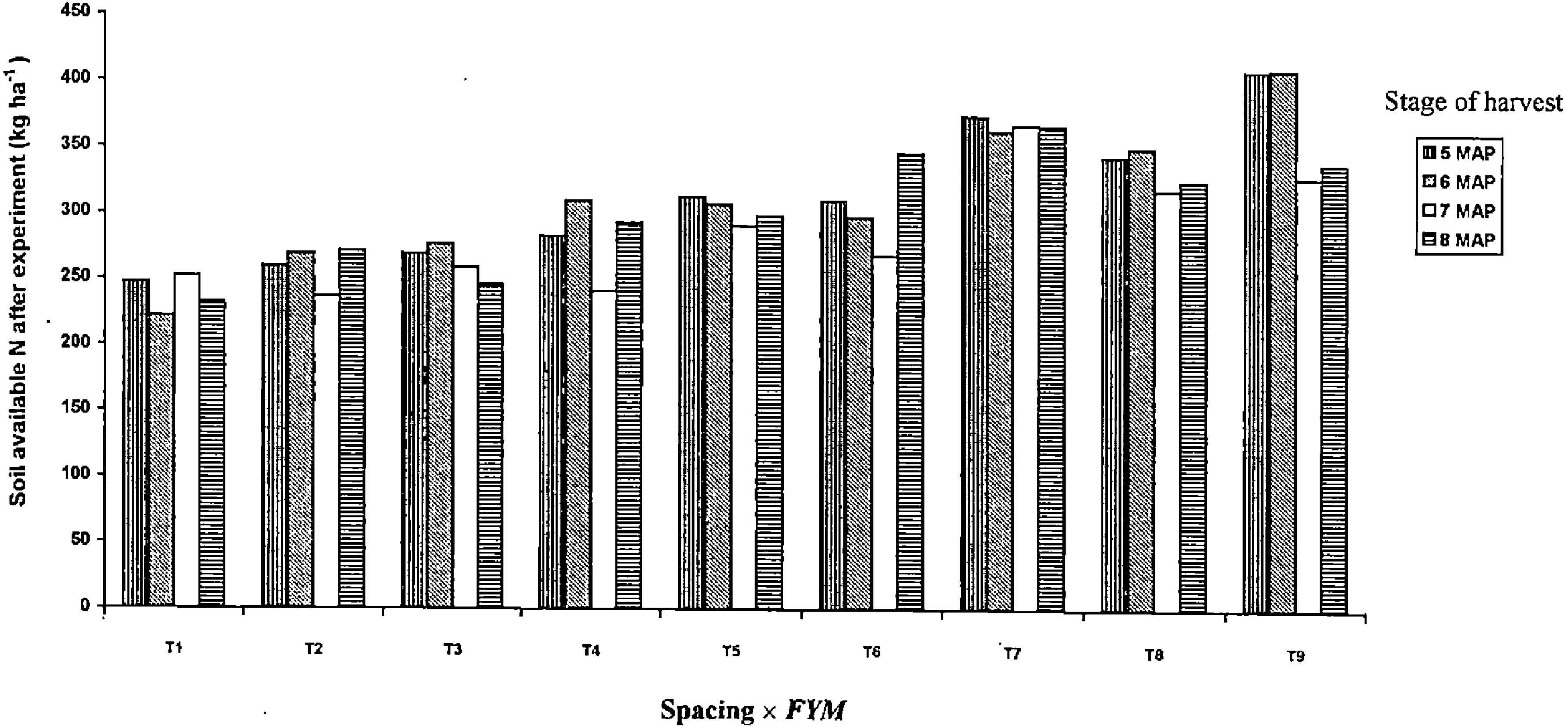


Fig.12 Interaction effect of spacing × *FYM* and stages of harvest on soil available N after experiment

The available P_2O_5 content of soil was found to be increasing with the advancing stage of harvest. Harvesting at 7 MAP resulted in the maximum soil P_2O_5 content of 18.4 kg ha^{-1}. Statistically similar values were noticed when harvested at 8 MAP. Harvesting at 5 MAP left only lower P_2O_5 content in soil (16.9 kg ha^{-1}).

The interaction effect of various treatments on soil available P_2O_5 content was found to be significant (Table 14c and Fig. 13). The treatments receiving FYM @ 10 t ha^{-1} planted at 20 × 20 cm spacing and harvested at 6 MAP recorded the maximum soil available P_2O_5 (20.8 kg ha^{-1}). Those planted at 15 × 15 cm spacing without any FYM application and harvested at 6 MAP, the minimum value (13.7 kg ha^{-1}).

4.4.3 **Available K_2O**

The treatments spacing × FYM and stages of harvest on available K_2O content of soil after the experiment was found to be significant (Table 14a). Irrespective of the spacings adopted, application of increasing levels of FYM resulted in a significant increase in the available K_2O left in the soil after the experimentation. The treatments receiving FYM @ 10 t ha^{-1} and planted at 10 × 10 cm spacing resulted in the maximum amount of available K_2O in soil

Table 14c. Interaction effect of treatments on soil available P_2O_5 after experimentation (kg ha^{-1})

Treatments	K_1	K_2	K_3	K_4
T_1	15.0	14.9	15.2	16.2
T_2	15.6	13.7	16.5	16.5
T_3	15.3	15.2	16.5	16.2
T_4	16.5	17.2	19.6	19.0
T_5	16.2	16.8	20.2	18.1
T_6	16.8	16.5	19.0	16.5
T_7	18.7	20.2	20.0	20.2
T_8	19.0	20.5	19.6	20.0
T_9	19.3	20.8	19.0	20.5
SEm ±	0.518			
CD (0.05)	14.698			

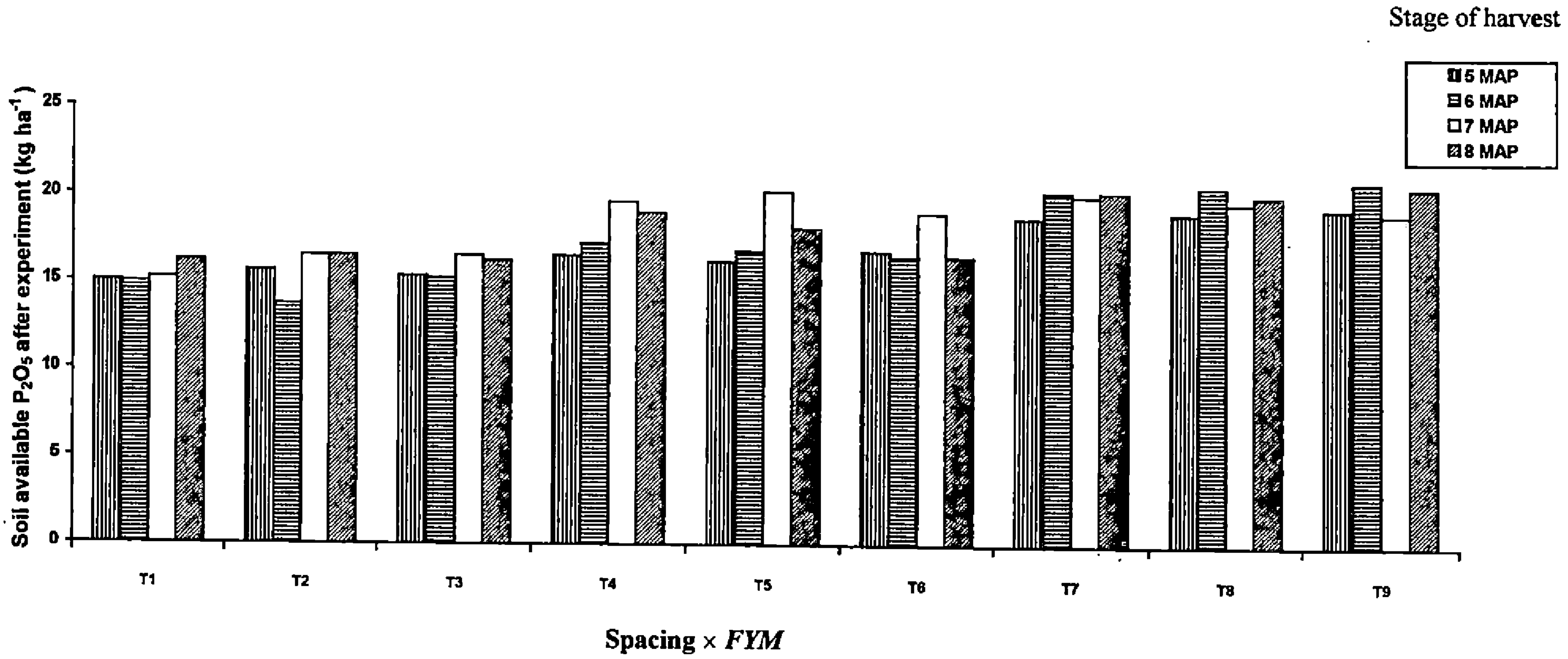


Fig. 13 Interaction effect of spacing × *FYM* and stages of harvest on soil available P_2O_5 after experiment

after the experimentation (197.1 kg ha^{-1}). Treatments receiving FYM @ 10 t ha^{-1} and planting at 15 × 15 cm and 20 × 20 cm was found to be on par with this. The treatments planted at 10 × 10 cm spacing without applying any FYM left the minimum K_2O in soil (175.8 kg ha^{-1}). Treatments planted at 15 × 15 cm and 20 × 20 cm without any organic manure addition also were found to be statistically similar to the above treatment in this character.

The available K_2O content in soil after the experimentation was found to be increasing with the advance in the stage of harvest. Harvesting at 7 MAP left the maximum content (192.3 kg K_2O ha^{-1}) and harvesting at 5 MAP, the lowest value (182.9 kg K_2O ha^{-1}).

