STUDIES ON THE EFFECT OF PLANT POPULATION DENSITY AND AGE AT TRANSPLANTING ON THE GROWTH, FREQUENCY OF HARVEST AND TOTAL VEGETATIVE YIELD IN AMARANTHUS
(*Amaranthus gangeticus* Linn.)

By

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THESIS

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE

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DECLARATION

I hereby declare that this thesis entitled "Studies on the effect of plant population density and age at transplanting on the growth, frequency of harvest and total vegetative yield in amaranthus (Amaranthus gangeticus Linn.)" is a bonafide record of research work done by me during the course of research 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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25-3-1980.

CERTIFICATE

Certified that this thesis, entitled "Studies on the effect of plant population density and age at transplanting on the growth, frequency of harvest and total vegetative yield in amaranthus (*Amaranthus gangeticus* Linn.)" is a bonafide record of research work done independently by Smt. SULEKHA, G.R. 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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INTRODUCTION

INTRODUCTION

Amaranth, believed to be a native of India, is one of the most popular and cheap leafy vegetables. All parts of this plant are used for culinary preparations. In countries like U.S.A., amaranth has been recognised as a "grain crop". Amaranth has received increased scientific attention in recent years and has been recognised as a "bypassed" crop having scope for being groomed as a commercial crop particularly for its grain. Two international seminars on amaranth, the first in 1977 and the second in 1979 have been organised in U.S.A. to review the available knowledge and to spur research efforts in the crop. However in India, amaranth is still mainly grown for the vegetative portions. Desirable vegetable types have been selected by the progressive cultivators and these dominate the area under amaranth in India. Amaranth is a C_4 plant, one of a small group of plants that most efficiently capture and use available sunlight and atmospheric carbon (Cunard, 1977). The plant produces a great amount of vegetative material. Initially, the plant generates large quantities of sacculent green matter. However, as the season progresses the large stem and overgrown leaves become fibrous, pithy and unpalatable. Besides, appearance of inflorescence impeds further harvest. Final halt to harvest is always brought about by flowering. Thus for harvesting delicate tender vegetative portions, we have only a relatively short span of time.

Several attempts have been made to obtain increased total vegetative yield, better leaf/stem ratio, more number of harvests, better nutritional quality etc. Mohideen and Rajagopal (1975) found transplanting to delay flowering and to increase the total duration of the vegetative phase, thus making it possible to have more harvests and ultimately higher vegetative yields. However, information on the effect of age of seedlings (at transplanting) on the total yield, number of harvests, leaf/stem ratio etc. are lacking. It has been demonstrated that by adjusting the height of each cutting also, total yield and number of harvests can be increased. Control of population density has been shown to increase the yield in other related vegetable crops, besides permitting more number of harvests, increasing the proportion of marketable produce etc. (Halsey et al., 1967; Wiebe and Uhrland, 1970; Bradley et al., 1971; Esch, 1975; Kays, 1975 and Helling et al., 1977). Research efforts on these lines are also lacking in amaranth. Working out acceptable population densities that produce maximum yield as well as allow better management is of utmost importance in amaranth.

Such studies should be aimed at encouraging rapid initial growth, faster recouperation after each harvest, production of more tender side branches after each harvest, overall continuous production, lateness in flowering, accumulation of quality constituents etc.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The many species of the family Amaranthacaeae form an extremely diverse group of plants with world wide distribution. Several species, with a history of thousands of years of cultivation, have been used as vegetables or as grain producing plants. Grain amaranth reached a peak of popularity as a staple crop during the Mayan and Aztec periods in Central America. The amaranth grain has high nutritional value, containing 12-15% protein with a high lysine level. The young leaves of types selected for vegetable purpose are similar to spinach and other crops normally used as cooked greens. These types are widely grown in Asia. The yield potential for both grain and vegetable types appears similar to that of currently used vegetable and cereal crops. Amaranth is more widely used as potherb. Cultivated for vegetable use throughout the tropics and eastern Asia, it is considered one of the best tropical greens. Its mild flavour, good yields, ability to grow in hot weather and high nutritive value have made it a popular vegetable.

For getting increased harvest of vegetative portion per unit area per unit time, there are a number of ways. The important of them are judicious fertilization, growing selected varieties, regulating population density and transplanting at the correct age.

Studies documenting the history of grain amaranth shed little light on the crop cultural practices used. Direct seeding is done in the tropics with the onset of the rainy season. Overseeding followed by thinning as well as planting to a pre-decided stand are both found in traditional cultures. Amaranth seed is small (0.5 to 0.9 mg each) and must be placed shallow to assure germination. Since the seed is placed close to the surface, rain or irrigation water can wash them out. Transplanting has been attempted to eliminate this problem and also to assure a given density of strong seedlings.

Mohideen and Rajagopal (1975) investigated the effects of transplanting versus direct seeding on yields of *Amaranthus leucocarpus*. Yield of transplanted crop was significantly lower than that of a direct seeded crop. Transplanting is a convenient and accurate method for scientific research; but it is not a method feasible for commercial grain production. Overseeding and thinning may be used; but it is a less desirable alternative.

In a transplanted crop, the spacing as well as the age of the seedling determine the performance of the individual plants. A varietal-population trial reported from Pennsylvania (USA) gave the following results: For the densest population of 16,000 plants/acre *A. cruentus* yielded 825 lb of seed/acre and *A. hypochondriacus* yielded 1000 lb of seed/acre (Cunard, 1977). The yield increases to those levels were linear for both varieties. In his 'reader research trials' with *A. hypochondriacus* (the only species grown), the highest yielding population of 32,000 plants/acre produced 2.3 tons of seed/acre. Another density trial indicated that 20,000 plants/ha was the acceptable density for yield as well as stand management of A. hypochondriacus plant types (Feine et al., 1979).

The studies reported above were with grain amaranth. Population studies as well as studies on the effect of age at transplanting on the growth and yield of vegetable types of amaranth are few. Hence the following review traces the work on these and related aspects in other leafy and flower vegetables.

In brussels sprouts, Verheij (1970) established that plants grown at higher densities were taller and more slender than low density plants. His spacing experiments also revealed that yields of dry matter per square metre rose sharply with increasing plant density upto about four plants per square metre, above which there was little further increase. The average weight per plant, however showed the reverse trend and declined with closer spacing. Wiebe and Uhrland (1970) confirmed that closer spacing with early planting brought about higher yields in brussels sprouts. They stressed the point that the closer the spacing, the higher was the proportion of small sprouts. Wood (1970) found that close spacing delayed maturity and the sprouts on plants at wider spacing were overmature at the late harvests. As against the above findings, Jones (1972) recorded that with brussels sprouts cultivar 'Jade Cross', total dry matter production/unit area was unaffected by density.

He observed that increasing plant density did not affect dry matter distribution; but increased the number of smaller sprouts. MacLeod et al. (1978) reported that flavour strength increased when brussels sprouts were grown closer together.

Improvement in the percentage of marketable heads was a result of low population density in cabbage. Halsey et al. (1967) studied the influence of spacing on yields of cabbage and observed a general trend that increase in spacing resulted in increases in the percentage of marketable heads and the average weight per head. Shumaker (1969) also reported that wider spacing increased the average weight of head and the percentage of marketable yield. However, in an earlier study, Jaghav and Sreenivas (1968) had found significant yield increment at closer spacing in the same crop and this they ascribed solely to the higher plant density. It is not reported by these workers whether the observed yield increment at closer spacing was a result of increased average weight of heads per se or due to increased population density. Akratanakul et al. (1977) reported that wider spacing of cabbage plants increased the weight of both axillary heads and main heads in an open-pollinated cultivar and an inbred line; weight of axillary heads increased more than that of the main head. They also found that transplanting greatly decreased the development of axillary heads compared with direct seeding.

Population studies have been reported in lettuce also. Ririe (1972) observed that at the lowest spacing, stand losses were greatest, yield tended to decline and head size was adversely affected. Similar results have been reported by Esch (1975) who came to the conclusion that in autumn lettuce, yield/m^2 was highest at the closest spacing; but head size was greatest at the widest spacing. This view also received support from the findings of Hendrix (1976) that head size was inversely related to plant number/m^2 with all the lettuce cultivars tried.

Similar studies have been reported in spinach, another leafy vegetable. Bradley et al. (1971) reported that when two cultivars of spinach were planted under different spacings, yields were much higher in the closer rows. According to Choudhury et al. (1974) yield significantly increased with close spacing in spinach. Wilhelm (1976) reported that close spacing shortened the growth period of leaf vegetables (e.g. Spinach).

Spacing trial in another leafy vegetable, New Zealand spinach (Tetragonia expansa Murr.) by Kays (1975) revealed that the closest of the three spacings (row spacing 20, 40 and 60 cm) yielded the highest average rate of production/unit area, as in other crops.

Population density trials have been reported in asparagus. In an asparagus spacing trial Wiebe (1966) observed highly significant yield differences due to spacing. Kauffmann (1968) reported that the total and marketable yields of asparagus were highest with the closest spacing and fell with decreasing plant density. However, his findings revealed that plants from the closest spacing were of poor quality. Bannerot *et al.* (1969) and Blassinsky (1969) also made similar observations. Regarding age of seedlings, Helling *et al.* (1977) recommended one-year old transplants to two year old plants because yields of green asparagus from both types were similar. Pinkau *et al.* (1978) revealed that closer spacing (49300 plants/ha) compared with (24700 plants/ha) between rows in asparagus, reduced the yield/plant; but increased the marketable yield/ha.

Because of cultural similarities between leafy and flower vegetables, work done on these lines in flower vegetables are also reviewed here.

The size of cauliflower transplants in relation to field performance was examined by Whitwell and Crofts (1972) who indicated that large transplants matured earlier than small transplants. It was suggested that transplants with a fresh weight of no more than 8.0 g are most likely to give satisfactory crops. In their studies on age at transplanting of cauliflower seedlings, Georgieva and Genkov (1973) observed that at the same transplanting date the youngest seedlings gave the highest yields. Though Salter *et al.* (1975) found that spacing had no effect on variability in time of curd initiation within crops of two cauliflower varieties, Skapski (1975) stressed that larger spacings significantly enhanced earliness in cauliflower. Thompson and Taylor (1975) grew cauliflower cultivars 'Finney's 110' and 'Kangaroo' at five population densities (between two and forty-three plants/m^2 each) in a square arrangement and also at three densities within this range in rows 71 cm apart. 'Finney's 110' gave greater yields than 'Kangaroo' for all comparable treatments apart from the lowest population density of each spatial arrangement. Yields of Finney's 110 increased considerably with increased density, whereas those of Kangaroo changed little or declined. Curd diameter was reduced as density increased and differed for the two cultivars only at the higher densities, Finney's 110 then having the greater diameter. For both cultivars, quality was adversely affected by increasing the population and wide rows yielded less than the square arrangement. Honma and Bert (1977) conducted a trial with cauliflower cultivar 'Snow Diana' grown at several different densities. They observed that the differences in total yield/acre were slight. Average curd size and weight, however were greatest with the widest spacings (18" x 36" and 18" x 30") and declined markedly at closer spacings. At the closest spacing (12" x 12"), however, maturity was advanced and by 28 August, 82.0 per cent of the total crop could be harvested, compared with 71.6 per cent for the widest spacing. Garner (1978) compared planting densities of winter hardy cauliflower cultivars 'Armado', 'Tardo' and 'June Glory' ranging from 21277 to 68966 plants/ha. Increasing density upto 47847 plants/ha increased yields. It has been suggested that the optimum profit margin can be obtained from densities around 35000 plants/ha. At higher densities, curd size was reduced and quality defects occurred.

Population density trials with broccoli gave findings more or less similar to those in cauliflower. Tereshkovich (1969) reported that 'Primo F_1 hybrid' broccoli plants at closer spacings produced lighter and smaller heads than the plants at wider spacing. Wider spacing increased the average head weight and the percentage of marketable yield. Late transplanting caused premature heading and total loss in broccoli. The percentage of premature heads was also increased by the use of large transplant sizes (Baggett and Mack, 1970). Palevitch (1970) reported that higher total and marketable yields were obtained by increasing the plant population density to as high as ten to eleven plants/m^2, especially in nearly equidistant spacing in broccoli. According to Cutcliffe (1971), crop maturity in broccoli was retarded as plant populations increased. In 1975 he observed that the yields increased and spear weight decreased as the distance between broccoli plants decreased from 50.8 x 50.8 cm to 20.3 x 20.3 cm.

In a related crop, marrow-stem kale (Brassica oleracea L.), Jhonston (1971) observed that the effects of plant density were significant for all the characters studied, except for stem and leaf yields. Willhelm (1979) planted kale plants at three densities (40 x 40 cm, 20 x 20 cm or 20 x 5 cm) in mid May, at the end of June, at the beginning of July or at the beginning of August. The tallest plants with most green leaves/plant were from the widest spaced plants and the earliest planting date. Plants at the closer spacing had more yellow leaves (which were produced earlier) at the base than plants at lower densities. The degree of leaf curling increased until mid summer and was maintained thereafter. The firmness of leaves increased until autumn and then decreased. The dry matter and the carbohydrate contents were lower in summer than in winter. In autumn, the decrease in yield/area was compensated for by an increase in dry matter content.

In Chinese Kale (Brassica alboglabra), Wong and Lee (1974) observed that transplanting at two weeks after sowing resulted in more vigorous plant growth and higher marketable fresh weight yield with greater mineral content than direct seeding. They reported that decreasing plant spacing within the row from 30 cm to 20 cm and 10 cm resulted in a progressive increase in fresh weight yield/ha and this was due mainly to a greater number of plants/ha.

In khol-rabi, a vegetable where the stem is the edible portion, Burg (1971) observed that dense plantings were the most profitable despite lower price fetched by the 'bulbs'. Persumably, the lower price per bulb was compensated by their larger number. Seitz and Lubitz (1973) were also of the opinion that the narrower spacings not only gave higher yields but also higher returns. Although the closest planting produced the highest yields and returns/unit area, it adversely affected earliness in kohl-rabi (Reimherr and Batz, 1971). Further closer spacings increased the proportion of low quality produce, retarded harvesting and raised expenditure (Reimherr and Batz, 1974).

Population density trials and trials on age at transplanting have been conducted in other vegetable crops which yield bulbs, roots and fruits. These works are reviewed hereunder, particularly to examine the trends of changes in yield and quality vis a vis population density and age at transplanting.

Bleasdale (1966) arrived at the conclusion that the total yield of ripe onion bulbs increased with increasing number of plants/sq.ft until an optimum was reached and thereafter the yield declined. Yu and Tseng (1966) from their studies using 25 to 60 day-old onion seedlings as planting material concluded that after transplanting the quickest growth, earliest maturity and largest bulbs were obtained with seedlings aged upto 30 days at planting. The lowest percentage of bulb division occurred in seedlings planted when 45 days old. Vik (1970) reported that with increasing plant density, maturity was advanced, yields were increased and bulb size was reduced. Storage quality was improved with increasing plant density. Verma et al. (1971) also studied the performance of bulb crop of onion as influenced by sowing dates and age of transplants. Seeds were sown on 1st, 8th, 15th or 22nd October and seedlings were transplanted when four, six, eight or ten weeks old. They observed that the earliest sowing date was the best in terms of yield and growth, eight week-old seedlings giving the highest yield. Frappel (1973) reported that at all densities there was a range of bulb size produced and as the density increased there was a progressive shift of the model size grade to smaller grades. Singh and Singh (1974) observed that when the seeds of onion cultivar 'Pusa Red' were sown on 16th October, 13th November, 11th December or 8th January and seedlings transplanted at the age of four, five, six or seven weeks, early sowing favoured leaf, root and bulb growth and gave the highest yield. They were of opinion that seedling age did not affect bulb yield; but seedlings aged five or six weeks performed better than the others and the bulbs they produced had a lower dry weight percentage. Randhawa and Singh (1974) reported that the closer spacing of 15 x 10 cm produced the maximum number of bulbs and higher bulb yield than wider spacing.

In a closely related crop garlic (cultivar 'Amarante'), there was an inverse correlation between spacing and yield as well as a direct correlation between spacing and average bulb weight (Menezes *et al.*, 1974). Om and Srivastava (1977) were also of the same opinion. They reported that maximum net return of garlic was obtained when planted at closer spacing.

A few studies on population density as influencing the performance of the resulting crop have been reported in carrot also, which is a direct sown crop. Abdel-Al (1974) observed that increasing populations enhanced the total yields and decreasing population increased individual root weight. Similar results have been obtained by Lipari (1975). He observed that there was a significant correlation between yield of marketable roots and plant density. But when yield was increased by a higher density of plants in the row, the number of unmarketable, deformed or immature roots increased and average weight of marketable roots fell. No significant differences were found for distance between rows. Root length, according to Bussel (1976), decreased as the plant population increased. Pavlek (1977) found a positive correlation between the number of plants and yield/ha. Similarly Dragland (1978) found that the total and the marketable yields rose with increasing plant density. The root size fell with increasing plant density; but the number of split or branched roots was not significantly affected by the plant spacing.

In the case of fruit vegetables (like tomato, chillies, peas and beans, etc.) also population density trials as well as transplanting studies have been carried out.

Loughton (1967) came to the conclusion that number of fruit per plant and fruit size in tomatoes decreased with increasing density. Seth and Choudhury (1970) reported that fruit and seed yields were not significantly affected by spacing in tomato cultivar, 'Pusa Ruby'. In glass house tomatoes, Amsen and Bredmose (1971) reported that yield/unit area rose with the increase in plant number/m^2. However, plant density did not affect earliness as a percentage of total yield; but did affect quality in that an increase in plant density reduced the average fruit size. Perry and Janick (1971) were also of the opinion that total fruit and total top yields increased asymptotically with increasing populations at all harvests in tomato. Similar observations were made by Postiglions (1972) that as the population increased individual fruit weight and total yield/plant fell. As far as Zahara and Timm (1973) were concerned, the leaf area/tomato plant reduced with increase in density. Differences in plant density had no significant effect on nutrient content of the plants. According to Rodriguez and Lambeth (1975) wide spacing with supplementary lighting increased the number of flowers, percentage fruit set, fruit size and total fruits/plant and contributed to greater early and total yields in tomato. The increases were related to increased apparent photosynthetic rate and efficiency. The relation between spacing and quality was studied by Meijndert (1976). He reported that tomato fruit quality was better at wider spacing especially with early planting. Fawusi (1977) from his density trials revealed that wide spacing delayed 50% flowering. As reported by the earlier workers, Gupta and Shukla (1977) also confirmed that closer spacing decreased the yield/plant; but increased the yield/ha in tomato. Yakovenko (1977) also reported that wider spacing resulted in significant yield decrease in two cultivars of tomato.

Chillies which closely resemble tomatoes in its cultural requirements also behaved more or less in the same way. Boominathan et al. (1971) observed that chillies planted at 30 x 30 cm out-yielded those planted at the conventional spacing of 45 x 45 cm by about 21 per cent. According to Silva et al. (1971), reducing the spacing increased the total number of fruits; but reduced the number of fruits/plant and the average fruit weight. Verheij et al. (1973) reported that density planting pattern and row orientation influenced light interception by plants of Capsicum frutescens cultivar, 'Caroussel'; but only density affected the dry matter yield. The biological yield (dry matter/m^2) was stable over a wide range of higher densities; but the proportion of dry matter recovered in the fruit, the individual fruit weight and the proportion of red fruits declined with rising density. Lim and Wong (1975) studied the influence of seedling age at transplanting on the performance of chillies (Capsicum annuum). The seedlings transplanted three to four weeks after seeding were more vigorous in vegetative growth particularly top growth, and flowered and fruited earlier than those transplanted at five, six and seven weeks after seeding. Total yield of fruits of the younger transplants were also higher than that of older transplants. The higher yield was associated with higher total fruit number, shorter fruit length and greater fruit dry matter. Sinha (1975) observed that the highest Vitamin C content and lowest yields resulted from the widest spacing in chillies.

In still another solanaceous vegetable brinjal, Goldwasser et al. (1970) observed that close spacing increased both the total and the exportable yield; but there was an increase in the incidence of leaf disease and a reduction in the fruit size with increasing plant density. Close spacing was considered advantageous for production of brinjal for the export market.

In beans and peas also, density trials have been reported to give more or less similar results as in the case of other vegetables mentioned earlier.

Appadurai et al. (1967) observed that closer spacing resulted in highest leaf area index at flowering in kidney bean (Phaseolus vulgaris). From their findings they also revealed that at closer spacing the reduction in pod number and weight per plant was more than offset by the higher yields/ha. Another trial was carried out by Ramos and Camacho (1969) in the same crop and they came to the conclusion that with higher populations, plants grew taller but yielded less per plant and per pod. Similar results were reported by Edje et al. (1971) in canning beans. They reported that yield rose with decreasing row width and plant spacing. They also arrived at the conclusion that plant height decreased and number of pods/plant and seeds/pod increased with increased row width and plant spacing. Brandes et al. (1972) were of the opinion that the number of leaves and pods/plant became less with increase in density whereas the number of leaves and pods/unit area were enhanced in Phaseolus vulgaris. They further reported that the ratio of dry matter of each plant part to the number of leaves or pods showed almost constant values across planting densities and seasons. The relative contribution of the various plant parts to dry matter weight was approximately the same for all densities and both seasons. In snap beans, Tompkins et al. (1972) reported that plant height and date of flowering were little affected by densities; but colour intensity and uniformity were poorer and fibre content was usually greater with narrow rows. In 1973, Brades et al. reported that the leaf area/plant varied inversely with the plant population in Phaseolus vulgaris. Edje et al. (1974) reported that the net economic return from the densest stand was only marginally greater than that from the medium density stand in beans. In 1974, White and Anderson reported that as the plant population increased, vine length, full pods/plant and peas/pod were all reduced. At lower populations maturity was delayed by three days and there were more flat pods and immature peas.

