STUDIES ON SOME COMPETING FACTORS IN THE INTERCROPPING SYSTEMS OF RUBBER (*Hevea brasiliensis* Muell. Arg.)

By
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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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Department of Agronomy
COLLEGE OF HORTICULTURE
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DECLARATION

I hereby declare that the thesis entitled "**STUDIES ON SOME COMPETING FACTORS IN THE INTERCROPPING SYSTEMS OF RUBBER (*Hevea brasiliensis* Muell. Arg.)**" is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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Above all I bow my head before God Almighty who blessed me with health and confidence for the successful completion of this endeavour.

MATHEW JOSEPH

Dedicated with grateful memory to the departed soul of my beloved sister Smt. Lucy Joseph B.Sc. B.Ed.

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ABBREVIATIONS USED

cm	-	centimeter
cpm	-	counts per minute
dia	-	diameter
g	-	gram
ha	-	hectare
ie.	-	that is
IAEA	-	International Atomic Energy Agency
kg	-	kilogram
m	-	metre
mCi	-	millie curie
RBD	-	randomised block design
CRB	-	completely randomised design
cv.	-	cultivar
viz.	-	namely
DAA	-	days after application
SRS	-	single row system of planting
DRS	-	double row system of planting

INTRODUCTION

INTRODUCTION

Natural rubber (*Hevea brasiliensis* Muell. Arg.) is one of the important commercial crops of Kerala. The share of natural rubber in total cropped area marked a steady increase in the state and it occupied 14.64 per cent of gross cropped area in 1995-96. Almost 85 per cent of national area and 94 per cent of production are concentrated in the state. It is being cultivated in estates and small holdings and nearly 86 per cent of rubber is produced in the small holding sector in India. Almost 73 per cent of the world's natural rubber is produced in small holdings (IRSG, 1999).

Natural rubber has a long gestation period of about seven years which can act as a disincentive to rubber cultivation particularly in the case of small holders. Land use efficiency is low during the initial establishment phases with rubber occupying only about one-fifth of the planted area under normal spacing. The under-utilized interspace and other resources like sunlight during the immature phase offer wide scope for intercropping. In order to supplement the income of the farmers or for subsistence, intercropping is recommended during the first three years. The intercrops are planted between the rows of young rubber trees.

Intercropping, in general, offersadvantages of improved utilisation of factors of production, greater total agricultural yield per unit of land and a more even utilisation of household labour (Vandermeer, 1989). Intercropping makes use of different plant characteristics such as growth period, photosensitivity, nutrient and water uptake and physical attributes in such a way that the `growth resources' available to each crop are more efficiently used (Willey, 1979).

Intercropping for us is an intrinsic part of traditional farming system in the tropics, but only a few farmers have experience in intercropping with rubber because of its later introduction as a small farmer's crop (Rodrigo, 1997). Nevertheless, the practice of multiple cropping in homesteads of rubber growers suggests that there is already an awareness of the importance of intercropping which has to be fully exploited. This can be achieved with the development of appropriate methodologies.

By and large, the type of crops selected for intercropping depends on the nature of the crop as to whether it is complementary or competitive to rubber, its input requirements, relative profitability and the preference of the farmer. The crops that are generally considered for intercropping are banana, pineapple, ginger, turmeric, vegetables etc. These crops differ widely in their input requirements and cost of production. The estimated cost of production of pineapple is five times that of banana (Gray, 1997). It is also estimated that almost 80 per cent of the small growers who adopted intercropping with rubber had chosen banana as the companion crop. The major reason for cultivating banana is the financial sustainability resulting from the lower capital cost, ready market and high profitability. A survey conducted in Kottayam district showed the highest profit for banana with a benefit cost ratio of 1.61 (Sreenivasan *et al.*, 1987). Another reason was that the labour requirement for banana cultivation was relatively low.

Some of the experiments have shown the feasibility of growing intercrops during the initial immaturity period of rubber (Mathew *et al.*, 1979). Studies also have shown that certain shade loving medicinal plants can be grown even in mature rubber, provided disturbance to rubber roots by tillage can be kept to the minimum. However, elaborate studies on competition, root activity and shade requirement of intercrops in rubber were not attempted earlier.

The present study aims at further studying the extent of involvement of two competing factors, root and light in the early years of growth of rubber so that recommendations on the choice of more suitable intercrops can be made.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The literature available on the different aspects pertaining to the present study are classified under the following heads.