The interaction effect of the various treatments significantly influenced the available K_2O content of the soil (Table 14d and Fig. 14). The values ranged from 172.9 kg K_2O ha^{-1} to 203.3 kg K_2O ha^{-1} and the treatments receiving FYM @ 5 t ha^{-1} planted at 20 × 20 cm spacing and harvesting at 7 MAP recorded the highest value (203.3 kg ha^{-1}). Those planted at 10 × 10 cm spacing without any FYM application and harvested at 5 MAP, the lowest

Table 14d. Interaction effect of treatments on soil available K_2O after experimentation (kg ha^{-1})

Treatments	K_1	K_2	K_3	K_4
T_1	172.9	174.1	176.2	180.1
T_2	174.3	177.8	175.5	180.9
T_3	175.4	174.6	178.3	183.7
T_4	181.6	183.5	200.5	195.5
T_5	181.8	186.9	196.0	189.1
T_6	185.1	186.3	203.3	187.4
T_7	187.7	197.2	200.9	202.5
T_8	191.6	197.4	202.8	187.4
T_9	195.3	192.3	196.7	189.9
SEm ±	2.69			
CD (0.05)	7.64			

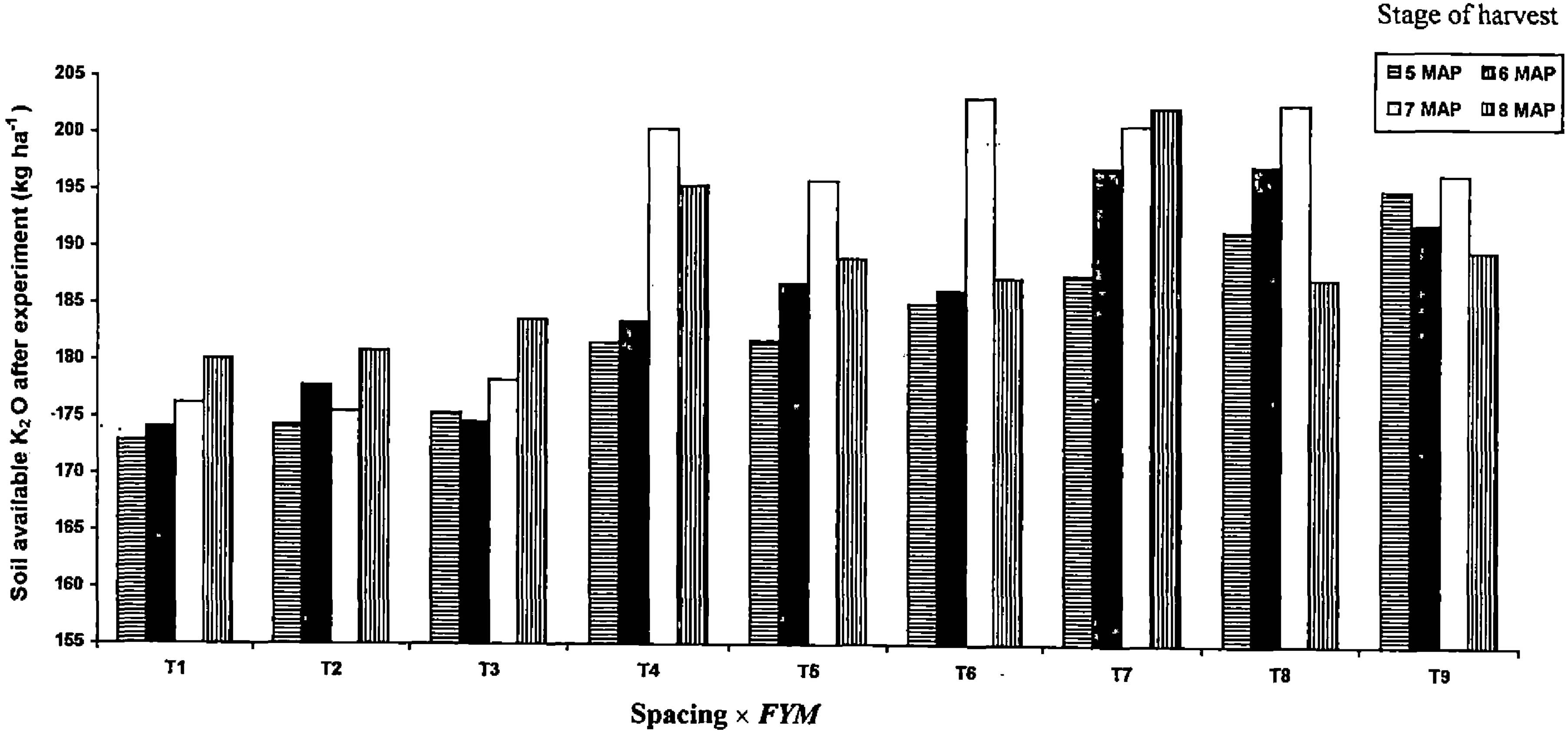


Fig. 14 Interaction effect of spacing × *FYM* and stages of harvest on soil available K_2O after experiment

(172.9 kg ha^{-1}). The treatments $T_7 K_2$, $T_8 K_2$, $T_4 K_3$, $T_7 K_3$, $T_8 K_3$ and $T_7 K_4$ were found to be statistically similar to former and the treatments $T_2 K_1$, $T_3 K_1$, $T_1 K_2$, $T_2 K_2$, $T_3 K_2$, $T_1 K_3$, $T_2 K_3$ and $T_3 K_3$ to that of the latter.

4.4.4 **Organic Carbon**

The treatments spacing × FYM and stages of harvest significantly influenced the organic carbon left in the soil after the experimentation (Table 14a). Irrespective of the spacings adopted, application of increasing levels of FYM resulted in the increased content of soil organic carbon left in the soil. The treatments receiving FYM @ 5 and 10 t ha^{-1} and planted at 20 × 20 cm and 10 × 10 cm spacing respectively recorded the highest soil organic carbon content (1.0 per cent) and the lowest value in those without any FYM application and planted at 10 × 10 cm spacing (0.81 per cent).

The stages of harvest also significantly influenced soil organic carbon content after the experimentation and the values ranged from 0.75 per cent to 0.97 per cent. Harvesting at 5 and 7 MAP left the maximum soil organic carbon content and that at 8 MAP, the lowest.

The interaction effect of the different treatments on the soil organic carbon content of soil after experimentation was found to be significant

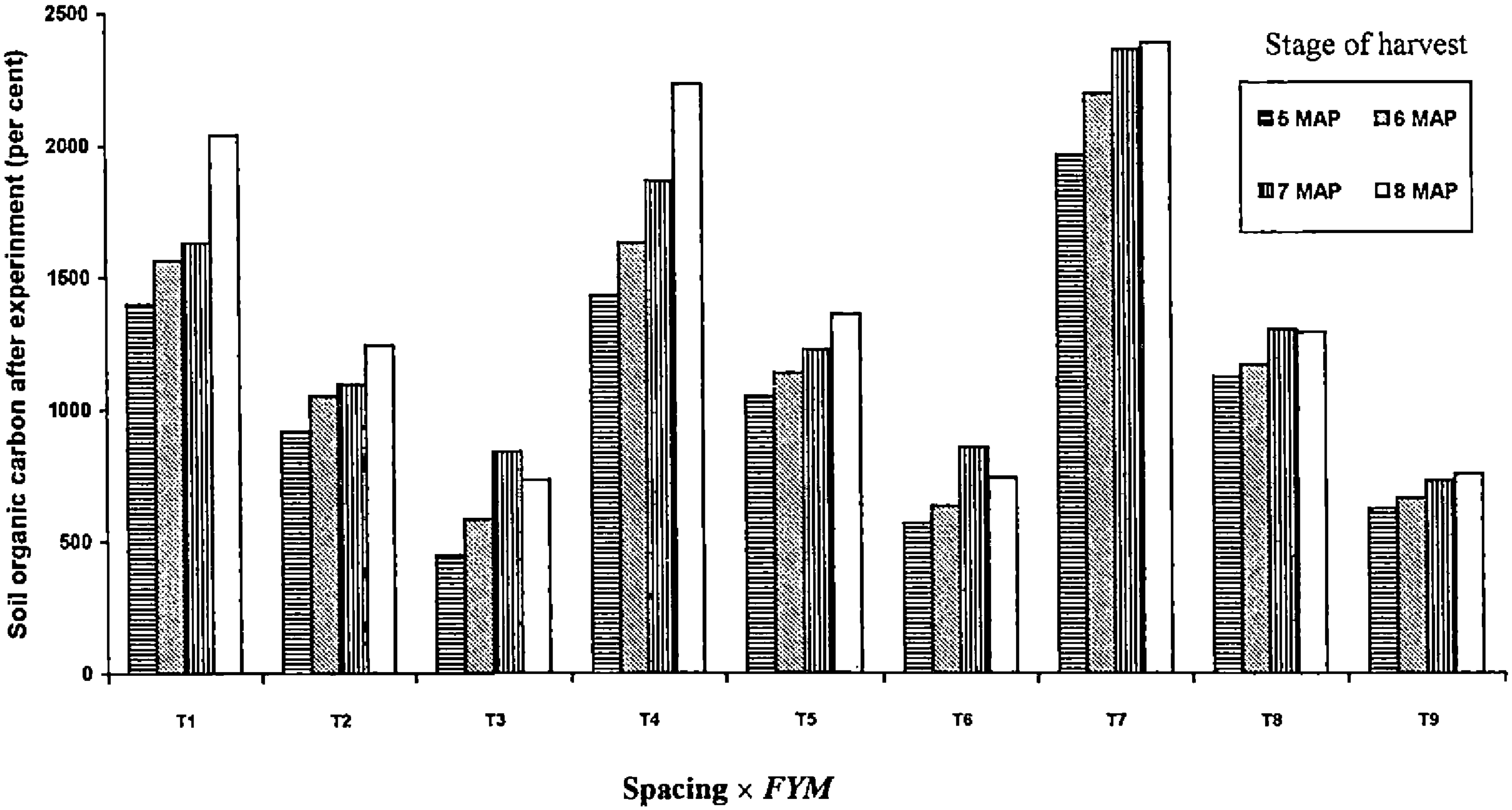


Fig.15 Interaction effect of spacing × *FYM* and stages of harvest on soil organic carbon after experiment

(Table 14e and Fig.15). The treatments receiving FYM @ 10 t ha^{-1} and planted at 20 × 20 cm spacing and then harvested at 5 MAP recorded the highest amount of soil organic carbon (1.25 per cent). The treatments T_8 K_1, T_8 K_2, T_9 K_2, T_9 K_4 were found to be on par with this. The treatments without any FYM application planted at 10 × 10 cm spacing and harvested at 7 MAP or 8 MAP resulted in the lowest soil organic carbon content (0.77 per cent).