In okra, a malvaceous vegetable, density studies have been reported by many. Commenting on the effect of planting density on okra yield, Kamalanathan et al. (1970) observed that an increase from one to two or three plants/hill reduced individual plant yield and vigour; but increased the overall yields. Two plants/hill spaced 60 x 20 cm were recommended for maximum economic returns. Grewal et al. (1974) observed that mature dry 'pod' numbers and weights and total fruit numbers/plant were highest with early sowing and wide spacing. Stalk diameter decreased with increasing density and plant stunting occurred at the highest density (Albregts et al., 1976) of okra.

Apart from vegetables, density studies on fodder beet, orchard grass, etc., (in which the vegetative portions are used) are also reviewed here:

In two cultivars of fodder beet, Vavilov *et al*. (1977) reported that the denser spacings produced smaller roots with higher sugar and dry matter contents. Dry matter yields with three plant densities (120,000; 80,000 and 50,000 plants/ha) were 6.67, 7.04 and 6.16 t/ha in the first cultivar and 7.57, 7.95 and 6.69 t/ha in the second cultivar. In orchard grass sward (*Dactylis glomerata*), Terai (1977) observed that dry matter yields/unit area were greater at high than low density plots in early growth stages. At later stages, dry matter yields decreased with increased density. It was concluded from his experiment that the yield and sowing density relationship depended on plant height at cutting and date and frequency of cutting.

MATERIALS AND METHODS

MATERIALS AND METHODS

The investigations were carried out at the Division of Horticulture, College of Agriculture, Vellayani during 1978-79.

The seeds of *Amaranthus gangeticus*, (a local red type) were obtained from the Instructional Farm, College of Agriculture, Vellayani and sown in a staggered manner to obtain seedlings of the required age levels for transplanting on the same day.

Experimental details

The trial was laid out as a 3^2 factorial experiment in Randomised Block Design with three replications.

Treatments

Three levels of spacing

S_1 = 10 x 10 cm or 100 cm^2

S_2 = 15 x 10 cm or 150 cm^2

S_3 = 20 x 10 cm or 200 cm^2

The spacings tried gave population densities of 480, 320 and 240 plants/plot or 100, 66.6 and 50 plants/m^2, respectively.

Three levels of age at transplanting

A_1 = 15 days after sowing

A_2 = 20 days after sowing

A_3 = 25 days after sowing

Replications - Three

Total number of plots - 27

Plot size	- 2.4 m x 2.0 m	Plot area	- 4.8 m^2
Net plot size		Net plot area	
S_1 = 2.30 m 1.90 m		4.370 m^2	
S_2 = 2.25 m x 1.90 m		4.275 m^2	
S_3 = 2.20 m x 1.90 m		4.180 m^2	

Cultivation.

Nursery preparation

After digging the soil to a depth of 30 cm and incorporating farm yard manure at the rate of 10 kg/m^2, raised nursery beds (3 m x 1 m) were formed. The seeds were broadcast in the prepared beds at the rate of 2.5 kg per hectare, after mixing with fine earth for obtaining uniform distribution. A thin layer (3 mm) of dry sand was spread over the seeds. Watering was done immediately using a rose can. BHC 10% dust was spread all around the nursery bed to guard against attack by ants and termites. The beds were watered regularly. The seeds started germinating in four days and germination was completed by about six days. The sowing of seeds was done in a staggered manner on the 15th, 20th and 25th January 1979 to produce seedlings of the three different age groups, namely 15, 20 and 25 days old at the time of transplanting. The seedlings were transplanted to the main field on the 9th February 1979.

Preparation of main field

The land was prepared by ploughing twice when a fine tilth was obtained. Plots of size 2.4 m x 2.0 m were formed with 30 cm spacing between plots.

Dried, powdered farm yard manure at the rate of 20 tonnes/ha was incorporated into the soil in each plot. According to Premnath (1976), fertilizers were applied at the rate of 27 kg nitrogen, 27 kg phosphorus and 54 kg potash/ha as basal dressing and 25 kg nitrogen after each cutting, as top dressing.

On 9th February 1979, healthy uniform seedlings of three different age groups were carefully uprooted and transplanted to the main field, by forming a small hole with a dibble, inserting the seedling into it and pressing the soil around the base of each seedling. Immediately after planting, shade was provided by planting twigs of glyricidia and the plants were watered. Shade was retained till the seedlings got established, i.e. for about three to four days. The plants were regularly watered and frequent weeding was also carried out.

Incidence of leaf feeding caterpillars was noticed ten days after transplanting and it was effectively controlled by spraying Malathion 0.1%.

<u>Sampling techniques</u>

Out of the three varying population densities, namely, 480, 320 and 240 plants per plot, 20, 15 and 10 plants, respectively were selected at random for recording the various biometric observations.

For chemical analysis, leaves and tender stem portions were washed with distilled water, air dried and the oven dried at 65°C. The dried leaves and stem were then separately powdered and used for the chemical analysis.

Observations.

The following observations were recorded at five day-intervals starting from ten days after transplanting and also at the time of first cutting.

1. Height of the plant

The height of plant was measured from the ground level to the top most leaf bud of all observational plants, averaged and expressed in centimeters.

2. Girth of the main stem

The girth of the main stem was measured using a non-elastic twine at the collar region of each plant, mean worked out and expressed in centimeters.

3. Number of branches

Total number of branches of each observational plant was counted and the average obtained for each plot.

4. Number of leaves

For each plot, the total number of leaves in the observational plants was counted and the average number recorded.

5. Spread of plant

Spread was obtained by taking the product of the distance between the terminal parts of the largest branches on both planes, averaged and expressed in square centimeters.

6. Individual leaf area

The area of the fourth, eighth and thirteenth leaves of each observational plant was measured graphically, the average for each plant calculated and recorded at the time of first cutting.

The following characters were recorded at the first harvest and subsequently at each cutting.

7. Frequency of harvest (cutting)

The presence of about 10 per cent flower primordia in the harvested portion was considered as the acceptable level for commercial purposes. Accordingly, the first cutting and subsequent cuttings were taken when about 10 per cent leaf axils showed presence of flower primordia. When more than 10 per cent flower primordia was seen initiated on the new sprouts as they grew, it was considered as non-acceptable for commercial purpose and hence further cutting was avoided.

Following the above criteria, cuttings were regulated and the frequency of harvest as well as the total number of cuttings possible were recorded.

8. Yield/plant

(a) Average yield/plant for each cutting:

This was arrived at by dividing the total yield of a plot by the number of plants, for each cutting.

(b) Total yield/plant upto three cuttings:

Yield/plant from the three cuttings were pooled and analysed.

(c) Total yield/plant from all possible cuttings (more than three cuttings wherever available):

The average yield per plant from all the possible number of cuttings in each treatment was totalled and recorded.

9. Yield/unit area

(a) Average yield/square metre:

Average yield/m^2 was obtained by dividing the plot yield by the net plot area.

(b) Total yield/m^2 upto three cuttings:

Yield/m^2 was pooled for three cuttings and analysed.

(c) Total yield/m^2 from all possible cuttings:

Grand total yield/m^2 for all the possible cuttings obtained from each treatment was recorded.

10. Weight of leaves/plant

(a) Average weight of leaves/plant for each cutting:

For each cutting, the average weight of leaves per plant was obtained as the weight of leaves per plot divided by the number of plants.

(b) Total weight of leaves/plant upto three cuttings:

The average weight of leaves per plant for each cutting was pooled inclusive of the third cut and the total recorded.

(c) Total weight of leaves/plant from all possible cuttings:

The average weight of leaves obtained from all the cuttings for each treatment was pooled and the grand total weight recorded.

11. Weight of stem/plant

(a) Average weight of stem/plant for each cutting:

For all individual cuts, the weight of stem/plant was recorded separately for each treatment by dividing the weight of stem by the number of plants.

(b) Total weight of stem/plant upto three cuttings:

The total yield of stem/plant from the three cuttings (common to all treatments) were taken together and recorded for analysis.

(c) Total weight of stem/plant from all possible cuttings:

The total yield from all the possible number of cuttings in each treatment was pooled and recorded.

12. Leaf/stem ratio

(a) Leaf/stem ratio for each cutting:

The ratio of leaf to stem was obtained by dividing the weight of leaves by the weight of stem and recorded for each harvest.

(b) Leaf/stem ratio upto three cuttings:

For each treatment, the leaf/stem ratio was obtained by taking into consideration the weight of leaves and stems in the three harvests.

(c) Leaf/stem ratio from all possible cuttings:

The leaf stem ratio from all the cuttings was obtained by taking into consideration the weight of leaves and stems from all the possible cuttings wherever applicable.

13. Dry weight of leaves and stem

The leaves and stem of known weight from the observational plants in each plot was dried separately for five hours at 65°C till two consecutive weights coincided. The final weight was expressed as percentage to the initial green weight.

14. Moisture content of leaves and stem

From the fresh weight and dry weight recorded, the percentage moisture content of leaves and stem was found out.

15. Iron content of leaves and stem

The iron content of the oven dried samples of leaf and stem from individual plot was estimated colorimetrically after digesting with concentrated sulphuric acid, nitric acid and perchloric acid (Jackson, 1958) and expressed as mg/100 g of dried leaves and stem. Iron content was estimated for three cuttings (common for all treatments).

16. Protein content of leaves and stem

The total nitrogen of the oven dried samples of leaves and stem from each plot for the three cuttings was estimated colorimetrically after digesting with concentrated sulphuric acid by following the method of Le-Poidevin and Robinson (1965). The nitrogen values were multiplied by the factor 6.25 to obtain the protein content of the leaves and stem (A.O.A.C., 1975). The values were expressed as percentage of the dry weight of leaves and stem.

17. Vitamin A content of leaves

Carotene content of fresh leaves from each plot for the three cuttings was estimated colorimetrically by following the method of Rao et al. (1968). The carotene values expressed in ~~International Units~~ µg/100 g. were divided by 0.6 to get the Vitamin A content of leaves IU (Vit A) (A.O.A.C., 1975). The values were then expressed as percentage of fresh weight of leaves.

Statistical analysis

Data relating to each character were analysed statistically by applying the technique of analysis of variance for 3^2 factorial experiment in randomised block design and the significance was tested by 'F' test (Panse and Sukhatme, 1957).

RESULTS

RESULTS

The results of analysis of data from field experimentation and laboratory estimation are presented below:

1. Height of the plant

Observations on height of the plant at the three spacings made at the 10th, 15th and 20th day after transplanting as well as at harvest are presented in Table 1a. When averaged over the three age groups, the medium spaced (S_2) plants were taller than the widely spaced (S_3) or closely spaced (S_1) plants at all stages of observation, except at 15th day after transplanting when S_1 plants were taller. At first harvest, though the S_2 plants were taller, the differences were not statistically significant (Table 1c, Fig.1, Appendix I).

Analysis of the height increment for five days from 10 to 15 days after transplanting revealed that at the closest spacing (S_1), plants grew taller and were superior to S_2 and S_3 plants which were on par. The analysis of the height increment between 10 and 20 days after transplanting also showed the same trend, though the differences between S_1 and S_2, and S_2 and S_3 plants were not statistically significant. The increment in height for the five days from 15 to 20 days after planting, when analysed showed no statistical difference between the spacings. However the medium spaced (S_2) plants exhibited a higher growth increment. This obviously accounted for the lessening of the difference in height of plants at the first cut (Table 1c, Fig.1, Appendix I).

Table 1a. Height of plants (cm) transplanted at different spacings (Mean over the replication and age groups)

Spacing	Days after transplanting 10	15	20	Harvest
S_1	16.29	26.45	38.34	46.98
S_2	17.51	26.00	38.87	48.32
S_3	17.07	24.23	35.73	46.86

S_1 - 10 x 10 cm
S_2 - 15 x 10 cm
S_3 - 20 x 10 cm

Table 1b. Height of plants (cm) belonging to different age groups (Mean over the replication and spacings)

Age group	Days after transplanting 10	15	20	Harvest
A_1	15.19	22.10	34.10	44.47
A_2	15.40	23.90	37.01	47.17
A_3	20.28	30.68	41.83	50.52

A_1 - 15 day old
A_2 - 20 day old
A_3 - 25 day old

Table 1c. Height of plants belonging to three age groups planted at three population densities.

Treatments	Mean increment from 10 to 15 DAP (cm)	Mean increment from 15 to 20 DAP (cm)	Mean increment from 10 to 20 DAP (cm)	Mean height at the time of first cut (cm)
S_1A_1	8.23	11.06	19.29	41.97
S_1A_2	10.46	14.11	24.56	48.73
S_1A_3	11.80	10.51	22.31	50.23
S_2A_1	7.17	13.03	20.00	46.40
S_2A_2	7.85	13.74	21.60	46.67
S_2A_3	10.64	11.83	22.47	51.90
S_3A_1	5.55	11.90	17.45	45.03
S_3A_2	7.21	11.48	18.69	46.10
S_3A_3	8.74	11.11	19.85	49.43
S_1	10.16	11.89	22.05	46.98
S_2	8.56	12.87	21.36	48.32
S_3	7.17	11.50	18.66	46.86
A_1	6.98	11.99	18.91	44.47
A_2	8.51	13.11	21.62	47.17
A_3	10.39	11.15	21.54	50.52
C.D.(P=0.05)				
S and A means	1.513	2.428	3.340	4.600
S x A means	2.620	4.206	5.790	7.970

DAP - Days After Transplanting

S_1 - 10 x 10 cm
S_2 - 10 x 15 cm
S_3 - 10 x 20 cm

A_1 - 15 day old
A_2 - 20 day old
A_3 - 25 day old

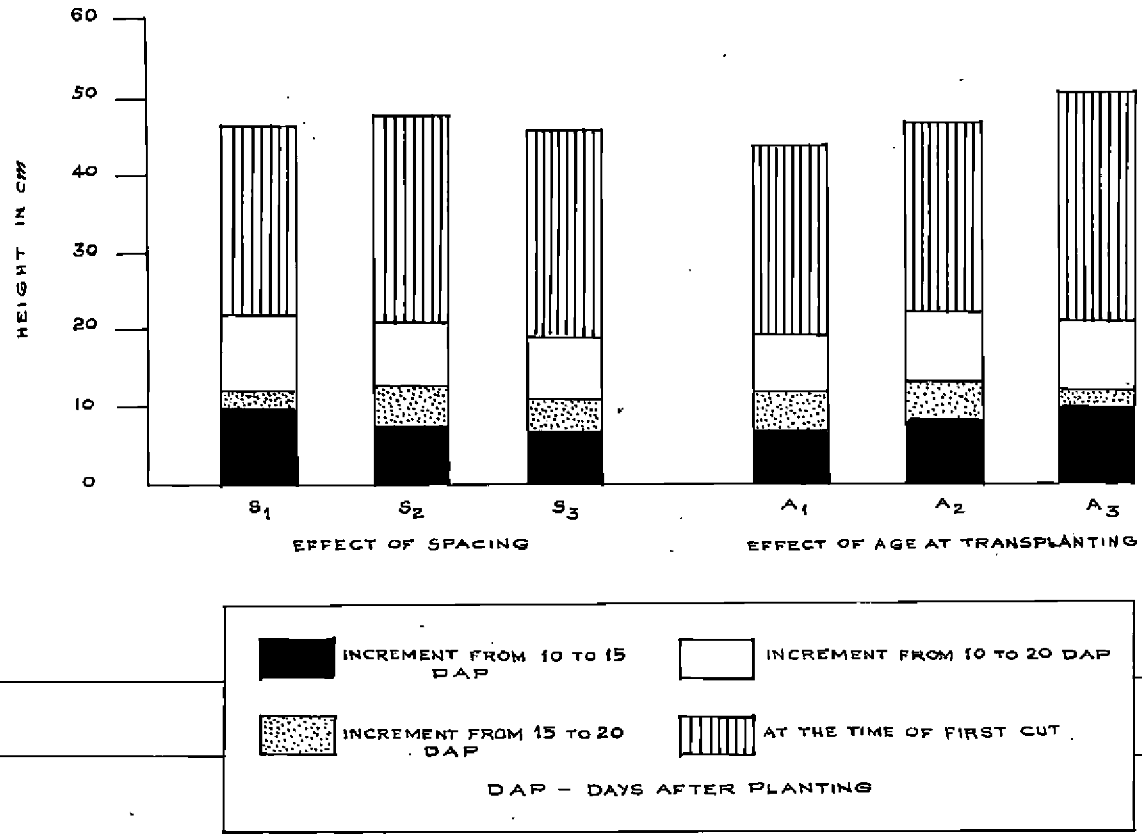


FIG. 1

GIRTH OF MAIN STEM AT COLLAR REGION

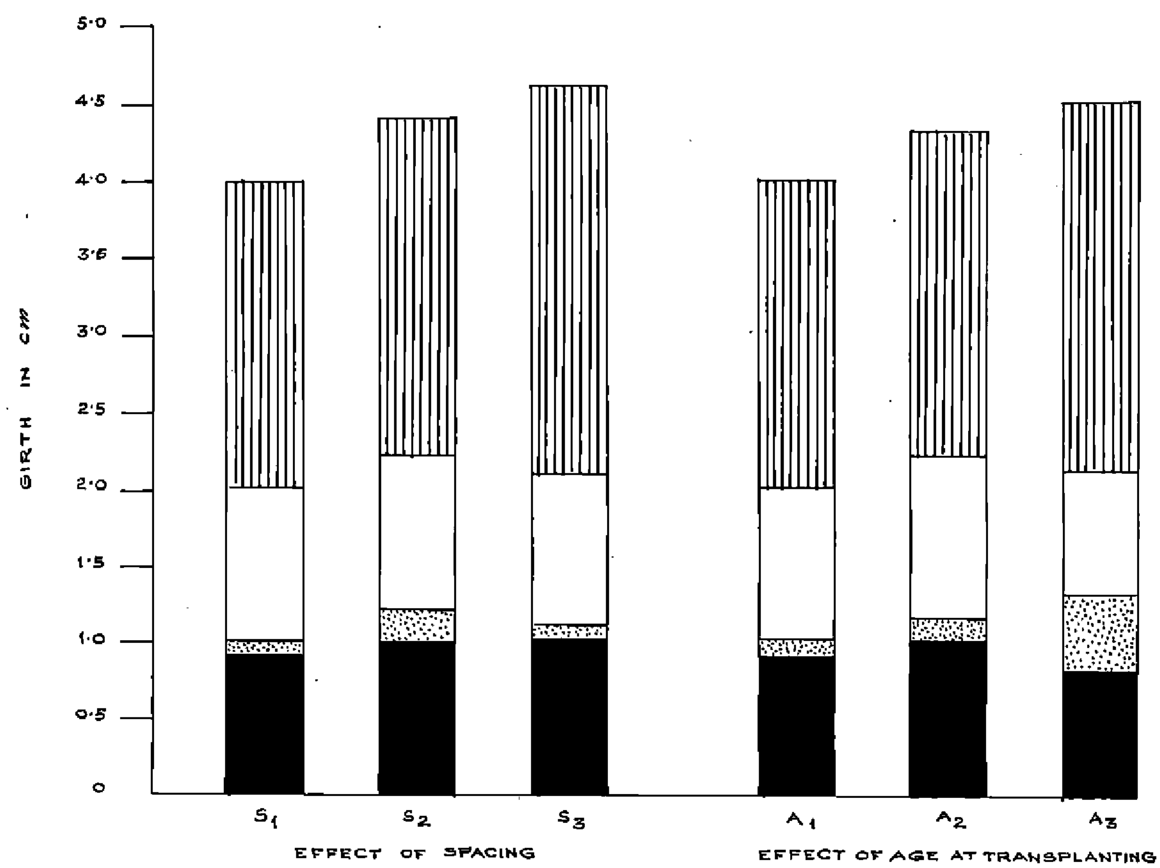


FIG. 2

The height of plants belonging to the three age groups averaged over the three spacings indicated that older plants were taller (Table 1b). At harvest, the difference in height was significant between the youngest (A_1) and oldest (A_3) plants. Analysis of the height increment from 10 to 15 days after planting and 15 to 20 days after planting showed that though the increment was more in the A_3 plants, in the first five-day period, the middle aged (A_2) plants exhibited higher growth increment during the second five-day period (Table 1c, Fig.1, Appendix I). The overall increment was also higher for the A_2 plants. But the differences were not significant for the three age groups.

The height varied significantly at different levels of population densities and for the different age groups (at transplanting). However, there was no significant difference among the treatment combinations, revealing absence of interaction between spacing and age. The two factors thus acted independently.

2. Girth of main stem at collar region

Analysis as done in the height of plants was also done with the stem girth. The figures revealed that the medium spaced (S_2) plants recorded the highest stem girth during the first three observational stages namely 10 days, 15 days and 20 days after transplanting (Table 2a). At harvest, however, the widely spaced (S_3) plants exhibited higher stem girth as compared to the younger plants (S_2 and S_1 in that order), which

Table 2a. Girth of plants (cm) transplanted at different spacings (Mean over the replication and age groups)

Spacing	Days after transplanting 10	15	20	Harvest
S_1	1.54	2.62	3.55	3.95
S_2	1.56	2.84	3.80	4.40
S_3	1.53	2.67	3.72	4.59

S_1 - 10 x 10 cm
S_2 - 15 x 10 cm
S_3 - 20 x 10 cm

Table 2b. Girth of plants (cm) belonging to different age groups (Mean over the replication and spacing)

Age group	Days after transplanting 10	15	20	Harvest
A_1	1.44	2.43	3.49	4.08
A_2	1.42	2.57	3.65	4.33
A_3	1.78	3.13	3.93	4.54

A_1 - 15 day old
A_2 - 20 day old
A_3 - 25 day old

were on par (Table 2c, Fig.2, Appendix II).

The increment in the girth of the main stem with reference to the three spacings revealed that the S_2 and S_3 plants exhibited higher incremental rates during the first five days and second five days respectively. During the first five-day period (10 to 15 days after transplanting), the incremental rate between S_2 and S_3 plants was not significantly different (Table 2c, Fig.2, Appendix II). In the second five day period, the three spacings were on par with regard to the stem girth.