1. Root studies
2. Root distribution pattern of crop plants
3. Crop competition in intercropping situations
4. Use of radioisotopes in root activity studies
5. Root activity studies in rubber and banana
6. Root activity studies in mixed crop stand
7. Light intensity studies

2.1 Root studies

The interest in root studies of crop plants started in early eighteenth century, with the studies of Hale in 1727 as reported by Bohm (1979). The increased fertilizer use in crop plants in fact necessitated the understanding of the root system which actually led to the discovery of more and more methods for root studies. Consequently, Weaver (1926) developed scientific excavation techniques. Later, the discoveries of profile wall method (Oskamp and Batjer, 1932) and monolith method (Pavlynehenko, 1937) led to more studies concerning roots.

The introduction of radiotracers in root research by Hall *et al.* (1953) seems to be an important landmark in the field of root studies. Improved techniques like construction of modern root laboratories and rhizotrons (Karnok and Kucharaki, 1982), facilitated more reliable and easy methods for studying root systems.

2.2 Root distribution pattern of crop plants

Root studies are extremely important in crop plants for evaluating their producing capacity in a given soil and to develop suitable cultural practices for maximising the yield. The direct methods provide a clear picture of the entire root system of a plant as it exits naturally.

2.2.1 Plantation crops

In the evaluation of the vertical distribution of feeder roots of rubber, Soong (1976) found that in most soils, the greatest root proliferation was in the top soil and the proliferation decreased rapidly with depth. Samarappuli *et al.* (1996) reported that feeder root density was significantly different between lateral distances from the base of the rubber plant and in their vertical distribution with the highest percentages of roots being in the surface soil layers, 0-10 cm and 10-20 cm in the region of 120 cm circle. The amount of feeder roots in the surface soil was more than 75 per cent of the total feeder roots and only 17.2 and 1.9 of the total weights were found in the lower soil layers, 20-50 cm and 50-90 cm, respectively.

Arrillaga and Gomez (1940) in Puerto Rico observed that 95 per cent of the root system of coffee was confined in the upper 30 cm of the soil and only 4 per cent in the 30 to 60 cm of the soil while 60-120 cm level contained less than one per cent only. Hatert (1958) studied the root system of robusta coffee and observed that the tap root extended to a length of 90 cm while lateral and secondary roots formed a dense mass around the tree covering an area of 7 to 8 sq. m. The root system of one-year-old coffee plants grown in loamy sand in Salvador was found to be concentrated in the top 30 cm layer of soil (Castro, 1960). Bavappa and Murthy (1961) reported that in arecanut, the root concentration was maximum at 60 to 90 cm from the base of the palm. In an eight-year-old arecanut palm, 61 to 67 per cent of the roots were concentrated within a radius of 50 cm while a few extended beyond 100 cm as reported by Bhat and Leela (1969). They also found that 85 to 79 per cent of the roots were within a depth of 50 cm of soil. The second soil layer of 50 to 100 cm depth contained 18 to 23 per cent of the roots. The maximum depth of penetration of roots was 2.6 m. More than 80 per cent of the roots was within a radius of 1 or 1.25 m from the trunk.

Mc Creary *et al.* (1943) studied the root distribution of cocoa in different soils of Trinidad by excavation and found that the stout laterals occurred in the top 30 to 40 cm soil layer. In tea, Patarava (1968) observed the greatest concentration of feeding roots at a depth of 10-30 cm and the minimum roots in the 50 to 60 cm layer of soil. Trereda and Chiba (1971) reported from Brazil that 90 to 98 per cent of the roots were in the upper 40 cm of soil layer in 2 to 4 year-old pepper plants. About 85 to 90 per cent of the roots were found in the upper 30 cm layer of soil.

2.2.2 Fruit plants

Fawcett (1913) observed that in banana the laterally spreading roots generally extended to a distance of 5.2 m and descended to a depth of 75 cm in the soil, with majority of the roots confining to a depth of 15 cm. He also found the minimum penetration to a depth of 140 cm. Godefroy (1969) stated that banana roots penetrated to a depth of 80-100 cm when grown in alluvial soils.

The studies conducted at the Indian Agricultural Research Institute, New Delhi by soil auger sampling technique revealed that the feeder roots of mango were mainly confined very close to the tree within a lateral distance of 60 cm and a depth of 15 cm and about 90 per cent of the feeder roots were within the peripheral 180 cm (Bojappa and Singh, 1975). The concentration of roots decreased with increasing distances from the tree and depth of soil. Average spread of roots of guava was found to be upto 215 cm away from the tree and laterals were fcund to develop 17.5 cm below the surface of soil (Burns and Kulkarni, 1920). The pineapple roots developed to a depth of 1.3 m and when 12 months old, 95 per cent of the roots were confined to the top 20 cm of soil (Inforzato *et al.*, 1968).