4.5 Chemical components

4.5.1 Essential oil content

The effect of spacing × FYM and stages of harvest on the essential oil content in the roots of *Hemidesmus indicus* are presented in Table 15 and Fig. 16.

Irrespective of the spacings adopted, application of increasing levels of FYM resulted in increasing the essential oil content in the plant. Also advancing the stage of harvest, the oil content was found to be increasing. Treatments where FYM was applied @ 10 t ha^{-1} and planted at spacing of 15 × 15 cm when harvested at eight month stage recorded the highest essential oil content (0.3 per cent).

Table 14e. Interaction effect of treatments on soil organic carbon content after experimentation (per cent)

Treatments	K_1	K_2	K_3	K_4
T_1	0.83	0.89	0.77	0.77
T_2	0.87	0.84	0.84	0.84
T_3	0.84	0.82	0.87	0.93
T_4	0.88	1.07	1.07	0.93
T_5	0.96	0.68	0.92	0.92
T_6	0.98	1.04	1.04	0.96
T_7	0.99	0.98	0.98	1.07
T_8	1.17	1.18	1.13	0.15
T_9	1.25	1.15	1.08	1.15
SEm ±	0.05			
CD (0.05)	0.14			

Table 15. Effect of spacing × FYM on essential oil content of roots of *Hemidesmus indicus* (on fresh weight basis) in different harvests (per cent)

Treatments	K_1	K_2	K_3	K_4
T_1	0.10	0.07	0.15	0.10
T_2	0.07	0.10	0.13	0.13
T_3	0.07	0.10	0.10	0.13
T_4	0.10	0.13	0.10	0.10
T_5	0.07	0.15	0.25	0.15
T_6	0.10	0.15	0.13	0.13
T_7	0.13	0.20	0.13	0.20
T_8	0.15	0.23	0.15	0.30
T_9	0.15	0.20	0.10	0.23

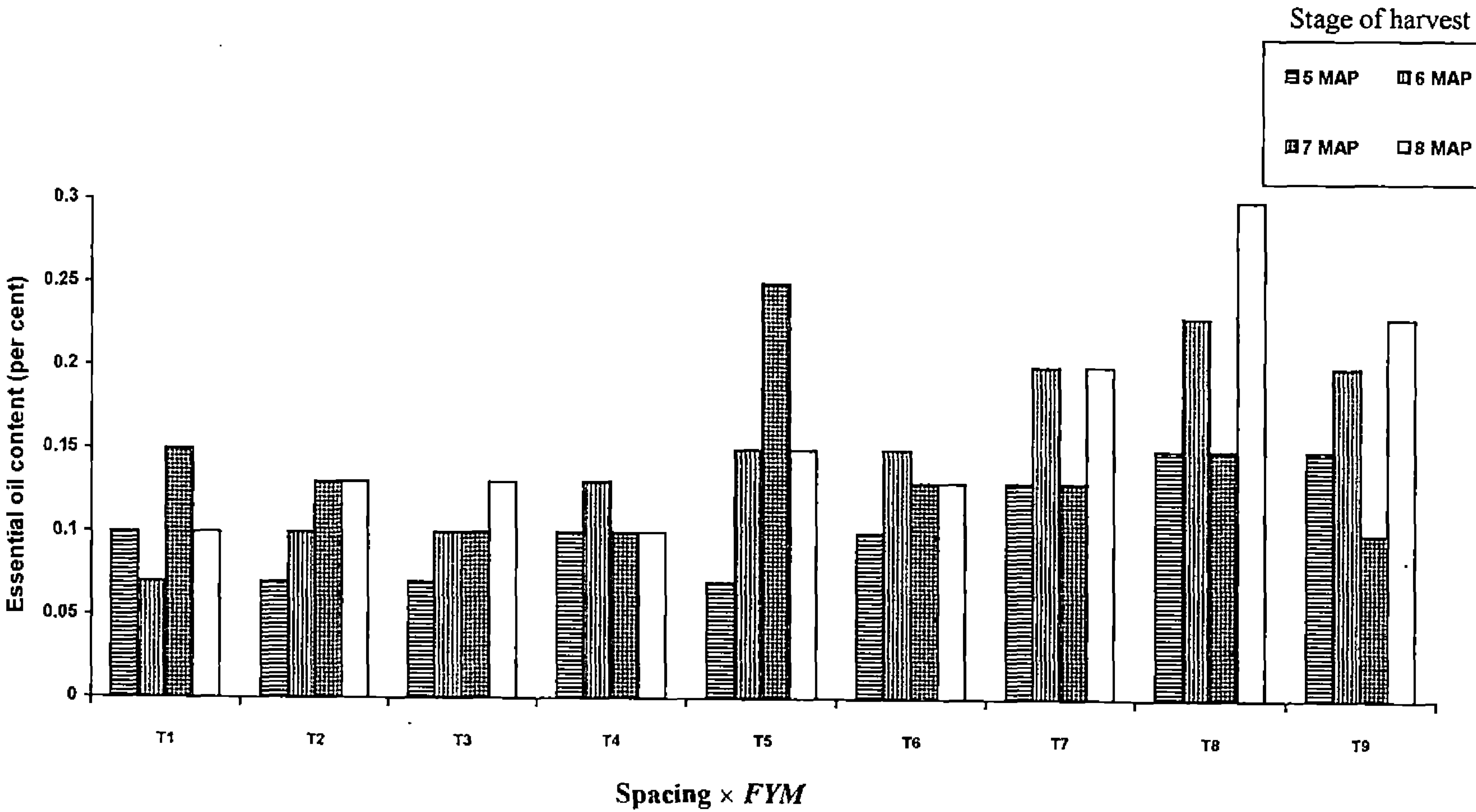


Fig.16 Effect of spacing × *FYM* and stages of harvest on essential oil content on fresh weight basis in different harvests

4.5.2 **Oil yield**

The effect of spacing × FYM and stages of harvest on the oil yield of *Hemidesmus indicus* are presented in Tables 16a and 16b.

The effect of spacing × FYM and stages of harvest on per plant oil yield of *Hemidesmus indicus* showed that planting at a wider spacing of 20 × 20 cm and applying FYM @ 10 t ha^{-1} when harvested at eight month stage resulted in highest oil yield of 4.8 μl / plant.

Application of increased levels of FYM in closer spacing of 10 × 10 cm recorded the higher oil yield per hectare (Table 16a and Fig 17). With advance in the stage of harvest the oil yield was found to be increasing. The highest oil yield of 3 l ha^{-1} was obtained from eight month old crop supplied with FYM @ 10 t ha^{-1} and planted at a spacing of 10 × 10 cm.

4.5.3 **Water soluble extract**

The effect of spacing × FYM and stages of harvest on water soluble extract of *Hemidesmus indicus* are presented in Table 17 and Fig.18. The values ranged from 2.04 per cent to 6.11 per cent.

Table 16a. Effect of spacing × FYM on the oil yield per hectare in *Hemidesmus indicus* in different harvests (l ha^{-1}).

Treatments	K_1	K_2	K_3	K_4
T_1	1.09	1.12	1.92	2.30
T_2	0.70	1.02	1.28	1.39
T_3	0.36	0.60	0.78	0.87
T_4	1.44	2.16	2.28	2.53
T_5	0.28	1.33	1.44	1.55
T_6	0.66	0.79	0.84	0.96
T_7	2.52	2.64	2.87	3.0
T_8	1.33	1.39	1.55	1.57
T_9	0.75	0.81	0.93	0.79

Table 16b. Effect of spacing × FYM on oil yield per plant in *Hemidesmus indicus* (μl / plant)

Treatments	K_1	K_2	K_3	K_4
T_1	0.9	1.0	1.9	2.1
T_2	1.6	2.2	2.4	3.2
T_3	1.6	2.5	2.8	3.4
T_4	1.2	0.6	2.3	2.4
T_5	0.6	2.4	2.7	3.3
T_6	2.5	3.2	3.2	4.1
T_7	0.2	2.8	2.9	3.1
T_8	2.9	3.1	3.0	3.9
T_9	3.0	3.3	4.6	4.8