Seedlings belonging to the three age groups, averaged over the three spacings exhibited a general trend of higher thickness of stem with increase in age (Table 2b). The increment was more in older plant (A_3) followed by that in middle aged (A_2) and younger plants (A_1) (Table 2c, Fig.2, Appendix II). The difference was statistically significant. During the second observation period, namely between 15 and 20 days after transplanting, there was a slowing down of the girth increment in older plants. During this stage the middle aged plants exhibited maximum girth increment, though not significantly different from that exhibited by younger plants. Overall increment between 10 to 20 days after planting showed no significant difference between the three groups of plant.

With regard to the stem girth also there was no statistically significant difference between the treatment combinations. The two factors seemed to have acted independently.

Table 2c. Stem girth of plants belonging to three age groups planted at three population densities.

Treatments	Mean increment from 10 to 15 DAP (cm)	Mean increment from 15 to 20 DAP (cm)	Mean increment from 10 to 20 DAP (cm)	Mean girth at first cut (cm)
S_1A_1	0.98	0.97	1.96	3.80
S_1A_2	1.04	1.18	2.22	3.93
S_1A_3	1.21	0.63	1.84	4.13
S_2A_1	1.14	1.06	2.20	4.12
S_2A_2	1.24	0.97	2.21	4.37
S_2A_3	1.46	0.83	2.29	4.73
S_3A_1	0.86	1.14	2.00	4.32
S_3A_2	1.17	1.07	2.24	4.69
S_3A_3	1.39	0.92	2.31	4.76
S_1	1.08	0.93	2.00	3.95
S_2	1.28	0.95	2.23	4.40
S_3	1.14	1.05	2.18	4.59
A_1	0.99	1.06	2.05	4.08
A_2	1.15	1.07	2.22	4.33
A_3	1.36	0.79	2.15	4.54
C.D.(P=0.05)				
S and A means	0.153	0.219	0.262	0.481
S x A means	0.264	0.379	0.454	0.833

DAP - Days After Transplanting

S_1 - 10 x 10 cm A_1 - 15 day old
S_2 - 10 x 15 cm A_2 - 20 day old
S_3 - 10 x 20 cm A_3 - 25 day old

3. Number of branches

As done in the girth of main stem at coller region, analysis was also done with the number of branches. During the first three observational stages, namely 10, 15 and 20 days after transplanting, the data indicated that the medium spaced (S_2) plants produced the largest number of branches (Table 3a). At harvest, however, the medium spaced (S_2) plants exhibited the largest number of branches as compared to the closely spaced (S_1) plants and the differences were statistically significant. But the difference between the medium spaced and widely spaced (S_3) plants was not statistically significant (Table 3c, Fig.3, Appendix III).

Analysis of the increment in the number of branches for five days from 10 to 15 days after transplanting revealed that the S_2 plants exhibited the higher incremental rate than the S_1 plants, the difference being statistically significant. But the differences between S_2 & S_3 plants and S_3 & S_1 plants were not statistically significant. On the other hand the observations during the second five-day period revealed that the increment was more in the widely spaced (S_3) plants, the difference being statistically significant over the other two spacings which were on par (Table 3c, Fig.3, Appendix III). The overall increment from 10 to 20 days after planting revealed that the two wider spacings (S_3 and S_2 in that order) exhibited highest increment in the number of branches than the closely spaced (S_1) plants, the differences being statistically significant.

Table 3a. Number of branches of plants transplanted at different spacings (Mean over the replication and age groups)

Spacing	Days after transplanting 10	15	20	Harvest
S_1	1.80	6.02	7.34	8.86
S_2	1.87	6.66	8.28	10.16
S_3	1.68	6.03	8.26	9.64

S_1 - 10 x 10 cm
S_2 - 15 x 10 cm
S_3 - 20 x 10 cm

Table 3b. Number of branches of plants belonging to different age groups (Mean over the replication and spacings)

Age group	Days after transplanting 10	15	20	Harvest
A_1	1.36	5.19	7.24	8.61
A_2	1.44	5.89	7.72	9.21
A_3	2.54	7.43	8.91	10.85

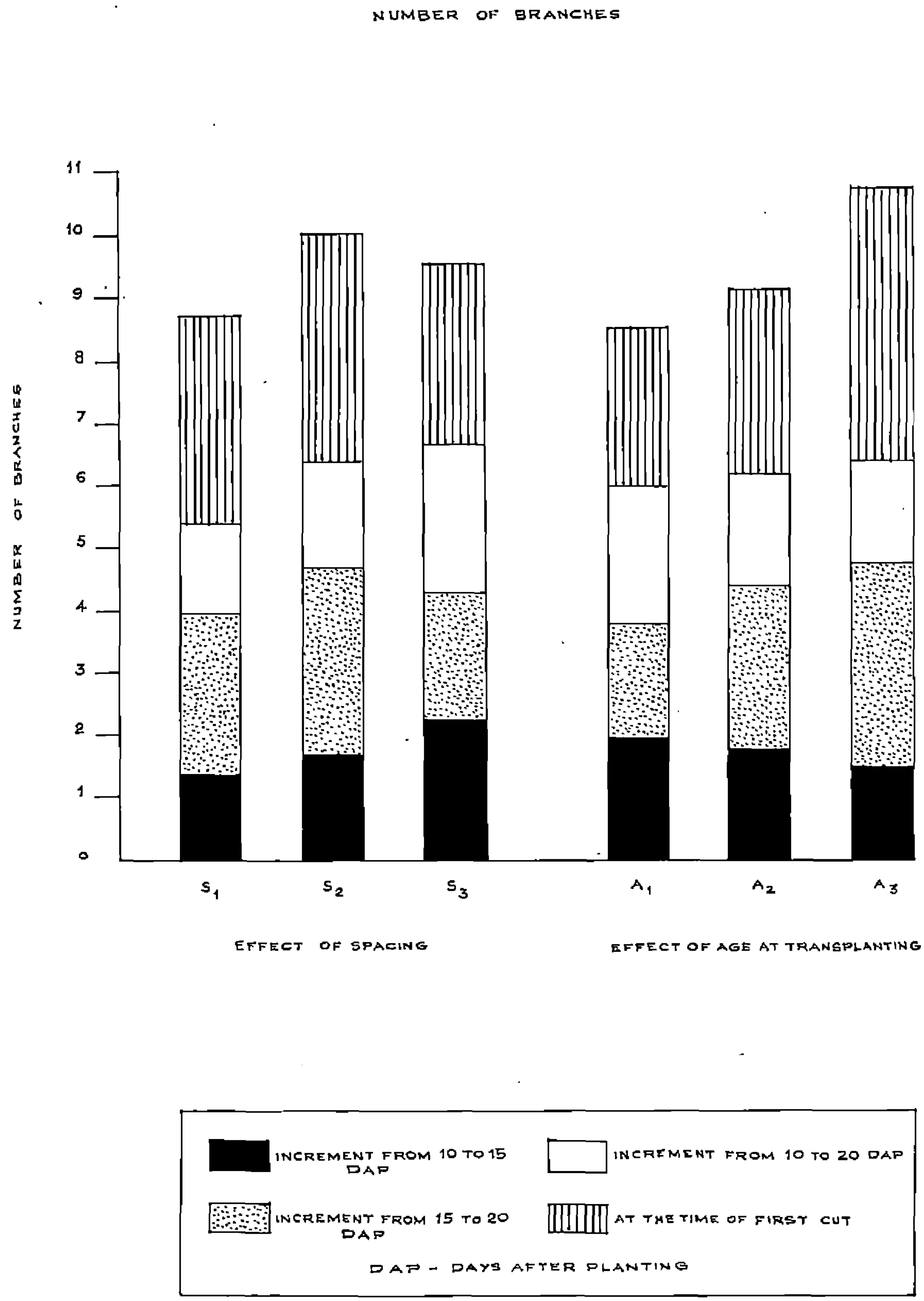
A_1 - 15 day old
A_2 - 20 day old
A_3 - 25 day old

Table 3c. Number of branches in plants belonging to three age groups planted at three population densities.

Treatments	Mean increment in number from 10 to 15 DAP	Mean increment in number from 15 to 20 DAP	Mean increment in number from 10 to 20 DAP	Mean number at the time of first
S_1A_1	3.53	1.57	5.10	7.60
S_1A_2	4.10	1.30	5.40	8.60
S_1A_3	4.43	1.40	5.83	10.37
S_2A_1	4.50	1.99	6.50	9.57
S_2A_2	4.87	1.63	6.50	10.03
S_2A_3	5.00	1.23	6.23	10.87
S_3A_1	3.47	2.60	6.07	8.67
S_3A_2	4.37	2.57	6.93	9.00
S_3A_3	5.23	1.80	7.03	11.27
S_1	4.02	1.42	5.44	8.86
S_2	4.79	1.62	6.41	10.16
S_3	4.36	2.32	6.68	9.64
A_1	3.83	2.05	5.89	8.61
A_2	4.44	1.83	6.28	9.21
A_3	4.89	1.48	6.37	10.83
C.D.(P=0.05)				
S & A means	0.524	0.540	0.580	0.766
S x A means	0.908	0.936	1.000	1.330

DAP - Days After Transplanting

S_1 - 10 x 10 cm A_1 - 15 day old
S_2 - 10 x 15 cm A_2 - 20 day old
S_3 - 10 x 20 cm A_3 - 25 day old


NUMBER OF BRANCHES
NUMBER OF BRANCHES
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11
S1
S2
S3
A1
A2
A3
EFFECT OF SPACING
EFFECT OF AGE AT TRANSPLANTING
INCREMENT FROM 10 TO 15 DAP
INCREMENT FROM 10 TO 20 DAP
INCREMENT FROM 15 TO 20 DAP
AT THE TIME OF FIRST CUT
DAP - DAYS AFTER PLANTING

FIG. 3

Regarding the seedlings belonging to the three age-groups averaged over the three spacings, a general trend of increased number of branches with increase in age was observed (Table 3b). The increment in number of branches for the first five days from 10 to 15 days after transplanting showed that the two older age groups (A_3 and A_2 plants) showed the highest increment from the younger seedlings (A_1), the difference being statistically significant. But A_3 and A_2 plants were on par. The second five-day increment and the overall increment in the number of branches for ten days, both showed no statistical difference between the treatment means (Table 3c, Fig.3, Appendix III).

No statistically significant difference could be obtained between the different treatment combinations with regard to the number of branches. The two factors thus acted independently.

4. Number of leaves

During the three observational stages namely 10 days, 15 days and 20 days after transplanting, the figures for the number of leaves revealed that the medium spaced plants produced more leaves than the plants in the other two spacings (Table 4a). At harvest, the medium spaced (S_2) plants and widely spaced (S_3) plants produced significantly larger number of leaves than the closely spaced (S_1) plants. But the difference between the former two spacings were statistically non-significant (Table 4c, Fig.4, Appendix IV).

Table 4a. Number of leaves of plants transplanted at different spacings (Mean over the replication and age groups)

Spacing	Days after transplanting 10	15	20	Harvest
S_1	13.27	28.89	35.30	39.44
S_2	13.49	33.97	42.29	49.26
S_3	12.60	30.02	41.46	46.52

S_1 - 10 x 10 cm
S_2 - 15 x 10 cm
S_3 - 20 x 10 cm

Table 4b. Number of leaves of plants belonging to different age groups (Mean over the replication and spacings)

Age group	Days after transplanting 10	15	20	Harvest
A_1	11.28	26.71	35.40	38.50
A_2	12.28	27.87	37.67	43.68
A_3	14.80	38.31	45.98	53.04

A_1 - 15 day old
A_2 - 20 day old
A_3 - 25 day old

For the first five days, S_2 plants exhibited a higher incremental rate than S_3 and S_1 plants which were on par. On the other hand, for the second five-day period, S_3 plants exhibited a higher incremental rate than the S_2 and S_1 plants which were on par. But the overall increment for the ten-day period from 10 to 20 days after transplanting showed that the S_3 and S_2 plants were on par, which in turn were statistically superior to the S_1 plants (Table 4c, Fig.4, Appendix IV).

Seedlings belonging to the three age groups, averaged over the three spacings exhibited a general trend of higher number of leaves with increase in age (Table 4b). The increment in number of leaves was more with the older seedlings (A_3) during the first five days from 10 to 15 days after planting. The difference was statistically significant over the middle aged seedlings (A_2) and the younger seedlings (A_1) which were on par. But during the second five day period (15 to 20 days after planting), the increment in the number of leaves showed no statistical significance between the different age groups (Table 4c, Fig.4, Appendix IV). The overall increment for ten days revealed that A_3 plants were statistically superior to A_2 and A_1 plants which were on par.

Between the different treatment combinations no statistical difference was obtained for the number of leaves. Thus it seemed that the two factors were acting independently and there was no interaction between them.

Table 4c. Number of leaves in plants belonging to three age groups planted at three population densities.

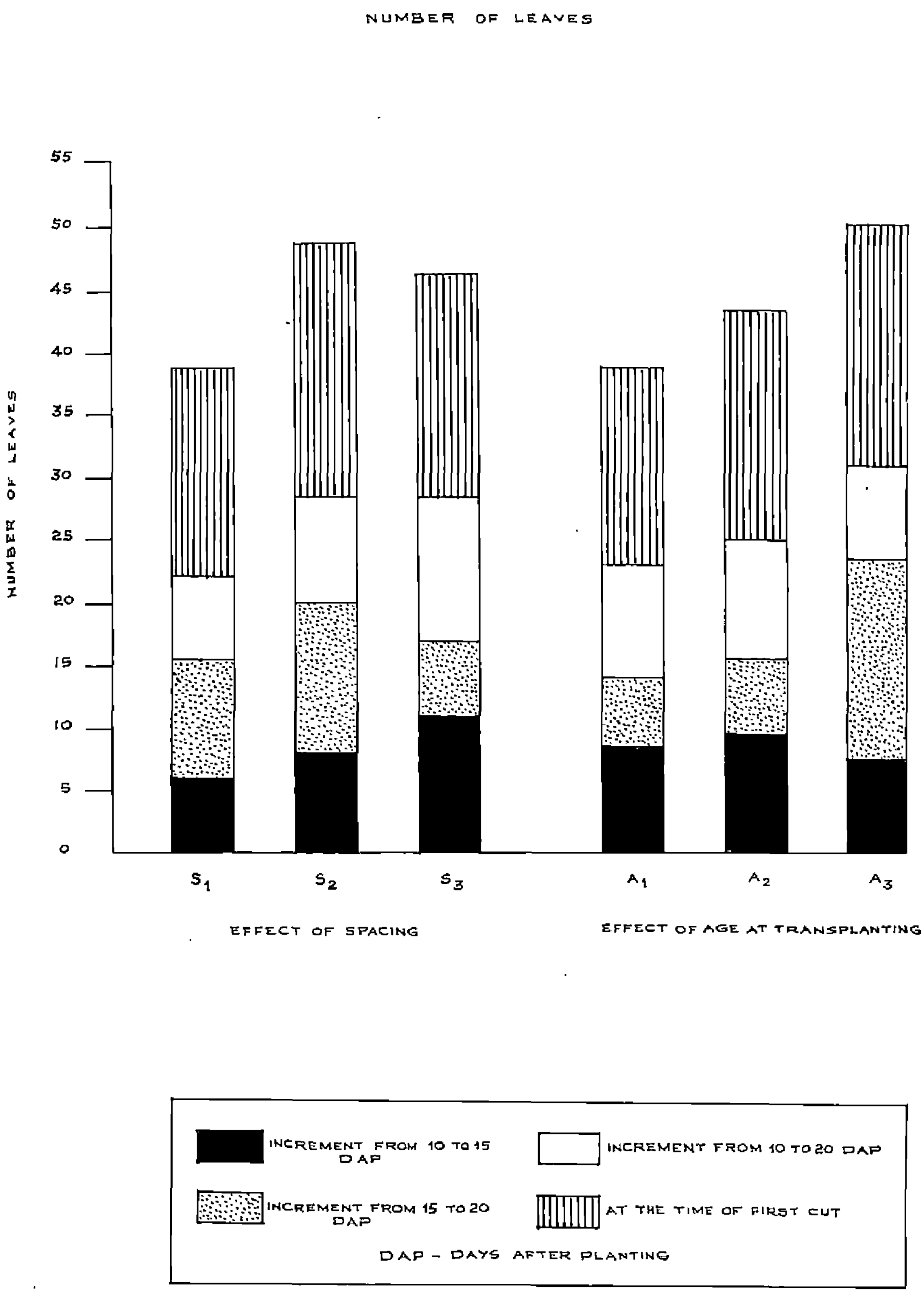
Treatments	Mean increment in number from 10 to 15 DAP	Mean increment in number from 15 to 20 DAP	Mean increment in number from 10 to 20 DAP	Mean number of leaves at first cut
S_1A_1	12.47	6.77	19.23	32.10
S_1A_2	14.20	7.77	21.97	30.93
S_1A_3	20.20	4.70	24.90	47.90
S_2A_1	18.79	6.72	25.50	45.33
S_2A_2	17.03	9.90	26.93	44.90
S_2A_3	25.63	8.33	33.97	57.53
S_3A_1	12.03	12.60	24.63	38.07
S_3A_2	15.53	11.73	27.27	47.20
S_3A_3	24.70	9.97	34.67	54.30
S_1	15.62	6.41	22.03	39.44
S_2	20.48	8.32	28.80	49.26
S_3	17.42	11.43	28.86	46.52
A_1	14.43	8.69	23.12	38.50
A_2	15.59	9.80	25.39	43.68
A_3	23.51	7.67	31.18	53.04
C.D.(P=0.05)				
S and A means	3.04	3.34	4.02	7.69
S x A means	5.26	5.79	6.97	13.33

DAP - Days After Transplanting

S_1 - 10 x 10 cm A_1 - 15 day old

S_2 - 10 x 15 cm A_2 - 20 day old

S_3 - 10 x 20 cm A_3 - 25 day old


NUMBER OF LEAVES
NUMBER OF LEAVES
55
50
45
40
35
30
25
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15
10
5
0
S1
S2
S3
A1
A2
A3
EFFECT OF SPACING
EFFECT OF AGE AT TRANSPLANTING
INCREMENT FROM 10 TO 15 DAP
INCREMENT FROM 10 TO 20 DAP
INCREMENT FROM 15 TO 20 DAP
AT THE TIME OF FIRST CUT
DAP - DAYS AFTER PLANTING

FIG. 4

5. Spread of plant

The spread of the plant was also analysed at various stages. The figures during the first two observational stages (10 and 15 days after planting) revealed that the medium spaced plants (S_2) gave the largest spread. At the 20th day after planting, the widely spaced plants (S_3) recorded the largest spread (Table 5a). At the time of harvest, S_3 and S_2 plants recorded significantly larger spread than the closely spaced (S_1) plants. However the difference between S_3 and S_2 plants were not significant (Table 5c, Fig.5, Appendix V).

The increment for the first and second five-day periods, exhibited no statistical differences between the three different spacings averaged over the three age groups. But the analysis of the overall increment from 10 to 20 days after planting revealed that S_3 and S_2 plants recorded the highest incremental rate than the S_1 plants (Table 5c, Fig.5, Appendix V).

As a general trend, for the different age groups (averaged over the three spacings) the spread of plants increased with increase in age of seedlings during the first three observational stages (Table 5b). But at harvest, though there was no statistically significant difference between the three different age groups, the middle aged (A_2) plants exhibited slightly larger spread than the oldest (A_3) plants (Table 5c, Fig.5, Appendix V). For the first five days from 10 to 15 days after planting, the increment in spread was the

Table 5a. Spread of plants (cm^2) transplanted at different spacings (Mean over the replication and age groups)

Spacing	Days after transplanting			
	10	15	20	Harvest
S_1	335.78	920.26	1201.50	1230.12
S_2	342.80	1012.22	1373.14	1545.71
S_3	299.45	961.53	1374.97	1715.29

S_1	- 10 x 10 cm
S_2	- 15 x 10 cm
S_3	- 20 x 10 cm

Table 5b. Spread of plants (cm^2) belonging to different age groups (Mean over the replication and spacings)

Age group	Days after transplanting			
	10	15	20	Harvest
A_1	260.63	825.66	1203.78	1449.94
A_2	287.98	900.81	1329.73	1526.76
A_3	429.43	1167.54	1416.11	1514.42

A_1	- 15 day old
A_2	- 20 day old
A_3	- 25 day old

Table 5c. Spread of plants belonging to three age groups planted at three population densities.

