EFFECT OF SPACING AND PLANTING MATERIAL ON THE GROWTH, YIELD AND ACTIVE PRINCIPLE IN *Plumbago rosea* L.

By

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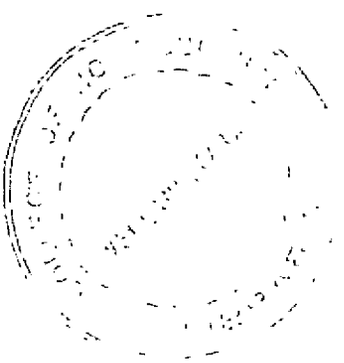

THESIS

Submitted in partial fulfilment of
the requirement for the degree of

Master of Science in Horticulture

Faculty of Agriculture
Kerala Agricultural University

Department of Plantation Crops & Spices.
COLLEGE OF HORTICULTURE
Vellanikkara - Trichur.
1990

DECLARATION

I hereby declare that this thesis entitled "Effect of spacing and planting material on the growth, yield and active principle in *Plumbago rosea* L." is a bonafide record of research work done by me during the course of research work and that this 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.

Vellanikkara.
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CERTIFICATE

Certified that this thesis entitled "Effect of spacing and planting material on the growth, yield and active principle in Plumbago rosea L." is a record of research work done independently by Smt. Subha. S., 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 Smt. Subha. S., a candidate for the degree of Master of Science in Horticulture agree that the thesis entitled "Effect of spacing and planting material on the growth, yield and active principle in Plumbago rosea L." may be submitted by Smt. Subha. S., in partial fulfilment of the requirement for the degree.

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Vellanikkara.
15-3 -1990.

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to

the memory

of

my beloved father

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Introduction

INTRODUCTION

Plumbago rosea L. of the family Plumbaginaceae is commonly called as Fire plant or Rosy flowered leadwort or Officinal leadwort, and is known as Chettikoduveli or Chuvannakoduveli in Kerala. This is a pretty ornamental plant, frequently grown in gardens for its showy bright red flowers. It is widely distributed in tropics and is reported to be wild or indigenous to Sikkim and Khasi hills, although in all Indian floras, it has been reported only as cultivated or as an escape from cultivation. Further it is stated to be found always in anthropogenic localities and locally run wild or persisting semispontaneously.

The plant grows well in partial shade. Flowering starts in winter and continues for two to three months. Propagation is by cuttings or division of clump.

Root of this plant is of great value as an important medicine. The root is mentioned as an abortifacient. The bruised root in its natural state is acrid and stimulating but when tempered with a little hard oil, it is used externally in rheumatic affections of joints and paralytic conditions. It cures certain cases of leucoderma, other skin diseases and is effective against scorpion sting. A tincture of the root is used in secondary syphilis, in leprosy and also in dyspepsia, piles, in instances of loss of appetite and in other complaints of the digestive

system. It serves as a good remedy to check post partum haemorrhage.

The active principle of the root is plumbagin, an orange yellow pigment. Plumbagin stimulates the central nervous system in small doses while in larger doses it brings in paralysis, leading ultimately to death. It lowers blood pressure. It is a powerful irritant and has well marked antiseptic properties. In small doses, the drug is sudorific, larger doses cause respiratory failure leading to death. Owing to its property of setting up of irritation of the skin, plumbagin is of use in the treatment of chronic skin diseases and leucoderma.

At present, the cultivation of this crop is restricted to localised tracts of Kerala. Since the ayurvedic system of treatment is predominent in Kerala, the use of such plants are wide spreading leading to its high demand in the market. Hence, large scale cultivation is to be considered in the near future. Now cultivators are growing this crop in a small scale without any set package of practices. This is also planted in ornamental gardens in flower beds or as potted plants and are also kept as perennial plants. Information is available on its medicinal uses and its chemical constituents , however no information is available regarding its agronomical and other cultural practices. Therefore this study was undertaken with the following objectives.

1. to standardise the size of shoots as planting material for commercial cultivation,
2. to standardise the best spacing for better growth, yield and active principle,
3. to explore the possibility of growing this plant as a commercial crop and
4. to explore the possibility of grooming this as an annual plant,

Review of Literature

REVIEW OF LITERATURE

Though Plumbago rosea L. (Rosy flowered leadwort) is an important medicinal plant used extensively in ayurvedic system of medicine, no systematic research have been done on the cultivation aspects of this crop. In this chapter, an attempt has been made to gather the available research information on this crop.

Since the literature on this crop is scanty, informations available on other medicinal plants pertinent to the present investigation are also reviewed in this section.

2.1. Spacing

Narayana et al., (1977) recommended a spacing of 45 cm between rows and 30 cm between plants within a row for a transplanted crop of Catharanthus roseus. Levy et al., (1981) reported that the optimal plant density for Catharanthus roseus cultivation was four rows per bed with 33cm between rows and 10 cm between plants. Increasing the row density per bed did not significantly affect the yields. In Catharanthus roseus, a spacing of 45 cm x 15 cm was best for the production of roots, stem and leaves yield (Hegde, 1985).

Cruzado et al., (1964) observed that in Dioscorea composita close spacing reduced tuber size and increased

yields per acre without affecting percentage of sapogenin. In the case of D. floribunda investigations carried out under irrigated conditions indicated that a spacing of 45 x 30 cm for a one-year crop and 60 x 45 cm for two year crop gave the highest tuber and diosgenin yields (Rao et al., 1981). According to Sharma and Bordoloi (1986), a spacing of 60 x 30 cm was suitable for good tuber yield and diosgenin yield/ha for both D. composita and D. floribunda.

Sarin et al.,(1977) reported that the spacing could be reduced in Costus speciosus to be harvested six to nine months after planting. Pandey et al., (1980) found that nine plants per square metre gave higher yields than three, four or six plants per square metre. Joseph (1983) observed that low density planting (75 x 75 cm) enhanced the overall vegetative growth in Costus speciosus. However, the per hectare yield of rhizomes and diosgenin were found to be significantly higher at the closest spacing (50 x 50 cm). The plant height increased with decrease in spacing.

In the case of Ashwagandha (Withania somnifera Dunal) closer spacings of 30 x 5 cm and 30 x 10 cm gave higher yields than widerspacings (Nigam et al.,1984).

According to Grabovsky (1964), a spacing of 30 x 30 cm was optimum for getting higher yields in Valeriana officinalis. Shah and Gupta (1983) reported that second

year digging of V. wallichii plants with a spacing of 50 x 45 cm gave the highest dry root yield with maximum content of essential oil. In Kaempferia galanga preliminary trials have shown that a spacing of 20 x 15 cm gave maximum rhizome yield (KAU, 1982 .

Loknath and Dash (1964) found that in ginger, a spacing of 15 cm x 15 cm was best for getting higher yield than 22.5 x 22.5 cm or 30 x 30 cm. Randhawa et al., (1972) reported that in ginger, highest yields resulted from 20 x 20 cm and 20 x 30 cm spacings. Sivan (1979) found that the highest total yield per ha, as well as net yield per ha was obtained at the closest spacing (60 x 10 cm). But the average yield per plant, however, was highest with the widest spacing (60 x 30 cm) . Increased plant density enhanced yield in ginger (Whiley, 1981).

Said and Hussain (1964) could get highest yield at a spacing of 12" x 16" in the case of turmeric. The highest numbers of tillers, mother rhizomes, primary rhizomes and secondary rhizomes per plant and per plot were obtained from plants spaced at 45 x 20 cm (Ponnuswamy and Muthuswamy, 1981). Chatterjee (1983) observed that the highest yield (fresh as well as cured dry turmeric) was obtained from the crop planted at 10 x 20 cm spacing. Ramachandran and Muthuswamy(1984) found that in turmeric, highest yield of rhizome was obtained from plants spaced at the closest spacing of 30 x 15 cm. The closest spacing

(30 x 15 cm) registered the maximum plant height and the minimum plant height was recorded in the case of widest spacing. The authors attributed this linear increment in height to the high density effect of planting.

2.2. Planting material

In pepper, single node cuttings of primary wood gave 90-95 per cent rooting (Hughes, 1966). According to Nambiar et al., (1977), for rapid multiplication of the hybrid pepper cv. Panniyur-1, two node cuttings prepared from mother plants could be used. Hegde (1983) found that three node cuttings of Panniyur-1 pepper rooted better than one or two node cuttings.

Mitra and Kushari (1985) observed that in Solanum khasianum the rooting percentage was highest with 4 node cuttings, lowest with one node cuttings and that the rooting of cutting was better under partial shade.

In Atropa belladonna, the best results were obtained with softwood cuttings 10-15 cm long with 2-3 leaves (Bhat et al.,1974).

In the case of essential oil rose, two node cuttings with the lower leaves removed were the best suited for propagation (Ivonova and Gladun., 1987).

In liquorice, Badalov (1985), reported that cuttings 10-15 cm long and 1.0-1.5 cm in diameter produced the best growth and the most productive plants but smaller cuttings

adversely affected the productivity of the plants.

El-keltawi and Croteau (1985), reported the use of single node cuttings to propagate several species of mint.

2.3 Tissue culture

Nitsch and Nitsch (1965) had taken internode sections of stems from the variety 'Angkor' of P. indica maintained in the vegetative condition. These sections were induced to flower in vitro and flowers of normal size appeared in the test tubes. The cultures were grown under inductive short days of ten hours in a three per cent sucrose medium. The addition of IAA at 0.1 mg/l inhibited bud formation at that sucrose concentration and only callus tissue developed. GA at 1 mg/l also reduced the number of buds formed. Sucrose concentration of 0.3 per cent and 1 per cent were insufficient for flower bud formation, although more vegetative development took place than in three per cent sucrose.

2.4 Yield of plumbagin

Roy and Dutt (1928) found that plumbagin is present to a maximum of about 0.91 per cent in the roots of all the species of Plumbago seen in India (quoted by Chopra et al., 1958). The proportion of plumbagin varies with the locality , growth, age, soil conditions and season of the year. In general, it was found that older the plant and drier the soil, the greater is the quantity of active

principle found in the roots. It has also been reported that the fresh roots yield a much greater proportion of plumbagin than roots which have been stored for a longer periods.

Mukhortova and Moiseenkova (1980) reported that plumbagin content of the fresh herbage of Ceratostigma plumbaginoides (cultivated in Crimea, U.S.S.R) varied between 0.08 and 0.20 per cent.

2.5 Pharmacological action of plumbagin and its therapeutic uses

Plumbagin stimulates the central nervous system in small doses, while in larger doses paralysis sets in ultimately leading to death. It lowers blood pressure. The minimum lethal dose has been found to be 0.5 mg per g of body weight for frogs, 0.1 mg per g of body weight for mice and 10 mg per kg of body weight for rabbits (Chopra et al ., 1958).

Bhatia and Lall (1933) found that plumbagin is a powerful irritant and has good antiseptic properties. In small doses, the drug is sudorific while large doses cause death due to respiratory failure. The action is probably due to the direct effect of the drug on the muscles (quoted by Chopra et al., 1958).

Owing to its property of setting up irritation of the skin, plumbagin may be of use in the treatment of chronic

skin diseases and in leucoderma (Chopra et al., 1958).

Krishnaswamy and Purushothaman (1980) found that when plumbagin was given intraperitoneally and orally at 2 mg/kg body weight showed 70 and 60 per cent regression of tumour in wistar rats, respectively. At 4 mg/kg body weight it also showed anticancer activity against P388 lymphocytic leukaemia. Plumbagin was also found to exhibit antibacterial and antifungal activities.

Plumbagin also exhibited insect antifeedant activity against larvae of African army worms and antimicrobial activity against yeasts (Kubo et al., 1980).

Santhakumari et al., (1980) found that plumbagin isolated from Plumbago rosea roots arrested the growth and proliferation in chick embryo fibroblast cultures, and decreased the mitotic index with accumulation of cells in metaphase. These changes were evident at 0.1 g concentration. Chromosomal aberrations were also noted. At lower concentrations plumbagin behaved like a spindle poison by inhibiting entry of cells into mitosis, like colchicine, but at higher concentrations it exhibited radio-metric neucleotoxic and cytotoxic effects.

Shcherbanovskii (1982) noticed that plumbagin could be commercially used as a preservative for non-alcoholic drinks and wines and that it has got activity against yeast and lactic acid bacteria.

Bhargava and Dixit (1985) reported that plumbagin showed early abortifacient activity.

2.6 Chemical analysis of the roots

Dulong (1885) was the first to isolate an active principle from the root of Plumbago and named it as plumbagin (as quoted by Chopra et al., 1958).

The root bark of the plant was examined by Tumminkatti and Patwardhan (1932) and was found to contain plumbagin (2 methyl - 5 - hydroxy - 1, 4 - naphtho quinone, $C_{11}H_8O_3$), a sitosterol glycoside ($C_{33}H_{56}O_6$), a sitosterol, a fatty alcohol probably arachidyl alcohol, tannin and an amorphous brown pigment (CSIR, 1969).

Materials and Methods

MATERIALS AND METHODS

The present investigation was carried out at the College of Horticulture, Vellanikkara during the period from June 1987 to June 1988. The details of the materials and methods employed in this investigation are described in this chapter.

3.1 Location

The College of Horticulture, Vellanikkara is situated at 10° 31' N latitude and 76° 13' E longitude, with an elevation of about 40.0 m above mean sea level. The soil of the experimental plot was a deep laterite with clay loam texture with a pH of 5.5 and was of moderate fertility.

3.2. General climatic features

The area is characterised with heavy rains during June-September (South West monsoon) and October-November (North East monsoon) months followed by a severe summer season from March to May.

The meteorological data for the experimental period as recorded at the Agrometeorological observatory at the College of Horticulture, Vellanikkara are presented in Appendix 1.

3.3. Description of the Plumbago plant

Plumbago rosea L. is a pretty dwarf shrub, about a metre in height. Stems herbaceous, erect, terete, slightly

striate, simple and branching upward. Leaves are alternate, large, ovate-elliptic, 5-10 cm long, 5-7 cm broad and dark green. Flowers are red, tubular on terminal long raceme of 18.0 to 22.0 cm long.

The root is cylindrical, sometimes irregularly bent or curved, 60-90 cm long and 1.3-2.0 cm thick, light yellowish brown, smooth, often with short transverse shallow fissures at the region of bends. The root bark of P. rosea contains an orange yellow pigment named plumbagin (2 methyl-5-hydroxy-1,4-naphthoquinone, $C_{11}H_8O_3$) which is the active principle.

Plumbagin, in small doses, has a stimulant action on central nervous system, on plain muscles, and on the secretion of sweat, urine and bile. It also lowers blood pressure. With larger doses, paralysis sets in leading ultimately to death (Chopra et al., 1958).

Plumbagin is a powerful irritant and has well marked antiseptic properties. Owing to its property of setting up irritation in the skin, plumbagin may be of use in the treatment of chronic skin diseases and leucoderma (Chopra et al ., 1958).

The root is stimulant, diapnoretic, stomachic, sialogogue,abortifacient and vesicant. It is given in dyspepsia, intermittent fevers, piles, diarrhoea, skin diseases, paralysis and rheumatism.

3.4 Experimental details and layout

The particulars of the treatments and other experimental details were as given below.

Types of planting materials

P_1 - Single node cuttings.

P_2 - Two node cuttings.

P_3 - Three node cuttings.