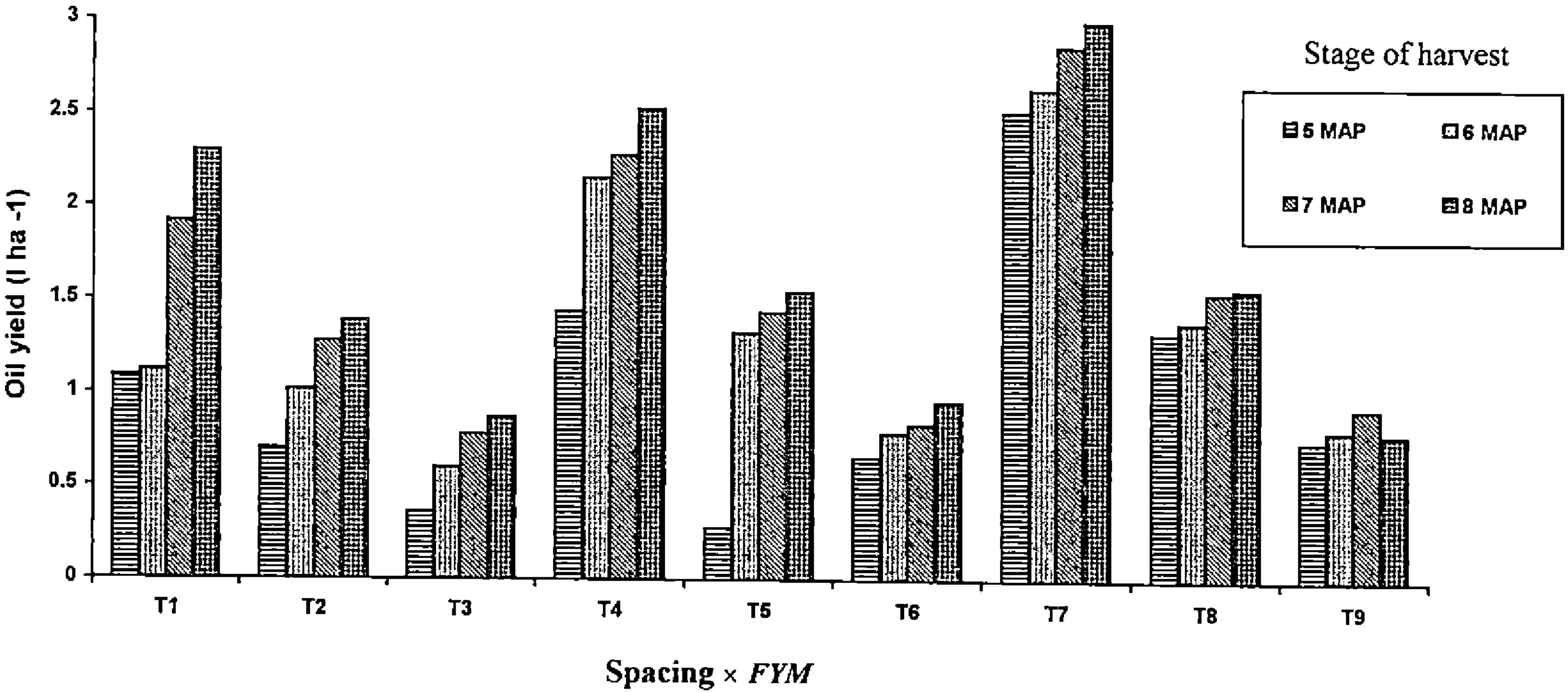


Fig. 17 Effect of spacing × *FYM* and stages of harvest on oil yield per hectare in *Hemidesmus indicus* in different harvests

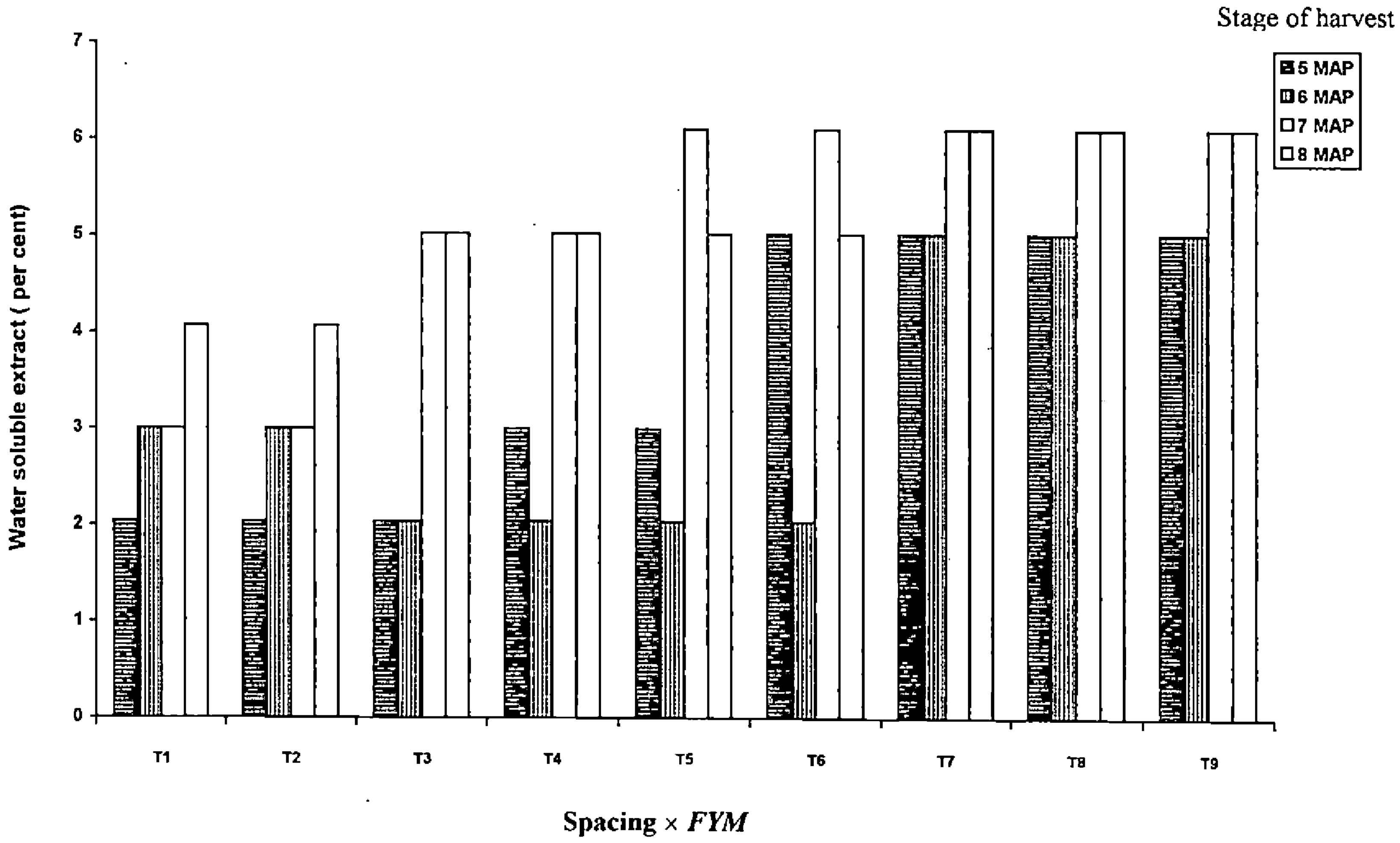


Fig. 18 Effect of spacing × *FYM* and stages of harvest on water soluble extract at different harvests

Table 17. Effect of spacing × FYM on water soluble extract in *Hemidesmus indicus* at different harvests (per cent)

Treatments	K_1	K_2	K_3	K_4
T_1	2.04	3.0	3.0	4.07
T_2	2.04	3.0	3.0	4.07
T_3	2.04	2.04	5.03	5.03
T_4	3.0	2.04	5.03	5.03
T_5	3.0	2.04	6.11	5.03
T_6	5.03	2.04	6.11	5.03
T_7	5.03	5.03	6.11	6.11
T_8	5.03	5.03	6.11	6.11
T_9	5.03	5.03	6.11	6.11

Irrespective of the planting density, increasing the levels of FYM application resulted in an increasing in the water soluble extract of the roots of *Hemidesmus indicus*. With advance in the stage of harvest, the water soluble extract of roots was found to be increasing. Irrespective of the spacing, seven and eight month old crop supplied with FYM @ 10 t ha^{-1} resulted in the higher amount of water soluble extract of 6.11 per cent.

4.5.4 **Alcohol soluble extract**

The effect of spacing × FYM and stages of harvest on the alcohol soluble extract of *Hemidesmus indicus* are presented in Table 18 and Fig. 19. The values ranged from 2.79 per cent to 3.16 per cent.

Application of increased levels of FYM in all the three spacings resulted in higher alcohol soluble extract. With advance in the stage of harvest, the alcohol soluble extract was also found to be increasing. The highest value of 3.16 per cent was obtained in eight month old crop receiving FYM @ 10 t ha^{-1} in medium and wider spacings of 15 × 15 cm and 20 × 20 cm.

4.6 **Economics of cultivation**

The economics of cultivation of *Hemidesmus indicus* was worked out for the best treatment combination i.e. treatments planted at 10 × 10 cm

Table 18. Effect of spacing × FYM on alcohol soluble extract on dry weight basis in *Hemidesmus indicus* at different harvests (per cent)

Treatments	K_1	K_2	K_3	K_4
T_1	2.79	2.80	2.89	2.94
T_2	2.79	2.84	2.89	2.95
T_3	2.80	2.84	2.95	3.0
T_4	2.80	2.86	3.10	3.12
T_5	2.84	2.89	3.12	3.12
T_6	2.84	2.84	3.0	3.16
T_7	2.85	3.1	3.10	3.14
T_8	2.85	3.0	3.0	3.16
T_9	2.85	2.95	3.0	3.16