Treatments	Mean increment from 10 to 15 DAP (cm^2)	Mean increment from 15 to 20 DAP (cm^2)	Mean increment from 10 to 20 DAP (cm^2)	Mean at the time of first cut (cm^2)
S_1A_1	507.47	270.74	778.21	1141.93
S_1A_2	581.08	448.53	1029.61	1355.63
S_1A_3	664.89	124.45	789.34	1192.80
S_2A_1	636.26	351.62	987.88	1487.73
S_2A_2	646.17	398.01	1044.18	1534.70
S_2A_3	725.83	333.14	1058.97	1614.70
S_3A_1	551.38	512.00	1063.41	1720.17
S_3A_2	611.25	440.21	1051.46	1689.93
S_3A_3	823.63	288.10	1111.73	1735.77
S_1	584.48	281.24	865.72	1230.12
S_2	669.42	360.92	1030.34	1545.71
S_3	662.08	413.44	1075.53	1715.29
A_1	565.04	378.12	943.17	1449.94
A_2	612.83	428.92	1041.75	1526.76
A_3	738.11	248.57	986.68	1514.42
C.D.(P=0.05)				
S and A means	120.105	129.798	161.810	227.690
S x A means	208.028	224.816	280.260	394.360

DAP - Days After Transplanting

S_1 - 10 x 10 cm A_1 - 15 day old
S_2 - 10 x 15 cm A_2 - 20 day old
S_3 - 10 x 20 cm A_3 - 25 day old

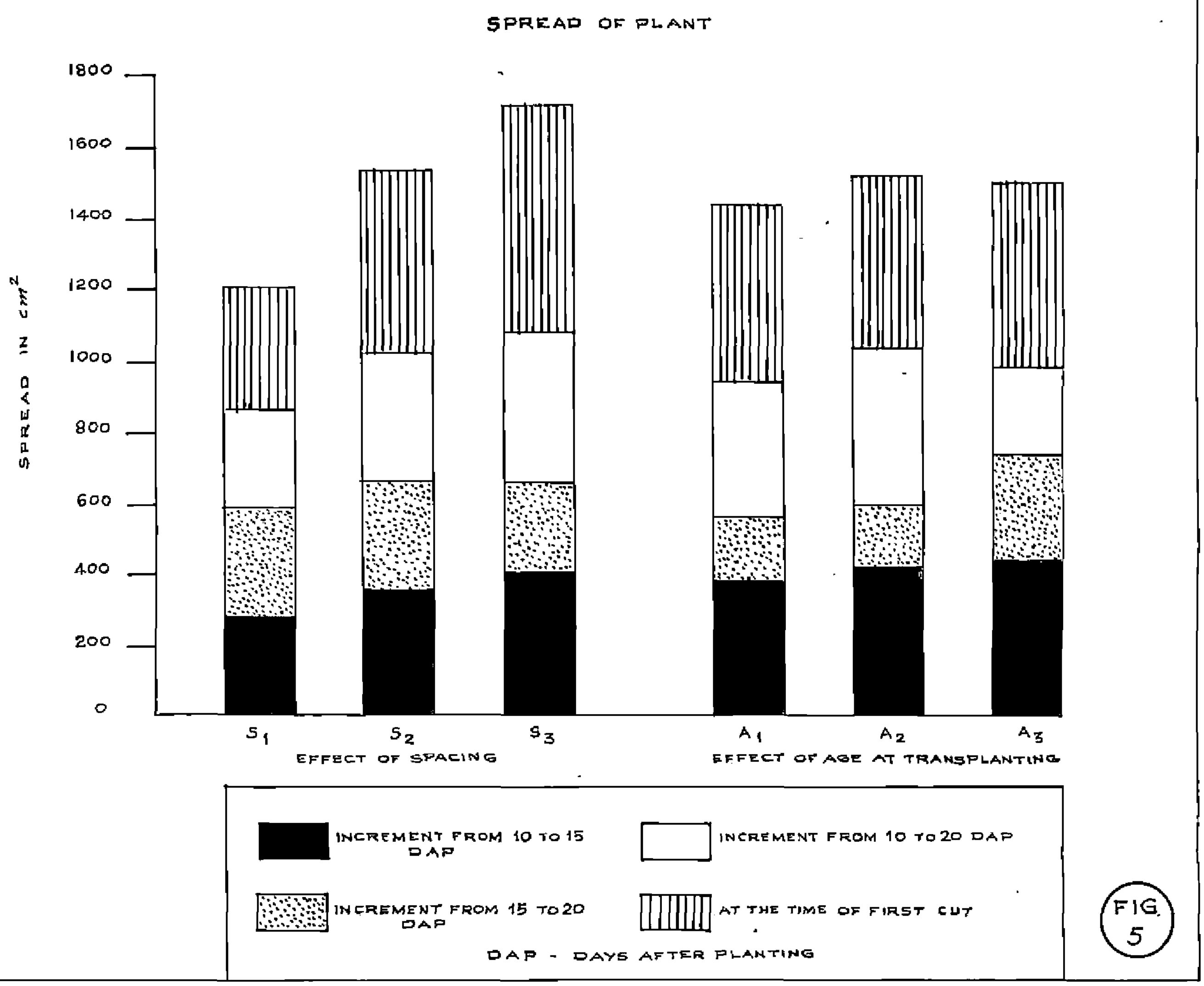

SPREAD OF PLANT
SPREAD IN cm^2
1800
1600
1400
1200
1000
800
600
400
200
0
S_1
S_2
S_3
A_1
A_2
A_3
EFFECT OF SPACING
EFFECT OF AGE AT TRANSPLANTING
INCREMENT FROM 10 TO 15 DAP
INCREMENT FROM 10 TO 20 DAP
INCREMENT FROM 15 TO 20 DAP
AT THE TIME OF FIRST CUT
DAP - DAYS AFTER PLANTING

FIG. 5

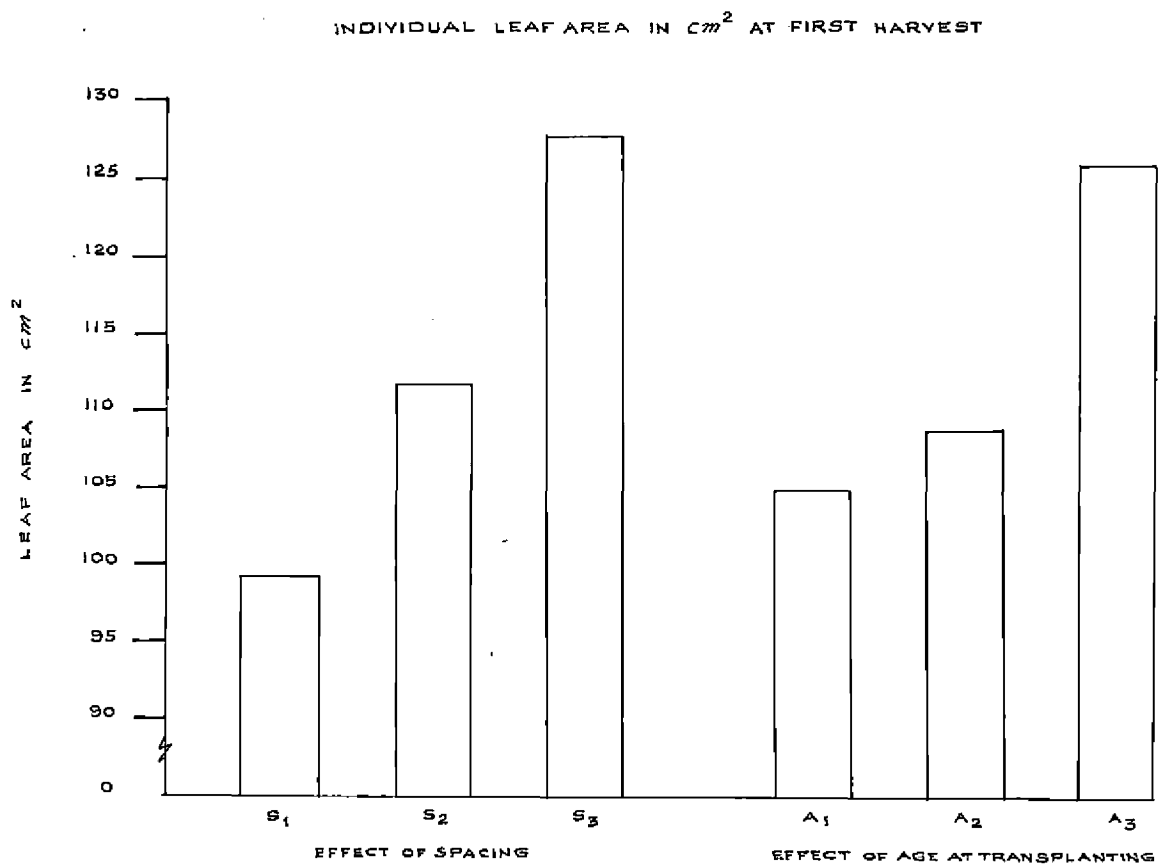

INDIVIDUAL LEAF AREA IN cm^2 AT FIRST HARVEST
LEAF AREA IN cm^2
130
125
120
115
110
105
100
95
90
0
S_1
S_2
S_3
A_1
A_2
A_3
EFFECT OF SPACING
EFFECT OF AGE AT TRANSPLANTING

FIG. 6

largest for the oldest seedlings (A_3) than the middle aged (A_2) and younger (A_1) seedlings. The differences between A_3, A_2 and A_1 plants were statistically significant. But during the second five-day period (15 to 20 days after planting), the incremental rate was the least for the A_3 plants. A_2 and A_1 plants were on par (Table 5c). But the overall increment for ten days from 10 to 20 days after planting showed no statistically significant difference.

For the treatment combinations between spacing and age of seedlings at transplanting, no statistical significance could be obtained, revealing that there was no interaction between these two factors and that they were acting independently.

6. Individual leaf area

The individual leaf area was found to vary significantly for the different spacings averaged over all the three age-groups. Plants spaced at 10 x 20 cm, (S_3) when compared to the other two spacings, recorded the maximum leaf area (128.03 cm^2) accounting for 28.36 per cent increase over 10 x 10 cm (S_1) and 13.89 per cent over 10 x 15 cm (S_2) spacing. But S_2 and S_1 were on par (Table 6, Fig.6, Appendix VI).

Regarding age of seedlings at transplanting, the 25 day old (A_3)seedlings averaged over the three spacings recorded a significant increase in leaf area compared to those of the other two age-groups. The youngest, 15 day old (A_1) seedlings recorded the least, the marginal means being 104.96 cm^2, 109.07 cm^2 and 125.16 cm^2 for 15, 20 and 25 day old seedlings.

Table 6. Individual leaf area of plants belonging to three age groups planted at three population densities

Treatments	Mean individual leaf area (at first cut) cm^2
S_1A_1	90.18
S_1A_2	95.73
S_1A_3	113.30
S_2A_1	102.77
S_2A_2	101.55
S_2A_3	132.91
S_3A_1	121.93
S_3A_2	129.93
S_3A_3	132.24
S_1	99.74
S_2	112.41
S_3	128.03
A_1	104.96
A_2	109.07
A_3	126.15
C.D.(P=0.05)	
S and A means	14.98
S x A means	25.95

S_1 - 10 x 10 cm
S_2 - 10 x 15 cm
S_3 - 10 x 20 cm

A_1 - 15 day old
A_2 - 20 day old
A_3 - 25 day old

respectively (Table 6, Fig.6, Appendix VI).

7. Frequency of harvest

Harvesting was done when the crop exhibited more than 10 per cent floral initiation. The number of days taken by each treatment for attaining the harvestable stage have been recorded in Table 7 (Fig.7, Appendix VII). Plants at the closest spacing (S_1) showed earlier initiation of flower primordia than those at the widest spacing (S_3), the medium spacing (S_2) coming in between. Plants at S_1, S_2 and S_3 spacings were harvested on the average at 21.67, 22.67 and 27.44 days after transplanting, respectively. Thus the plants at closer spacing attained harvestable stage earlier than those at the other two spacings. The same trend was reflected for the subsequent cuts also. The interval between the first and the second cut was 7.33, 9.00, 11.67 days for S_1, S_2 and S_3 plants respectively. The corresponding figures for the third cut was 6.00, 7.00 and 9.33 days respectively. In certain treatments more than three harvests were possible. Those treatments which produced more than three cuts also exhibited the same trend in the initiation of 10 per cent flower primordia which was fixed as the criterion for harvest. The treatment combinations S_2A_1, S_2A_2, S_3A_1 and S_3A_2 gave four cuts and S_3A_1 and S_3A_2 gave five cuts each. It was evident that the plants at the lower population densities (wide and medium spacing) gave more number of cuttings when compared to those at the highest population density (close spacing).

Table 7. Frequency of harvest of plants belonging to three age groups planted at three population densities.

Treatments	First cut Frequency of harvest (days)	Second cut Frequency of harvest (days)	Third cut Frequency of harvest (days)	Fourth cut Frequency of harvest (days)	Fifth cut Frequency of harvest (days)
S_1A_1	23	7	7	-	-
S_1A_2	22	8	5	-	-
S_1A_3	20	7	6	-	-
S_2A_1	25	10	8	6	-
S_2A_2	23	8	7	5	-
S_2A_3	20	9	6	-	-
S_3A_1	30	13	11	9	6
S_3A_2	27	12	9	9	5
S_3A_3	25	10	8	-	-
S_1	21.67	7.33	6.00	-	-
S_2	22.67	9.00	7.00	3.67	-
S_3	27.33	11.67	9.33	6.00	3.67
A_1	26.00	10.00	8.67	5.00	2.00
A_2	24.00	9.33	7.00	4.00	1.67
A_3	21.67	8.67	6.67	-	-
C.D.(P=0.05)					
S and A means	0.53	0.45	0.60	-	-
S x A means	1.02	0.92	1.54	-	-

S_1 - 10 x 10 cm $\quad$ A_1 - 15 day old

S_2 - 10 x 15 cm $\quad$ A_2 - 20 day old

S_3 - 10 x 20 cm $\quad$ A_3 - 25 day old

FREQUENCY OF HARVEST

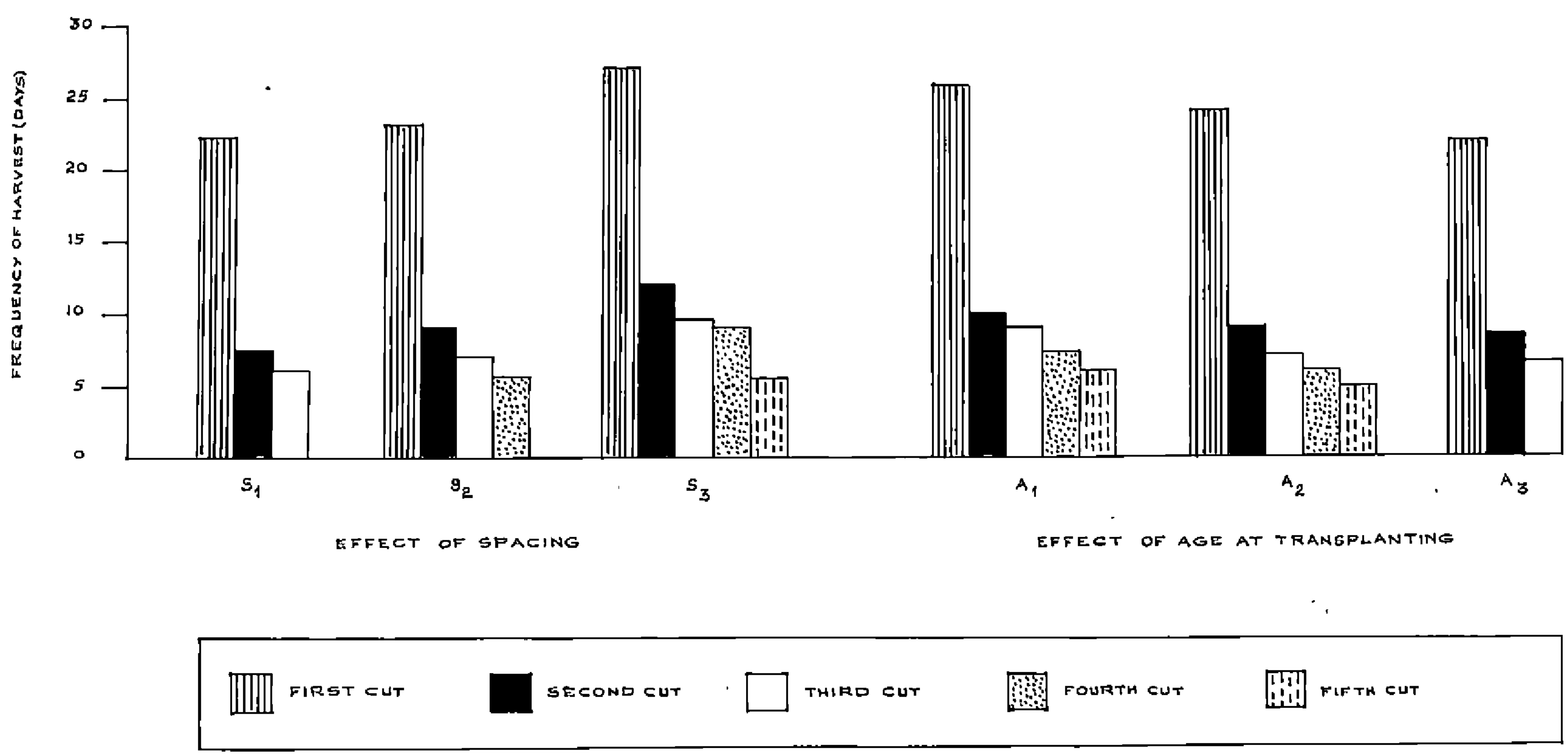


FIG. 7

Highly significant difference was observed in the frequency of harvest between the three different age groups (Table 7, Fig.7, Appendix VII). The 25 day old (A_3) seedlings planted at the three densities showed earlier initiation of flower primordia. The plants belonging to A_3, A_2 and A_1 groups took 21.67, 24.00 and 26.00 days, respectively to produce 10 per cent flower primordia for effecting the first harvest. The plants belonging to the same three age groups took 8.67, 9.33 and 10.00 days after the first cut for giving the second harvest. For the third cut, they took 6.67, 7.00 and 8.67 days, respectively, after the second cut. Those treatments that gave more than three cuts also showed the same trend; i.e. the younger the seedlings at transplanting, the more was the number of cuttings possible. Evidently, A_1S_2, A_1S_3 and A_2S_2 and A_2S_3 gave four cuts and A_1S_3 and A_2S_3 gave five cuts each.

8. <u>Yield/plant</u>.

During the first cut, plants at different spacings averaged over all the three age-groups showed that the widest spacing (S_3) gave the maximum yield/plant and was superior to the closest spacing (S_1). However, the S_3 plants were on par with those of S_2 and S_2 plants were not significantly different from S_1 plants with respect to yield/plant (Table 8, Fig.8, Appendix VIII). The widest spacing gave 48.02 per cent more yield than the closest spacing at the time of first harvest. But the differences were not significant during the second and third harvests. Yield per plant obtained from all the three cuts when pooled and analysed revealed that S_3 plants gave maximum yield followed by S_2 and S_1 plants, recording an increase of 31.79 per cent over S_1 plants. Though S_3 plants were superior to S_1 plants, they were on par with those of S_2 plants. In certain treatments, more than three cuts were possible. When the yield total from all the possible number of cuttings was analysed, S_3, S_2 and S_1 plants gave yields of 99.40, 76.77 and 62.82 g/plant, S_3 plants being statistically superior to S_2 and S_1 plants which were on par.

Analysis of yield of plants belonging to the three different age groups averaged over the three spacings did not give significant difference in the first and second harvests (Table 8, Fig.8, Appendix VIII). But for the third cut, the youngest seedlings (A_1) recorded the highest yield/plant and the difference between the A_1 plants and A_3 plants was statistically significant. However, there was no significant difference between the youngest (A_1) and middle aged (A_2) plants and middle aged and oldest (A_3) plants. Yield total from all the three cuts when pooled and analysed, showed no statistical significance. However, the yield total from all the possible cuttings revealed that the middle aged (A_2) plants gave significantly the higher yield/plant over the other two age-groups which were on par. The mean yield per plant during the entire growth period of A_1, A_2 and A_3 plants were 83.06, 85.26 and 70.67 g respectively.

Table 8. Yield/plant of those belonging to three age groups planted at three population densities.

Treatments	Mean weight of first cut in g	Mean weight of second cut in g	Mean weight third cut in g	Mean of three cuts in g	Mean of fourth cut in g	Mean weight of fifth cut in g	Mean weight of all cuts in g
S_1A_1	36.15	15.03	11.12	62.28	-	-	62.28
S_1A_2	38.03	17.60	12.87	68.51	-	-	68.51
S_1A_3	33.40	15.45	8.83	57.67	-	-	57.67
S_2A_1	39.63	16.35	12.69	68.67	10.58	-	79.26
S_2A_2	43.11	12.58	10.17	65.87	10.83	-	76.70
S_2A_3	51.50	13.13	9.73	74.36	-	-	74.36
S_3A_1	46.49	21.60	13.52	81.59	13.50	12.57	107.65
S_3A_2	59.23	16.30	11.29	86.82	12.33	11.42	110.57
S_3A_3	53.53	15.66	10.78	79.98	-	-	79.98
S_1	35.86	16.03	10.94	62.82	-	-	62.82
S_2	44.75	14.02	10.86	69.63	7.14	-	76.77
S_3	53.08	17.85	11.86	82.79	8.61	7.99	99.40
A_1	40.75	17.66	12.44	70.85	8.03	4.19	83.06
A_2	46.79	15.50	11.44	73.73	7.72	3.81	85.26
A_3	46.14	14.75	9.78	70.67	-	-	70.67
C.D.(P=0.05)							
S and A means	10.48	4.77	1.75	13.80	-	-	14.17
S x A means	18.15	8.25	3.03	23.90	-	-	24.54