2.3 Crop competition in intercropping situations

Nair (1978) reported that plant community interactions with perennials were of a different nature and of greater magnitude than in the case of sole crops. Plant interactions have been referred to as `interference effects' (Harper, 1961) or `neighbouring effects' (Trenbath and Harper, 1973). Interaction between the components of the multispecies crop combinations may result in sharing of growth factors and cause changes in the physical and biological variables in the ecosystem. Manifestations of such complementary interactions involve favourable ecoclimate, increased activity of beneficial rhizosphere micro-organisms and higher efficiency in the use of native and applied nutrients. Other interaction effects include annidation, allelopathy, plant parasites, economic complementarity etc. But normally in a plant community, interferences between plants lower absorption or interception rates of growth factors relative to those in isolated plants and competition will begin.

Therefore, interactions between neighbouring plants with respect to growth factors are often described as forms of competition for the growth factors absorbed through both leaves (light and CO_2) and roots (water, nutrients and oxygen). A knowledge of plant community interactions in crop combinations are indispensable in the design of mixed and intercropping systems. The underlying principle of intercropping in rubber is one of `ecodevelopment', which aims at maximum utilisation of available resources through rational choice and management of crops that can be successfully grown in the interspaces of immature rubber. The yield advantage or disadvantage of intercropping systems is the resultant of several interacting components.

2.3.1 Root level competitions

According to Trenbath (1974), the advantages in some mixed crop situations are due to the differences in the rooting pattern which occur from the mutual avoidance of different root systems. There is a tendency for crops to avoid areas that have already been depleted of resources by an associated crop. The roots of crop plants of adjacent rows intermix in intercropping, depending on the row spacing and crop species involved. This may have implications of root competition for water and nutrient uptake between the species. The presence of the roots of one species may change the course of development of the roots of the other crop. The root system of sole pigeon pea was compared with that of intercropped pigeon pea at ICRISAT (Narayanan and Sheldrake, 1976). In the intercropping system, the growth of pigeon pea roots was slow prior to the harvest of the intercrop, sorghum. Thus the pigeon pea roots were influenced not only by the competition from companion crops but also by its own roots. Gregory and Reddy (1982) studied the root systems of groundnut-pearlmillet intercropping system in comparison with rooting pattern of the monocrops. The pattern of rooting was intermediate between the two monocrops.

Under mixed crop condition, the orientation and spread of cocoa roots get modified considerably. Bhat (1983) reported that cocoa plants when grown mixed with arecanut showed more expansion of roots both laterally and vertically compared to sole cropped cocoa. In the sole crop situation, over 67 per cent of the roots were seen in the 0-50 cm soil layer whereas only about 40 per cent of the total roots could be found in this layer in the mixed garden. Further, the preponderance of fine roots in the top 50 cm soil layer in the sole crop situation was about twice as that in the mixed crop.

In intercropping systems, roots of two or more species share the same space and compete for moisture and nutrients. The characters which contribute to success in competition for soil factors include early and fast penetration of roots through soil (Mc Cown and Williams, 1968), high root density (Andrews and Newman, 1970), high productivity of actively growing roots (Slatyar, 1967; Barley, 1970) and a high uptake potential for the nutrients (Bowen, 1973).

In crop combinations with coconuts where the canopies of components occupy different vertical layers, the coconut palm is not subjected to competition for factors which are absorbed through leaves. But they could be subjected to competition for factors absorbed by roots. The crops grown along with coconut could be subjected to short supply of one or all of these factors (Nair, 1978).

Water, nutrients and oxygen are taken up from the soil by the roots. The uptake of dissolved nutrients or oxygen by root surface establishes a concentration gradient, which enables supplies of the substance through diffusion towards the roots (Dunham and Nye, 1974). Similar is the case with water also. The movement of nutrients, oxygen and water to the roots deplete the soil of these factors in the vicinity of the root. Competition for soil factors among different components of a crop community begins when the depletion zones around individual root systems overlap although competition among individual roots of the same plant may begin earlier. In many situations, the density of active absorbing roots is such that the depletion around adjacent roots overlap and there is a significant decline in the average concentration of solute throughout the zone exploited by roots (Nye *et al.*, 1975 and Nye and Tinker, 1977). The distance of the depletion zone depends on a variety of factors. The depletion zone for water and mobile ions like nitrates which are carried away passively in moving soil water extends to much longer distance than for nutrients like phosphates and adsorbed cations (NH_4, K, Ca, Mg) which are at low concentrations in soil water, and therefore, move almost exclusively by slow diffusion (Brewster and Tinker, 1970). This narrowness of non-mobile nutrients tends to prevent competition for these nutrients between root systems of different crops in a crop combination except at high density of roots. The knowledge of the pattern of active roots of different crops alone and in a crop combination, then becomes important.