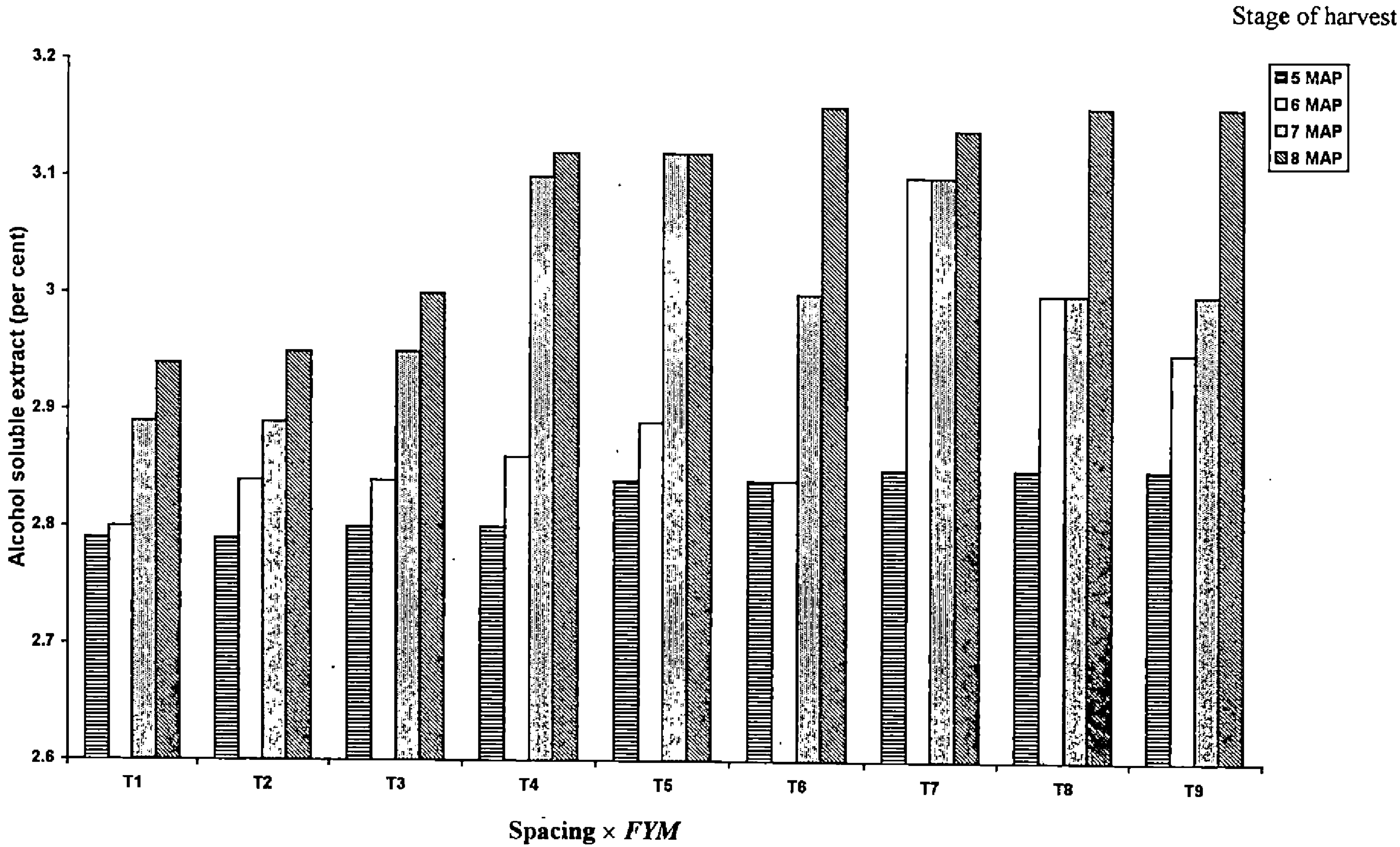


Fig.19 Effect of spacing × *FYM* and stages of harvest on alcohol soluble extract on DWB in *Hemidesmus indicus* at different harvests

spacing and receiving FYM @ 10 t ha^{-1} when harvested at eight month stage (Appendix II). The yield of fresh tuber from one hectare was worked out to be 2389.91 kg. At the current market price of Rs. 45 kg for fresh roots, the gross return from one hectare was Rs. 1,07,541.45. The total cost of cultivation is Rs. 74, 650 with a net return of Rs. 32,891.45.

DISCUSSION

DISCUSSION

The results obtained during the course of investigation are discussed in this chapter in the light of available literature with explanations on the cause effect relationship as far as possible.

5.1 Growth and yield

In general it can be seen that irrespective of the density of planting, application of organic manure @ 10 t ha^{-1} resulted in higher oil yield over a period of eight months as compared to that in no manure application (Table 16a). Among the spacings adopted, high density planting resulted in higher oil yield. At high density planting, application of FYM @ 5 and 10 t ha^{-1} resulted in an increase of oil yield to the tune of 1.2 and 1.3 times respectively as compared to that in the control plots without any FYM application (Table 16a). This higher oil yield may be due to the production of higher fresh and dry root yields in these treatments (Table 11a).

Application of FYM @ 10 t ha^{-1} and planting at 10 × 10 cm spacing resulted in 1.4 and 1.3 times more fresh and dry roots yield, respectively over and above that obtained in control plots at the same level of planting density, whereas the increase in fresh and dry root yields was only 1.1 times by the application of FYM @ 5 t ha^{-1} at the higher density planting (Table 11a). This higher yield due to the application of organic manure may be because of the higher fresh and dry root yield consequent to the application of organic manure (Table 11a). Higher oil yield as a result of the application of higher levels of FYM were also reported in other medicinal crops. Balashanmugham *et al.* (1989) obtained highest yield in turmeric by applying FYM @ 25 t ha^{-1} compared to other levels of 12.5, 15.0, 17.5, 20.0 and 22.5 t ha^{-1}. In palmarosa, Maheshwari *et al.* (1991) obtained 10 per cent more oil yield by applying FYM @ 15 t ha^{-1} as compared to control treatment. In *Piper longum*, Sheela (1996) and Ayisha (1997) obtained higher alkaloid yield by the application of FYM @ 20 t ha^{-1} as compared to that at 0 and 10 t ha^{-1}. Also this may be one of the reasons for the luxuriant growth of *Hemidesmus indicus* in forest areas where the soil is rich in organic matter content. When planted in fields *Hemidesmus indicus* may require heavy dose of organic manure as reported in other crops like garlic (Kultunov, 1984), *Piper nigrum* (Adiyoga, 1987), rainfed niger (Ram *et al.*, 1992), *Piper nigrum* (Mathew *et al.*, 1995), *Piper longum* (Viswanathan, 1993 and 1995, Sheela, 1996 and Ayisha, 1997).

Application of FYM @ 10 t ha^{-1} along with high planting density (10 × 10 cm), the root yield obtained was 2.2 times more than that of wider spacing (20 × 20 cm) and 0.8 times greater than that of medium spacing (15 × 15 cm) (Table 11a). The fresh and dry root yield of 2255.9 and 733.3 kg ha^{-1}, respectively was obtained in this particular treatment. This higher yield in this treatment may be due to the fact that the root yield being a function of yield per plant and number of plants per unit area, may be the result of the maximum number of plants per unit area. It can be seen that high density planting accommodate 2.25 and 4 times more plants than that in the medium (15 × 15 cm) and low (20 × 20 cm) density planting. Similar results of higher yield at dense planting were reported in other medicinal plants like Java citronella (Bommegowda *et al.*, 1980), hops (Goren *et al.*, 1981), senna (Nandi and Chatterjee, 1981), *Papaver somniferum* (Hatakeyama, 1981), *Ocimum gratissimum* (Balyan *et al.*, 1988) and Japanese mint (Singh *et al.*, 1989).

Application of FYM @ 10 t ha^{-1} at (15 × 15 cm) spacing resulted in higher oil content and it was 2.3 times higher than that of control plots without any FYM application at the same spacing (Table 15a). The application of FYM @ 5 t ha^{-1} resulted in more or less similar oil content as compared to that in the control. This may be due to the better growth of plants which turn may be the result of better availability and absorption of nutrients from heavily manured plots with medium density. Application of higher levels of FYM resulted in maximum essential oil content as reported by Sheela (1996) and Ayisha (1997), where they obtained maximum crude alkaloid content in roots of *Piper longum* by applying FYM @ 20 t ha^{-1} as compared to control treatment without any FYM application and FYM @ 10 t ha^{-1}. But in palmarosa, Maheshwari *et al.* (1991) found that the application of FYM @ 15 t ha^{-1} did not affect the geraniol content.

The influence of spacing and FYM on the oil yield per plant showed that the highest oil yield per plant was obtained in the treatment receiving FYM @ 10 t ha^{-1} and planted at a wider spacing of 20 × 20 cm (Table 16b). The values were 1.4 and 1.2 times more than that in the treatments receiving zero and 5 t ha^{-1} FYM respectively at the same planting density and it was 1.2 and 1.5 times greater than that in medium (15 × 15 cm) and higher (10 × 10 cm) density planting receiving FYM @ 10 t ha^{-1}. This may be due to higher root yield per plant which in turn may be due to better plant growth at wider spacing with lesser plant to plant competition for the factors of production.

The influence of spacing and FYM on growth and yield characters like plant height, number of leaves per plant, number of branches per plant, leaf area, root length, root girth, fresh and dry weight of roots per plant (Tables 4, 5a, 6a, 7a and 10a) showed that all these attributes were influenced favourably by the medium spacing of 15 × 15 cm and with the application of FYM @ 10 t ha^{-1}. Similar results were obtained in 20 × 20 cm spacing also. Better plant growth at wider spacing may be due to lesser competition for nutrients, water and light. Closely spaced plants were perhaps subjected to a greater degree of competition for nutrients, moisture and sunlight which in turn was reflected in reduced growth. The results therefore indicated that a spacing of 15 × 15 cm would be better than other spacing treatments for increasing the growth of the plant and this could be due to optimum utilisation of the various factors of production. The results are in conformity with the findings of Ponnuswamy and Muthuswami (1981) in *Curcuma longa*, Joseph (1983) in *Costus speciosus*, Subha (1990) in *Plumbago rosea*, Sheela (1996) and Ayisha (1997) in *Piper longum*. With respect to growth and yield attributes, treatments receiving FYM @ 10 t ha^{-1} and 15 × 15 cm spacing was superior to that in the other treatments. This may be due to the increased availability of nutrients from heavily manured plots and thus resulting in luxuriant growth of plant. Similar results were noticed by Chairani (1987) in *Costus speciosus*, Behura *et al.* (1988) in palmarosa, Sheela (1996) and Ayisha (1997) in *Piper longum* on the effect of organic manure on biometric characters and dry matter production.

Thus the oil yield, fresh and dry root yield, and total plant dry matter yield were found to be higher in plots receiving heavy dose of organic manure and with high density of planting (Tables 11a & 16a), whereas the vegetative characters and yield attributes like root length, root girth, fresh and dry weight of root per plant were higher in plots receiving organic manure @ 10 t ha^{-1} and planted at a medium spacing of 15 × 15 cm (Tables 4, 5a, 6a, 7a and 10a).

The stage of harvest had a significant influence on the oil yield. The oil yield was found to be higher in eight month old crop (3.0 l ha^{-1}) as compared to that in other growth stages (Table 16a). Harvesting at eight month stage resulted in the maximum root yield on fresh and dry weight basis. This may be due to the better growth of the plant by advancing age. This is reflected in the growth characters viz., plant height, leaf area, LAI, number of branches etc. The results are in agreement with those reported in other medicinally important crops viz., ginger (Nybe, 1978), *Mentha arvensis* (Chandra and Singh, 1983), *Kaempferia galanga* (Rajagoplan, 1983), *Acorus calamus* (Philip *et al.*, 1991), *Holostemma annulare* (Meera, 1994) and *Piper longum* (Sheela, 1996).