Levels of spacing

S_1 - 50 x 15 cm

S_2 - 50 x 30 cm

S_3 - 50 x 45 cm

Treatment combinations

P	S
1	1
1	2
1	3
2	1
2	2
2	3
3	1
3	2
3	3

Total number of treatments	: Nine
Experimental design	: 3^2 factorial Randomised Block design (RBD)
Number of replications	: Three (3)
Total number of plots	: Twenty seven (27)
Net Plot size	: 3 m x 3 m
Net experimental area	: 243 m^2

3.5 Nursery

The land was ploughed to bring the soil to a fine tilth, and raised beds, 3 m x 1 m size and 25 cm height, with 30 cm wide channels in between them were prepared. Cattle manure was applied at the rate of 10 kg per bed and raked well into the soil. Sand was spread on the beds to a thickness of about 5 cm.

The planting material required for the experiment was collected from the cultivators of Valanchery (Malappuram District, Kerala State).

The cuttings were prepared from the semihardwood portions. Single node, two node and three node cuttings were planted in the nursery beds, shaded and watered for better rooting.

3.6 Main field

The land was dug and the soil was brought to a fine tilth. Plots of size 3 m x 3 m were prepared. Cattle

manure was applied at the rate of 10 tonnes/ha, and ridges of about 30 cm height and 30 cm width were prepared with 50 cm spacing between ridges.

Three months old rooted cuttings were transplanted in the mainfield.

3.6.1 Crop management

Fertilizers were applied at the rate of 50:50:50 kg N: P_2O_5 : K_2O/ha. Whole of P_2O_5 was given as basal dose and N and K_2O were applied as top dressing at 2 months and 4 months after planting.

Weeding was carried out four times during the cropping season. Earthing up was done two times along with the fertilizer application.

3.7 Sampling technique

Random sampling technique was adopted to select the sample plants for recording various morphological characters. Twelve plants were selected at random from each plot eliminating the border rows for recording the data. The entire population in the plot except the border rows was taken for recording the yeild of roots. For chemical analysis (per cent of plumbagin), fresh roots from three samples selected at random were bulked together to get a representative sample of 100 g for each plot.

3.8 Collection of data

3.8.1 Pre-harvest observations

3.8.1.1. Height of the plants

The height of the plants was measured at monthly intervals after planting in the main field. The measurements were taken from the ground level to the tip of the topmost leaf and expressed in centimetres (cm).

3.8.1.2. Spread of the plant (NS/EW)

Spread of the plants was measured in both North South and East West directions at monthly intervals and expressed in cm.

3.8.1.3. Number of suckers per plant

The number of suckers per plant was counted and recorded.

3.8.1.4. Number of leaves per sucker

The number of leaves on one sucker was counted from each observational plant and the average number of leaves per sucker was worked out.

3.8.1.5. Length of the leaf

The length of the first fully opened leaf from the top (4th leaf from the top) was recorded. The distance between the point of attachment of the leaf blade to the stem; and upto the tip of the blade was taken as the length and expressed in centimetres (cm).

3.8.1.6. Width of the leaf

The width of the first fully opened leaf whose length was recorded was measured at the point of maximum width and expressed in centimetres (cm).

3.8.1.7. Leaf area (Individual leaf area)

A preliminary study was conducted to develop a rapid method for estimating the leaf area. For this purpose, 100 leaves were collected at random, covering all the treatments. The length and width of individual leaves were measured and their area was also arrived at graphically. The leaf area was calculated using the following mathematical equation.

$Y=0.7x$ (where x= the product of length and breadth, and
Y= the leafarea.

3.8.1.8. Number of days taken for blooming

Number of days taken for 90 per cent floweing in each plot was recorded.

3.8.1.9. Diameter of the stem

Diameter of the stem was recorded in each observational plant at about 2 cm from the ground level using a nonelastic twine, measured in scale and was recorded in centimetres (cm).

3.8.1.10. Internodal length

The distance between the point of attachment of the

first fully opened leaf to the stem, from top; and to that of the leaf just below it was measured and recorded as the internodal length in centimeters (cm).

3.8.2. Post harvest observations

Harvesting was done 9 months after transplanting to the mainfield. Plants were dug out separately, taking care to keep the roots intact. Then the roots were seperated, cleaned with tap water to remove the adhering soil particles and the following data were collected.

3.8.2.1. Length of the main root

The length of the root was measured seperately for each observational plant and the mean was worked out for each plot and expressed in centimetres (cm.)

3.8.2.2. Diameter of the main root

The diameter of the main root was measured separately for each observational plant and the mean was worked out for each plot and expressed in centimetres (cm.).

3.8.2.3. Yield of roots (Fresh weight)

Fresh weight of all the roots per plant was recorded in each plot and mean root yield per plant and root yield per plot was worked out and expressed in grams and kilograms respectively. The total yield of fresh roots per ha was arrived at, taking the net area of the plots for calculation.

3.8.2.4. Yield of roots (Dry weight)

After taking the fresh weights, the root samples of each observational plant were dried in an oven at 70°C to a constant weight on test weighing. After drying, the samples were weighed separately and the mean dry weight of the roots per plant was expressed in grams. From this, dry weight of the roots per plot was worked out and expressed in kilograms. The total yield of dry roots per ha was arrived at taking into consideration the net area of the plots and was expressed in tonnes.

3.8.2.5. Fresh weight of the shoots

Fresh weight of the shoots per plant was recorded separately for each observational plant and the mean for each plot was worked out and expressed in grams.

3.8.2.6. Dry weight of the shoots

Shoots samples after recording the fresh weight were transferred to an oven kept at 70°C and were dried to a constant weight on test weighing. Then the samples were weighed separately and the mean value for each plot was expressed in grams.

3.8.2.7. Isolation and quantitative estimation of plumbagin

A partial modification of the procedure described by Tumminkatti and Patwardhan (1932) was adopted (quoted by Chopra et al., 1958).

i) Extraction of plumbagin

The macerated fresh root sample (100 g) was constantly agitated with 250 ml of acetone. The contents were kept for 24 hours in darkness. The clear supernatent solution containing plumbagin was collected by decantation and filtration. The root mass was repeatedly washed with acetone till it became almost colourless. The combined extract was used for further estimation.

The combined extract was taken in a separating funnel and light petroleum ether (b.p. 40-60 °C) was added. It was carefully swirled and 250 ml of water was added and allowed to stay for 10 minutes. The epiphase of light petroleum containing plumbagin was carefully separated. The extraction was repeated. The combined extract was reduced to almost dryness in a waterbath maintained at 50 °C.

ii) Saponification of the plumbagin extract and quantification

About 10 ml of 3 per cent NaoH (W/V) was added to the concentrate. Then it was kept in a water bath at 60 °C for 30 minutes. The saponified material was transferred to the separating funnel. The free plumbagin was extracted with petroleum ether. The extract was concentrated and was allowed to cool slowly until plumbagin crystallised out. It was desiccated and weighed repeatedly until constant reading was obtained. The yield was expressed as per cent

of plumbagin on fresh weight basis. From that per cent recovery of plumbagin on dry weight basis was calculated using the drying per cent of the roots. Yield of plumbagin per plant, per plot and per ha were also arrived at and expressed in grams and kilograms respectively.

iii) Purification of plumbagin by column chromatography

For purification of plumbagin, column chromatographic technique was adopted.

About 25 gm of silicagel was taken in a mortar and mixed well with light petroleum ether (b.p 40-60 °C). A long glass column (45 x 1 cm) was taken and using a long tube a thin layer of cotton was placed at the constriction. The silica gel slurry was carefully transferred into this column. The sides of the column was tapped gently so as to let out air bubbles and to get uniform packing of silica gel in the column. The excess petroleum ether was drained off.

A small quantity of plumbagin taken in petroleum ether was loaded in the column through a pipette. The column was developed by the continuous addition of light petroleum ether. Plumbagin formed a brightly coloured band in the silica gel. It was carefully eluted out by the addition of light petroleum. The red band of plumbagin slowly traversed downwards and pure plumbagin was collected at the

bottom. The petroleum ether in the receiver was evaporated almost to dryness and pure plumbagin was collected and crystallised.

3.9. Statistical analysis

The data was statisticaly, analysed as per the procedure outlined by Panse and Sukhatme (1978). Level of significance used in 'F' and 't' values was P=0.05 and P=0.01. The simple and multiple correlations were also worked out for characters which were significantly influencing the root yield and plumbagin yield.

3.10 Economics of cultivation

The economics of cultivation and cost benefit ratio for the best treatment combination were also worked out. The cost of cultivation and the net income were worked out using the actual cost of cultivation and receipts. The economics of cultivation was worked out for one hectare as detailed in Table 15.

Results

RESULTS

The results of the investigation on the effect of spacing and planting material on the growth, yield and active principle in Rosy Leadwort (Plumbago rosea L.) are presented in this chapter.

4.1. Morphological characters

4.1.1. Height of the plant

The data relating to height of the plant as influenced by the treatments are presented in Table 1 and Fig.1.

The height of the plant was significantly influenced by the spacings. However, planting materials had no effect on this character. The interaction between spacing and planting material was also found to be not significant.

Height of the plant was found to be increased with decrease in spacing. The closest spacing S_1 (50x15 cm) recorded the maximum height of 76.54 cm which was significantly superior to the other spacings S_2 and S_3. S_2 (50 x 30 cm) recorded a height of 64.30 cm, while the widest spacing S_3 (50 x 45 cm) showed the lowest height (58.39 cm). The difference between S_2 and S_3 was also significant. The data also revealed that the height of the plants in general increased at a faster rate during the early period and the growth was almost nil in summer months. Further height increases was noted during June.

Table .1 Effect of spacing and planting material on the height of the plants (cm) in *Plumbago rosea* L.

Treatments	October	November	December	January	February	March	April	May	June
PLANTING MATERIAL									
P_1	24.70	40.87	55.46	60.82	61.00	61.21	61.51	62.00	66.18
P_2	24.82	40.65	55.69	62.47	62.64	62.89	63.20	63.65	66.86
P_3	25.51	40.65	54.36	61.33	61.48	61.80	62.18	62.65	66.18
	NS	NS	NS	NS	NS	NS	NS	NS	NS
SPACING									
S_1	32.69	46.78	61.88	71.88	71.96	72.20	72.50	72.96	76.54
S_2	23.83	40.66	54.18	59.29	59.49	59.73	60.08	60.57	64.30
S_3	18.50	34.74	49.44	53.45	53.67	53.97	54.32	54.77	58.39
C.D.(0.05)	0.726	0.793	2.293	2.475	2.474	2.530	2.593	2.555	2.195
INTERACTIONS									
$P_1 S_1$	32.35	47.13	61.87	69.95	70.00	70.08	70.47	71.18	75.77
$P_1 S_2$	23.67	40.11	55.12	58.72	59.13	59.57	59.89	60.14	64.28
$P_1 S_3$	18.07	35.38	49.38	53.80	53.87	53.97	54.18	54.69	58.50
$P_2 S_1$	32.24	46.50	62.96	73.10	73.25	73.53	73.77	74.20	77.02
$P_2 S_2$	23.78	41.07	54.23	60.63	60.70	60.91	61.33	61.73	65.05
$P_2 S_3$	18.43	34.39	49.88	53.67	53.97	54.22	54.50	55.01	58.51
$P_3 S_1$	33.49	46.70	60.82	72.60	72.63	72.97	73.25	73.50	76.82
$P_3 S_2$	24.05	40.80	53.18	58.53	58.63	58.71	59.01	59.84	63.56
$P_3 S_3$	18.99	34.45	49.07	52.87	53.17	53.71	54.28	54.61	58.17
	NS	NS	NS	NS	NS	NS	NS	NS	NS

P_1 = Single node cuttings P_2 = Two node cuttings P_3 = Three node cuttings

S_1 = 50 x 15 cm S_2 = 50 x 30 cm S_3 = 50 x 45 cm NS = Not significant.

4.1.2. Spread of the plant

4.1.2.1. North South spread of the plants

The data on north south spread of the plants are presented in Table 2 and Fig.2.

The north south spread of the plant increased with increase in spacing. The widest spacing S_3 registered the highest spread (N.S) of 67.15 cm, followed by S_2 (57.71 cm) and S_1 (48.60 cm). The spacings S_3, S_2 and S_1 differed significantly.

Type of planting material did not show significant influence on the north south spread of the plants.

There was no significant interaction between spacing and planting material.

The spread of plants during early period was faster whereas in other months the increments were lesser.

4.1.2.2. East west spread of the plant

Data presented in Table 3 and Fig. 3 revealed that the spacing had significant influence on the east west spread of the plants. However, type of planting material exerted no significant influence on this character. Spacing and planting material were found to be not interacting.

East west spread of the plants under widest spacing (S_3) was significantly superior to the other spacings, S_2

Table .2 Effect of spacing and planting material on the

Treatments	October	November	December	January
PLANTING MATERIAL				
P_1	16.05	24.24	34.41	40.39
P_2	15.46	24.17	35.67	40.65
P_3	15.70	24.61	35.46	40.51
	NS	NS	NS	NS
SPACING				
S_1	10.94	17.47	24.92	29.73
S_2	14.48	23.73	35.81	40.99
S_3	21.79	31.81	44.80	50.84
C.D.(0.05)	0.533	0.842	1.193	1.099
INTERACTIONS				
$P_1 S_1$	11.09	17.42	23.63	29.42
$P_1 S_2$	14.74	23.03	35.08	40.65
$P_1 S_3$	22.33	32.27	44.53	51.11
$P_2 S_1$	10.59	17.86	26.05	30.46
$P_2 S_2$	14.06	23.94	36.15	40.35
$P_2 S_3$	21.73	30.70	44.82	51.14
$P_3 S_1$	11.13	17.14	25.10	29.29
$P_3 S_2$	14.64	24.22	36.21	41.97
$P_3 S_3$	21.32	32.48	45.06	50.26
	NS	NS	NS	NS

P_1 = Single node cuttings P_2 = Two node cuttings

S_1 = 50 x 15 cm S_2 = 50 x 30 cm S_3 = 50 x 45 cm

spread (North South) of the plants (cm) in Plumbago rosea L.

February	March	April	May	June
43.73	47.66	50.12	53.44	57.70
43.99	48.79	51.00	53.84	58.08
43.60	47.28	50.25	52.88	57.68
NS	NS	NS	NS	NS
33.47	38.25	41.27	43.96	48.60
43.79	47.18	49.90	53.35	57.71
54.06	58.31	60.20	62.84	67.15
1.324	0.832	0.718	1.363	0.999
32.77	37.48	41.03	44.47	49.07
43.62	46.80	49.57	52.61	57.01
54.80	58.71	59.76	63.25	67.04
33.84	39.81	42.04	44.13	48.68
43.97	47.78	50.14	54.21	58.10
54.18	58.76	60.80	63.17	67.45
33.81	37.46	40.74	43.28	48.05
43.79	46.94	49.97	53.23	58.03
53.20	57.45	60.04	62.12	66.95
NS	NS	NS	NS	NS

P_3 = Three node cuttings

NS = Not significant.

Table .3 Effect of spacing and planting material on the spread (East West) of the plants (cm) in *Plumbago rosea* L.