2.4 Use of radioisotopes in root activity studies

Studies on roots are of prime importance in plant nutrition as they are responsible for the absorption of soil nutrients and extraction of soil moisture besides its function to anchor the plants. Despite the importance of the root system, studies on it have been very few primarily because of the difficulties encountered in examining roots in their natural environment. Now-a-days, it has been found that isotopic techniques serve as a quick and reliable means for root system studies. The development and activity of plant root system in a natural soil profile was first measured with a radioactive tracer by Lott *et al.* (1950) and then by Hall *et al.*(1953).

Among the isotopic techniques, two methodologies are generally followed. One is the plant injection technique of Raez *et al.*(1964) which was subsequently improved and modified by Rennie and Halstead (1964). This is used for studying the root distribution pattern in small plants. Another method is soil injection technique for studying the root activity pattern of tree crops. Several workers like Fox and Lipps (1964) and Russel and Ellis (1968) have suggested that root distribution and root activity in different soil depths and lateral distances from the plant can be accurately and easily assessed by studying the uptake of radioisotopes placed at specified spots in the soil. Wahid *et al.* (1985) developed a simple device for soil injection of ^{32}P solution which is very successful in root activity studies.

For radiotracer studies, generally ^{32}P, a hard beta emitter, is used because of its convenient half life (14.3 days) and ease of measurement. It is a slowly diffusing nuclide and with its restricted mobility in the soil and rapid absorption and translocation in the plant, the position of the label can be correlated with root activity (Hall *et al.*, 1953; Nye and Tinker, 1977 and Vose, 1980). Sometimes other nuclides like ^{15}N, ^{86}Rb and non-radioactive strontium (Fox and Lipps, 1964; Ellis and Barnes, 1973; IAEA, 1975) are also used.

The recovery of radioactivity in the plant from a particular soil zone is determined by the proportion of active roots in that zone. This will serve as an index of the rate of nutrient uptake. The determination of total radioactivity absorbed by the plant is difficult in the case of trees unlike small plants. In such cases, IAEA (1975) recommended the radioassay of a suitable plant part to evaluate the uptake of the applied label from various root zones.

2.5 Root activity studies in rubber and banana

Literature on root system studies concerning fine root dynamics, root biomass and root architecture of trees is scanty. Most of the root studies using ^{32}P were made in monocrop situations.

2.5.1 Root activity studies in rubber (*Hevea brasiliensis* Muell. Arg.)

Soong *et al.* (1971), from ^{32}P studies in rubber, observed that maximum root activity was within 3.7 m radius from the base. It was also noticed that ^{32}P uptake was more from the subsoil than from top soil. This finding was, however, not consistent with the physical measurements which showed preponderance of roots in top soil. Singh *et al.* (1972) examined the techniques for the measurement of phosphorus uptake by mature trees of *Hevea brasiliensis* from different soils and soil zones using ^{32}P. Although leaf and latex assay gave similar results, latex assay was found to be less tedious and more reliable because leaf assay was affected by variations caused by age of leaf and position on the tree. Uptake of tracer was found to increase rapidly after two weeks and leaf radioactivity tended to decrease after six weeks. Activity of latex continued to increase. The best time of assay was concluded to be four to six weeks after tracer application. Soong (1976) in the evaluation of the vertical distribution of feeder roots, found that in most soils the greatest root proliferation was in the top soil and the proliferation decreased rapidly with depth. The results also showed significant changes in feeder root development at certain seasons. The maximum root development occurred in February/March, corresponding to the period of active refoliation and peak uptake of moisture and nutrients by the tree. The inimum root development was around August to December when leaf senescence sets in.

Chong-Qun Liu (1984) observed that the roots in the 10-30 cm soil layer below ground level gave the highest radioactivity. He also observed in the rubber seedling nursery that the ^{32}P absorbing capacity of roots was low when phosphate fertilizer was applied at the soil surface or at soil depths below 25 cm. The highest radioactivity of rubber seedlings was found in the 5-15 cm soil layer when ^{32}P labelled superphosphate was used. For rubber trees of 10-15, 25-30 and 50-55 cm girth, the highest root activity was found at the lateral distances of <30, 50-80 and 100-150 cm, respectively, from the tree trunk.