S_1 - 10 x 10 cm S_2 - 15 x 10 cm S_3 - 20 x 10 cm

A_1 - 15 day old A_2 - 20 day old A_3 - 25 day old

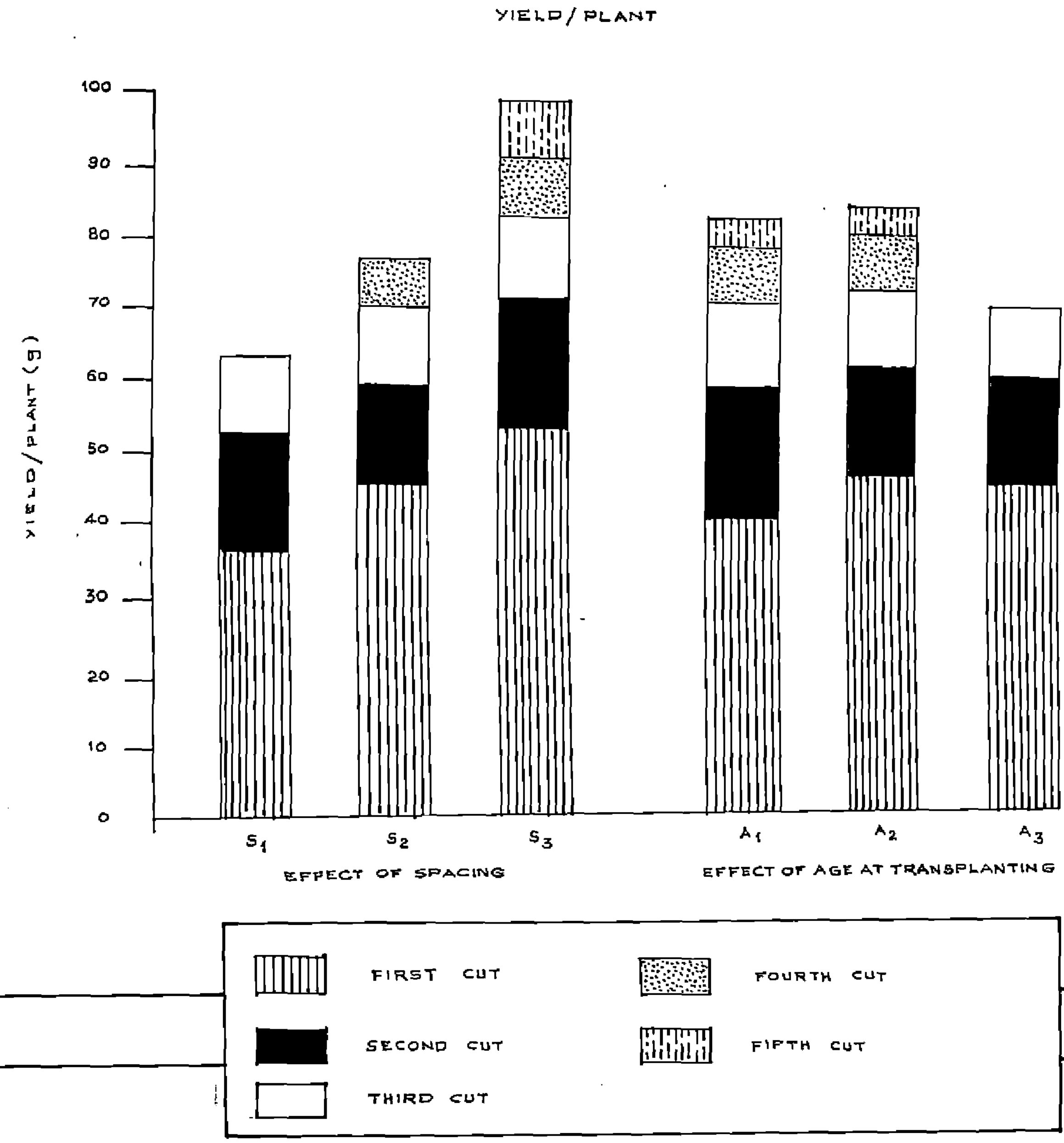

YIELD / PLANT
YIELD / PLANT (g)
100
90
80
70
60
50
40
30
20
10
0
S1
S2
S3
A1
A2
A3
EFFECT OF SPACING
EFFECT OF AGE AT TRANSPLANTING
FIRST CUT
SECOND CUT
THIRD CUT
FOURTH CUT
FIFTH CUT

FIG. 8

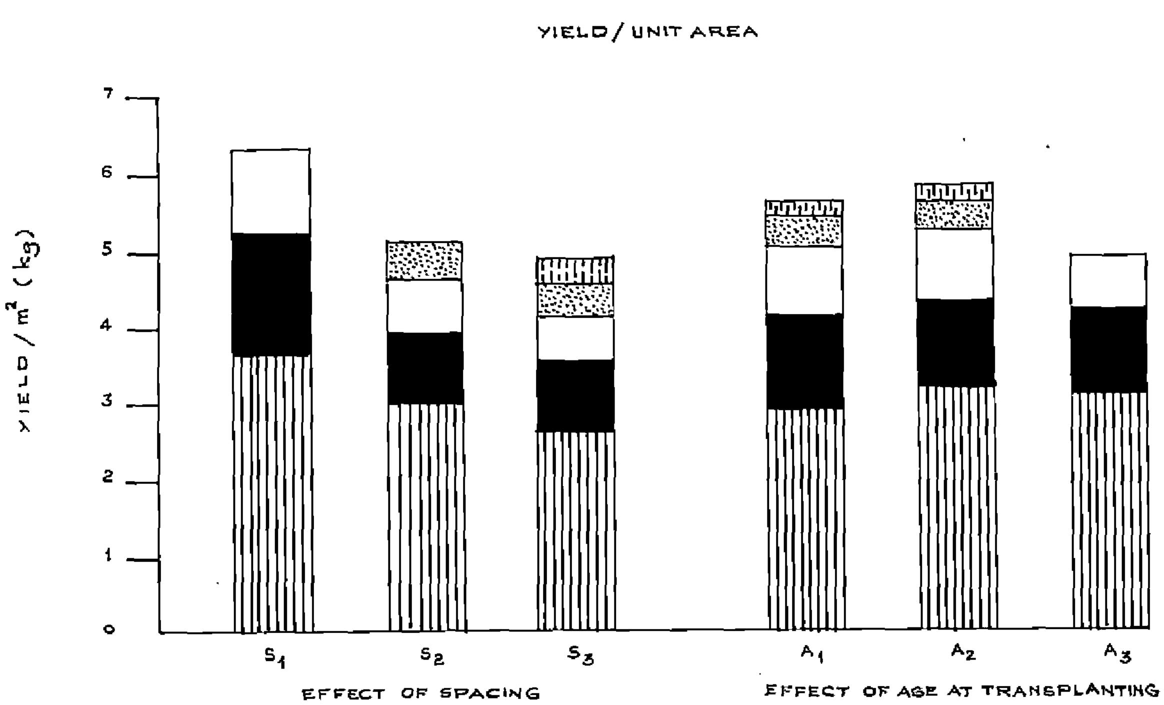

YIELD / UNIT AREA
YIELD / m² (kg)
7
6
5
4
3
2
1
0
S1
S2
S3
A1
A2
A3
EFFECT OF SPACING
EFFECT OF AGE AT TRANSPLANTING

FIG. 9

There was no statistical difference between the different treatment combinations. Thus it was concluded that there was no interaction between spacing and age of seedlings with reference to this character also.

9. <u>Yield/square metre</u>.

During the first and the second harvests, the closely spaced (S_1) plants recorded significantly higher yield/m^2 over the medium spaced (S_2) and widely spaced (S_3) plants, which were on par. However, for the third harvest, yield/m^2 rose with decrease in spacing. The differences between S_1, S_2 and S_3 plants were all statistically significant (Table 9, Fig.9, Appendix IX). The total yield from all the three cuts, as well as that from all the possible cuts showed the same trend as in the first and second harvests i.e. S_1 plants being statistically superior to S_2 and S_3 plants which in turn were on par. The mean yield/m^2 from all the possible cuts recorded by S_1, S_2 and S_3 plants were 6.28, 5.12 and 4.97 kg respectively.

The performance of seedlings belonging to the three age groups, averaged over the three spacings showed no significant differences during the first and second harvests. However, during the third cut, the younger (A_1) plants and middle aged (A_2) plants were statistically superior to the older (A_3) plants. The former two were statistically on par. Yield/m^2 from the three cuts taken together as well as that from all the possible cuts showed no statistically significant difference between the different treatment means (Table 9, Fig.9, Appendix IX).

Table 9. Yield/m^2 of plants belonging to three age groups planted at three population densities.

Treatments	Mean of first cut in kg	Mean of second cut in kg	Mean of third cut in kg	Mean of three cuts in kg	Mean of fourth cut (kg)	Mean of fifth cut (kg)	Mean weight of all cuts in kg
S_1A_1	3.61	1.50	1.11	6.23	-	-	6.23
S_1A_2	3.80	1.76	1.29	6.85	-	-	6.85
S_1A_3	3.34	1.54	0.88	5.77	-	-	5.77
S_2A_1	2.64	1.09	0.85	4.58	0.70	-	5.29
S_2A_2	2.88	0.84	0.68	4.40	0.72	-	5.12
S_2A_3	3.44	0.88	0.65	4.96	-	-	4.96
S_3A_1	2.32	1.08	0.68	4.08	0.68	0.63	5.38
S_3A_2	2.96	0.82	0.56	4.34	0.62	0.57	5.53
S_3A_3	2.68	0.78	0.54	3.99	-	-	4.00
S_1	3.59	1.60	1.09	6.28	-	-	6.28
S_2	2.99	0.94	0.72	4.64	0.46	-	5.12
S_3	2.65	0.89	0.59	4.14	0.43	0.40	4.97
A_1	2.86	1.22	0.88	4.96	0.46	0.21	5.63
A_2	3.21	1.14	0.84	5.20	0.45	0.19	5.83
A_3	3.15	1.07	0.69	4.91	-	-	4.91
C.D. (P=0.05)							
S and A means	0.815	0.393	0.123	1.140	-	-	1.140
S x A means	1.498	0.680	0.212	1.970	-	-	1.970

S_1 - 10 x 10 cm S_2 - 15 x 10 cm S_3 - 20 x 10 cm

A_1 - 15 day old A_2 - 20 day old A_3 - 25 day old

There existed no interaction between spacing and age at transplanting with regard to yield/m^2. The two factors thus acted independently.

10. Average weight of leaves/plant.

During the first cut, the widely spaced (S_3) plants recorded the highest average weight of leaves/plant and they were statistically superior to the medium spaced (S_2) plants as well as to the closely spaced (S_1) plants which were on par (Table 10, Fig.10, Appendix X). But for the second and third harvests, no statistically significant differences could be obtained between the three different spacings. The average weight of leaves/ plant from all the three cuts, when pooled and analysed showed that the S_3 plants were statistically superior to S_2 and S_1 plants which were on par. The total yield from all the possible cuttings revealed highly significant differences between S_3, S_2 and S_1 with a mean weight of 61.01, 44.71 and 36.49 g/plant respectively.

Plants belonging to the different age groups, averaged over the three spacings showed no statistically significant difference for the first and second harvests. But during the third harvest, there existed statistical difference between the younger (A_1) and older (A_3) plants. But the younger plants and middle aged (A_2) ones were on par and so also were A_2 and A_3 (Table 10, Fig.10, Appendix X). The yield from all the three cuts when taken together and analysed showed no statistically significant difference. However, the total yield

Table 10. Average weight of leaves/plant of those belonging to three age groups planted at three population densities.

Treatments	Mean of first cut (g)	Mean of second cut (g)	Mean of third cut (g)	Mean of three cuts (g)	Mean of fourth cut (g)	Mean of fifth cut (g)	Mean of all cuts (g)
S_1A_1	16.93	11.43	8.55	36.91	-	-	36.91
S_1A_2	16.57	12.79	9.83	39.19	-	-	39.19
S_1A_3	15.73	10.83	6.80	33.37	-	-	33.37
S_2A_1	17.23	12.22	9.93	39.38	8.00	-	47.38
S_2A_2	17.15	9.62	7.95	34.72	8.50	-	43.22
S_2A_3	26.54	9.40	7.58	43.52	-	-	43.52
S_3A_1	21.00	16.00	10.82	47.82	14.28	10.40	69.17
S_3A_2	27.60	12.13	8.36	48.09	9.50	9.17	66.76
S_3A_3	28.67	10.03	8.41	47.10	-	-	47.10
S_1	16.41	11.68	8.39	36.49	-	-	36.49
S_2	20.31	10.41	8.49	39.21	5.50	-	44.71
S_3	25.76	12.72	9.20	47.67	7.93	6.52	61.01
A_1	18.39	13.21	9.77	41.37	7.43	3.40	51.15
A_2	20.44	11.51	8.71	40.67	6.00	3.06	49.72
A_3	23.65	10.09	7.59	41.33	-	-	41.33
C.D.(P=0.05)							
S and A means	4.99	3.53	1.18	8.03	-	-	8.26
S x A means	8.64	6.11	2.04	13.91	-	-	14.31

S_1 - 10 x 10 cm S_2 - 15 x 10 cm S_3 - 20 x 10 cm

A_1 - 15 day old A_2 - 20 day old A_3 - 25 day old

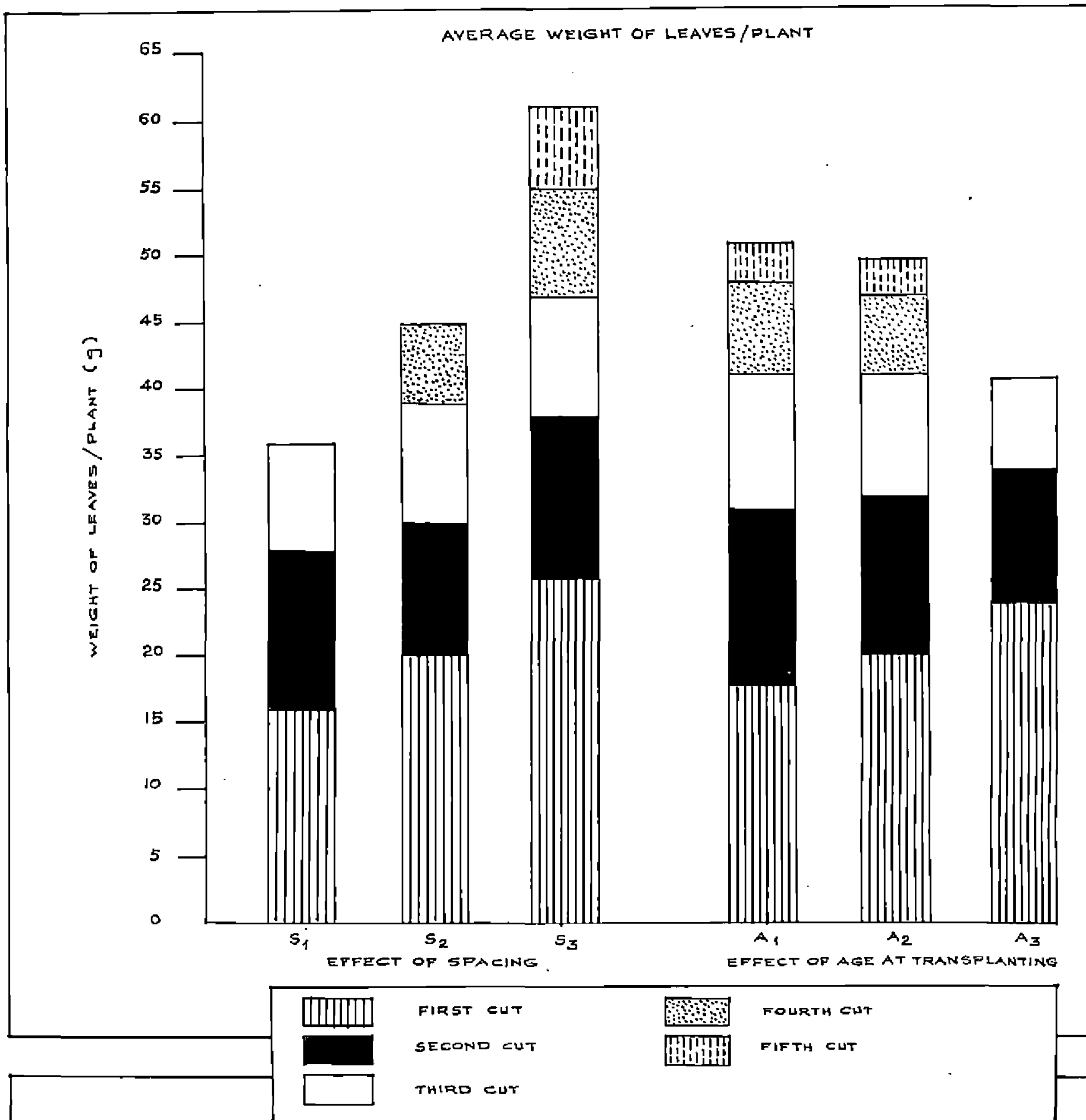

AVERAGE WEIGHT OF LEAVES/PLANT
WEIGHT OF LEAVES/PLANT (g)
65
60
55
50
45
40
35
30
25
20
15
10
5
0
S1
S2
S3
A1
A2
A3
EFFECT OF SPACING
EFFECT OF AGE AT TRANSPLANTING
FIRST CUT
SECOND CUT
THIRD CUT
FOURTH CUT
FIFTH CUT

FIG. 10

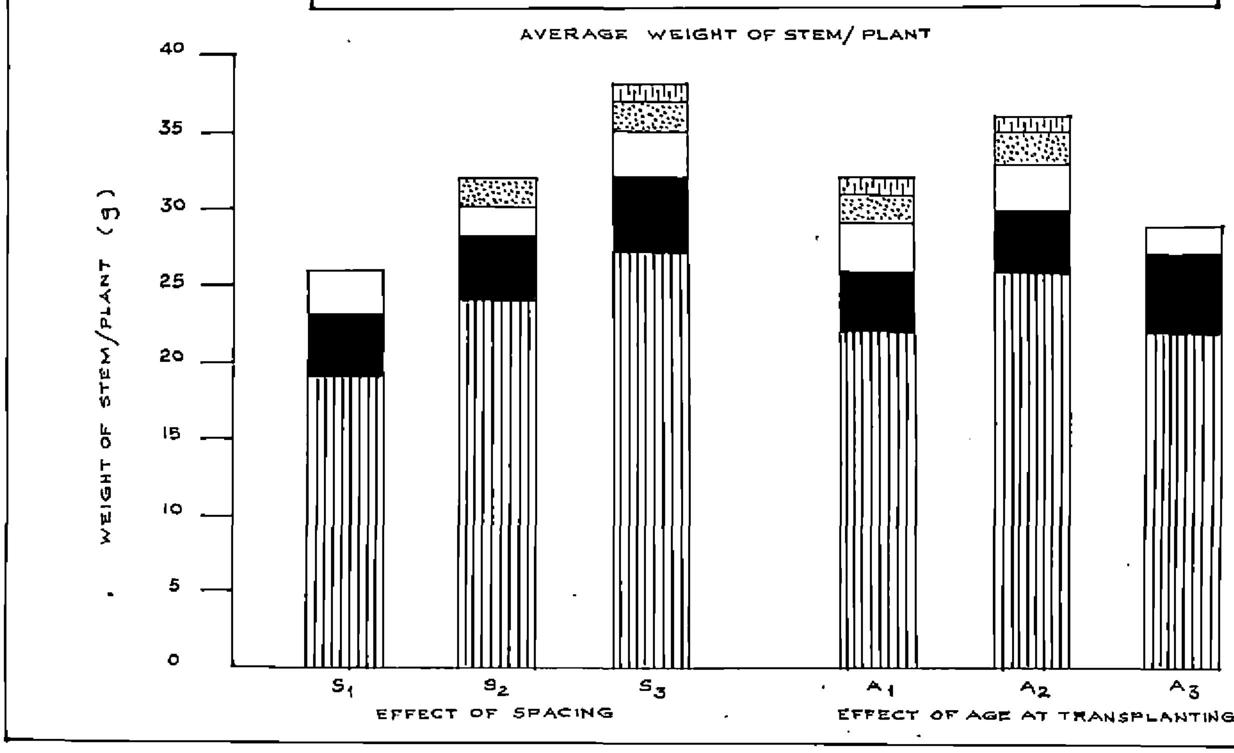

AVERAGE WEIGHT OF STEM/ PLANT
WEIGHT OF STEM/PLANT (g)
40
35
30
25
20
15
10
5
0
S1
S2
S3
A1
A2
A3
EFFECT OF SPACING
EFFECT OF AGE AT TRANSPLANTING

FIG. 11

from all the possible cuttings revealed that A_1 and A_2 plants were statistically superior to A_3 plants and the former two age groups were on par, the mean yields being 51.15, 49.72 and 41.33 g.

The treatment combinations showed no interaction.

11. Average weight of stem/plant.

During the first cut, the widely spaced (S_3) plants producing 27.33 g and the medium spaced (S_2) plants producing 24.44 g recorded statistically significant differences over the closely spaced (S_1) plants producing 19.44 g (Table 11, Fig.11, Appendix XI). The performance of S_3 and S_2 plants were statistically on par. But no statistical significance could be obtained in the weight of stem/plant during the second and third harvests. The total yield from all the three cuts when pooled and analysed showed that the S_3 plants recorded the highest weight (38.39 g) when compared to S_1 plants (26.33 g) and the difference was statistically significant. But the difference between S_3 & S_2 and S_2 & S_1 were statistically non significant. The same trend could be seen when the total yield from all the possible cuttings was pooled and analysed.

Performance of the plants belonging to the three age groups averaged over the spacings showed no significant difference for the first, second and third harvests as well as for the three cuts considered together. The total yield from all possible cuttings also showed no statistically

Table 11. Average weight of stem/plant from those belonging to three age groups planted at three population densities.

Treatments	Mean of first cut (g)	Mean of second cut (g)	Mean of third cut (g)	Mean of three cuts (g)	Mean of fourth cut (g)	Mean of fifth cut (g)	Mean of all cuts (g)
S_1A_1	19.20	3.61	2.57	25.38	-	-	25.38
S_1A_2	21.47	4.81	3.03	29.31	-	-	29.31
S_1A_3	17.67	4.61	2.03	24.30	-	-	24.30
S_2A_1	22.40	4.13	2.76	29.29	2.58	-	31.87
S_2A_2	25.97	2.97	2.22	31.15	2.33	-	33.48
S_2A_3	24.96	3.73	2.14	30.84	-	-	30.84
S_3A_1	25.49	5.60	2.70	33.79	2.55	2.16	38.50
S_3A_2	31.63	4.17	2.93	38.73	2.83	2.25	43.81
S_3A_3	24.87	5.64	2.37	32.87	-	-	32.87
S_1	19.44	4.34	2.54	26.33	-	-	26.33
S_2	24.44	3.61	2.37	30.43	1.64	-	32.06
S_3	27.33	5.14	2.66	35.13	1.79	1.47	38.39
A_1	22.36	4.45	2.68	29.48	1.71	0.72	31.92
A_2	26.36	3.98	2.73	33.06	1.72	0.75	35.53
A_3	22.50	4.66	2.18	29.34	-	-	29.34
C.D.(P=0.05)							
S and A means	5.97	1.40	0.78	6.66	-	-	6.85
S x A means	10.34	2.43	1.35	11.54	-	-	11.87

S_1 - 10 x 10 cm S_2 - 15 x 10 cm S_3 - 20 x 10 cm

A_1 - 15 day old A_2 - 20 day old A_3 - 25 day old

significant difference. Although the differences were not significant, the middle aged (A_2) plants gave the highest weight of stem/plant (35.53 g) when compared to the younger (A_1) plants (31.92 g) and the older (A_3) plants (29.34 g).