Treatments	October	November	December	January	February	March	April	May	June
PLANTING MATERIAL									
P_1	16.03	24.21	33.26	41.16	44.81	47.30	50.48	52.76	57.43
P_2	16.00	23.45	32.35	40.13	44.23	48.25	51.56	54.44	58.22
P_3	15.13	23.24	32.83	41.08	44.92	48.85	50.98	53.73	57.76
	NS	NS	NS	NS	NS	NS	NS	NS	NS
SPACING									
S_1	12.23	16.42	22.49	27.79	31.50	34.58	38.23	41.38	46.43
S_2	14.17	22.67	34.02	42.48	47.14	50.42	51.76	53.59	57.61
S_3	20.75	31.81	41.93	52.10	55.32	59.39	63.02	65.96	69.37
C.D.(0.05)	1.175	1.035	1.427	1.629	1.360	1.595	1.038	1.028	1.073
INTERACTIONS									
$P_1 S_1$	12.88	16.91	23.04	29.04	32.33	34.62	38.44	41.19	46.37
$P_1 S_2$	14.15	23.60	34.67	42.63	46.97	48.32	49.96	51.69	56.52
$P_1 S_3$	21.05	32.13	42.07	51.79	55.13	58.46	63.05	65.38	69.39
$P_2 S_1$	13.03	16.36	21.06	25.99	30.68	34.42	38.37	42.11	45.86
$P_2 S_2$	14.13	22.26	33.62	42.16	46.47	51.31	53.18	54.99	59.30
$P_2 S_3$	20.83	31.73	42.39	52.24	55.54	59.01	63.13	66.21	69.49
$P_3 S_1$	10.79	15.98	23.39	28.34	31.47	34.72	37.89	40.83	47.06
$P_3 S_2$	14.22	22.14	33.76	42.64	47.99	51.13	52.15	54.09	57.00
$P_3 S_3$	20.38	31.58	41.34	52.27	55.30	60.70	62.89	66.27	69.23
	NS	NS	NS	NS	NS	NS	NS	NS	NS

P_1 = Single node cuttings P_2 = Two node cuttings P_3 = Three node cuttings

S_1 = 50 x 15 cm S_2 = 50 x 30 cm S_3 = 50 x 45 cm NS = Not significant.

and S_1. The difference between S_2 and S_1 was also significant. The treatment S_3 recorded an average east west spread of 69.37 cm, while the corresponding figures in S_2 and S_1 were 57.61 cm and 46.43 cm respectively. In general the spread of plants in initial period of growth was faster and then rate of spread slowed down.

4.1.3. Number of suckers per plant

Data on number of suckers per plant are presented in Table 4.

Spacing and planting material had no significant influence on the number of suckers per plant. The interaction was also found to be not significant.

4.1.4. Average number of leaves per sucker

Data on average number of leaves per sucker are furnished in Table 4.

Average number of leaves per sucker was found to be not significantly influenced by the spacing and the planting material. There was also no significant interaction between spacing and planting material.

4.1.5. Number of days taken for blooming

No significant differences were observed due to different planting materials and spacings on the number of days taken for blooming (Table 5). The interaction was also found to be not significant.

Table 4. Effect of spacing and planting material on the number of suckers produced per plant and number of leaves per sucker in *Plumbago rosea* L.

Treatments	Number of suckers produced per plant	Number of leaves per sucker
PLANTING MATERIAL		
P_1	3.12	6.40
P_2	2.97	5.89
P_3	3.39	6.58
	NS	NS
SPACING		
S_1	3.10	6.76
S_2	3.34	6.09
S_3	3.04	6.02
	NS	NS
INTERACTIONS		
$P_1 S_1$	2.77	6.57
$P_1 S_2$	3.40	6.23
$P_1 S_3$	3.20	6.39
$P_2 S_1$	3.04	6.79
$P_2 S_2$	3.10	5.50
$P_2 S_3$	2.77	5.38
$P_3 S_1$	3.50	6.92
$P_3 S_2$	3.53	6.55
$P_3 S_3$	3.14	6.27
	NS	NS

P_1 = Single node cuttings S_1 = 50 x 15 cm

P_2 = Two node cuttings S_2 = 50 x 30 cm

P_3 = Three node cuttings S_3 = 50 x 45 cm

NS = Not significant

Table 5. Effect of spacing and planting material on the number of days taken for blooming in *Plumbago rosea* L.

Treatments	Number of days taken for flowering
PLANTING MATERIAL	
P_1	211.00
P_2	212.33
P_3	213.78
	NS
SPACING	
S_1	211.67
S_2	212.11
S_3	213.33
	NS
INTERACTIONS	
$P_1 S_1$	211.33
$P_1 S_2$	211.00
$P_1 S_3$	210.67
$P_2 S_1$	210.33
$P_2 S_2$	211.00
$P_2 S_3$	215.67
$P_3 S_1$	213.33
$P_3 S_2$	214.33
$P_3 S_3$	213.67
	NS

P_1 = Single node cuttings S_1 = 50 x 15 cm

P_2 = Two node cuttings S_2 = 50 x 30 cm

P_3 = Three node cuttings S_3 = 50 x 45 cm

NS = Not significant

Plate I. Three node cuttings at flowering stage

a. Three node cuttings 50 x 15 cm.

b. Three node cuttings 50 x 30 cm.

c. Three node cuttings 50 x 45 cm.

Plate II. Two node cuttings at flowering stage.

a. Two node cuttings 50 x 15 cm.

b. Two node cuttings 50 x 30 cm.

Plate III Single node cutting at flowering stage.

Plate IV Plots of different treatment comninations.

a Two node cuttings 50 x 15 cm.

b. Three node cuttings 50 x 30 cm.

c. Three node cuttings 50 x 45cm

4.1.6. Average size of the leaves

Data pertaining to the effect of spacing and planting material on the average size of the leaves viz., length, width and mean leaf area are presented in Table 6.

4.1.6.1. Length of the leaves

Spacing and planting material had no significant influence on the leaf length.

4.1.6.2. Width of the leaves.

Width of the leaves was found to be not significantly influenced by the spacing and planting material.

4.1.6.3. Average leaf area

Spacing and planting material did not influence the average leaf area significantly.

4.1.7. Inter nodal length

The different spacings and planting materials did not influence the inter nodal length (Table 7).

4.1.8. Diameter of the stem

Diameter of the stem was also found to be not influenced by spacing and planting material as shown in Table 7.

Table 6. Effect of spacing and planting material on the length, breadth and area of the leaves in *Plumbago rosea*.

Treatments	Length (cm)	Breadth (cm)	Area (cm^2)
PLANTING MATERIAL			
P_1	10.09	6.13	44.43
P_2	10.14	6.13	44.50
P_3	9.86	5.84	41.99
	NS	NS	NS
SPACING			
S_1	9.66	6.06	42.73
S_2	9.94	5.74	40.50
S_3	10.49	6.31	47.68
	NS	NS	NS
INTERACTIONS			
$P_1 S_1$	9.73	6.20	42.58
$P_1 S_2$	10.09	5.90	42.22
$P_1 S_3$	10.45	6.30	48.49
$P_2 S_1$	9.78	6.09	43.18
$P_2 S_2$	10.08	5.78	41.20
$P_2 S_3$	10.55	6.52	49.10
$P_3 S_1$	9.46	5.90	42.42
$P_3 S_2$	9.65	5.53	38.08
$P_3 S_3$	10.46	6.10	45.46
	NS	NS	NS

P_1 = Single node cuttings S_1 = 50 x 15 cm

P_2 = Two node cuttings S_2 = 50 x 30 cm

P_3 = Three node cuttings S_3 = 50 x 45 cm

NS = Not significant

Table 7. Effect of spacing and planting material on the internodal length and diameter of the stem in *Plumbago rosea* L.

Treatments	Internodal length (cm)	Diameter of the stem (cm)
PLANTING MATERIAL		
P_1	7.57	2.23
P_2	7.94	2.12
P_3	7.69	2.21
	NS	NS
SPACING		
S_1	7.79	2.18
S_2	7.59	2.20
S_3	7.82	2.17
	NS	NS
INTERACTIONS		
$P_1 S_1$	7.28	2.19
$P_1 S_2$	7.64	2.23
$P_1 S_3$	7.80	2.25
$P_2 S_1$	7.68	2.17
$P_2 S_2$	7.93	2.18
$P_2 S_3$	8.21	2.01
$P_3 S_1$	8.43	2.17
$P_3 S_2$	7.21	2.20
$P_3 S_3$	7.45	2.25
	NS	NS

P_1 = Single node cuttings S_1 = 50 x 15 cm

P_2 = Two node cuttings S_2 = 50 x 30 cm

P_3 = Three node cuttings S_3 = 50 x 45 cm

NS = Not significant

4.2. Yield characters.

4.2.1. Length of the main root

The effect of treatments on the length of main root was not significant (Table 8).

4.2.2. Diameter of the main root.

Spacing and planting material had no significant impact on the diameter of the main root as shown in Table 8.

4.2.3. Yield of fresh roots per plant

The data on this parameter are presented in Table 9. and Fig. 4.

The analysis revealed that spacing significantly influenced the yield of the roots per plant on fresh weight basis. But the planting material had no significant effect on the yield of fresh roots per plant. The interaction between spacing and planting material was also found to be insignificant.

Yield of fresh roots per plant was found to be increased with increase in spacing. The widest spacing S_3 recorded the maximum yield of roots per plant (257.40 g), followed by S_2 (179.86 g) and S_1 (129.38 g) which was the lowest.

4.2.4. Yield of fresh roots per plot

The data presented in Table 9 and Fig. 5 showed that

Table 8. Effect of spacing and planting material on the length of the main root and diameter of the main root in *Plumbago rosea*.

Treatments	length of the main root(cm)	Diameter of the main root (cm)
PLANTING MATERIAL		
P_1	88.38	3.51
P_2	88.04	3.45
P_3	88.05	3.53
	NS	NS
SPACING		
S_1	88.54	3.59
S_2	88.81	3.36
S_3	87.12	3.54
	NS	NS
INTERACTIONS		
$P_1 S_1$	88.70	3.70
$P_1 S_2$	88.78	3.33
$P_1 S_3$	87.67	3.48
$P_2 S_1$	88.10	3.41
$P_2 S_2$	90.27	3.33
$P_2 S_3$	85.77	3.62
$P_3 S_1$	88.83	3.67
$P_3 S_2$	87.40	3.42
$P_3 S_3$	87.92	3.52
	NS	NS

P_1 = Single node cuttings S_1 = 50 x 15 cm

P_2 = Two node cuttings S_2 = 50 x 30 cm

P_3 = Three node cuttings S_3 = 50 x 45 cm

NS = Not significant

Table 9. Effect of spacing and planting material on the yield of fresh roots per plant, per plot and per hectare in *Plumbago rosea* L.

Treatments	Yield of roots per plant (gm)	Yield of roots per plot (kg)	Yield of roots per ha(tonnes)
PLANTING MATERIAL			
P_1	189.27	6.19	6.88
P_2	189.98	6.27	6.97
P_3	187.38	6.16	6.84
	NS	NS	NS
SPACING			
S_1	129.38	8.71	9.68
S_2	179.86	5.25	5.84
S_3	257.40	4.66	5.18
CD (0.05)	4.412	0.232	0.258
INTERACTIONS			
$P_1 S_1$	129.32	8.72	9.69
$P_1 S_2$	180.15	5.21	5.78
$P_1 S_3$	258.35	4.65	5.17
$P_2 S_1$	130.45	8.80	9.78
$P_2 S_2$	180.70	5.28	5.87
$P_2 S_3$	258.78	4.74	5.27
$P_3 S_1$	128.38	8.63	9.59
$P_3 S_2$	178.72	5.27	5.86
$P_3 S_3$	255.05	4.58	5.09
	NS	NS	NS

P_1 = Single node cuttings S_1 = 50 x 15 cm

P_2 = Two node cuttings S_2 = 50 x 30 cm

P_3 = Three node cuttings S_3 = 50 x 45 cm

NS = Not significant

yield of roots per plot on fresh weight basis was significantly influenced by different spacings. The closest spacing S_1 gave the highest yield of 8.71 kg fresh roots followed by S_2 (5.25 kg) and S_3 (4.66 kg). The treatments S_1, S_2 and S_3 differed significantly.

Planting material had no effect on this character. The interaction was also not significant.

4.2.5. Yield of fresh roots per hectare

Spacing imparted a significant influence on the per hectare yield of fresh roots (Table 9, Fig. 6). Planting material had no significant influence on the per hectare yield of fresh roots.

The yield of fresh roots per hectare was found to be increased with decrease in spacing. Highest yield of 9.68 tonnes per hectare was obtained from the closest spacing S_1 which was significantly superior to S_2 and S_3. Yield in S_2 was 5.84 tonnes and that in S_3 was 5.18 tonnes per hectare. The difference between S_2 and S_3 was also significant.

4.2.6. Yield of dry roots per plant

Spacing had a significant influence on the yield of dry roots per plant. Whereas this character was unaffected by the type of planting material. The interaction between spacing and planting material was also found to be non significant.

Table 10. Effect of spacing and planting material on the yield of dry roots per plant, per plot and per hectare in *Plumbago rosea* L.

Treatments	Yield of roots per plant (gm)	Yield of roots per plot (kg)	Yield of roots per ha(tonnes)
PLANTING MATERIAL			
P_1	49.27	1.62	1.79
P_2	50.21	1.64	1.82
P_3	49.36	1.61	1.79
	NS	NS	NS
SPACING			
S_1	33.71	2.28	2.53
S_2	46.43	1.37	1.52
S_3	68.71	1.22	1.35
CD (0.05)	2.024	0.061	0.065
INTERACTIONS			
$P_1 S_1$	33.42	2.28	2.52
$P_1 S_2$	45.93	1.36	1.51
$P_1 S_3$	68.47	1.22	1.35
$P_2 S_1$	34.33	2.30	2.56
$P_2 S_2$	47.28	1.38	1.53
$P_2 S_3$	69.03	1.24	1.38
$P_3 S_1$	33.38	2.25	2.50
$P_3 S_2$	46.07	1.38	1.53
$P_3 S_3$	68.63	1.20	1.33
	NS	NS	NS

P_1 = Single node cuttings S_1 = 50 x 15 cm
P_2 = Two node cuttings S_2 = 50 x 30 cm
P_3 = Three node cuttings S_3 = 50 x 45 cm
NS = Not significant

Widest spacing S_3 was superior to S_2 and S_1. Dry yield of roots per plant in S_3 was 68.71 g, those in S_2 and S_1 were 46.43 g and 33.71 g respectively (Table 10 and Fig. 7).

4.2.7. Yield of dry roots per plot

Data presented in Table 10 and Fig. 8 revealed that the spacing had significant influence on the yield of dry roots per plot. However, type of planting material had no significant influence on this character. Spacing and planting material were found to be not interacting.

Yield of dry roots per plot under closest spacing (S_1) was significantly superior to the other spacings S_2 and S_3. The difference between S_2 and S_3 was also significant. S_1 recorded a dry root yield of 2.28 kg, while the corresponding figures in S_2 and S_3 were 1.37 kg and 1.22 kg respectively.

4.2.8. Yield of dry roots per hectare

The data on yield of dry roots per hectare are presented in Table 10 and Fig. 8.

The yield of dry roots per hectare increased with decrease in spacing. Type of planting material did not show significant influence on the yield of dry roots per hectare. There was no significant interaction between spacing and planting material. The closest spacing S_1 registered the

Plate V Root characters of three node cuttings as influenced by different spacings

a. Three node cuttings 50 x 15 cm

b. Three node cuttings 50 x 30 cm.

c. Three node cuttings 50 x 45 cm.

Plate VI. Root characters of Two node cuttings as influenced by different spacings

a. Two node cuttings 50 x 30 cm.

b. Two node cuttings 50 x 45 cm.

a. Single node cuttings 50 x 15 cm

b. Single node cuttings 50 x 30 cm.

c. Single node cuttings 50 x 45 cm.

highest dry root yield of 2.53 tonnes per ha followed by S_2 (1.52 tonnes) and S_3 (1.35 tonnes). The spacings S_1, S_2 and S_3 differed significantly.