The oil content, water soluble extract and alcohol soluble extract were higher in eight month old crop as compared to that in other stages. This may be due to the fact that the content increases with advancing stage of the plant. Similar observations were made by Bouverat - Bernier (1989) in pepper mint where he obtained high quality of essential oil containing 2 per cent pulegone at advancing stage of harvest. In peppermint highest essential oil content and menthol content was obtained at last stage of harvest (Leela and Angandi, 1994). Maximum soluble carbohydrate content and total amino acid content in *Holostemma annulare* was noticed when the crop was harvested at 18 month stage as compared to that in 12 month and 6 month old crop (Meera, 1994).

The growth characters and yield attributes (Tables 4, 5a, 6a, 7a and 10a) were found to increase with advance in the stage of harvest and highest value of these characters were obtained at eight month stage. This may be due to better water and nutrient uptake by way of promoting the root growth with advance in stage of harvest. The results are in conformity with those reported by Laughlin (1980) in *Papaver somniferum*, Prasad and Saxena (1980) in peppermint, Nair *et al.* (1983) in *Eucalyptus citriodora*, White *et al.* (1987) in peppermint, Kuriakose (1989) in palmarosa, Meera (1994) in *Holostemma annulare*, Sheela (1996) in *Piper longum*.

Thus the advance in the stage of harvest improves the growth in *Hemidesmus indicus* resulting in better oil yield of good quality. The increased oil yield obtained at eight month stage might be due to an increase in root yield as well as oil content in the crop at this stage.

The interaction effect of spacing × FYM and stage of harvest on total oil yield over eight months (Table 16a) showed that the treatment combination receiving FYM @ 10 t ha^{-1} with the highest planting density (10 × 10 cm spacing), when harvested at eight month stage (T_7K_4) resulted in the maximum oil yield of 3.0 l ha^{-1} as compared to that in the other treatment combinations. Therefore for producing higher oil yield, the crop may be closely planted (10 × 10 cm spacing) along with the application of organic manure @ 10 t ha^{-1} and may be harvested at eight month stage. The increased oil yield in the treatment might be due to the higher root yield of 2389.8 kg ha^{-1}, in this particular treatment.

5.2 **Nutrient content and uptake**

It can be seen that at wider spacing (20 × 20 cm) application of organic manure @ 10 t ha^{-1} resulted in higher content of N, P and K in the shoot and root of *Hemidesmus indicus* (Table 12a). The increase in nutrient content was to the tune of 165, 160, 115 per cent respectively in shoot and 207, 166, 125 per cent respectively in root as compared to that of control plots without any FYM application. This might be due to the increased availability of these nutrients in the soil due to the application of heavy dose of manure. Tisdale *et al.* (1993) and Joseph *et al.* (1995) reported the role of organic matter in enhancing phosphorus availability from the soil. Sheela (1996) and Ayisha (1997) also made similar observations in *Piper longum* i.e, a higher concentration of N, P and K in vegetative parts with higher levels of organic manure. The N, P and K content was found to be higher in lower density planting as compared to that in high density planting. This may be due to the fact that when space between the plants was increased, there would be lesser number of plants per unit area resulting in lesser competition for the factors of production viz., water, nutrients and light resulting in better absorption of nutrients from the soil. So the nutrient content of shoot and root portion was more in wider spacing and vice versa in high density planting. In *Piper nigrum*, Reddy *et al.* (1992) have reported a decreasing trend of potassium content when the plant population was increased. In *Piper longum*, Sheela (1996) and Ayisha (1997) also made similar observations of decreasing content of nutrients in vegetative parts with increasing plant population. Thus the treatments receiving FYM @ 10 t ha^{-1} and planted at 20 × 20 cm spacing recorded higher nutrient content and the N, P and K content in this treatment was 1.65, 0.08, 1.84 per cent respectively in the shoot and 1.45, 0.5 and 1.77 per cent respectively in root which was significantly superior to that in the absolute control.

Stage of harvests influenced significantly the N content of shoot and root which showed an increasing trend upto the seventh month and then decreased in the last harvest (Table 12a). The higher concentration of N in vegetative parts in early stages may be due to the fact that the growth rate and biomass production during the early stage is considerably low. With advancing stage, a rapid increase in the total dry matter production is noticed resulting in a decrease in the concentration of nitrogen in vegetative parts. Similar variation in the leaf nitrogen content of *Piper nigrum* was reported by Sushama (1982). The stage of harvest did not affect P and K content of shoot and root, even though the P and K content of the roots showed an increasing trend with advancing age where as the P and K content decreased in shoot at eight month stage. In *Piper longum* there was a slight increase in P content when the plant growth was reduced after the peak bearing stage (Ayisha, 1997).

The interaction effect of spacing × FYM and the stage of harvest on the nutrient content of shoot and root was not found to be significant. Among the interaction treatments, those planted at 20 × 20 cm spacing receiving FYM @ 10 t ha^{-1} and harvested at eight month stage (T_9 K_4) resulted in root N content significantly higher than that in the other treatment combinations.

Planting at 10 × 10 cm spacing along with the application of FYM @ 10 t ha^{-1} resulted in the highest nutrient uptake (Table 13a). This may be due to the enhanced mineralisation of nutrients at higher levels of organic manure as reported by Joseph *et al.* (1995). This may also be due to the maximum dry matter accumulation in higher density plots. Significantly higher uptake of all the three nutrients were noticed with the application of organic manure @ 10 t ha^{-1} as compared to control and the increase was 1.53, 1.17 and 1.50 times more than that in the treatment without any FYM application. This increased nutrient uptake might be due to an increased availability and absorption of these nutrients in soil which helped the plant to produce more dry matter (Table 11a), uptake being a function of dry matter production and nutrient content. Similar results of enhanced nutrient availability by the addition of organic manure has been reported by Richards (1969), Thampatti (1985), Tisdale *et al.* (1993) and Joseph *et al.* (1995). Among the different spacing levels, narrow spacing of 10 × 10 cm recorded higher uptake of N, P and K (Table 13a). This may be due to the enhanced dry matter accumulation in higher density plots due to the presence of maximum number of plants per unit area thus increasing the uptake. The P uptake was around 20 per cent of nitrogen uptake which was in conformity with the reports of Kamwar *et al.* (1982). Similar observations on the significant increase in N, P and K uptake by higher density of planting are also reported by Tisdale *et al.* (1985), Sheela (1996) and Ayisha (1997).

Stage of harvest also showed significant influence on the N, P and K uptake by the plant. The nutrient uptake increased with ageing and was found to be the maximum in eight month old plants (Table 13a). This may be due to the higher dry matter yield with advancing age of the crop. A gradual increase of nutrient uptake in *Piper nigrum* with the growth of plant has been reported by Dewaard (1969) and Sushama (1982) and in *Piper longum* by Sheela (1996). But Ayisha (1997) observed a decreasing trend in N, P, K uptake by the plant after 17 MAP in *Piper longum*.

The interaction effect of spacing × FYM and stages of harvest was significant only on N and K uptake of plant. The most significant interaction on N and K uptake by root and shoot was obtained in the treatments receiving FYM @ 10 t ha^{-1} planted at 10 × 10 cm spacing and harvested at eight month stage. This may be due to increased availability and absorption of these nutrients with advancing age of plant.

5.3 **Soil fertility parameters**

Irrespective of spacing, treatments receiving FYM @ 10 t ha^{-1} was found to increase the available N, available P_2O_5, available K_2O and organic carbon content in the soil after the experimentation (Table 14a). Higher dose of organic manure @ 10 t ha^{-1} left more nutrients in the soil which was significantly superior to that in the control plots without any FYM application.

This may be due to the increased microbial activity due to the application of organic manure which may lead to greater mineralization. With organic manure application Muthuvel (1973), McIntosh and Varney (1973), Thampatti (1985), Joseph *et al.* (1995), Sheela (1996) and Ayisha (1997) have reported an increase in the nutrient content in the soil after experimentation. The treatments planted at a wider spacing of 20 × 20 cm and receiving FYM @ 10 t ha^{-1} was significantly superior in the case of available N and available P_2O_5. (Table 14a). The depletion of nutrients from the soil with closer spacing was due to more number of plants per unit area extracting nutrients from soil resulting in the reduction in soil nutrient status. This is in conformity with findings of Tisdale *et al.* (1985), Sheela (1996) and Ayisha (1997). Those planted at a narrow spacing of 10 × 10 cm and receiving FYM @ 10 t ha^{-1} left more available K_2O and organic carbon in the soil after experimentation.

Reddy *et al.* (1992) reported an increased nutrient content in soil at higher plant densities.

The stage of harvest also showed a significant influence on soil nutrient status after experiment (Table 14a). The available nitrogen content of soil showed a progressive decrease after each harvest and showed a slight increase after the last harvest at eight month stage. The maximum value of 302.2

kg ha^{-1} was obtained after harvesting at eight month stage (Table 14a). In the case of all the other nutrients, their content in soil was less after last harvest as compared to first harvest. The decrease in nutrient content in the soil after the experiment may be due to extraction of more nutrients for a larger period of time by the plants. Similar trend of decreasing nutrient content of soil with advancing stage of harvest has been reported by Ayisha (1997).

The interaction effect of spacing × FYM and stage of harvest also showed a significant influence on soil nutrient content (Tables 14b, 14c and 14d). In all the cases the nutrient content was found to be higher in lower density planting with organic manure @ 10 t ha^{-1} and with advance in the age, the nutrient content was found to be decreasing.

5.4 **Economics of cultivation**

The economics of cultivation worked out for the best treatment combination, i.e., treatments receiving FYM @ 10 t ha^{-1} planted at 10 × 10 cm spacing when harvested at eight month stage showed that a net return from a hectare to be of Rs. 32, 891.45 is obtained with total cost of cultivation of Rs. 74,650 (Appendix 11). Even without applying any FYM and planting at a lower density of 20 × 20 cm, when harvested at eight month stage recorded fresh root yield of 734.08 kg and the net return obtained was Rs. 9268.60 (Appendix III). The total cost of cultivation in this case was Rs. 23,765. This shows that *Hemidesmus indicus* can be grown as a profitable crop under Kerala conditions.