There was no interaction between spacing and age of seedlings with reference to weight of stem/plant.

12. Leaf/stem ratio.

Seedlings planted at the different spacings, averaged over all the three age groups did not show any significant difference during the first, second and third harvests for this character. The leaf/stem ratio was increasing from the first to the third harvest. The leaf/stem ratio from all the three cuts considered together also showed no statistical difference between the treatment means(Table 12, Fig.12, Appendix XII). Similar was the case when the ratio was examined for all the possible cuts together. Though the difference was not significant, the low density plants (S_3) recorded the highest leaf/stem ratio of 1.59 when compared to the medium density (S_2) and high density (S_1) plants.

However, the performance of seedlings belonging to the three age groups during the first cut showed that the older (A_3) plants gave the highest leaf/stem ratio than the younger (A_1) plants and the middle aged (A_2) plants, the former being statistically superior to the latter two which were on par (Table 12, Fig.12, Appendix XII). During the second cut, younger (A_1 & A_2) plants were statistically superior to the

Table 12. Leaf/stem ratio of plants belonging to three age groups planted at three population densities.

Treatments	Mean of first cut	Mean of second cut	Mean of third cut	Mean of three cuts	Mean of fourth cut	Mean of fifth cut	Mean of all cuts
S_1A_1	0.913	3.280	3.310	1.482	-	-	1.482
S_1A_2	0.785	2.650	3.300	1.347	-	-	1.347
S_1A_3	0.925	2.200	3.370	1.419	-	-	1.419
S_2A_1	0.778	3.060	3.590	1.357	3.220	-	1.497
S_2A_2	0.667	3.370	3.580	1.120	3.730	-	1.294
S_2A_3	1.081	2.520	3.640	1.440	-	-	1.440
S_3A_1	0.824	2.850	4.120	1.413	4.400	4.835	1.796
S_3A_2	0.868	2.980	3.360	1.231	3.600	4.524	1.528
S_3A_3	1.154	1.910	3.870	1.437	-	-	1.437
S_1	0.874	2.710	3.270	1.420	-	-	1.420
S_2	0.842	2.980	3.600	1.310	2.316	-	1.411
S_3	0.949	2.580	3.780	1.360	2.680	3.120	1.590
A_1	0.838	3.060	3.670	1.420	2.540	1.610	1.590
A_2	0.773	3.000	3.420	1.230	2.440	1.510	1.390
A_3	1.054	2.210	3.630	1.430	-	-	1.430
C.D.(P=0.05)							
S and A means	0.128	0.507	0.826	0.213	-	-	0.209
S x A means	0.221	0.878	1.430	0.370	-	- -	0.364

S_1 - 10 x 10 cm S_2 - 15 x 10 cm S_3 - 20 x 10 cm

A_1 - 15 day old A_2 - 20 day old A_3 - 25 day old

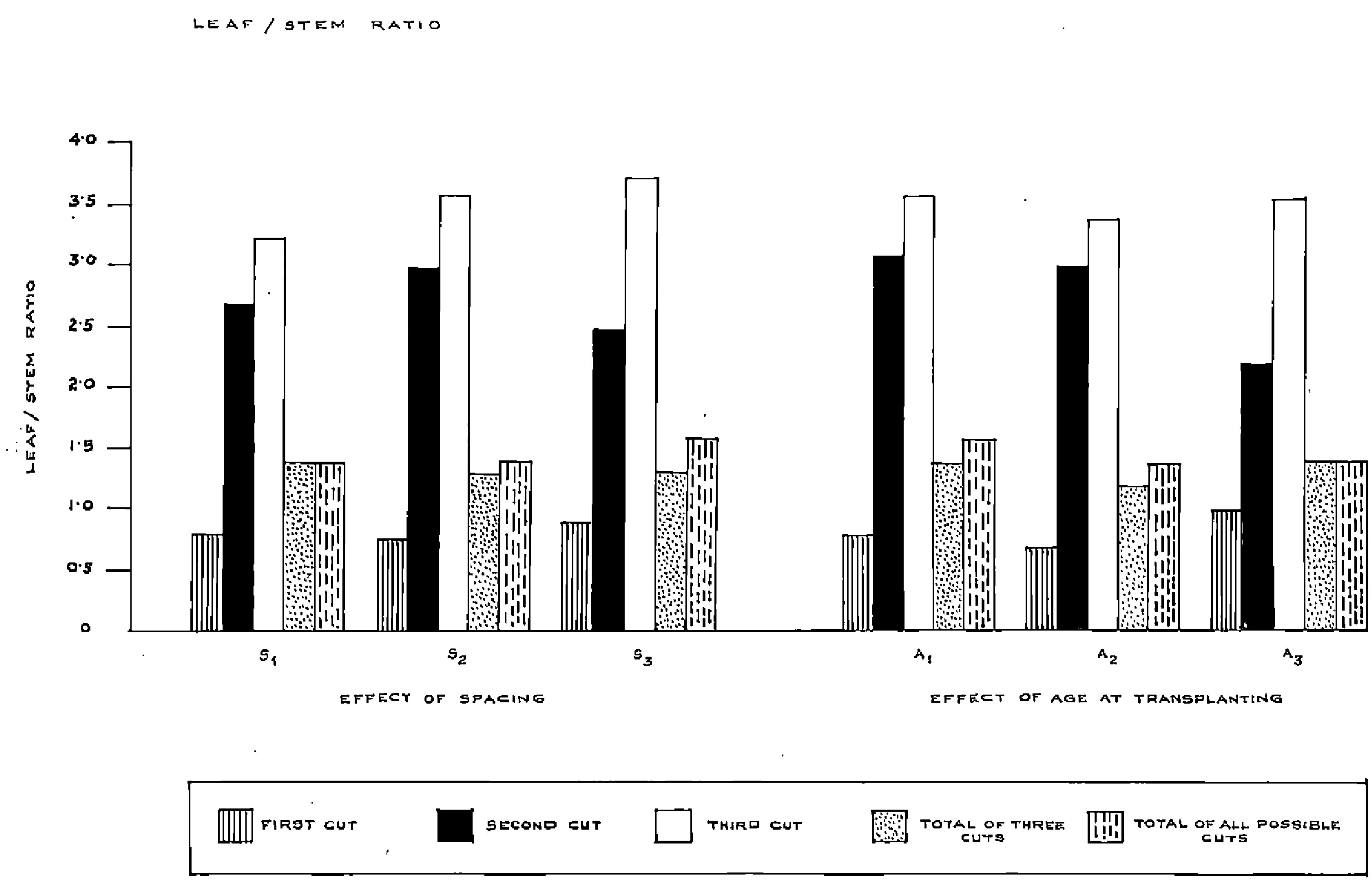

LEAF / STEM RATIO
4·0
3·5
3·0
2·5
2·0
1·5
1·0
0·5
0
LEAF / STEM RATIO
S1
S2
S3
A1
A2
A3
EFFECT OF SPACING
EFFECT OF AGE AT TRANSPLANTING
FIRST CUT
SECOND CUT
THIRD CUT
TOTAL OF THREE CUTS
TOTAL OF ALL POSSIBLE CUTS

FIG. 12

older (A_3) plants. However, during the third harvest no statistical difference could be obtained between the three age groups. The same was the case when all the three cuts were taken together as well as when all the possible cuttings were considered together. Though the differences were not significant, the younger (A_1) plants gave the highest leaf/stem ratio when all the possible cuttings were taken together. Here also, as in the case of spacing, for the different age groups, the leaf/stem ratio showed an increasing trend from the first to the third harvest, which was common for all the treatments.

There existed no interaction between spacing and age of seedlings at transplanting with reference to leaf/stem ratio.

13. <u>Dry matter content of leaves and stem.</u>

Dry matter percentage of leaves and stem at the three spacings averaged over the three age groups showed no statistically significant differences (Table 13, Appendix XIII). Medium density (S_2) plants recorded the maximum accumulation of dry matter in the leaves at the time of first, second and third cut. Per cent dry matter accumulation in leaves increased with subsequent cuts. This trend was applicable only upto the third harvest. For the subsequent cuts the dry matter percentage showed a decreasing tendency.

As far as the dry matter in the stem was concerned, the S_3 plants exhibited highest accumulation during the first cut. In the subsequent cuts S_2 plants recorded highest

Table 13. Percentage dry matter in leaves and stem of plants belonging to three age groups planted at three population densities.

Treatments	First cut Mean % dry matter		Second cut Mean % dry matter		Third cut Mean % dry matter		Fourth cut Mean % dry matter		Fifth cut Mean % dry matter	
	Leaves	Stem	Leaves	Stem	Leaves	Stem	Leaves	Stem	Leaves	Stem
S_1A_1	10.50	6.57	11.75	5.89	13.36	7.87	-	-	-	-
S_1A_2	12.04	6.65	12.16	5.15	12.87	8.33	-	-	-	-
S_1A_3	11.87	6.43	12.02	7.52	13.73	8.97	-	-	-	-
S_2A_1	13.07	6.63	12.25	6.94	15.85	10.20	14.68	10.10	-	-
S_2A_2	11.86	6.67	13.72	6.19	16.20	8.99	15.36	8.15	-	-
S_2A_3	11.19	5.92	12.15	7.06	13.65	3.51	-	-	-	-
S_3A_1	10.92	6.26	11.70	6.35	13.92	9.03	13.89	8.84	11.02	7.79
S_3A_2	10.60	6.34	13.06	7.25	12-40	7.71	13.76	9.84	11.84	8.97
S_3A_3	11.02	7.04	12.20	6.74	14.31	7.80	-	-	-	-
S_1	11.47	6.55	11.98	6.19	13.32	8.39	-	-	-	-
S_2	12.07	6.41	12.71	6.83	15.24	9.23	10.01	6.08	-	-
S_3	11.85	6.64	12.32	6.78	13.54	8.18	9.22	6.23	7.62	5.59
A_1	11.49	6.49	11.90	6.39	14.38	9.03	9.52	6.31	3.67	2.59
A_2	11.50	6.55	12.98	6.20	13.82	8.35	9.71	5.99	3.95	2.99
A_3	11.36	6.46	12.12	7.11	13.90	8.42	-	-	-	-
C.D.(P=0.05)										
S & A means	1.23	0.73	1.35	0.84	2.05	1.55	-	-	-	-
S x A means	2.12	1.27	2.33	1.57	3.55	2.68	-	-	-	-

S_1 - 10 x 10 cm S_2 - 15 x 10 cm S_3 - 20 x 10 cm

A_1 - 15 day old A_2 - 20 day old A_3 - 25 day old

dry matter accumulation. Here also, upto the third harvest the per cent dry matter accumulation in stem increased with subsequent cuts and then decreased.

During the first and the third harvests, the 20 day-old (A_2) and 15 day-old (A_1) plants respectively recorded highest dry matter percentage in leaves as well as in stem (Table 13, Appendix XIII). However, during the second cut, the 25 day-old plants recorded maximum dry matter in the stem while 20 day-old plants recorded maximum dry matter in the leaves. The differences in all the cases were not statistically significant.

There was no interaction between spacing and age of seedlings with regard to the dry matter accumulation in leaves and stem.

14. <u>Moisture content of leaves and stem</u>.

No statistical significance could be obtained for the percentage moisture content in the leaves and stem during all the harvests (Table 14, Appendix XIV). For the first cut, the widely spaced (S_3) plants recorded the highest moisture percentage in both leaves and stem. But during the second and third cut, the closely spaced (S_1) plants showed the highest moisture percentage in leaves and stem.

Considering the moisture levels with respect to age of seedlings at transplanting during the first harvest, the 25 day-old (A_3) plants had more moisture in their leaves and stem as compared to those of the other two age groups.

Table 14. Percentage moisture in leaves and stem of plants belonging to three age groups planted at three population densities.

Treatments	First cut Mean % moisture		Second cut Mean % moisture		Third cut Mean % moisture		Fourth cut Mean % moisture		Fifth cut Mean % moisture	
	Leaves	Stem	Leaves	Stem	Leaves	Stem	Leaves	Stem	Leaves	Stem
S_1A_1	89.50	93.49	88.25	94.11	86.64	92.13	-	-	-	-
S_1A_2	87.96	93.35	87.84	94.85	87.25	91.67	-	-	-	-
S_1A_3	88.13	93.57	87.98	92.48	86.27	91.03	-	-	-	-
S_2A_1	86.93	93.37	87.75	93.06	84.15	89.80	85.32	89.90	-	-
S_2A_2	88.14	93.33	86.28	93.81	83.80	91.00	84.64	91.85	-	-
S_2A_3	88.81	94.08	87.85	92.94	86.35	91.49	-	-	-	-
S_3A_1	89.09	93.74	88.30	93.65	86.08	90.97	86.11	91.16	88.98	92.21
S_3A_2	89.40	93.66	86.94	92.75	87.60	92.29	86.24	90.16	88.16	91.03
S_3A_3	88.98	92.96	87.80	93.26	85.69	92.20	-	-	-	-
S_1	88.53	93.47	88.02	93.81	86.72	91.91	-	-	-	-
S_2	87.96	93.59	87.29	93.27	84.76	90.77	56.65	60.58	-	-
S_3	89.15	93.66	87.68	93.22	86.46	91.82	57.45	60.44	59.05	61.08
A_1	88.50	93.54	88.10	93.61	85.62	90.97	57.14	60.35	29.66	30.74
A_2	88.50	93.45	87.02	93.80	86.22	92.65	56.96	60.67	29.39	30.34
A_3	88.64	93.64	87.88	92.89	86.10	91.58	-	-	-	-
C.D. (P=0.05)										
S & A means	1.23	0.73	1.34	0.84	2.08	1.55	-	-	-	-
S x A means	2.12	1.27	2.33	1.45	3.60	2.68	-	-	-	-

S_1 - 10 x 10 cm S_2 - 15 x 10 cm S_3 - 20 x 10 cm

A_1 - 15 day old A_2 - 20 day old A_3 - 25 day old

But during the second cut, though the same trend was shown by the leaves, in the case of stem, the 20 day-old (A_2) plants exhibited the highest percentage moisture. At the time of third cut also, the A_2 plants recorded the highest moisture percentage when compared to A_3 and A_1 plants (Table 14, Appendix XIV).

With regard to the moisture percentage also, there was no statistically significant difference between the treatment combinations. The two factors thus acted independently.

15. Iron content of leaves and stem (mg/100 g).

The analysis of iron content in leaves for the individual cuts were carried out and highly significant differences were observed for the three different spacings averaged over the three age groups during the first harvest. The low density (S_3) plants were superior to the medium density (S_2) and high density (S_1) plants accounting for 19.14 per cent increase over S_1 and 7.90 per cent over S_2 plants (Table 15, Fig.13a, Appendix XV). For the other two cuts, though the trend exhibited was the same, the differences due to the marginal means of the three spacings were not statistically significant. The widely spaced plants contained more iron in their leaves than the densely spaced ones.

The iron content in stem showed the same trend as that in leaves. During all the three cuts, the widely spaced (S_3) plants contained more iron their stem than the medium spaced (S_2) and closely spaced (S_1) plants. S_1 plants recorded the

Table 15. Iron content in leaves and stem of plants belonging to three age groups planted at three population densities.

Treatments	First cut Mean iron content in mg/100 g Leaves	 Stem	Second cut Mean iron content in mg/100 g Leaves	 Stem	Third cut Mean iron content in mg/100 g Leaves	 Stem	Fourth cut Mean iron content in mg/100 g Leaves	 Stem	Fifth cut Mean iron content in mg/100 g Leaves	 Stem
S_1A_1	48.82	32.22	62.22	31.11	78.89	37.78	-	-	-	-
S_1A_2	48.89	34.44	61.11	35.56	86.67	41.11	-	-	-	-
S_1A_3	53.33	37.78	62.22	34.44	80.00	44.44	-	-	-	-
S_2A_1	54.45	36.67	66.67	36.67	87.78	41.11	91.11	58.89	-	-
S_2A_2	56.67	38.89	80.00	37.78	95.56	41.11	102.96	56.67	-	-
S_2A_3	55.56	37.78	83.33	38.89	100.00	47.78	-	-	-	-
S_3A_1	57.78	43.33	81.11	45.55	101.11	50.00	104.44	58.89	106.17	70.00
S_3A_2	62.22	38.89	87.78	41.11	96.50	46.67	102.96	62.22	104.44	67.41
S_3A_3	60.00	40.00	87.78	40.00	100.00	45.56	-	-	-	-
S_1	50.35	34.81	61.85	33.70	81.85	41.11	-	-	-	-
S_2	55.56	37.78	76.67	37.78	94.45	43.33	64.69	38.52	-	-
S_3	59.99	40.74	85.55	42.22	99.20	47.41	69.12	40.37	70.20	45.80
A_1	53.68	37.41	70.00	37.78	89.26	42.96	65.18	39.26	35.39	23.33
A_2	55.93	37.41	76.30	38.15	92.91	42.96	68.64	39.63	34.81	22.47
A_3	56.30	38.52	77.78	37.78	93.33	45.93	-	-	-	-
C.D.(P=0.05)										
S & A means	6.154	5.297	20.090	11.050	14.905	7.380	-	-	-	-
S x A means	10.660	9.175	34.790	19.150	25.820	12.790	-	-	-	-

S_1 - 10 x 10 cm S_2 - 15 x 10 cm S_3 - 20 x 10 cm

A_1 - 15 day old A_2 - 20 day old A_3 - 25 day old

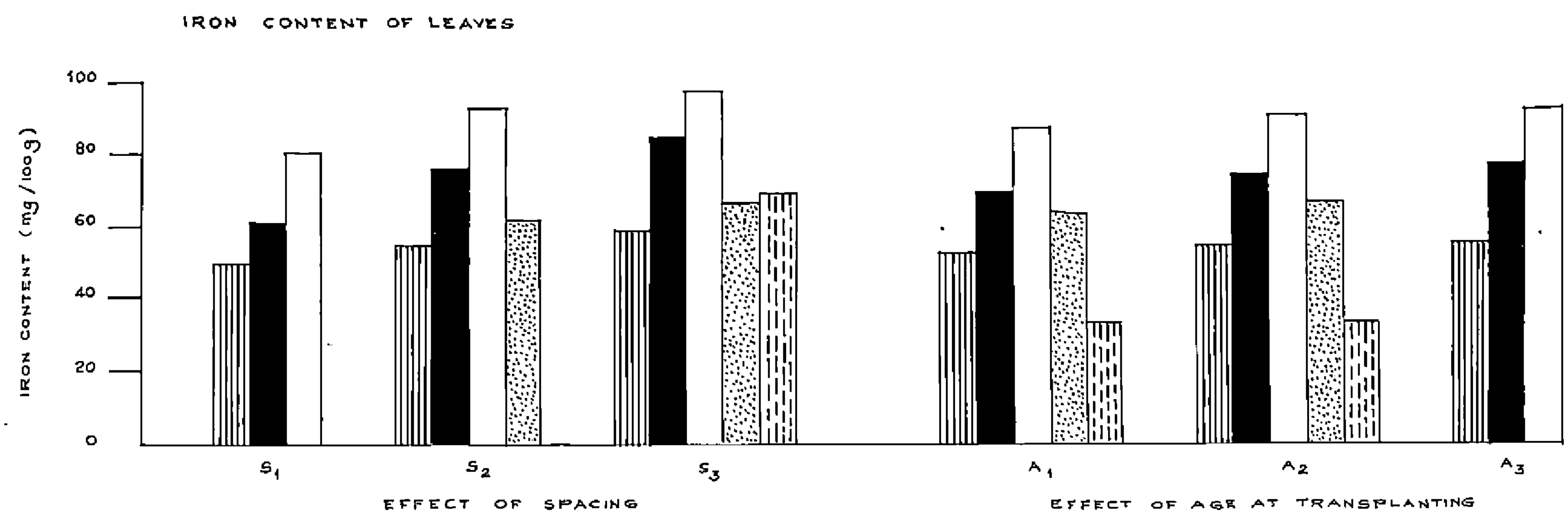
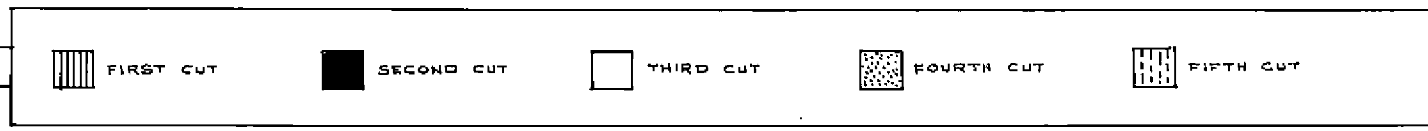


FIG. 13a



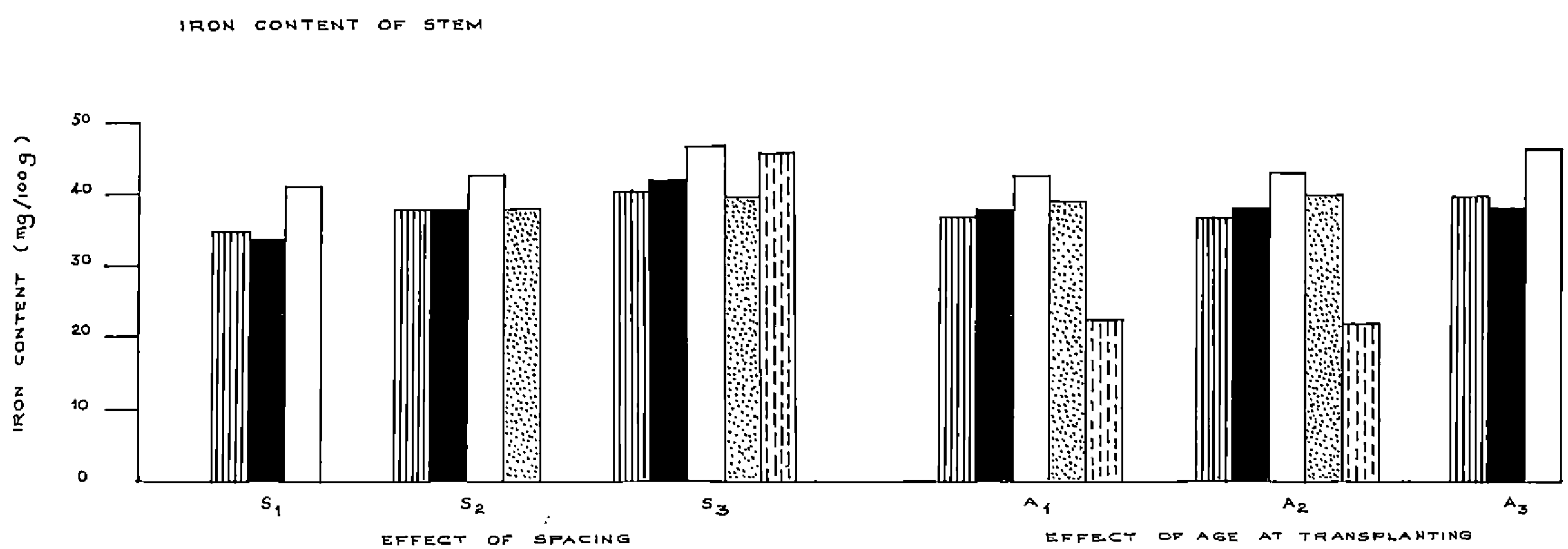


FIG. 13b

least iron content in their stem. However, in all these cases, the differences between the treatment means were not statistically significant (Table 15, Fig.13b, Appendix XV).