4.2.9. Fresh weight of the shoots per plant

The data presented in Table 11 and Fig. 9 showed that fresh weight of shoots per plant was significantly influenced by the spacing. Widest spacing(S_3) recorded the highest fresh weight of 245.66 g followed by S_2 (169.81 g) and S_1 (129.56 g) respectively . The treatments S_1, S_2 and S_3 differed significantly.

Planting material had no significant effect on this character. Interaction between spacing and planting material was also found to be not significant.

4.2.10. Dry weight of the shoots per plant

Dry weight of the shoots per plant was influenced by spacing as shown in Table 11. and Fig. 10. Planting material had no influence on this character. There was no significant interaction between spacing and planting material.

Dry weight of the shoots per plant obtained from the widest spacing S_3 was 71.32 g. The treatment S_2 recorded a dry weight of shoots of 47.55 g and that in S_1 was 37.27 g which was the lowest.

Table 11. Effect of spacing and planting material on the fresh and dry weight of the shoots per plant in *Plumbago rosea* L.

Treatments	Fresh weight of the shoots per plant (g)	Dry weight of the shoots per plant (g)
PLANTING MATERIAL		
P_1	183.87	52.46
P_2	182.13	51.96
P_3	179.03	51.72
	NS	NS
SPACING		
S_1	129.56	37.27
S_2	169.81	47.55
S_3	245.66	71.32
CD (0.05)	6.298	1.824
INTERACTIONS		
$P_1 S_1$	130.53	37.50
$P_1 S_2$	171.54	47.67
$P_1 S_3$	249.53	72.22
$P_2 S_1$	130.32	37.30
$P_2 S_2$	170.37	47.42
$P_2 S_3$	245.72	71.17
$P_3 S_1$	127.83	37.00
$P_3 S_2$	167.53	47.57
$P_3 S_3$	241.74	70.58
	NS	NS

P_1 = Single node cuttings S_1 = 50 x 15 cm

P_2 = Two node cuttings S_2 = 50 x 30 cm

P_3 = Three node cuttings S_3 = 50 x 45 cm

NS = Not significant

4.2.11. Plumbagin content (%) and yield of plumbagin

The data pertaining to the above characters are presented in Table 12 and Fig. 11 & 12. Plumbagin content was not affected by both spacing and planting material, or their interaction.

However the yield of plumbagin per plant, per plot and per hectare was found to be significantly influenced by the spacing. But planting material had no influence on these three characters. The widest spacing (S_3) recorded highest plumbagin yield per plant (0.1131g) followed by S_2 (0.0824 g) and S_1 (0.0572 g), and they differed significantly. Closest spacing S_1 recorded the highest per plot yield (3.86 g) and also highest per ha yield of plumbagin (4.29 kg). Yield of plumbagin per plot and per ha in S_2 were 2.41 g and 2.67 kg, respectively, while the corresponding figures in S_3 were 2.05 g and 2.28 kg, respectively.

4.3. Economics of cultivation of Plumbago rosea

Economics of cultivation of Plumbago rosea was worked out and the details are given in Table 15. Economics was worked out based on the expenditure actually incurred for the experiment. For calculating yield the treatment combination which has recorded the highest yield ($P_2 S_1$) was taken into account. The produce was marketed after drying. The total cost of cultivation was Rs. 23,646/=. The total income was Rs. 38,400/=. It was evident that a net income of Rs. 14,754.00 per hectare could be obtained from the cultivation of Plumbago rosea.

Table 12. Effect of spacing and planting material on the content (on dry and fresh weight basis); and yield of plumbagin in *Plumbago rosea* L

Treatments	Plumbagin % (on fresh weight basis)	Plumbagin % (on dry weight basis)	Yield of plumbagin per plant (g)	Yield of plumbagin per plot (g)	Yield of plumbagin per ha (kg)
PLANTING MATERIAL					
P_1	0.04	0.1700	0.0845	2.74	3.05
P_2	0.04	0.1697	0.0839	2.77	3.08
P_3	0.05	0.1737	0.0844	2.81	3.12
	NS	NS	NS	NS	NS
SPACING					
S_1	0.04	0.1697	0.0572	3.86	4.29
S_2	0.05	0.1754	0.0824	2.41	2.67
S_3	0.04	0.1683	0.1131	2.05	2.28
CD (0.05)	NS	NS	0.007	0.216	0.240
INTERACTIONS					
$P_1 S_1$	0.04	0.1673	0.0565	3.81	4.23
$P_1 S_2$	0.04	0.1694	0.0798	2.31	2.56
$P_1 S_3$	0.05	0.1734	0.1172	2.11	2.34
$P_2 S_1$	0.04	0.1664	0.0567	3.83	4.25
$P_2 S_2$	0.05	0.1783	0.0841	2.45	2.73
$P_2 S_3$	0.04	0.1644	0.1108	2.04	2.27
$P_3 S_1$	0.05	0.1754	0.0583	3.95	4.39
$P_3 S_2$	0.05	0.1786	0.0833	2.46	2.74
$P_3 S_3$	0.04	0.1672	0.1131	2.01	2.23
	NS	NS	NS	NS	NS

P_1 = Single node cuttings
P_2 = Two node cuttings
P_3 = Three node cuttings

S_1 = 50 x 15 cm
S_2 = 50 x 30 cm
S_3 = 50 x 45 cm

NS = Not significant

Plate VIII Plumbagin crystals. (crude form)

4.4. Correlation studies

Morphological characters namely height and spread of the plants were correlated with the root yield per plant and per plot (both fresh and dry), plumbagin content and the yield of plumbagin per plant and per plot. Both simple and multiple correlations were worked out. Regression equations were fitted to assess the individual and combination effects of spread and height of the plants on the root and plumbagin yield. (Table. 13 & 14)

Simple correlation studies

(i) Relationship between spread and root yield per plant on fresh and dry weight basis.

Highly significant positive correlation existed between spread and root yield per plant on fresh and dry weight basis (Table. 13)

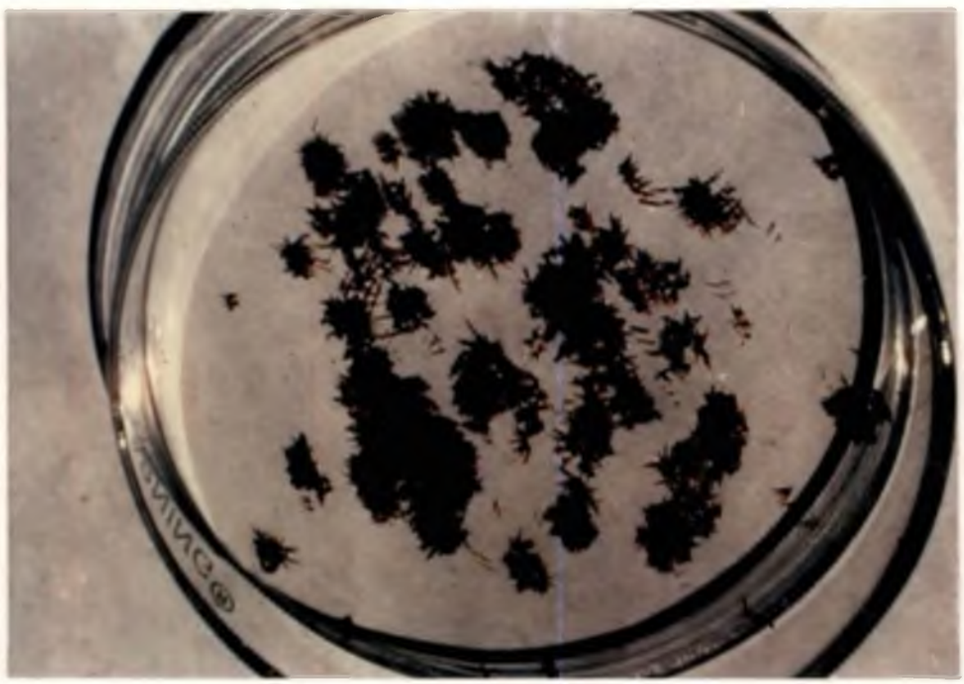
(ii) Relationship between spread and root yield per plot on fresh and dry weight basis.

Highly significant negative correlation existed between spread and root yield per plot (on fresh and dry weight basis) (Table. 13).

(iii) Relationship between spread and percentage of plumbagin on fresh and dry weight basis.

Correlation between spread and percentage of plumbagin on fresh weight and dry weight basis was found to be not significant. (Table. 13).

Plate VIII Plumbagin crystals. (crude form)



4.4. Correlation studies

Morphological characters namely height and spread of the plants were correlated with the root yield per plant and per plot (both fresh and dry), plumbagin content and the yield of plumbagin per plant and per plot. Both simple and multiple correlations were worked out. Regression equations were fitted to assess the individual and combination effects of spread and height of the plants on the root and plumbagin yield. (Table. 13 & 14)

Simple correlation studies

(i) Relationship between spread and root yield per plant on fresh and dry weight basis.

Highly significant positive correlation existed between spread and root yield per plant on fresh and dry weight basis (Table. 13).

(ii) Relationship between spread and root yield per plot on fresh and dry weight basis.

Highly significant negative correlation existed between spread and root yield per plot (on fresh and dry weight basis) (Table. 13).

(iii) Relationship between spread and percentage of plumbagin on fresh and dry weight basis.

Correlation between spread and percentage of plumbagin on fresh weight and dry weight basis was found to be not significant. (Table. 13).

Table 13 Correlation coefficients of characters studied.

	Spread		Height	
	Correlation coefficient	Regression equation	Correlation coefficient	Regression equation
1. Fresh root yield per plant	0.9862 **	Y = -129.7620 + 5.5126 X	-0.9231 **	Y = 605.7580 + 6.2775 X
2. Dry root yield per plant	0.9816 **	Y = -37.8762 + 1.5136 X	-0.9125 **	Y = 163.3030 + -1.7119 X
3. Fresh root yield per plot	-0.9036 **	Y = 16.162 - 0.172 X	0.9489 **	Y = -8.401 + 0.220 X
4. Dry root yield per plot	-0.9036 **	Y = 4.224 - 0.045 X	0.9489 **	Y = -2.196 + 0.057 X
5. Percentage of plumbagin (fresh weight basis)	-0.0701	N.S	0.0549	N.S
6. Percentage of plumbagin (dry weight basis)	-0.0425	N.S	0.0268	N.S
7. Yield of plumbagin per plant	0.9620 **	Y = -0.0548 + 0.0024 X	-0.9037 **	Y = 0.2672 + -0.0028 X
8. Yield of plumbagin per plot	-0.9046 **	Y = 7.232 - 0.077 X	0.9492 **	Y = -3.765 + 0.098 X

** Significant at 1 % level

Y = Fresh root yield or dry root yield or plumbagin yield as the case may be.

X = Spread or height as the case may be.

(iv) Relationship between spread and plumbagin yield per plant.

Highly significant positive correlation existed between spread and plumbagin yield per plant (Table. 13).

(v) Relationship between spread and total yield of plumbagin per plot

Highly significant negative correlation existed between spread of the plant and total yield of plumbagin per plot. (Table. 13).

(vi) Relationship between height and root yield per plant on fresh and dry weight basis

Highly significant negative correlation existed between height and root yield per plant on fresh and dry weight basis (Table. 13)

(vii) Relationship between height and root yield per plot on fresh and dry weight basis.

Highly significant positive correlation existed between height of the plant and fresh as well as dry root yield per plot. (Table .13).

(viii) Relationship between height and percentage of plumbagin on fresh and dry weight basis

Correlation between height and percentage of plumbagin on fresh and dry weight basis was found to be non significant. (Table. 13).

(ix) Relationship between height and plumbagin yield per plant

Highly significant negative correlation existed between height and plumbagin yield per plant. (Table. 13).

(x) Relationship between height and total yield of plumbagin per plot

Highly significant positive correlation existed between height of the plant and total yield of plumbagin per plot. (Table. 13)

In general, the spread of the plants had a significant positive correlation with root yield both on fresh and dry weight basis and the plumbagin yield per plant, whereas the height of the plants had a significant negative relationship with the above characters. At the same time when the relationship of the above characters were compared on plot basis just reverse effects were obtained.

Multiple correlation studies.

The simple correlation studies revealed that spread and height of plant had effects on the important characters like root and plumbagin yield. And hence multiple correlation studies were carried out to study their combined effects on the above characters. Multiple linear regression equations were also fitted to predict the root and plumbagin yield in relation to the

Table 14. Multiple regression analysis of root yield and plumbagin yield as influenced by spread and height of the plants

Characters	Multiple regression equations	R^2 value	Predicted values based on average values of characters studied
1. Yield of roots per plant (fresh weight basis)	$Y = -199.3639 + 5.9986^{**} X_1 + 0.6251 X_2$	0.9730	188.86 g
2. Yield of roots per plant (dry weight basis)	$Y = -69.3566 + 1.7334^{**} X_1 + 0.2827 X_2$	0.9661	49.61 g
3. Yield of roots per plot (fresh weight basis)	$Y = -6.923 - 0.011 X_1 + 0.207 X_2$	0.9007	6.19 kg
4. Yield of roots per plot (dry weight basis)	$Y = -1.811 - 0.003 X_1 + 0.054 X_2$	0.9007	1.60 kg
5. Yield of plumbagin per plant	$Y = -0.0749 + 0.0026^{**} X_1 + 0.0002 X_2$	0.9260	0.08 g
6. Yield of plumbagin per plot	$Y = -3.026 - 0.006 X_1 + 0.092 X_2$	0.9013	2.74 g
7. Root yield (Dry)/ ha			2.205 T

X_1 = Spread of the plant in cm. X_2 = Height of plant in cm.

Table . 15 Economics of cultivation of *Plumbago rosea* L.
(for one hectare.)

Particulars	Men @ Rs.30/=	Women @ Rs.28/=	Amount Rs.
1) Cost of planting material (800 kg stems @ Rs.10/= per kg)			8000.00
2) Land preparation			
Nursery			
Weeding and digging	10	12	636.00
Taking beds	8		240.00
Main field			
Weeding and digging	25	30	1590.00
Taking ridges and bunds	30		900.00
3) Planting	4,	15	540.00
4) Interculture			
Weeding		200	5600.00
Earthing up	10		300.00
5) Manures and manuring			
Farm yard manure (10 tonnes)			500.00
50 kg N (@ Rs.5/ kg)			250.00
50 kg P_2O_5 (@Rs.4.50/ kg)			225.00
5 kg K_2O(@ Rs.2.50/kg)			125.00
Transport and application	3	5	230.00
6) Irrigation	60		1800.00
7) Harvesting (digging out roots) and collecting roots	25	25	1450.00
8) Processing (cleaning and drying)		45	1260.00
9) Total cost of cultivation			23646.00
10) a) Yield of dry roots per hectare 2.56 tonnes/ha. b) Total amount @ Rs.15 per kg of dry roots Rs.38400.00			
11) Net income (10 b - 9)			:Rs.14754.00
12) Cost benefit ratio			:1:1.62

morphological characters viz. spread and height of plants. The coefficient of determinations (R^2) for the multiple equations were also obtained (Table . 14). The studies revealed that plant height is the most important contributing character in increasing root yield per plot whereas spread is the most important contributing character in increasing yield per plant. Based on the height as well as the spread of the plants from a crop of average stand we can predict the root yield and plumbagin yield.

Discussion

DISCUSSION

Studies to find out the effect of spacing and planting material on the growth, yield and active principle in Plumbago rosea L. was undertaken at the College of Horticulture, Vellanikkara during 1987-1988. The results are discussed in the following section.