5.5 **Future line of work**

In *Hemidesmus indicus* there is possibility of increasing yield by further addition of higher doses of FYM. Since it is a perennial crop, by enhancing the stages of harvest there should be possibility of getting higher yield. The results showed that *Hemidesmus indicus* supplied with 10 t ha^{-1} FYM and planted at 10×10 cm spacing, the root yield is showing an increasing trend upto the experimental period of eight months. This calls for the further improvement in the following aspects:

(i) A wider spacing may be tried to find out the optimum for getting highest yield per plant.

(ii) The experiment may be conducted for a period of two years from planting and harvesting at bimonthly intervals that the optimum stage of harvest can be arrived at.

(iii) A higher dose of organic manure may also be tried @ 20 t ha^{-1}.

SUMMARY

SUMMARY

Investigations were carried out at the Department of Agronomy, College of Horticulture, Vellanikkara, Trichur, Kerala during 1996 - '97 to standardise the agrotechniques in Indian sarsaparilla (*Hemidesmus indicus* [Linn] R. Br.). The investigation included 2 parts (i) Nursery studies. (ii) Field experiment. The propagules selected for nursery screening were 5 cm root cuttings planted horizontally, 5 cm root cuttings planted vertically, 5 cm root stumps and 5 cm vine cuttings.

The experiment was laid out in split plot design with three replications. There was nine main plot treatments which are combinations of three levels of spacing (10 × 10 cm, 15 × 15 cm and 20 × 20 cm) and three levels of organic manure (0, 5 and 10 t ha^{-1} FYM) and four stages of harvest formed the subplot treatments viz., five, six, seven and eight months after planting. The main objectives of the study were to standardise the planting material in *Hemidesmus indicus* and to arrive at the optimum spacing for getting maximum yield . It also aimed to work out the optimum stage of harvest so as to get the highest yield of good quality. The important results of the study are:

I. **Nursery Studies**

Among the four propagules tested, the 5 cm long root cuttings planted vertically showed superiority over others in terms of germination percentage, height of the plant, number of leaves, root length and root girth. Hence the root cuttings planted vertically was selected for the field trial.

II. **Field experiment**

The results of the field experiment can be summerised as follows

A. **Effect of spacing × FYM**

Irrespective of the spacings adopted, the plant height increased with increasing levels of FYM and the plots receiving FYM @ 10 t ha^{-1} had the tallest plants.

Number of leaves produced per plant varied significantly due to the application of FYM. In all the three spacings, application of FYM @ 10 t ha^{-1} recorded the maximum number of leaves per plant.

Irrespective of the planting density,the treatments receiving FYM @ 10 t ha^{-1} had the maximum number of branches per plant which was significantly superior to that in all the other treatments.

The plots receiving FYM @ 10 t ha^{-1} recorded the maximum leaf area in all the three spacings.

The crops planted at 10 × 10 cm spacing, where FYM @ 10 t ha^{-1} was applied, recorded the maximum leaf area index, which was significantly superior to that of the other treatments.

Irrespective of the varying plant densities, application of FYM @ 10 t ha^{-1} and planted at a spacing of 20 × 20 cm had the longest root.

Planting at 20 × 20 cm spacing and applying FYM @ 10 t ha^{-1} resulted in the thickest roots which was significantly superior to that in the other treatment combinations.

The maximum root dry matter content was obtained in the treatments planted at 20 × 20 cm spacing and applying FYM @ 5 t ha^{-1}.

Plants receiving FYM @ 10 t ha^{-1} and planted at a spacing of 20 × 20 cm resulted in the highest fresh root yield per plant. Treatments receiving FYM @ 10 t ha^{-1} and planted at 15 × 15 cm spacing also produced root yield on per plant basis similar to that in the widely spaced plants.

The maximum dry weight of root per plant was recorded by treatments receiving FYM @ 10 t ha^{-1} and planted at 20 × 20 cm spacing.

Plots receiving FYM @ 10 t ha^{-1} at a spacing of 10 × 10 cm recorded the highest fresh root yield which was statistically similar to that in the treatments receiving FYM @ 5 t ha^{-1} and planted at 15 × 15 cm spacing.

The highest dry root yield was obtained in the treatments receiving FYM @ 10 t ha^{-1} along with a closer spacing of 10 × 10 cm.

Plants receiving FYM @ 10 t ha^{-1} and planted at a spacing of 10 × 10 cm recorded the highest dry shoot yield which was significantly superior to that of the other treatment combinations.

The highest total dry matter yield was obtained in the treatments planted at 10 × 10 cm and supplied FYM @ 10 t ha^{-1} .

Harvest index was not affected by the treatment combination spacing × FYM.

The highest essential oil content was obtained in the treatments where FYM was applied @ 10 t ha^{-1} and planted at a spacing of 15 × 15 cm.

Application of FYM @ 10 t ha^{-1} with high density planting (10 × 10 cm) recorded the higher oil yield per hectare, whereas the per plant oil yield was higher in the treatment with lower plant density (20 × 20 cm spacing).

Irrespective of the spacing, the plots supplied with FYM @ 10 t ha^{-1} resulted in the higher amount of water soluble extract.

In all the three spacings, the crops receiving FYM @ 10 t ha^{-1} had the higher alcohol soluble extract.

Planting at 10 × 10 cm spacing with an application of FYM @ 10 t ha^{-1} resulted in the highest N content in shoot where as the root N content was highest in those planted at 20 × 20 cm spacing with an application of FYM @ 10 t ha^{-1}.

Irrespective of the spacing, the P content in shoot was highest in the treatment receiving FYM @ 10 t ha^{-1} and the P content of root was not affected by the treatment combination spacing × FYM.

The highest shoot and root K content was noticed in the treatments planted at a spacing of 20 × 20 cm and supplied with FYM @ 10 t ha^{-1}.

Closest planting (10 × 10 cm) along with the application of FYM @ 10 t ha^{-1} resulted in the maximum N, P and K uptake by the plant.

Planting at 20 × 20 cm spacing along with the application of FYM @ 10 t ha^{-1} left the highest amount of available N and available P_2O_5 in the soil after experimentation whereas those planted at 10 × 10 cm spacing along with the application of FYM @ 10 t ha^{-1} left more K_2O and organic carbon content in the soil.

B. **Effect of stages of harvest**

The plant height was significant only in the seventh month stage and tallest plants were obtained in the seventh month. The different stages of harvest did not affect the rate of leaf production in the plant. The maximum number of branches was obtained in the seventh month stage. The maximum leaf area of 210.9 cm^2 was obtained at seven month stage. Stage of harvest significantly influenced the leaf area index in sixth and seventh month stages and the maximum LAI was obtained in seven month stage. The number of roots was found to increase with the advancing age of plant and maximum value of 3.2 was obtained when harvested at eight month stage. The plants harvested after eight months had the longest roots. The girth of root was maximum in eight month old plants. Higher root dry matter content was obtained when the plants were harvested at six month stage (33.9 per cent) followed by that at eight month (33.4 per cent) stage. Harvesting the plants at eight months after planting resulted in the maximum fresh root yield of 2.8 g per plant. Maximum dry weight of root per plant was recorded in plants harvested after eight months (0.94 g). The fresh root yield per hectare was highest at eight month stage (1422.7 kg ha^{-1}). The highest dry root yield (474.2 kg ha^{-1}) was obtained in eight month old crop. The highest dry shoot yield (1411.7 kg ha^{-1}) was obtained from eight month old crop. The plants harvested after eight month stage recorded higher dry matter yield (1886.0 kg ha^{-1}). The harvest index was found to be decreasing with the increasing age of the plant. The maximum value was obtained for the five month old plants (0.29) and the minimum in the eight month old plants (0.25).

Seven month old plants recorded the highest value of shoot N content (1.41 per cent) closely followed by that in eight month old plants (1.39 per cent). The root N content was highest in seven month old plants (1.34 per cent). The P content of shoot, K content of shoot and root were not found to be significantly influenced by the stage of harvest. The eight month old crop removed maximum quantity of N, P and K from the soil which were 26.20, 1.09, 31.30 kg ha^{-1} respectively. Harvesting at five month stage left higher amount of available soil N (312.2 kg ha^{-1}). Harvesting at seven month stage resulted in higher amount of available P_2O_5 content (18.4 kg ha^{-1}) in the soil. The available K_2O content in soil after experimentation was found to be increasing with the advance in the stage of harvest and harvesting at seven month stage left the maximum content of 192.3 kg ha^{-1} available K_2O in the soil. Harvesting at five and seven month stages left the maximum organic carbon content (0.97) in the soil. Harvesting at eight month stage resulted in the highest essential oil content of (0.3 per cent) in the roots of *Hemidesmus indicus*. The per hectare and per plant oil yield was highest when harvested at eight month stage. The seven and eight month old crop resulted in the higher amount of water soluble extract of roots (6.11 per cent). The highest value of alcohol soluble extract was obtained in eight month old crop (3.16 per cent).

C. **Interaction effect of spacing × FYM and stages of harvest**

The treatment combinations did not affect the height of plant in *Hemidesmus indicus*.

The interaction effect of treatments on the number of leaves per plant was significant at four, five and seven month stages. At four and five month stage, the treatments receiving FYM @ 10 t ha^{-1} planted at 10 × 10 cm spacing and harvested at six month stage recorded maximum value. At seven month stage, the treatment receiving FYM @ 10 t ha^{-1} and planted at 10 × 10 cm spacing recorded the highest value of 44.4.

Irrespective of the spacings, the treatments receiving FYM @ 10 t ha^{-1} and plants at eight month stage recorded the highest value of 2.9 in the case of number of branches per plant.

The interaction effect of the various treatments on the leaf area per plant was significant at five, six and seven month stages. At five and six month stage, the treatment receiving FYM @ 10 t ha^{-1} with 10 × 10 cm spacing (T_7 K_2) recorded the maximum value. At seven month stage, the treatments planted at 15 × 15 cm spacing receiving FYM @ 5 t ha^{-1} (T_7K_3) recorded the highest value.