Though there was difference between the plants belonging to three age groups with regard to iron content in leaves and stem, statistically the difference due to the marginal means averaged over the three spacings were not significant (Table 15, Fig.13a & b, Appendix XV). The figures revealed a trend that the oldest plants contained the highest quality of iron, both in leaves and stem for all the cuts.

In general, the percentage iron content increased progressively as the number of cuts advanced upto the third harvest. For the subsequent cuts, the percentage decreased. But for the widely spaced (S_3) plants though the iron content decreased at the time of fourth cut, it increased slightly during the fifth cut (Table 15, Fig.13 a & b).

There was no interaction between spacing and age of seedlings at transplanting with regard to this character.

16. Protein content of leaves and stem (percentage).

Regarding the protein content of leaves and stem, the low density (S_3) plants were found to be statistically superior to the medium density (S_2) and high density (S_1) plants for the three cuts, except during second harvest for stem, when S_3 and S_2 plants were on par (Table 16, Fig.14a, Appendix XVI). From the figures it was evident that protein content in leaves and stem increased as the density decreased.

Table 16. Protein content in leaves and stem of plants belonging to three age groups planted at three population densities.

Treatments	First cut		Second cut		Third cut		Fourth cut		Fifth cut	
	Mean protein %		Mean protein %		Mean protein %		Mean protein %		Mean protein %	
	Leaves	Stem	Leaves	Stem	Leaves	Stem	Leaves	Stem	Leaves	Stem
S_1A_1	4.64	1.50	6.71	4.80	8.68	5.56	-	-	-	-
S_1A_2	4.87	1.85	7.52	4.68	7.76	5.33	-	-	-	-
S_1A_3	4.40	2.09	6.71	4.40	7.99	5.79	-	-	-	-
S_2A_1	4.98	1.97	7.41	5.33	8.33	6.14	9.03	6.60	-	-
S_2A_2	4.98	2.20	7.06	5.33	8.80	6.37	9.33	6.37	-	-
S_2A_3	4.98	1.85	7.41	5.21	8.56	6.37	-	-	-	-
S_3A_1	6.03	2.55	9.96	6.25	9.49	7.17	9.49	7.18	10.78	7.87
S_3A_2	5.68	2.66	8.68	5.91	9.95	6.94	10.11	6.83	10.57	7.98
S_3A_3	5.44	2.90	8.80	5.67	9.95	6.83	-	-	-	-
S_1	4.64	1.81	6.98	4.63	8.14	5.56	-	-	-	-
S_2	4.98	2.01	7.29	5.29	8.56	6.29	6.12	4.32	-	-
S_3	5.72	2.70	9.15	5.94	9.80	6.98	6.53	4.67	7.12	5.28
A_1	5.22	2.01	8.03	5.46	8.84	6.29	6.17	4.59	3.59	2.62
A_2	5.18	2.24	7.76	5.31	8.84	6.21	6.48	4.40	3.52	2.66
A_3	4.94	2.28	7.64	5.09	8.84	6.33	-	-	-	-
C.D.(P=0.05)										
S & A means	0.483	0.633	1.080	0.986	0.679	0.577	-	-	-	-
S x A means	0.837	1.096	1.860	1.670	1.180	0.999				

S_1 - 10 x 10 cm S_2 - 15 x 10 cm S_3 - 20 x 10 cm

A_1 - 15 day old A_2 - 20 day old A_3 - 25 day old

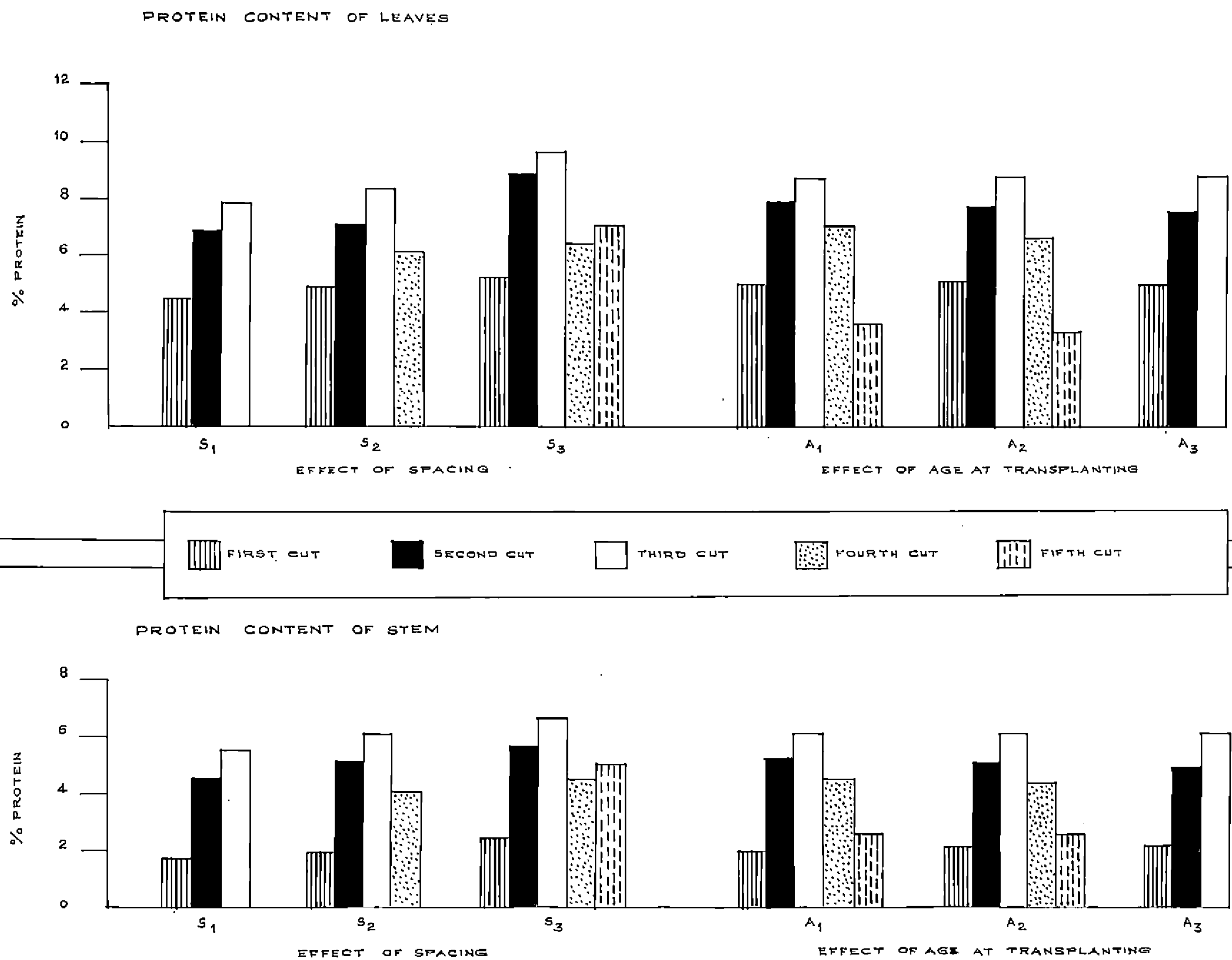


FIG. 14a

FIG. 14b

Further, the figures for the individual cuts revealed that protein content of both leaves and stem increased with subsequent cuts upto the third harvest and then decreased (Table 16, Fig.14 a & b).

The effect of age at transplanting, however, was found to be not statistically significant and the differences due to the varying levels were not pronounced. But the overall effect showed that the youngest (A_1) plants contained the highest percentage protein in their leaves. But the protein content in stem during the first and third cut was highest for the oldest (A_3) plants (Table 16, Fig. 14 a & b, Appendix XVI).

The combinations between the different levels of spacings and age at transplanting were found to be non-significant, showing that there was no interaction between the two factors with regard to protein content of leaves and stem.

17. Vitamin A content of leaves (IU).

When averaged over the age-groups, the plants at the three spacings showed that the Vitamin A content of leaves did not exhibit statistical significance for the three harvests, except the second. During the second cut, with regard to Vitamin A content of leaves, the low density plants (S_3) were statistically superior to the high density plants (S_1). But the differences between S_3 and S_2 plants and S_2 & S_1 plants were not significant (Table 17, Fig.15, Appendix XVII).

Table 17. Vitamin A content in leaves of plants at three age groups planted at three population densities.

Treatments	First cut Vit.A(IU)	Second cut Vit.A(IU)	Third cut Vit.A(IU)	Fourth cut Vit.A(IU)	Fifth cut Vit.A(IU)
S_1A_1	5223.88	4353.23	3731.35	-	-
S_1A_2	5223.88	4726.37	2985.08	-	-
S_1A_3	5970.15	4104.48	3855.72	-	-
S_2A_1	6592.04	4601.99	5233.88	3648.42	-
S_2A_2	6467.66	5099.50	5099.50	4601.99	-
S_2A_3	6343.28	5223.88	4228.86	-	-
S_3A_1	6716.42	5970.15	5472.64	5058.04	5845.77
S_3A_2	6965.17	7213.93	5845.77	4393.69	5638.47
S_3A_3	6965.17	7462.69	5472.64	-	-
S_1	5472.64	4394.69	3524.05	-	-
S_2	6467.66	4975.12	4850.75	2750.14	-
S_3	6882.26	6716.42	5597.02	3150.58	3828.08
A_1	6177.45	4975.12	4809.29	2902.15	1948.59
A_2	6218.91	5679.95	4643.45	2998.56	1879.49
A_3	6426.20	5597.02	4519.07	-	-
C.D.(P=0.05)					
S and A means	1204.87	1603.11	1683.04	-	-
S x A means	2086.90	2776.66	2915.11	-	-

S_1 - 10 x 10 cm S_2 - 15 x 10 cm S_3 - 20 x 10 cm

A_1 - 15 day old A_2 - 20 day old A_3 - 25 day old

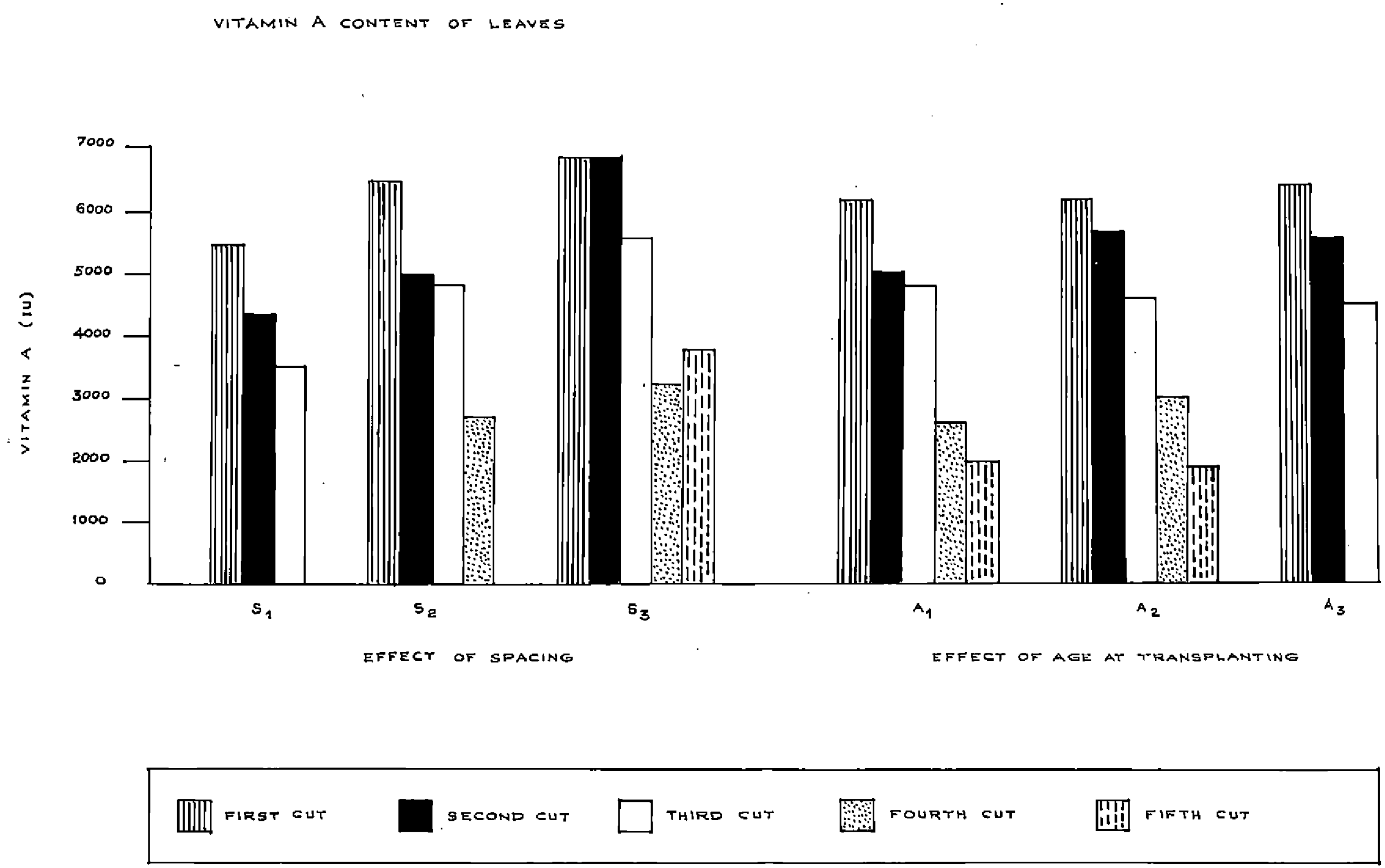

VITAMIN A CONTENT OF LEAVES
VITAMIN A (IU)
7000
6000
5000
4000
3000
2000
1000
0
S1
S2
S3
A1
A2
A3
EFFECT OF SPACING
EFFECT OF AGE AT TRANSPLANTING
FIRST CUT
SECOND CUT
THIRD CUT
FOURTH CUT
FIFTH CUT

FIG. 15

The trend that increase in spacing resulted in increased quality of Vitamin A content of leaves, could be seen reflected during all the harvests.

Vitamin A content in leaves showed no statistical difference for the three age groups tried (Table 17, Fig.15, Appendix XVII). But the oldest (A_3) plants had high Vitamin A content in their leaves during the first cut. For the second and third harvests, the middle aged (A_2) plants and youngest (A_1) plants recorded the highest quantities of Vitamin A in their leaves, respectively.

Considering Vitamin A quantity wise, it was found to be decreasing during the subsequent cuts with respect to spacing as well as age of seedlings at transplanting.

The age-spacing combinations were statistically non-significant revealing that there was no interaction between these two factors and that they were acting independently.

DISCUSSION

DISCUSSION

Obtaining higher yields of vegetative portion, large number of harvests, better quality of the produce etc. are problems facing the amaranth cultivation. The investigations reported in this thesis were undertaken at the College of Agriculture, Vellayani with a view to understanding the effect of population density and age at transplanting on the growth, yield and quality in amaranth. The studies were limited to six growth parameters (height, girth, spread, number of branches, number of leaves and leaf area), six characters contributing to total yield (weight of leaves, weight of stem, leaf/stem ratio, yield/plant, yield/m^2 and frequency of harvest) and five important quality factors (percentage dry matter, percentage moisture, iron, protein and vitamin A). The results obtained in the present investigations have been presented in the previous chapter. A critical discussion of the findings follows:

Each of the growth parameters was studied in relation to the population density as well as the age of the seedlings at transplanting. It was observed that plants at medium density (15 x 10 cm) were taller than the low density (20 x 10 cm) or high density (10 x 10 cm) plants. Normally one would expect the high density plants to be taller due to the competition for light (Verheij, 1970 in brussels sprouts). In the present experiment, the plants at medium density had an initial advantage and exhibited faster increments during the first 20 days after transplanting. Thus the medium density plants were clearly the tallest at harvest time. Besides being taller, the medium density plants exhibited equal girth at collar as the low density plants. It has been observed that the stem girth of the plants at the lowest density, though more than that of medium density plants at the harvest stages, the difference was not statistically significant. This result at the present instance was similar to that observed by Albregts et al. (1976) in okra. Regarding the spread of the plant, the initial spread (at 10 and 15 days after transplanting) was more in the case of medium density plants. The low density plants exhibited larger spread towards the harvest, mainly through higher increments during the interval between planting and harvest. Production of more number of branches is a character that will eventually contribute to the total yield of vegetative portions. The medium density plants produced the largest number of branches as compared to the low density and high density plants. However, due to the higher incremental rate, the low density plants equalled the medium density plants at the harvest stage with regard to the number of branches. In respect of the number of leaves/plant also, the medium density plants exhibited a slight advantage over the low density and high density plants. However at harvest stage, the medium and low density plants were on par. Increased light at wider spacing caused a greater tendency for branching and production of more number of leaves. The low density plants were clearly superior to the others with respect to the leaf area. This need not be an advantage in the accumulation of larger quantities of dry matter, the reason being that there could be higher rate of utilization also. Population density trial revealed that increase in density decreased the leaf area. This was because leaf size was big under the wider spacing. This result at the present instance was in confirmity with the findings of Zahara and Timm (1973) in tomato and Brandes et al. (1973) in Phaseolus vulgaris. In general, a critical examination of data on population density with regard to growth characters revealed that the low density plants fared slightly better than the medium density plants.

The benefits derived in vegetative growth should also be reflected in the ultimate yield at harvest, better leaf/stem ratio, more number of harvests etc. The present investigations revealed that the low density plants yielded more leaves/plant. This could be expected because these plants had significantly larger leaf area. With regard to stem portion also, the low density plants outyielded the others. However, the differences between the low density plants and medium density plants were not significant. Based on the weight of leaves and weight of stem obtained at each harvest, the leaf/stem ratio was worked out. The results were erratic; but considering all the harvests together, the low density plants gave a better leaf/stem ratio. This can be expected because of larger leaf yield in the case of low density plants.

Total yield per plant was computed for each harvest as well as for all the three harvests taken together and from all the possible harvests. Low density plants gave the highest yield/plant when the total yield per plant from all possible harvests was considered. In all the other cases, there existed no statistically significant difference between the low density plants and medium density plants. It is pertinent to recall here that in the case of weight of leaves/plant and weight of stem/plant also, the low density plants and medium density plants showed no statistically significant difference. The increased number of harvests may also contribute to the highest yield/plant of the low density plants, when the total yield per plant from all the possible harvests was taken into account. The highest yield/plant at wider spacing may be viewed in terms of light exposure. With wide spacing (low density), there was less overlapping and shading of leaves, better light penetration to the basal leaves, less competition for light, water and nutrients and higher and more efficient carbondioxide fixation and consequently better yields. The increased photosynthetic efficiency with wider spacing was due mainly to increased light energy. The result at the present investigation is in agreement with the findings of Halsey et al. (1967) and Shumaker (1969). They observed a general trend that increase in spacing resulted in increases in the percentage of marketable heads and the average weight per head in cabbage. Tereshkovich (1969) in 'Primo F_1 hybrid' broccoli also reported similar result. Further the result gets support from the findings of Pinkau et al. (1978) who reported that closer spacing reduced the yield/plant in asparagus.

The yield per unit area would normally be higher under dense plantings. In the present study also, the yield/m^2 for each harvests, as well as for the three cuts taken together was highest in the case of high density planting (10 x 10 cm). The same was true when the yield from all possible harvest was considered. This is due to the larger number of plants/unit area under this treatment. The work of many lends support to this finding. Sreenivas (1968) found significant yield increment at closer spacing and Esch (1975) reported that yield/m^2 was highest at the closest spacing in lettuce. The result is also in conformity with the findings of Kays (1975) in New Zealand spinach, Bradley et al. (1971) in spinach, Gupta and Shukla (1977) in tomato and so on. The high density plants gave an yield of 6.28 kg/m^2 (62.80 tonnes of vegetative yield/ha). This high yield could be expected due to the increased number of plants/unit area (100 plants/m^2). Vegetable amaranth yields have been reported to as high as 40 MT/ha by Grubben (1976).

The high density plants showed earlier initiation of flower primordia. In other words, high density plants attained harvestable stage earlier than medium density and low density plants. The difference between the three spacings was statistically significant. The low density plants, thus was slow to come to flowering and gave more than three cuttings. The result at the present investigation is supported by the studies of Wilhelm (1976). He reported that close spacing shortened the growth period of leafy vegetables. Honma and Bert (1977) in cauliflower and Vik (1970) in onions, observed that at close spacing, maturity was advanced. At the present instance also, maturity was advanced with increasing plant density. Considering the yield and yield attributes together, it can be stated that low density plants topped the list, except when yield/m^2 was considered. Further, the low density plants were slow in coming to flowering, thus facilitating more number of harvests.