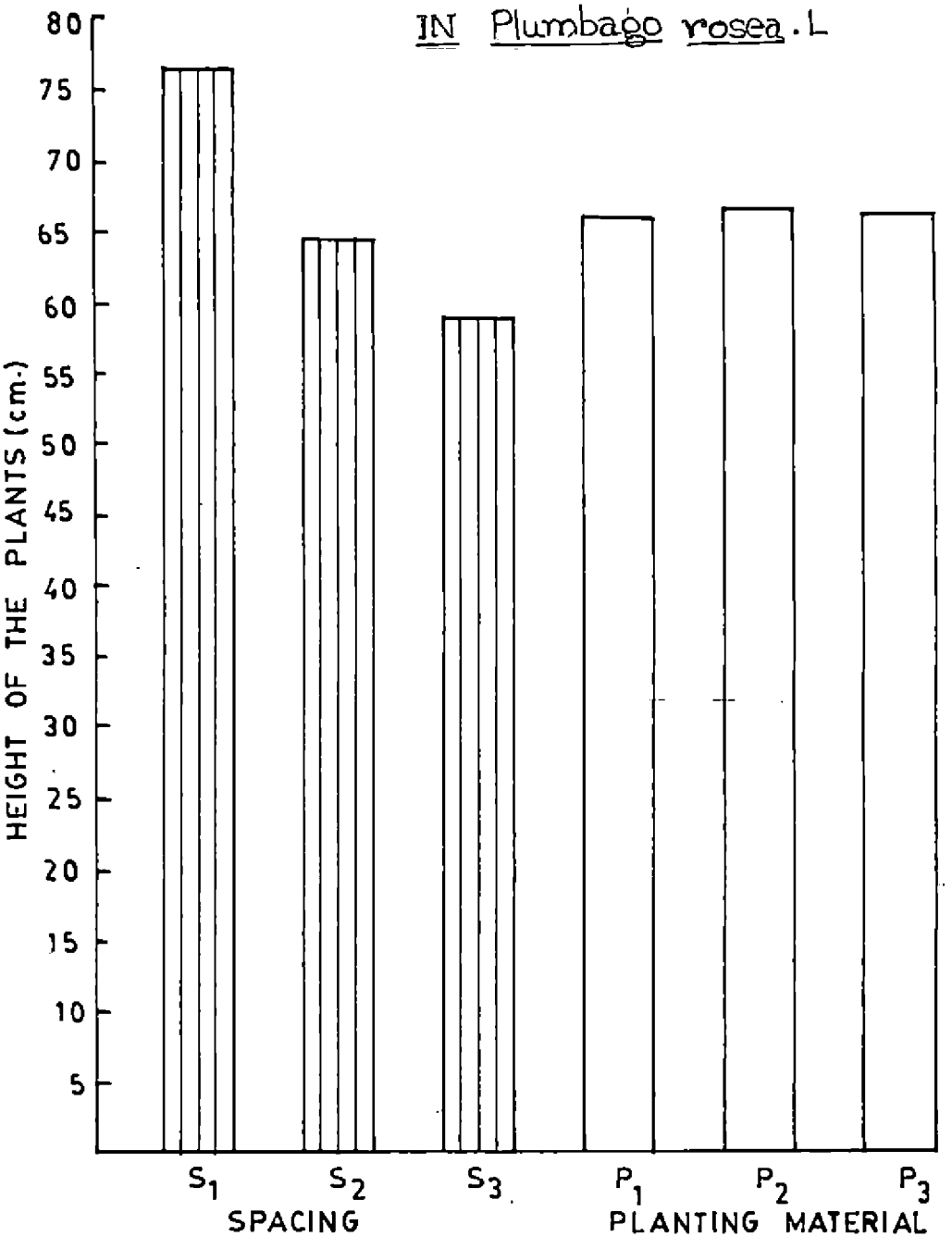
5.1. Morphological characters

The morphological characters studied in the present investigations were the height of the plant, spread of the plant , number of suckers per plant, average number of leaves per sucker, number of days taken for blooming, length and width of the leaves, average leaf area, internodal length and diameter of the stem. These characters normally reflect the vigour of the plants.

Data on the effect of different planting materials and spacing on morphological characters revealed that the type of planting material did not exert any significant effect. This may be due to similar growth pattern of plants though raised from different sizes of cuttings. The well sprouted cuttings were transplanted in the main field under uniform care and management.

In the present investigation, it was revealed that spacing had significant influence over the height of the plant. Height of the plant was found to be increased with decrease in spacing. The closest spacing S_1 (50 x 15 cm)

FIG:1 EFFECT OF SPACING AND PLANTING MATERIAL ON THE HEIGHT OF THE PLANTS IN *Plumbago rosea*. L



recorded the maximum height of 76.54 cm which was significantly superior to the other spacings viz. S_2 (50 x 30 cm) and S_3 (50 x 45 cm). The widest spacing S_3 showed the lowest height (58.39 cm). The greater plant height under closer spacings may be due to more linear growth of plants as a result of competition for light among the plants as the plant density per unit area was more. The results obtained were in confirmity with the findings of Joseph (1983) in Costus speciosus and Ramachandran and Muthuswamy (1984) in tumeric.

Spacing exerted a definite influence on the spread (both north south and east west) of the plants. Spread of the plants increased with increase in spacing. The widest spacing S_3 registered the highest north south spread of 67.15 cm followed by S_2 (57.71 cm) and S_1 (48.60 cm). The spacing S_3 also registered the highest east west spread of 69.37 cm, while the corresponding figures in S_2 and S_1 were 57.61 cm and 46.43 cm respectively. The increased spread under wider spacings may be due to the increased branching. The greatly enhanced vegetative growth under wider spacings resulted in more branches per plant due to the availability of large foraging area for the roots and consequent greater utilisation of nutrients and also due to the higher photosynthetic area. The results obtained here were in line with the findings of Joseph (1983) in Costus speciosus.

Contrary to what is normally observed, both the

FIG:2 EFFECT OF SPACING AND PLANTING MATERIAL ON THE NORTH SOUTH SPREAD OF THE PLANTS IN *Plumbago rosea* L.

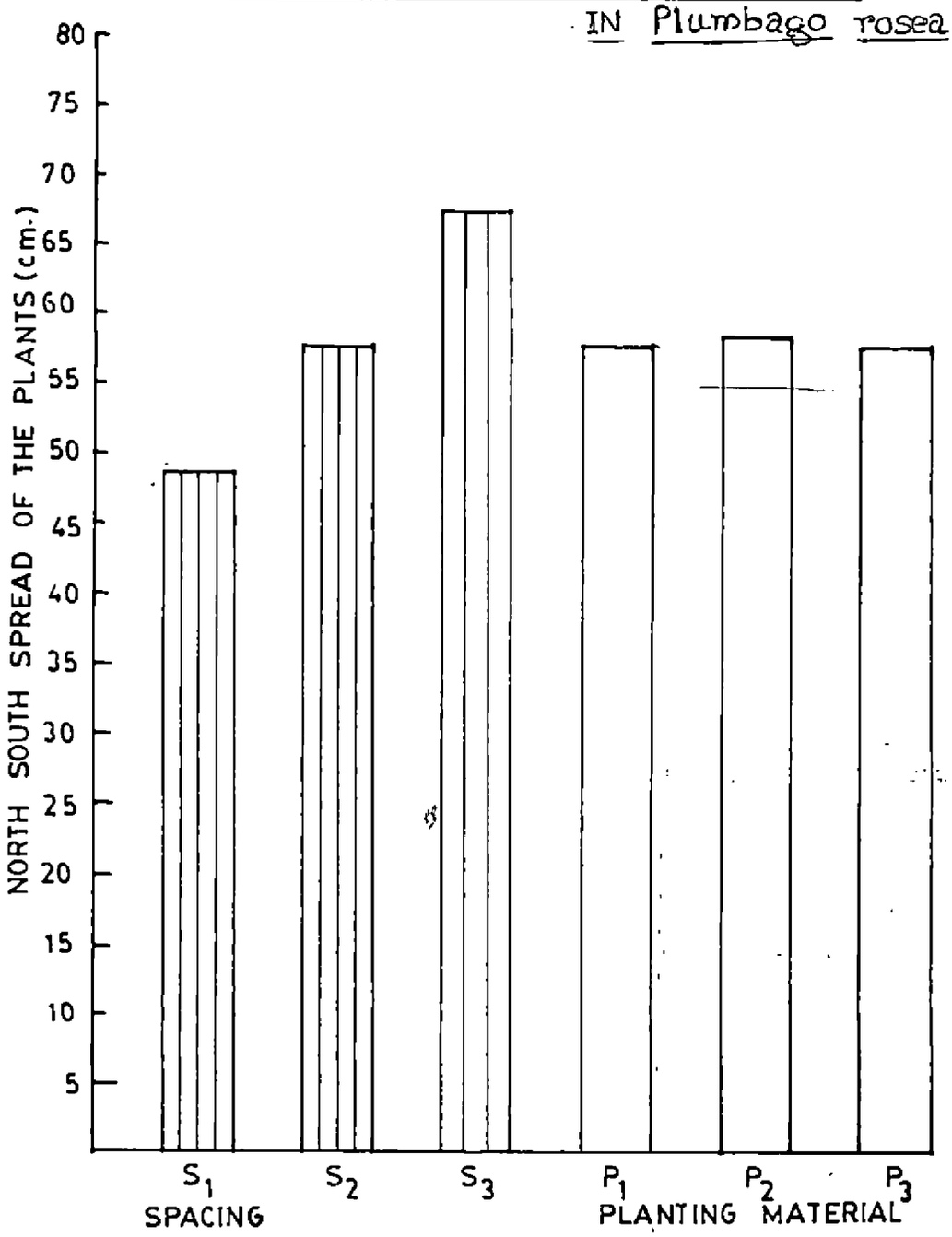
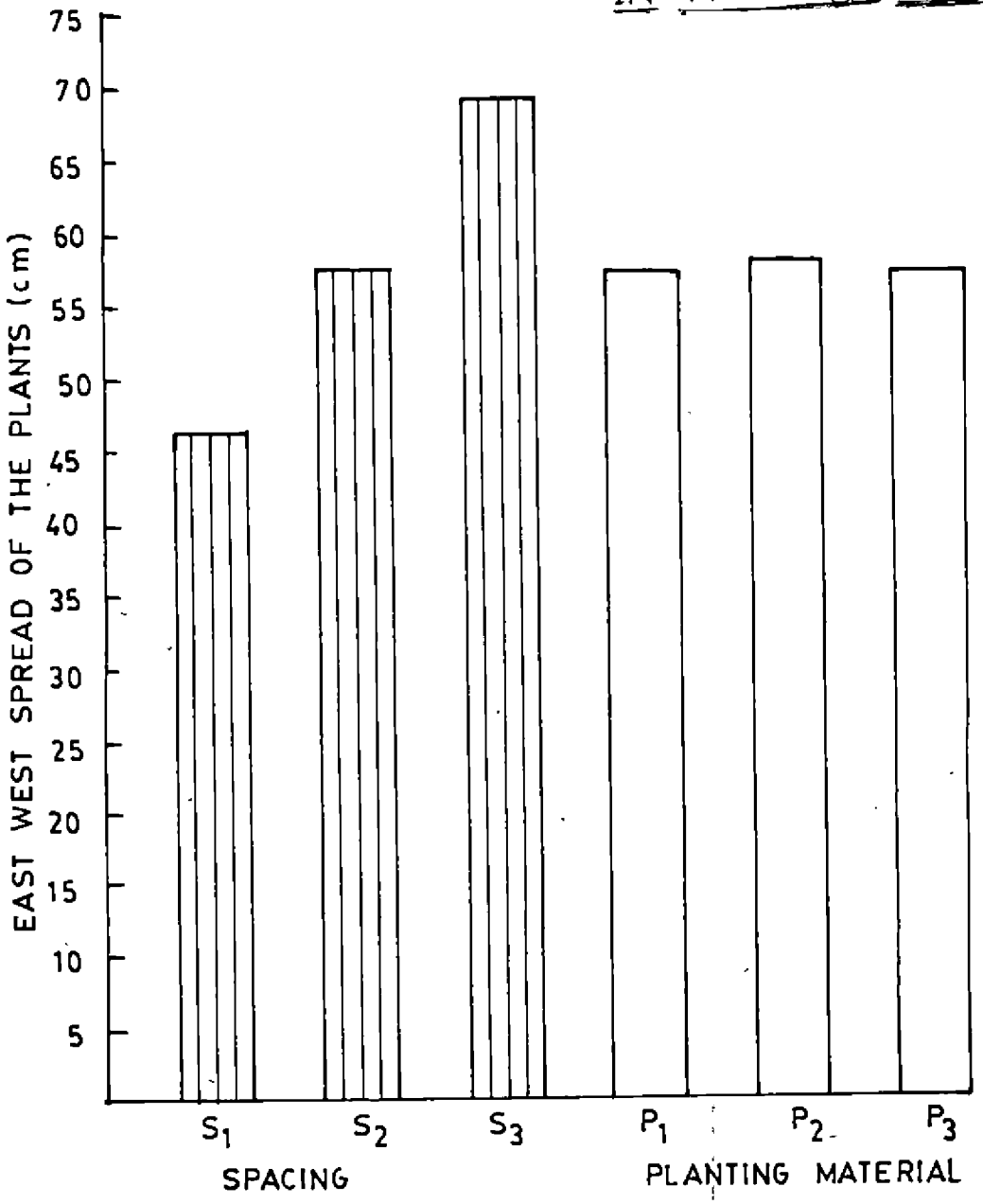


FIG: 3 EFFECT OF SPACING AND PLANTING MATERIAL ON THE EAST WEST SPREAD OF THE PLANTS IN *Plumbago rosea* L.



spacing and planting material did not interact or exhibit any significant influence on vegetative characters such as number of suckers per plant, average number of leaves per sucker, number of days taken for blooming, length of leaves, width of leaves, average area of the leaves, internodal length and diameter of the stem. The planting materials were prepared in the nursery and then transplanted to the main field. And almost uniform plants from different groups were planted. This may be the reason as to why the above characters have shown similarity. Further they were given similar manuring and other management practices.

5.2. Yield characters

The results revealed that the type of the planting material did not exert significant influence on any of the yield characters such as length of main root, diameter of the main root, yield of root per plant, yield of root per plot, yield of root per hectare, (either on dry weight basis or on fresh weight basis). Fresh and dry weight of the shoots per plant, plumbagin content and yield of plumbagin per plant, per plot and per hectare were also not influenced by the planting material. This proved that three node cuttings, two node cuttings and single node cuttings were equally suitable for getting higher yield. But in the case of single node cuttings, initial establishment was low compared to two node and three node cuttings and they also required much care during

the nursery stage. Once they get established, they behaved similar to three node and two node cuttings.

Spacing exerted definite influence on the yield characters except in respect of length and diameter of the main root, whereas the effects of spacing on the length and diameter of the mainroot were not found to be significant.

Spacing had a highly significant influence on the yield of fresh roots. Yield of fresh roots per plant was found to be increased with increase in spacing. The widest spacing S_3 recorded the maximum yield of fresh roots per plant (257.40 g), S_2 recorded an yield of 179.86 g and S_1 with 129.38 g which was the lowest. Yield of dry roots per plant was also significantly influenced by the spacing. Widest spacing S_3 (50 x 45 cm) was superior to S_2 and S_1. Dry weight of roots per plant in S_3 was 68.71 g, those in S_2 and S_1 were 46.43 g and 33.71 g, respectively. The greater per plant yield under wider spacings may be due to the availability of large feeding area and availability of high quantum of nutrients per plant. Under wider spacings, there will be less competition among the plants for light, nutrients, space etc. It will result in better growth of the crop and subsequently higher yield. The results obtained are in confirmity with the findings of Sivan (1979) in ginger; and Joseph (1983) in Costus speciosus.