The interaction effect of the treatments on leaf area index was significant at four, five, six and seven month stages. At four, five, six months stages, the treatments planted at 10 × 10 cm spacing receiving FYM @ 10 t ha^{-1} when harvested at six month stage (T_7K_4) recorded maximum LAI. At seven month stage the treatment T_7K_3 recorded the maximum value of 2.60.

The number of roots per plant was found to be highest in those treatments planted at medium (15 × 15 cm) and wider (20 × 20 cm) spacings receiving FYM @ 10 t ha^{-1} when harvested at eight month stage.

The treatment receiving FYM @ 5 t ha^{-1} planted at a spacing of 15 × 15 cm and harvested at eight month stage was found to be superior in the case of length of root. The treatments T_3K_4, T_6K_4, T_9K_4 and T_8K_4 was found to be similar to this treatment.

The girth of main root was not affected by the interaction effect of various treatments.

The highest root dry matter content was obtained in the treatments receiving FYM @ 5 t ha^{-1} planted at 20 × 20 cm spacing and harvested at eight month stage (T_6K_4).

The fresh root yield per plant was not affected by the interaction between spacing × FYM and stages of harvest.

In the case of dry root yield per plant, the treatment combinations receiving FYM 5 t ha^{-1} planted at 20 × 20 cm spacing and harvest at eight month stage (T_6K_4) showed values significantly superior to that of the other treatment combinations.

Treatments receiving FYM @ 10 t ha^{-1} at a spacing of 10 × 10 cm and harvested at eight months after planting recorded the highest fresh root yield of 2389.8 kg ha^{-1}.

The highest dry root yield (816.7 kg ha^{-1}) was obtained in seventh and eight month old plants in treatments receiving FYM @ 10 t ha^{-1} planted at a spacing of 10 × 10 cm.

The treatments receiving FYM @ 10 t ha^{-1} planted at 10 × 10 cm and harvest at eight month stage recorded the highest dry shoot yield of 2025 kg ha^{-1}.

Dense planting at 10 × 10 cm spacing along with the application of FYM @ 10 t ha^{-1} when harvested at eight month stage recorded the highest dry matter yield (3250 kg ha^{-1}).

The five month old plants planted at 15 × 15 cm without any FYM application (T_2K_1) and those planted at 10 × 10 cm receiving FYM @ 10 t ha^{-1} (T_7K_1) recorded the maximum harvest index (0.34).

The interaction effect of various treatments was not found to influence the N content of shoot. The highest N content in root was noticed by the application of FYM @ 10 t ha^{-1} and planting at 20 × 20 cm spacing and harvested at seven month stage.

The highest P content in shoot was obtained in treatments receiving FYM @ 5 t ha^{-1} planted at a spacing of 20 × 20 cm when harvested at eight month stage (0.11 per cent).

The interaction effect of various treatments was not found to influence the P content of roots and K content of shoot and roots.

The treatments planted at 10 × 10 cm spacing along with the application of FYM @ 10 t ha^{-1} when harvested at eight month stage resulted in the maximum N uptake (63.8 kg ha^{-1}).

The interaction effect of various treatments was not found to affect the P uptake by the plant.

The treatments receiving FYM @ 10 t ha^{-1} and planted at 10 × 10 cm spacing and harvested at seven month stage (T_7K_3) recorded the highest K uptake by the plant (57.1 kg ha^{-1}).

The treatments planted at 20 × 20 cm spacing receiving FYM @ 10 t ha^{-1} and harvested at six month stage left higher amount of available N and available P_2O_5 in the soil.

The treatments receiving FYM @ 5 t ha^{-1} planted at 20 × 20 cm spacing and harvested at seven month stage left the highest amount of available K_2O in the soil.

The treatments receiving FYM @ 10 t ha^{-1} and planted 20 × 20 cm spacing when harvested at five month stage recorded the highest amount of soil organic carbon (1.25 per cent).

The highest value of essential oil content was obtained in the treatments where FYM was applied @ 10 t ha^{-1} and planted at spacing of 15 × 15 cm when harvested at eight month stage.

The highest oil yield of 3 l ha^{-1} was obtained from eight month old crop supplied with FYM @ 10 t ha^{-1} and planted at a spacing of 10 × 10 cm.

Irrespective of the spacing, seven and eight month old crop supplied with FYM @ 10 t ha^{-1} resulted in the higher amount of water soluble extract of 6.11 per cent.

The highest value of alcohol soluble extract (3.16 per cent) was obtained in eight month old crop receiving FYM @ 10 t ha^{-1} in medium and wide spacings of 15 × 15 cm and 20 × 20 cm.

The economics of cultivation worked out for the best treatment combination showed that *Hemidesmus indicus* can be grown as a profitable crop under Kerala conditions.

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APPENDICES

APPENDIX - I

Weather at Vellanikkara, Trichur, Kerala during the period March 1996 to March 1997.

Month	Max. temp. 0°C	Min. temp. 0°C	Total rainfall (mm)	No. of rainy days	Mean RH (%)	Mean sunshine hours
1996						
March	36.4	24.3	0	0	59.5	9.3
April	34.6	25.0	152.0	7	73	8.3
May	32.8	25.2	95.4	4	77	7.7
June	30.5	23.8	400.3	16	84.5	4.7
July	28.8	23.1	588.7	25	89.5	2.7
August	29.1	23.6	310.0	20	86.5	3.7
September	29.2	23.7	391.6	17	84	4.3
October	30.1	22.9	219.3	12	81.5	6.0
November	31.5	23:6	22.1	2	71.5	7.1
December	30.5	21.8	60.4	2	67.5	6.8
1997						
January	32.0	22.9	0.0	0	61.5	9.6
February	33.9	21.8	0.0	0	60.5	9.3
March	35.7	24.0	0.0	0	59.5	9.6

APPENDIX - II

Cost of cultivation of *Hemidesmus indicus* (1 hectare) based on treatment combination receiving FYM @ 10 t ha^{-1} planted at 10 × 10 cm spacing when harvested at eight month stage ($T_7 K_4$).

A. Cost of inputs *

Item	Quantity	Rate (Rs.)	Cost (Rs.)
Root cuttings	250 kg	45 /kg	11,250
FYM	10 t ha^{-1}	300 / ton	3000
B. Labour cost			
Particulars	Men @ 80	Women @ 75	Amount (Rs.)
Tractor ploughing (Rs. 80 / hr, 5 hrs / ha)	-	-	400
Layout and preparation of beds	125	-	10,000
Planting	100	150	19,250
Gap filling	-	150	11,250
1st weeding	-	60	4500
2nd weeding	-	40	3000
Harvesting	150	-	12,000
Grand Total			74,650

*Based on the treatment combination $T_7 K_4$ which recorded the maximum yield with the highest density and 10 t ha^{-1} FYM and harvested at 8 months stage.

Total fresh root yield was 2389.81 kg.

Gross return = 2389.81 × 45 = Rs. 1,07,541.45

Net return = 1,07,541 . 45 - 74,650 = Rs. 32,891.45

APPENDIX - III

Cost of cultivation of *Hemidesmus indicus* (1 hectare) based on treatment combination planted at 20 × 20 cm spacing without any FYM application when harvested at eight month stage ($T_3 K_4$).

A. Cost of inputs*

Item	**Quantity**	**Rate (Rs.)**	**Cost (Rs.)**
Root cuttings	63 kg	45 / kg	2835
B. Labour cost			
Particulars	Men @ 80	Women @ 75	Amount (Rs.)
Tractor ploughing (Rs. 80 / hr, 5hrs/ ha)	-	-	400.00
Layout and preparation of beds	31	-	2480
Planting	25	38	4850
Gap filling	-	38	2850
1st weeding	-	60	4500
2nd weeding	-	40	3000
Harvesting	38	-	2850
Grand Total			23,765

*Based on the treatment combination $T_3 K_4$ which recorded lowest yield, with lower density and without FYM and harvested at 8 months stage.

Total fresh root yield was 734.08 kg.

Gross return = 734.08 × 45 = Rs. 33, 033. 60

∴ Net return: 33033.60 - 23,765 = Rs. 9268.60

ABSTRACT

AGROTECHNIQUES IN INDIAN SARSAPARILLA

(*Hemidesmus indicus* [Linn] R. Br)

By

K. C. SHINA

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree

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ABSTRACT

Investigations were undertaken at the Department of Agronomy, College of Horticulture, Vellanikkara, Trichur, Kerala during 1996 - '97 to standardise the agrotechniques in Indian sarsaparilla (*Hemidesmus indicus* [Linn] R. Br).

The main objectives of the study were to standardise the planting material in *Hemidesmus indicus* and to arrive at the optimum spacing for getting maximum yield. The study also aims to workout the optimum stage of harvest so as to get the highest yield of good quality. The salient findings of the study are abstracted below.

The nursery studies revealed that 5 cm long root cuttings planted vertically formed the best propagule in *Hemidesmus indicus*. Hence the experiment was carried out using 5 cm long root cuttings planted vertically. The application of FYM @ 10 t ha^{-1} and high density planting at (10 × 10 cm) resulted in increased nutrient uptake and thus improved the growth and yield of *Hemidesmus indicus*. The oil yield, water and alcohol soluble extract obtained in this treatment was superior as compared to that with control plots without any FYM application. The available N, P_2O_5, K_2O and organic carbon content of soil was more in heavily manured plots. The available N and P_2O_5

left in the soil was higher in widely spaced plots (20 × 20 cm) where as available K_2O and organic carbon content more in dense planting of 10 × 10 cm.

The different stages of harvest were compared with regard to their effect on growth and yield of hemidesmus. The nutrient uptake by the crop was highest in the eight month stage and hence this particular treatment resulted in the highest oil yield as compared to that in the other stages of harvest. Excepting available N, the nutrients left in the soil was found to be decreasing by eight month crop stage.

The interaction effect of spacing × FYM and stages of harvest showed that the treatments receiving FYM @ 10 t ha^{-1} and high density planting at 10 × 10 cm spacing when harvested at eight month stage, recorded the highest oil yield. Also this particular treatment recorded highest root yield, total returns and net returns as compared to the other treatment combinations.