Accumulation of dry matter and content of moisture, iron, protein and Vitamin A gave an indication of the quality changes <u>vis</u> a <u>vis</u> population density. In medium density plants there was more accumulation of dry matter in leaves; but the low density plants accumulated more dry matter in the stem during the first cut. However, the medium density plants overtook the low density plants in subsequent cuts with respect to dry matter accumulation in stem. In the light of the earlier observation that the low density plants produced significantly larger leaf area/plant than medium density and high density plants, this could be explained as due to the over utilization of the dry matter produced by the low density plants. Thus with regard to this character, the medium density plants seemed better, although the differences were not statistically significant as reported by Jones (1972) in brussels sprouts. In the case of moisture content also, though there was no statistically significant difference, the low density plants recorded higher percentage moisture in leaves and stem during the first cut. In the subsequent cuts, however, the high density plants registered higher values for this character. This could be due to the mutual shading effect of the plants under higher densities and resultant low evapo-transpiration. With regard to the other three quality characters the low density plants seemed to be better than medium density and high density plants. The results are in agreement with the findings of Thompson and Taylor (1975) in cauliflower, Kauffmann (1968) and Bannerot et al. (1969) in asparagus, Meijndert (1976) in tomato and Sinha (1975) in chillies. From their studies they came to the conclusion that plants at the closest spacing were of poor quality, as evidenced in the present investigation. It is interesting to note that with increase in spacing, the levels of iron, protein and Vitamin A increased. The better quality at wider spacing might be due to availability of more feeding area in terms of nutrients and light to plant under wider spacing in comparison to plants under close spacing. Further, the iron and protein content increased and levels of Vitamin A decreased as the season progressed, as observed in the later harvests. Delay in cutting is reported to increase the iron content in amaranth (Mathai, 1978). In the case of iron and protein, the increase was observed only upto the third harvest which was common for all treatments and then found to be decreasing. This might be due to the limited number of treatments effecting the subsequent cuts. Out of the nine treatment combinations tried, only four treatments gave four cuts and two , five cuts each. So the effects when averaged over the three age-groups and spacings, reduced the quantities of iron and protein. In general the low density plants seemed to be better with respect to the quality aspects.

The growth characters, yield and yield attributes as well as the quality aspects were studied in relation to age of seedlings at the time of transplanting. 15, 20 and 25 day-old seedlings were used for the study. In respect of all the growth characters, the 25 day-old seedlings performed better. The difference in performance between 25 and 20 day-old seedlings was not statistically significant in the case of height of plants and number of branches. From the present investigations it seemed that 25 day-old seedlings should be transplanted for obtaining better growth. However, since the studies did not include still older seedlings definite conclusions cannot be made.

With reference to the yield and yield attributes, the trend of behaviour of plants resulting from 15, 20 and 25 day-old seedlings was not uniform. The younger plants (15 day-old) were better with respect to weight of leaves/plant, leaf/stem ratio and total number of cuts and second best for weight of stem/plant and yield/m^2. In the latter two the older plants (20 day-old) were better. With regard to yield/plant also the older seedlings (20 day-old) fared better. The oldest seedlings (25 day-old) performed rather poorly giving lowest weight of leaves/plant, weight of stem/plant and yield/m^2. The result gets support from the findings of Georgieva and Genkov (1973) and Silva et al. (1973), that older transplants gave poor yields in cauliflower and chillies respectively. In the present investigation, further earlier flowering was also pronounced when older seedlings were transplanted thus limiting the number of possible harvests. This view is shared by Whitwell and Crofts (1972) in cauliflower and they indicated that large transplants matured earlier than small transplants.

It is interesting to note that in certain age-spacing combinations involving 15 day-old (A_1) and 20-day-old (A_2) seedlings (A_1S_2, A_1S_3, A_2S_2 and A_2S_3), i.e. A_1 and A_2 seedlings transplanted at 15 x 10 cm (S_2) and 20 x 10 cm (S_3), more than the general average of three cuts were possible. The combinations involving oldest seedlings (25 day-old) did not give more than three cuts in any instance. This interaction is to be studied with greater precision.

With regard to the quality aspects, the behaviour of seedlings belonging to the three age groups was erratic.

Though the differences were not statistically significant, the oldest seedlings (25 day-old) had high dry matter content in stem (second cut), high moisture in leaves (first and second cut), high iron content in leaves and stem (all the cuts), high protein content in stem (first and third cut) and high Vitamin A content in leaves (first cut). However, because the differences were not statistically significant and because seedlings older than 25 days of age were not utilized in the studies, valid conclusions could not be drawn.

Summing up, 25 day-old seedlings when transplanted gave better growth. With regard to the quality aspects also, the 25 day-old seedlings seemed to have a slight edge over the others. However, these plants showed early initiation of flowering, thus limiting the number of possible harvests. Further, when the yield and yield attributes were considered, 15 and 20 day-old seedlings performed better. Considering all these aspects together, transplanting of 15 to 20 day-old seedlings can be recommended for obtaining higher weight of leaves/plant, higher weight of stem/plant, better leaf/stem ratio, higher yield/plant, higher yield/m^2 and more number of harvests.

In the population density trial, the low density plants (transplanted at 20 x 10 cm) exhibited overall better growth and quality characteristics. With regard to all the characters contributing to yield/harvest and total yield, except yield/unit area, the low density plants exhibited their clear superiority over the medium density plants and high density plants. In addition, planting at wider spacing facilitated more number of harvests also. However, for obtaining higher yield/unit area, transplanting at closer spacing (10 x 10 cm) seemed to have advantage over the others. Such closely planted amaranths came to flowering faster than the widely spaced ones.

In the light of results obtained from the present investigation that upto five harvests could be obtained in certain age-spacing combinations, (A_1S_2, A_1S_3, A_2S_2 and A_2S_3) it is suggested that the interaction between age at transplanting and spacing should be studied with more precision. In future studies, still older seedlings and slightly wider spacings should also be included. Further, investigations on the response of different amaranth genotypes to changes in population density and age at transplanting also should be undertaken.

SUMMARY

SUMMARY

An experiment was laid out at the College of Agriculture, Vellayani during 1978-79 to assess the effect of population density and age at transplanting on the growth, yield and quality in amaranth. The studies were limited to six growth parameters (height, girth, spread, number of branches, number of leaves and leaf area), six yield contributing characters (weight of leaves, weight of stem, leaf/stem ratio, yield/plant, yield/m^2 and frequency of harvest) and five important quality factors (percentage dry matter, percentage moisture, iron, protein and Vitamin A). The results obtained in the present investigation are summarised as follows:

Each of the growth parameters was studied in relation to the population density as well as the age of the seedlings planted. It was observed that plants at medium density (15 x 10 cm) were taller than the low density (20 x 10 cm) or high density (10 x 10 cm) plants. Further, the medium density plants exhibited equal girth at collar asthe low density plants. It has been observed that the stem girth of the plants at the lowest density though more than that of medium density plants at the harvest stage, the difference was not statistically significant. Regarding the spread of plant, the initial spread was more in the case of medium density (S_2) plants. The low density (S_3) plants exhibited larger--

spread towards the harvest. As far as the number of branches was considered, the medium density plants produced the larger number of branches as compared to the low density and high density plants. In respect of the number of leaves/plant also, the medium density plants exhibited a slight advantage over the low and high density plants. However at harvest stage, the medium and low density plants were on par. The low density plants were clearly superior to the others with respect to leaf area. Plants spaced at 20 x 10 cm (S_3) recorded the highest leaf area of 128.03 cm^2 accounting for 28.36 per cent increase over 10 x 10 cm (S_1) and 13.89 per cent over 15 x 10 cm (S_2) spacing.

The growth characters were studied in relation to the age of seedlings at the time of transplanting. In respect of all the growth characters studied, the 25 day-old seedlings performed better. The difference in performance between 25 and 20 day-old seedlings was not statistically significant in the case of height of plants and number of branches.

The characters contributing to yield, at the present investigation revealed that the low density plants yielded more leaves/plant. With regard to stem portion also, the low density plants outyielded the others. However, the differences between the low density plants and medium density plants were not significant. Though there was no significant difference between the treatments with regard to leaf/stem ratio, the low density plants gave a better leaf/stem ratio. Further, the low density plants gave the highest yield/plant when the total yield per plant from all possible harvests was considered. The yield/plant of low, medium and high density plants in this case were 99.40, 76.77 and 62.82 g respectively. The yield/plant for each harvest showed no statistically significant difference between the low density and medium density plants. On the other hand, the yield/m^2 for each harvest as well as for all the possible cuts taken together, was highest in the case of high density planting. The high density (S_1) planting gave a total yield of 6.28 kg/m^2 (62.80 tonnes of vegetative yield/ha).

With reference to the yield and yield attributes, the trend of behaviour of plants resulting from 15, 20 and 25 day old seedlings was not uniform. The youngest plants (15 day old) were better with respect to weight of leaves/plant, leaf/stem ratio and total number of cuts and second best for weight of stem/plant and yield/m^2. In the latter two the older plants (20 day old) were better. With regard to yield/plant also the older seedlings fared better.

Taking into consideration the frequency of harvest, the high density plants showed earlier initiation of flower primordia i.e. high density plants attained harvestable stage earlier than medium density and low density plants. The difference between the three spacings was statistically significant. The low density plants were thus slow in coming to flowering and gave more than three harvests. The treatment combinations involving the two lower population densities i.e. S_2A_1, S_2A_2, S_3A_1 and S_3A_2 gave four cuts and S_3A_1 & S_3A_2 gave five cuts each.

Regarding age of seedlings, earlier flowering was pronounced when older seedlings were transplanted, thus limiting the number of possible harvests. The age-spacing combinations involving 15 and 20 day old seedlings (A_1S_2, A_1S_3, A_2S_2 and A_2S_3) gave more than the general average of three cuts. The combinations involving the oldest (25 day old) seedlings did not give more than three cuts in any instance.

Considering the quality characters, it was observed that the medium density plants, there was more accumulation of dry matter in leaves, but the low density plants accumulated more dry matter in the stem during the first cut, though the difference was not statistically significant in any instance. However, the medium density plants overtook the low density plants in subsequent cuts. Thus the medium density plants seemed to be better with regard to this character. In the case of moisture content, though the differences were not significant, the low density plants recorded higher percentage moisture in leaves and stem during the first cut. In the subsequent cuts, however, the high density plants registered higher values for this character. With regard to the other three quality characters (iron, protein and Vitamin A), the low density plants seemed to be better than the medium density and high density plants.

With regard to the quality aspects, the behaviour of seedlings belonging to the three age groups was erratic. Though the differences were not statistically significant, the oldest (25 day-old) seedlings had high dry matter content in stem (second cut), high moisture content in leaves (first and second cut), high iron content in leaves and stem (all cuts), high protein content in stem (first and third cut) and high Vitamin A content in leaves (first cut). However, because the differences were not statistically significant, valid conclusions cannot be drawn.

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*Originals not seen.

APPENDICES

Appendix I

Abstract of ANOVA

Height

Source	df	MS			
		Increment from 10 to 15 DAP	Increment from 15 to 20 DAP	Increment from 10 to 20 DAP	At the time of first cut
Replications	2	13.565	10.009	21.750	10.440
S	2	20.210**	4.506	28.850	5.960
A	2	26.280**	8.705	21.350	82.830*
S x A	4	0.633	2.919	4.360	10.010
Error	16	2.291	5.904	11.170	21.210

DAP - Days After Transplanting

* Significant at 0.05 level

** Significant at 0.01 level

Appendix II

Abstract of ANOVA

Girth of main stem

Source	df	MS			
		Increment from 10 to 15 DAP	Increment from 15 to 20 DAP	Increment from 10 to 20 DAP	At the time of first cut
Replications	2	0.1898	0.0138	0.2640	0.4910
S	2	0.0980*	0.0349	0.1280	0.9740*
A	2	0.2960**	0.2203*	0.0660	0.4800
S x A	4	0.0210	0.0440	0.0670	0.0270
Error	16	0.0230	0.0479	0.0690	0.2320

DAP - Days After Transplanting

* Significant at 0.05 level

** Significant at 0.01 level

Appendix III

Abstract of ANOVA

Number of branches

Source	df	MS			
		Increment from 10 to 15 DAP	Increment from 15 to 20 DAP	Increment from 10 to 20 DAP	At the time of first cut
Replications	2	1.292	0.155	0.730	0.525
S	2	1.330*	2.012**	3.790**	3.860**
A	2	2.500**	0.762	0.580	11.890**
S x A	4	0.319	0.172	0.373	0.649
Error	16	0.275	0.292	0.337	0.588

DAP - Days After Transplanting

* Significant at 0.05 level

** Significant at 0.01 level

Appendix IV

Abstract of ANOVA

Number of leaves

Source	df	MS			
		Increment from 10 to 15 DAP	Increment from 15 to 20 DAP	Increment from 10 to 20 DAP	At the time of first cut
Replications	2	45.71	10.25	98.50	15.16
S	2	54.39*	57.65*	138.50**	230.74*
A	2	219.70**	10.25	155.31**	489.13**
S x A	4	9.92	5.05	5.78	18.87
Error	16	9.22	11.20	16.19	59.26

DAP - Days After Transplanting

* Significant at 0.05 level

** Significant at 0.01 level

Appendix V

Abstract of ANOVA

Spread of plant

Source	df	MS			
		Increment from 10 to 15 DAP	Increment from 15 to 20 DAP	Increment from 10 to 20 DAP	At the time of first cut
Replications	2	75049.46	9016.22	42273.27	36307.63
S	2	19937.99	39674.87	109747.72*	545609.98*
A	2	71902.16*	77838.13*	21967.22	15314.34
S x A	4	7672.32	21871.19	22917.83	18031.76
Error	16	14443.12	16868.44	26213.51	51905.59

DAP - Days After Transplanting

* Significant at 0.05 level

** Significant at 0.01 level

Appendix VI

Abstract of ANOVA

Individual leaf area at first harvest

Source	df	MS
Replications	2	268.35
S	2	1808.25**
A	2	1136.37*
S x A	4	167.56
Error	16	224.74

*Significant at 0.05 level

**Significant at 0.01 level

Appendix VII

Abstract of ANOVA

Frequency of harvest in days

Source	df	First cut	Second cut	Third cut
Replications	2	21.23	17.26	5.45
S	2	54.89**	14.33**	8.78**
A	2	28.22**	1.33	3.44**
S x A	4	1.78	1.17	0.44
Error	16	1.05	2.39	0.58

* Significant at 0.05 level

** Significant at 0.01 level

Appendix VIII

Abstract of ANOVA

Yield per plant

Source	df	MS				
		First cut	Second cut	Third cut	Total of three cuts	Total yield from all the possible cuts
Replications	2	56.82	222.28	48.52	617.15	798.63
S	2	668.11*	33.08	2.78	927.83*	3066.99**
A	2	99.05	20.59	16.30*	26.57	556.91
S x A	4	75.57	14.70	5.04	78.34	202.49
Error	16	109.91	22.74	3.07	190.61	201.03

* Significant at 0.05 level

** Significant at 0.01 level

Appendix IX

Abstract of ANOVA
Yield per square metre

Source	df	MS				
		First cut	Second cut	Third cut	Total of three cuts	Total yield from all the possible cuts
Replications	2	0.235	1.250	0.245	3.320	4.032
S	2	3.006*	1.420**	0.606**	11.270	4.630*
A	2	0.319	0.056	0.089*	0.209	2.130
S x A	4	0.323	0.067	0.042	0.508	0.488
Error	16	0.749	0.155	0.015	1.297	1.300

* Significant at 0.05 level

** Significant at 0.01 level

Appendix X

Abstract of ANOVA

Average weight of leaves per plant

Source	df	MS				
		First cut	Second cut	Third cut	Total of three cuts	Total from all the possible cuts
Replications	2	14.03	115.80	31.68	338.32	457.96
S	2	198.27**	12.03	1.73	306.07*	1401.84**
A	2	63.19	22.06	10.58**	1.41	253.38*
S x A	4	38.52	7.94	3.54	41.73	114.04
Error	16	24.92	12.44	1.38	64.54	68.34

* Significant at 0.05 level

**Significant at 0.01 level

Appendix XI

Abstract of ANOVA

Average weight of stem per plant

Source	df	MS				
		First cut	Second cut	Third cut	Total of three cuts	Total yield from all the possible cuts
Replications	2	15.76	17.28	2.23	48.81	60.42
S	2	143.22*	5.24	0.19	174.48*	327.82**
A	2	46.27	1.09	0.82	40.02	87.16
S x A	4	8.41	1.66	0.26	6.76	14.36
Error	16	35.65	1.96	0.61	44.42	46.99

*Significant at 0.05 level

**Significant at 0.01 level

Appendix XII

Abstract of ANOVA

Leaf/stem ratio

Source	df	MS				
		First cut	Second cut	Third cut	Total of three cuts	Total from all the possible cuts
Replications	2	0.006	0.134	1.060	0.127	0.168
S	2	0.027	0.381	0.475	0.027	0.091
A	2	0.194**	2.036**	0.169	0.112	0.102
S x A	4	0.029	0.214	0.143	0.012	0.025
Error	16	0.016	0.257	0.684	0.046	0.045

* Significant at 0.05 level

** Significant at 0.01 level

Appendix XIII

Abstract of ANOVA

Percentage dry matter of leaves and stem

Source	df	MS					
		First cut		Second cut		Third cut	
		Leaves	Stem	Leaves	Stem	Leaves	Stem
Replications	2	3.380	1.650	7.980	2.029	9.520	7.370
S	2	3.200	0.060	1.200	0.970	9.890	2.810
A	2	0.057	0.020	2.920	2.053	0.820	1.270
S x A	4	2.490	0.554	0.468	1.820	4.280	1.770
Error	16	1.505	0.537	1.810	0.709	4.210	2.400

Appendix XIV

Abstract of ANOVA

Percentage moisture in leaves and stem

Source	df	MS					
		First cut		Second cut		Third cut	
		Leaves	Stem	Leaves	Stem	Leaves	Stem
Replications	2	3.380	1.670	7.980	2.030	9.490	7.370
S	2	3.200	0.052	1.200	0.970	10.150	2.810
A	2	0.060	0.020	2.920	2.053	0.900	1.270
S x A	4	2.490	0.550	0.470	1.820	4.320	1.770
Error	16	1.510	0.536	1.810	0.702	4.320	2.400

Appendix XV

Abstract of ANOVA

Iron content in leaves and stem

Source	df	MS					
		First cut		Second cut		Third cut	
		Leaves	Stem	Leaves	Stem	Leaves	Stem
Replications	2	7.09	19.77	12.76	2.88	11.66	0.41
S	2	209.97*	79.03	1290.49	163.35	723.34	91.81
A	2	18.01	3.71	153.43	0.41	45.13	26.36
S x A	4	10.27	19.77	62.76	22.61	70.03	33.75
Error	16	37.92	28.10	403.98	122.35	222.42	54.55

*Significant at 0.05 level

Appendix XVI

Abstract of ANOVA

Protein content in leaves and stem

Source df	df	MS					
		First cut		Second cut		Third cut	
		Leaves	Stem	Leaves	Stem	Leaves	Stem
Replications	2	0.031	0.031	0.595	1.040	0.050	0.503
S	2	2.737**	1.970*	12.310**	3.910*	6.670**	4.545
A	2	0.196	0.193	0.350	0.308	0.000	0.312
S x A	4	0.112	0.129	0.960	0.046	0.530	1.380
Error	16	0.234	0.401	1.160	0.974	0.462	0.333

* Significant at 0.05 level

** Significant at 0.01 level

Appendix XVII

Abstract of ANOVA

Vitamin A in fresh leaves

		MS		
Source	df	First cut	Second cut	Third cut
Replications	2	252675.21	531134.25	5156.80
S	2	4723479.48	15243012.50*	9921350.63
A	2	159856.63	1335571.84	190795.60
S x A	4	252674.38	600745.79	747711.61
Error	16	1453528.65	2573156.10	2836148.36

* Significant at 0.05 level

STUDIES ON THE EFFECT OF PLANT POPULATION DENSITY AND AGE AT TRANSPLANTING ON THE GROWTH, FREQUENCY OF HARVEST AND TOTAL VEGETATIVE YIELD IN AMARANTHUS (*Amaranthus gangeticus* Linn.)

By

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ABSTRACT OF THE THESIS

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE

MASTER OF SCIENCE IN HORTICULTURE

FACULTY OF AGRICULTURE
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ABSTRACT

Investigations were undertaken at the College of Agriculture, Vellayani to study the effect of plant population density and age at transplanting on the growth, frequency of harvest and total vegetative yield in amaranthus. Each of the three groups of amaranth seedlings, aged 15 days (A_1), 20 days (A_2) and 25 days (A_3) were transplanted at three spacings namely 10 x 10 cm (S_1), 15 x 10 cm (S_2) and 20 x 10 cm (S_3).

In the population density trial, low density plants (transplanted at 20 x 10 cm) exhibited overall better growth and quality characteristics. With regard to all the characters contributing to yield/harvest, and total yield, except yield/unit area, the low density plants exhibited their clear superiority over the medium density and high density plants. Increased number of harvests was also obtained when planted at wider spacing. However, for obtaining higher yield/unit area, transplanting at 10 x 10 cm seemed to have advantage over the others. Such closely planted amaranthus came to flowering faster than the widely spaced ones.

The investigation carried out with a view to understanding the effect of age at transplanting on the growth, yield and quality in amaranth, revealed that the 25 day-old seedlings when transplanted gave better growth. With regard to the quality aspects also, the 25 day-old seedlings seemed

to have a slight edge over the others. However, these plants showed early initiation of flowering, thus limiting the number of possible harvests. Further, when yield and yield attributes were considered, the 15 and 20 day-old seedlings performed better. Considering all the aspects together, transplanting of 15 to 20 day-old seedlings can be recommended for obtaining higher weight of leaves/plant, higher weight of stem/plant, better leaf/stem ratio, higher yield/plant, higher yield/m^2 and more number of harvests.