Though the yield of dry and fresh roots per plant was high under wider spacings, the per plot and per hectare

FIG : 4 EFFECT OF SPACING AND PLANTING MATERIAL ON THE YEILD (FRESH WEIGHT) OF THE ROOTS PER PLANT IN *Plumbago rosea* L

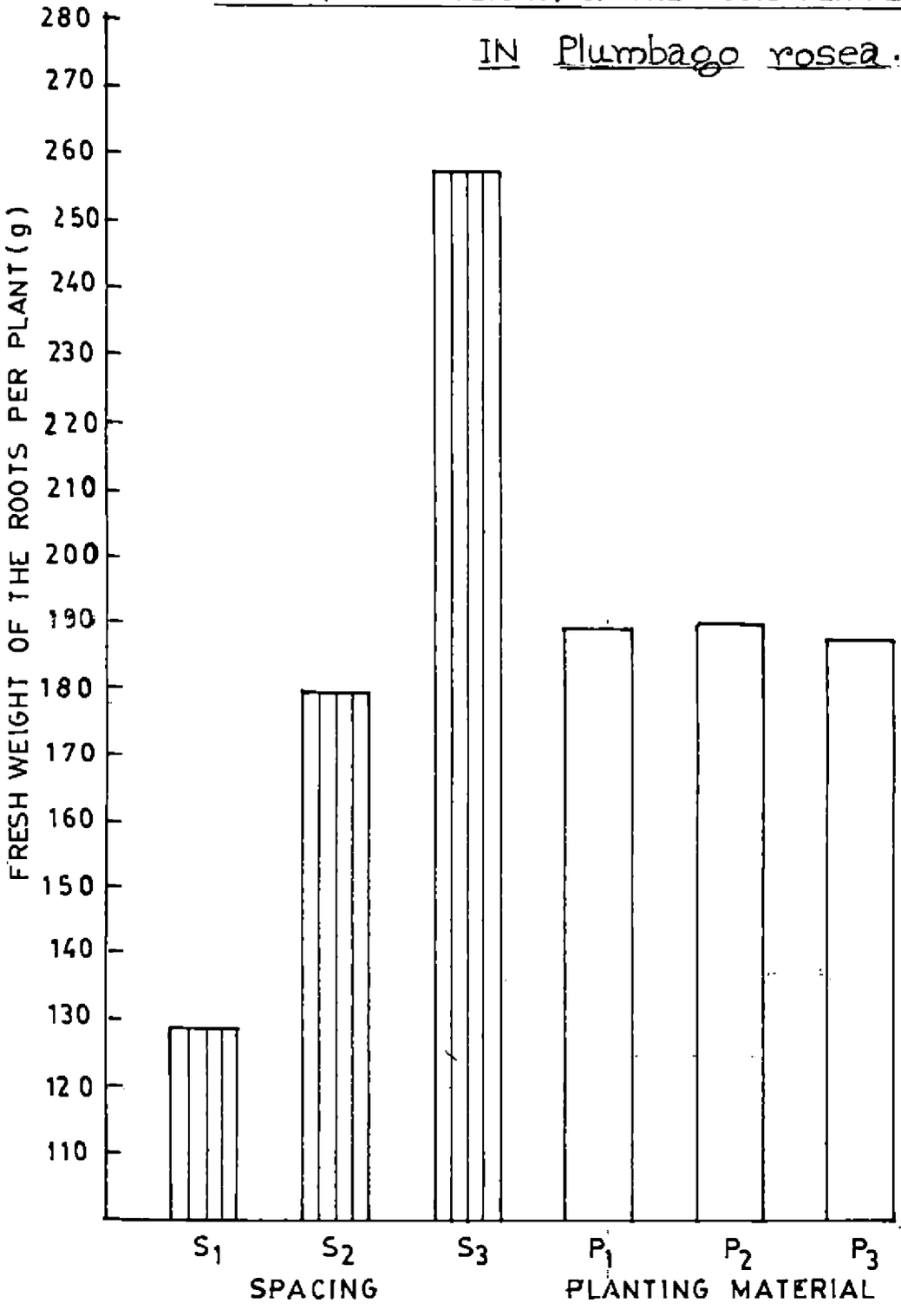


FIG : 6 EFFECT OF SPACING AND PLANTING MATERIAL ON THE YIELD (FRESH WEIGHT) OF ROOTS PER HECTARE IN *Plumbago rosea* L

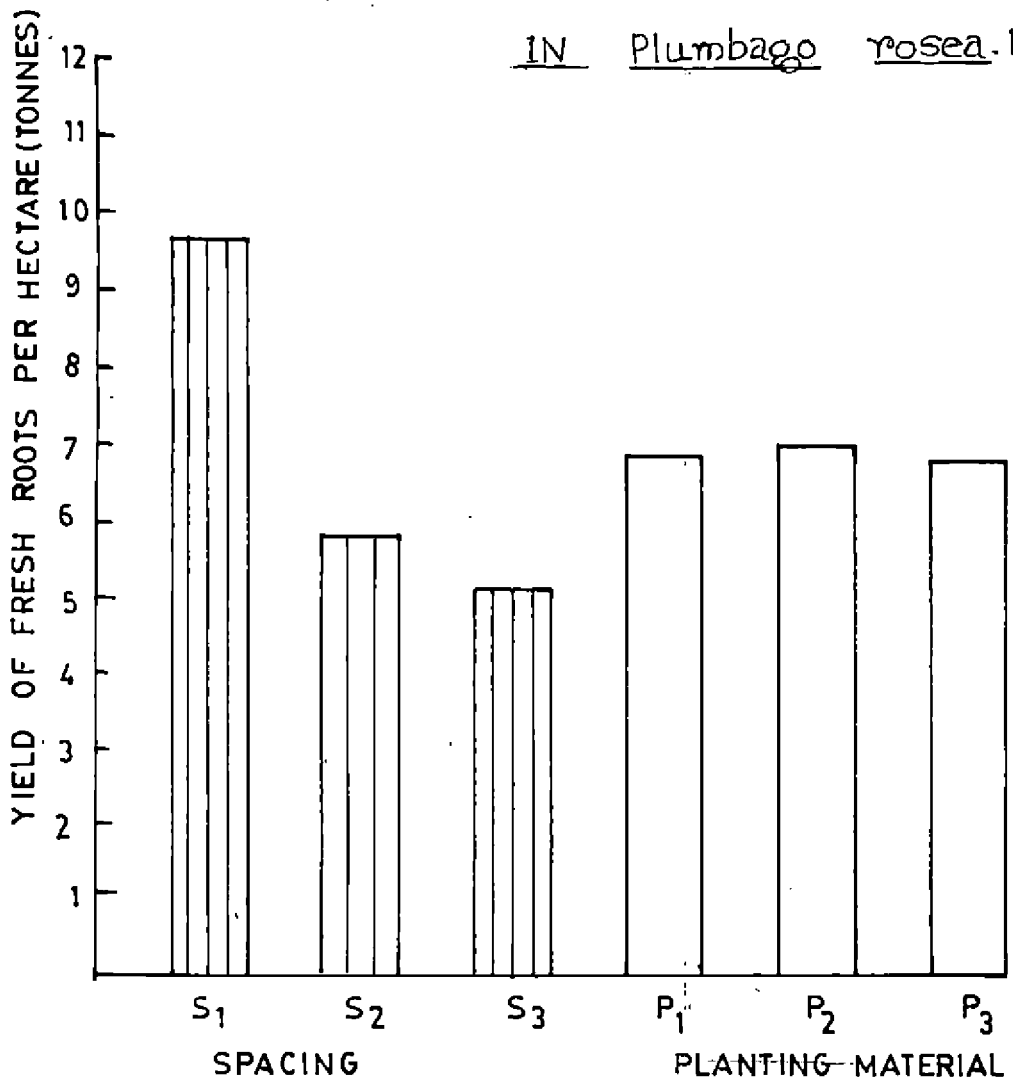


FIG: 7 EFFECT OF SPACING AND PLANTING MATERIAL ON THE YIELD (DRY WEIGHT) OF THE ROOTS PER PLANT IN *Plumbago rosea*. L

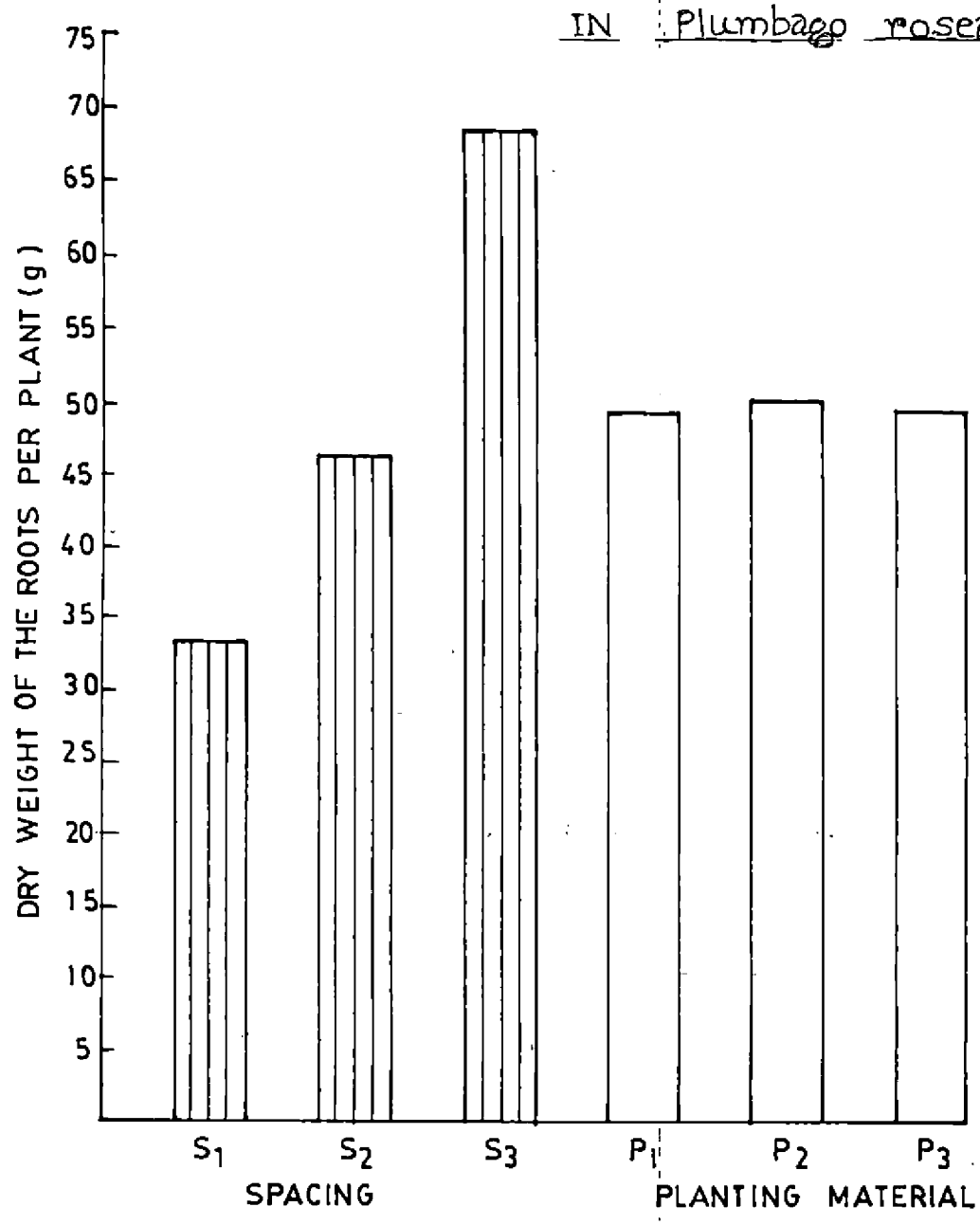
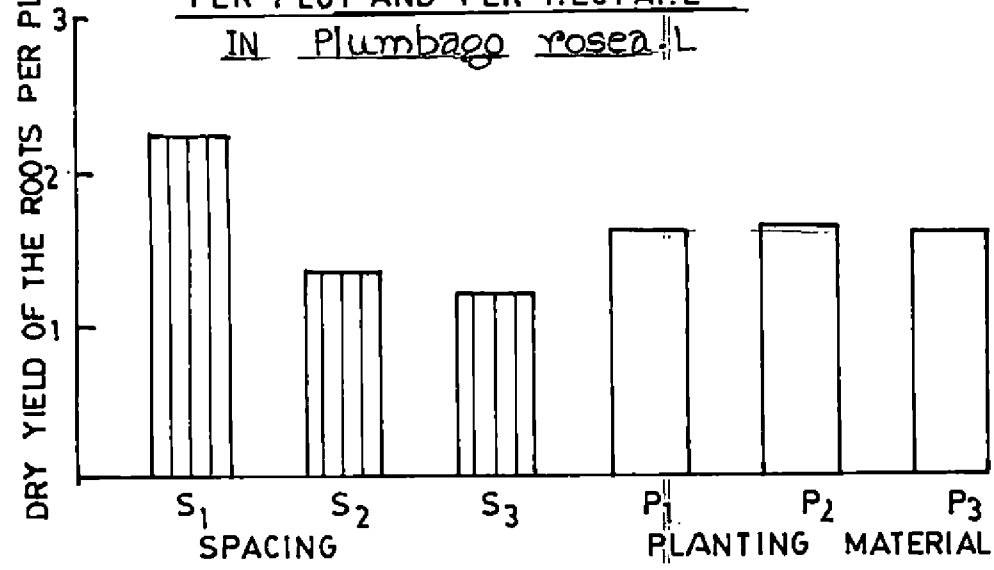
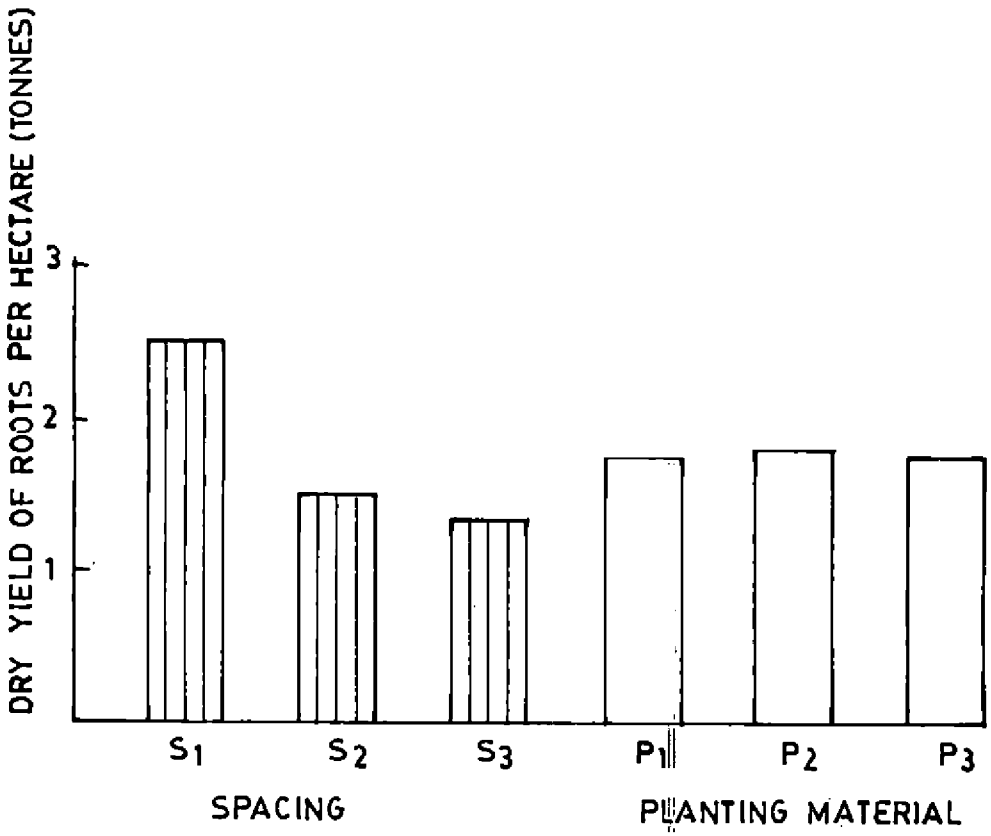


FIG:8 EFFECT OF SPACING AND PLANTING MATERIAL ON THE YEILD (DRY WEIGHT OF THE ROOTS) PER PLOT AND PER HECTARE IN *Plumbago rosea* L.





yield of roots (both dry and fresh) and plumbagin were found to be significantly higher at the closest spacing. The closest spacing S_1 gave the highest per plot yield of 8.71 kg fresh roots and 2.28 kg of dry roots followed by S_2 and S_3. Per ha yield of roots was also highest in S_1 (9.68 tonnes fresh roots and 2.53 tonne of dry roots). Percentage of plumbagin was found to be not affected by both spacing and planting material. While the per plant, per plot and per ha yield of plumbagin was found to be significantly influenced by the spacing. Yield of plumbagin per plant was highest under widest spacing S_3 (0.1131 g), while closest spacing S_1 recorded the highest per plot (3.86 g) and per hectare yield of plumbagin (4.29kg). Per plot and per ha yield of plumbagin in S_2 were 2.41 g and 2.67 kg , while the corresponding figures in S_3 were 2.05 g and 2.28 kg, respectively. The plumbagin content was not influenced by the spacing. At the same time the root yield per plot as well as per ha had recorded significantly higher values. This effect was due to the higher number of plants per unit area in the closest spacing. The higher values for plumbagin yield per plant, per plot and per ha was actually a reflection of the corresponding higher yields.

The influence of closer spacings on yield of crops have been proved by many workers in various crops. Chatterjee (1983) observed that in turmeric, higher yield of green and dry rhizomes were obtained under closer

FIG:9 EFFECT OF SPACING AND PLANTING MATERIAL ON THE FRESH WEIGHT OF THE SHOOTS PER PLANT IN *Plumbago rosea*. L

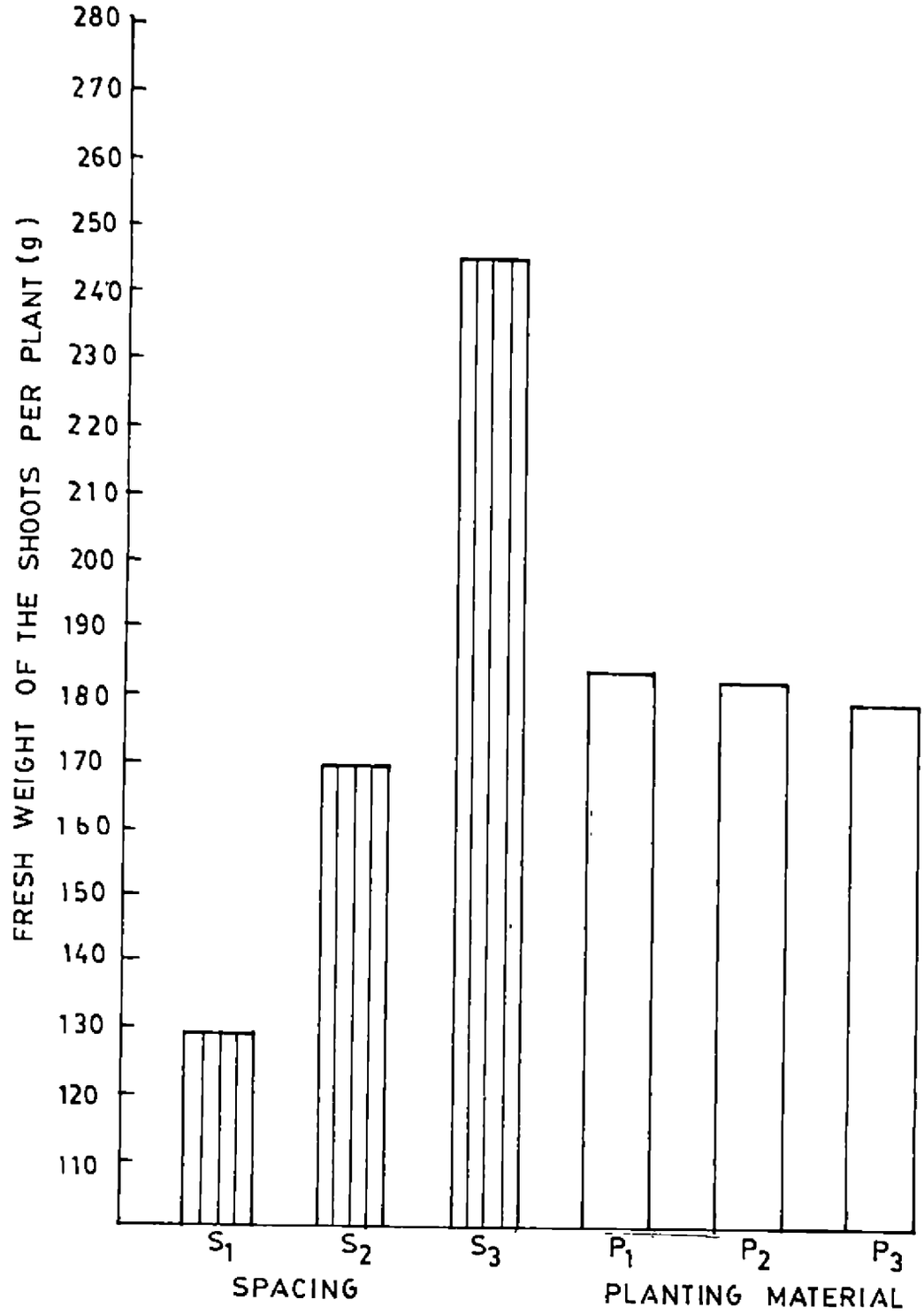


FIG:10 EFFECT OF SPACING AND PLANTING MATERIAL ON THE DRY WEIGHT OF THE SHOOTS PER PLANT IN *Plumbago rosea.L*

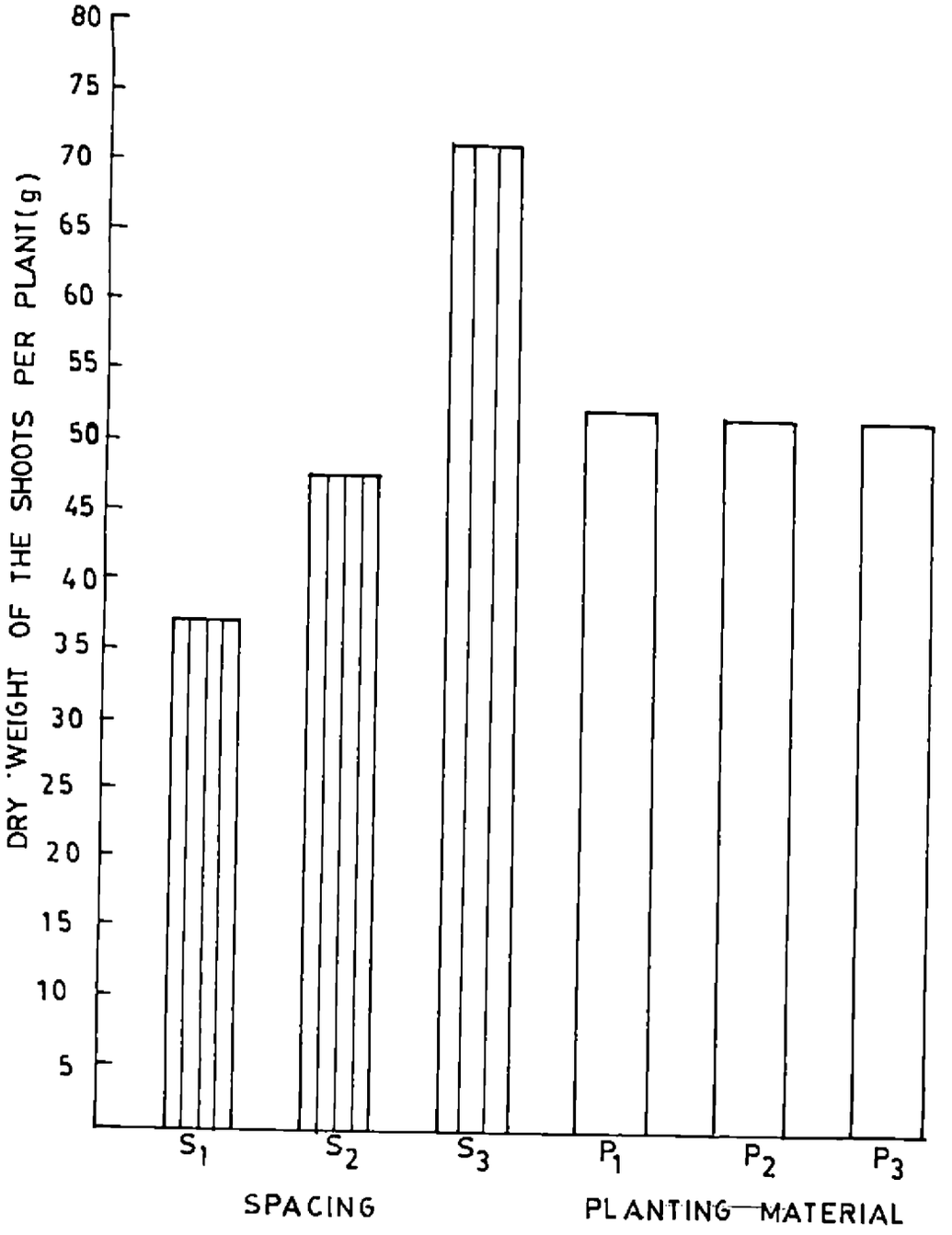


FIG :11 EFFECT OF SPACING AND PLANTING MATERIAL ON THE YIELD OF PLUMBAGIN PER PLANT IN *Plumbago rosea*-L

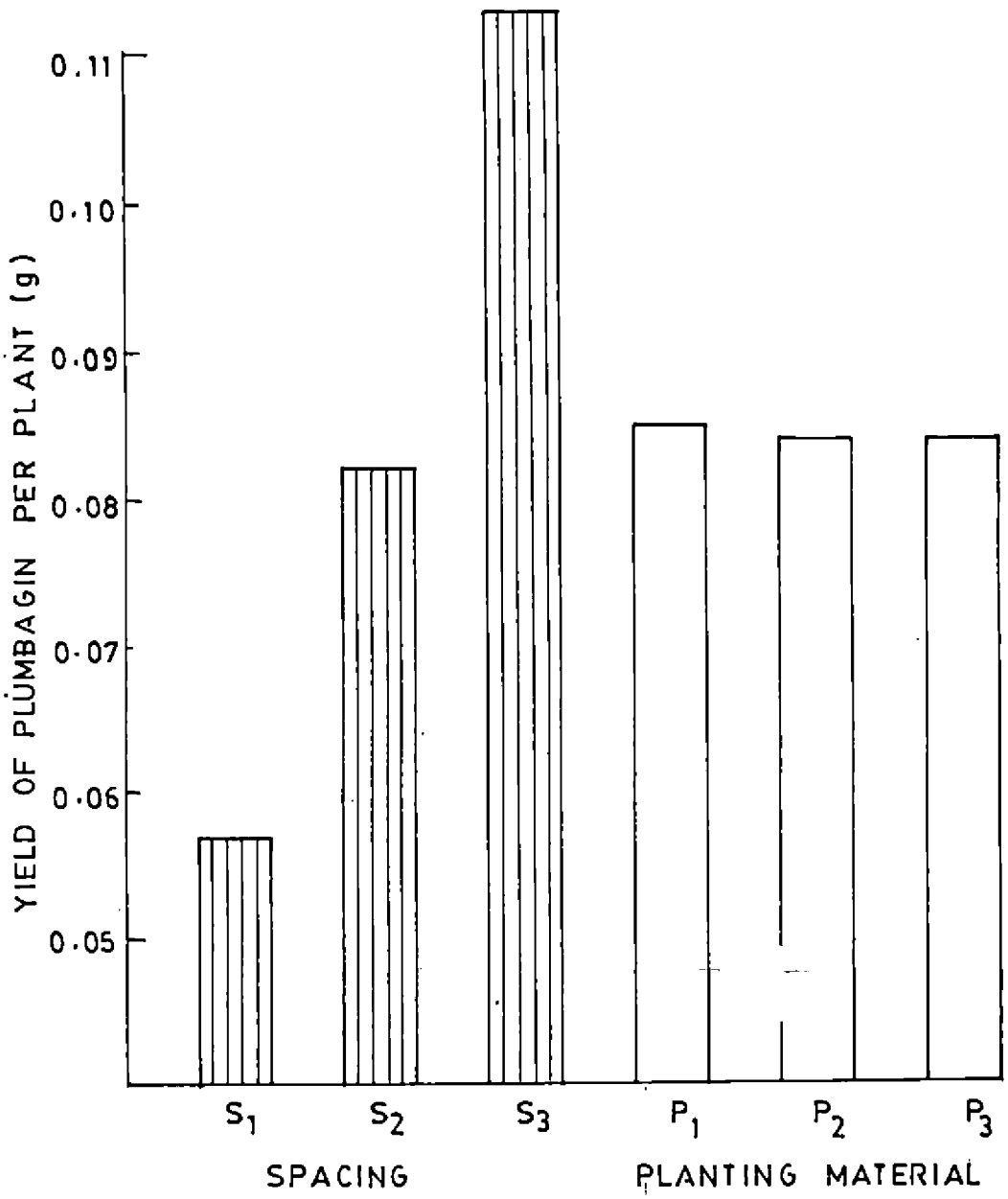
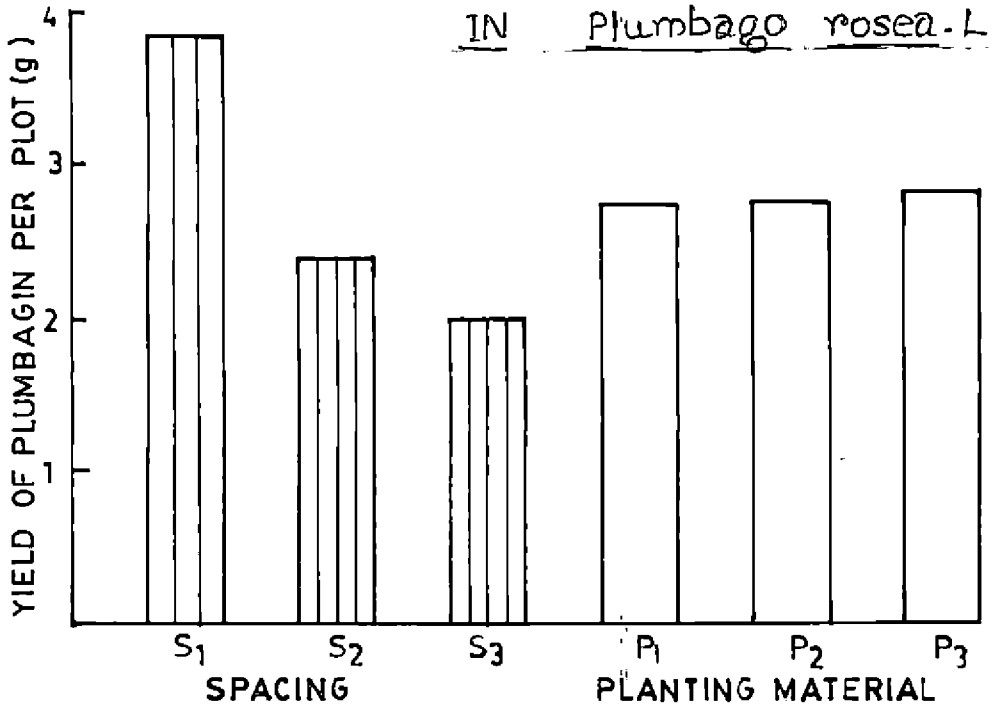
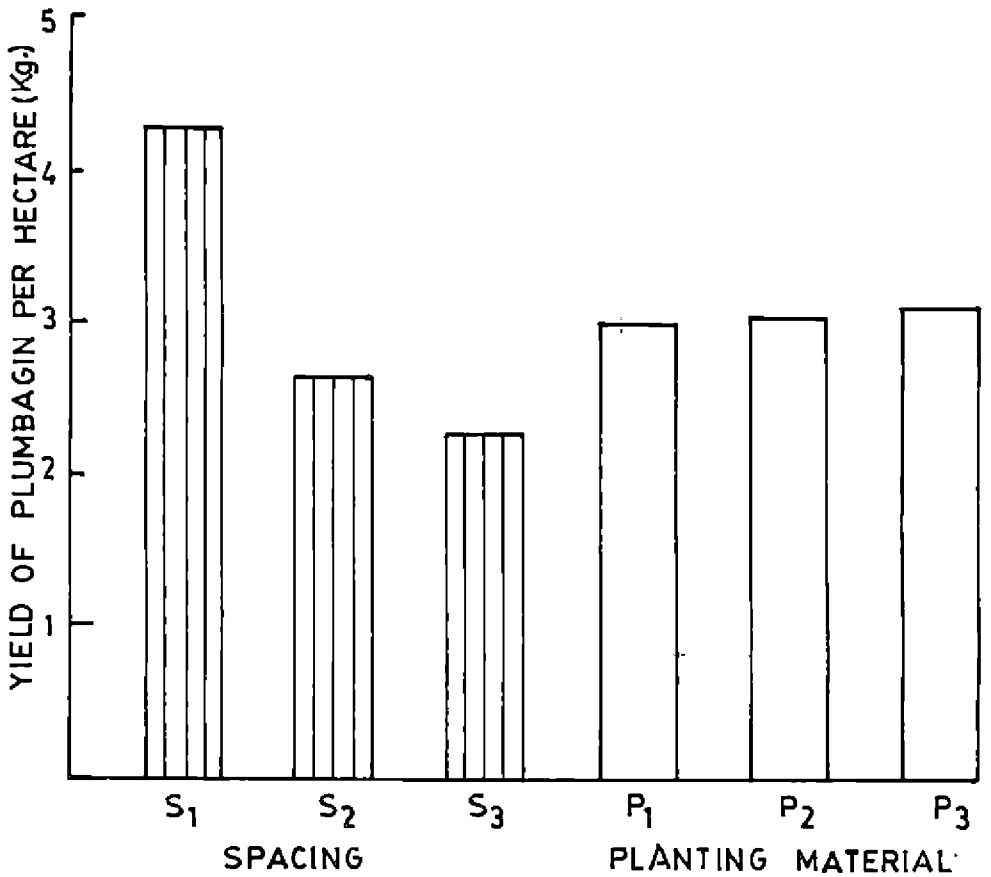


FIG : 12 EFFECT OF SPACING AND PLANTING MATERIAL ON THE YIELD OF PLUMBAGIN PER PLOT & PER HECTARE.

IN *Plumbago rosea* - L





spacing, whereas spacing did not significantly influence the oleoresin content. In turmeric, the closest spacing produced the highest yield of rhizomes (Ramachandran and Muthuswamy, 1984). Joseph (1983) reported that the per hectare yield of rhizomes and diosgenin were found to be significantly higher at the closest spacing. According to Cruzado et al. (1964), closer spacing increased yields per acre without affecting percentage of Sapogenin. Nigam et al., (1984) also reported that closely spaced plants gave higher yields compared to wider spacings in Withania somnifera. These references were in confirmity with the present findings.

There were significant differences in the fresh and dry weight of the shoots per plant due to different spacing treatments whereas the type of planting material did not show significant influence on these characters. The Widest spacing S_3 recorded the highest fresh (245.66 g) and dry weight (71.32 g) of shoots per plant followed by S_2 and S_1. This may be due to the increased vegetative growth under wider spacings, due to the availability of large foraging area for the roots and consequent greater utilisation of nutrients.

The correlation studies indicated that root and plumbagin yield per plant were highly correlated with the spread of the plant, whereas the same characters when studied on plot basis showed significant negative correlation. This clearly brought out the effect of

spacing on plant spread. When closer spacing was adopted, the number of plants per unit area had increased and there by the spread of the plants was restricted. Further, the favourable effect of spread of individual plants on root yield and plumbagin yield was masked by the number of plants per plot. Thus the favourable effect of closer spacing, in other words the high density planting was brought out here. This can be further explained by the significant negative correlation of root yield and plumbagin yield per plant, and with height of plants. In short the correlation studies indicated the possibility of growing Plumbago rosea L. adopting closer spacing.

This view was further strengthened by multiple correlation studies which indicated that the height of plants had a favourable effect on the yield of roots per plot, whereas the spread of the plant had a negative effect only. The plot yield was influenced by the number of plants per plot. When number of plants per plot was increased, the plants had the tendency to grow higher and has less spreading. This may be the reason as to why the plant height had a positive effect and spread had a negative effect on the total root yield per plot.

Multiple correlation studies indicated that based on the height as well as spread of the plants from a crop of average stand, the plumbagin yield, fresh root yield and

dry root yield can be predicted. The predicted yield of 2.205 T / ha of dry roots based on average values seems to be close to the total yield achieved in this experiment.

At present, the roots are marketted in the form of dry roots and used mainly in ayurvedic preparations. Plumbagin is not produced on a commercial scale. Therefore the economics of cultivation was worked out based on the present market price of roots (Rs.15/ kg). It was evident that a net income of Rs.14,754.00 per hectare could be obtained. The net income based on predicted yield values was Rs.9,429.00 per hectare which was comparable with the net income from actual experimentation. Higher net income could be expected, if plumbagin can be produced on a commercial scale.

Summary

SUMMARY

An investigation was carried out to find out the optimum spacing and best planting material in Koduveli (Rosy leadwort) (Plumbago rosea L.) at the College of Horticulture, Vellanikkara during 1987-88. The salient results are summarised below.

Spacing imparted a definite influence on the height and spread of the plants. Height of the plant was found to be increased with decrease in spacing, whereas spread (north south and east west) of the plants increased with increase in spacing. But the type of planting material had no significant effect on these two characters. The interaction between the spacing and planting materials was also not significant.

Both spacing and planting material did not interact or exhibit any significant influence on other vegetative characters such as number of suckers per plant, average number of leaves per sucker, number of days taken for blooming, length of leaves, width of leaves, average area of the leaves, internodal length and diameter of the stem.

Root characters such as the length of main root and diameter of the main root were not found to be influenced by both spacing and planting material.

On both fresh and dry weight basis, the spacing had a highly significant influence on the yield of roots.

The greater yield of roots per plant was observed under wider spacings whereas the per plot and per hectare yield of roots were found to be significantly higher at the closest spacing. But the yield of roots was found to be not affected by the type of planting material either fresh or dry weight basis.

Plumbagin content was found to be not affected by both spacing and planting material, while the yield of plumbagin per plant, per plot and per hectare was found to be significantly influenced by the spacing. Closest spacing registered the highest per plot and per hectare yield of plumbagin. At the same time the widest spacing registered significantly higher values for plumbagin yield per plant. While the type of planting material exerted no significant influence on these three characters.

There was significant differences in the fresh and dry weight of the shoots per plant due to different spacing treatments, whereas the type of planting material did not show significant influence on these characters. Widest spacing recorded the highest fresh weight and dry weight of shoots per plant.

The correlation studies indicated that closer spacing was advantageous for better root and plumbagin yield.

The study revealed that Koduveli (Plumbago rosea L) can be profitably cultivated using single, double or three nodal rooted stem cuttings under our conditions as annual crop. And the best spacing for profitable cultivation is 50 cm x 15 cm.

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* Originals not seen.

Appendices

APPENDIX I

Meteorological data (Monthly average) for the period from June 1987 to June 1988.

Parameters	Temparature °C		Rainfall mm	R.H. %	Sunshine hours
	Max.	Min.			
June	30.7	23.7	837.7	83	4.2
July	30.3	23.5	336.5	84	5.7
August	29.6	23.5	388.4	87	3.7
September	31.5	23.9	174.0	79	7.4
October	31.9	23.9	280.4	79	6.4
November	31.6	22.8	224.4	77	6.7
December	31.6	23.3	64.6	70	8.1
January	32.4	22.0	0	56	10.4
February	35.8	23.1	7.8	56	10.0
March	35.7	24.4	37.9	67	9.1
April	35.1	24.3	145.4	70	8.8
May	33.7	25.4	242.6	76	6.2
June	30.0	23.7	632.1	86	4.2

APPENDIX II

Analysis of variance for the effect of spacing and planting material on the height of the plants

Sources of variation	df	Mean squares
Total	26	
Block	2	0.801
Planting material (P)	2	1.379
Spacing (S)	2	770.574 *
Interaction (P x S)	4	0.875
Error	16	4.824

* Significant at 5 % level

APPENDIX III

Analysis of variance for the effect of spacing and planting material on the spread (East West and North South) of the plants

Sources of variation	df	Mean squares	
		EW spread	NS spread
Total	26		
Block	2	1.949	2.113
Planting material (P)	2	1.418	0.461
Spacing (S)	2	1184.430 *	773.801 *
Interaction (P x S)	4	3.170	0.834
Error	16	1.153	1.000

* Significant at 5 % level

APPENDIX IV

Analysis of variance for the effect of spacing and planting material on the yield of roots per plant, per plot and per hectare (fresh weight)

Sources of variation	df	Mean squares		
		Yield of roots per plant	Yield of roots per plot	Yield of roots per hectare
Total	26			
Block	2	2.437	0.035	0.043
Planting material (P)	2	16.219	0.031	0.038
Spacing (S)	2	37422.282 *	43.191 *	53.321 *
Interaction (P x S)	4	1.281	0.008	0.009
Error	16	19.492	0.054	0.067

* Significant at 5 % level

APPENDIX V

Analysis of variance for the effect of spacing and planting material on the yield of roots per plant, per plot and per hectare (dry weight)

Sources of variation	df	Mean squares		
		Yield of roots per plant	yield of roots per plot	yield of roots per hectare
Total	26			
Block	2	0.883	0.002	0.003
Planting material (P)	2	2.453	0.002	0.003
Spacing (S)	2	2825.141 *	2.951 *	3.612 *
Interaction (P x S)	4	0.164	0.001	0.001
Error	16	4.100	0.004	0.004

* significant at 5 % level

APPENDIX VI

Analysis of variance for the effect of spacing and planting material on the fresh weight of the shoots per plant and on the dry weight of the shoots per plant

Sources variation	df	Mean squares	
		Fresh weight of the shoots per plant	Dry weight of the shoots per plant
Total	26		
Block	2	30.563	1.562
Planting material (P)	2	54.000	1.301
Spacing (S)	2	31279.189 *	2746.352 *
Interaction (P x S)	4	5.547	0.504
Error	16	39.715	3.330

* Significant at 5 % level

APPENDIX VII

Analysis of variance for the effect of spacing and planting material on the yield of plumbagin per plant, per plot and per hectare

Sources of variation	df	Mean squares		
		Yield of plumbagin per plant	Yield of plumbagin per plot	Yield of plumbagin per hectare
Total	26			
Block	2	0.000059	0.023	0.028
Planting material (P)	2	0.000001	0.010	0.012
Spacing (S)	2	0.00706 *	8.303 *	10.250 *
Interaction (P x S)	4	0.000027	0.020	0.024
Error	16	0.000045	0.047	0.058

* Significant at 5 % level

EFFECT OF SPACING AND PLANTING MATERIAL ON THE GROWTH, YIELD AND ACTIVE PRINCIPLE IN *Plumbago rosea* L.

By

SUBHA, S.

ABSTRACT OF A THESIS

Submitted in partial fulfilment of
the requirement for the degree of

Master of Science in Horticulture

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Department of Plantation Crops & Spices.
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ABSTRACT

Investigations on "Effect of spacing and planting material on the growth, yield and active principle in Plumbago rosea L." was conducted at the Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara during 1987-'88, using factorial RBD design for exploiting this valuable medicinal plant with the following objectives:

1. To standardise the size of shoots as planting material for commercial cultivation.

2. To standardise the best spacing for better growth, yield and active principle.

3. To explore the possibility of growing Plumbago rosea L. as a commercial crop.

4. To explore the possibility of grooming this plant as an annual plant.

The treatments included in the investigation were three types of planting materials (stem cuttings) viz., single node cuttings, two node cuttings and three node cuttings and three levels of spacing, viz. 50 x15 cm, 50 x 30 cm and 50 x 45 cm.

The cuttings were prepared from the semihardwood portions and were first planted in the nursery. Three months old rooted cuttings were transplanted to the

mainfield. The morphological characters studied in the present investigations were the height of the plant, spread of the plant, number of suckers per plant, average number of leaves per sucker, number of days taken for blooming, length and width of the leaves, average leaf area, internodal length and diameter of the stem. The yield parameters studied were length of the main root, diameter of the main root, yield of roots per plant (both on fresh weight and dry weight basis), yield of roots per plot (both on fresh weight and dry weight basis), yield of roots per hectare (both on fresh weight and dry weight basis), fresh weight of shoots per plant, dry weight of the shoots per plant, plumbagin content, yield of plumbagin per plant, yield of plumbagin per plot and yield of plumbagin per hectare.

The results indicated that spacing had significant influence on the height of the plants spread of the plants and yield characters. The widest spacing 50 x 45 cm registered the highest sread of the plants, yield of roots per plant (both on fresh weight and dry weight basis), yield of plumbagin per plant, fresh weight of shoots per plant and dry weight of shoots per plant. Whereas the closest spacing 50 x 15 cm was superior to the other spacings with respect to the height of the plants, yield of roots per plot and per hectare (both on fresh weight and on dry weight basis), yield of plumbagin per plot and per hectare. However, spacing did not influence the percentage

of plumbagin which is the active principle of this plant.

The type of planting material and the interaction between spacing and planting material did not exert any significant effect on any the characters studied.

Cost benefit analysis indicated a net income of Rs.14,754/= per hectare could be obtained from this crop.

The study revealed the possibility of commercial cultivation of Plumbago rosea L. using stem cuttings as planting materials at closer spacing. A high density planting is ideal for higher productivity and higher net return.