2.5.2 Root activity studies in banana

Walmsly and Twyford (1968) conducted studies in heavy clay and sandy loam soils of West Indies to find out the zone of nutrient uptake by banana cv. Robusta using ^{32}P soil injection technique. Radioactive ^{32}P was injected at specified spots and the plants were grown at different distances from the active spot. No radioactivity was detected in plants growing more than 2.4 m away from the radioactive soil in any of the sites and they concluded that the feeding roots of `Robusta' banana did not extend for more than a circle of 2.4 m radius in both heavy and light soils. It was also found that most of the plants in sandy loam soil had no feeding roots extending beyond 1.2 m. Root activity studies in two year old banana var. `Naketengu' in dry and wet seasons at Makeresa University in Uganda using radioactive ^{32}P showed that in wet season the maximum root activity occurred near the surface of soil at a distance of 40 cm from the plant (IAEA, 1975). The root activity decreased slightly to 15 cm and 30 cm depths and sharply declined at 60 cm depth during the wet season. In the dry season, the highest root activity was found at lateral distance of 40 cm and 80 cm. It was evident that during dry season, the highest root activity occurred at distant zones indicating an extensive development of root system. Moreover, during this season lateral roots were found to be very active at 120 cm and 160 cm distances at depths of 30 and 15 cm, respectively. Sobhana (1985) found that rainfed banana cv. Nendran had its maximum percentage of active roots (30%) at a soil zone of 30 cm depth and 40 cm away from the plant. As the lateral distances increased from 20 cm to 120 cm, a reduction was noticed in the percentage activity of roots.

2.6 Root activity studies in mixed crop stand

Studies of root activity pattern of crops are important in understanding the extent of soil space explored by component species in polyculture in view of competitive or complementary root - level interactions taking place among them (Willey, 1979). As the studies on root level interaction in mixed stands of rubber and banana by employing radiotracer techniques are scarce, similar studies in other mixed crop stands are also reviewed.

Lawton *et al.* (1954) studied the uptake of ^{32}P by brome grass and alfalfa grown in mixed stand. They concluded that more efficient use of phosphorus was from the surface in the case of brome grass and from a depth of 7.5 to15 cm in the case of legume. The root competition for the radiophosphorus by species grown in intercropping systems including corn - field bean, corn-sesame, corn-castorbean, castorbean-sesame were studied by Lai and Lawton (1962). They observed that corn was the most effective feeder of fertilizer phosphorus. Its roots penetrated the less extensive zone of the root system of beans and sesame to obtain phosphorus banded close to other component crops. In contrast, there was little cross feeding between adjacent rows of beans or sesame. Cooper and Ferguson (1964) found that the vertical and lateral growth of alfalfa, birds foot trefoil and orchard grasses were reduced when grown as companion crops with barley. Barley was able to compete with forage seedlings for moisture and nutrients early in the established period due to rapid root growth. Absorption of ^{32}P by component species in some grass-legume and cereal - legume mixtures had been reported by De *et al.* (1984).

Studies on complementary or competitive interactions in nutrient uptake among the plants in mixed cultures involving widely spaced crops/trees are very few. In a cassava - banana - elephant foot yam intercropping system, it was found that radio-phosphorus applied to the root zone of one of the component species was absorbed not only by the treated plant but also by the neighbouring plants (Ashokan *et al.*, 1988). In this system, banana was found to be the most dominant species which accumulated the major portion of radioactivity recovered by the root system. Sankar *et al.* (1988) analysed root activity patterns of black pepper vine and various support trees in relation to the root competition. It was found that 90 per cent of pepper root activity was confined to a radial distance of 30 cm from the vine. Pepper vines trailed on *Erythrina sp.* had a larger lateral root spread than those trailed on teak poles. George (1994) studied the root interaction in a silvi - pastoral system and he concluded that 65 to 85 per cent of the fine roots responsible for water and nutrient absorption were concentrated in the 0 to 15 cm layer of the soil profile. George *et al.* (1995) evaluated the root competition in poly culture systems involving combinations of four tree species and four grass species based on ^{32}P recovery by each species in mixed and sole crop situations. They found that grass species in sole crop situations absorbed more ^{32}P than in mixed systems. None of the grass species when grown in association with tree components affected the absorption of ^{32}P by trees.

2.7 Light intensity studies

Since literature available on light infiltration studies in rubber is meagre, similar pieces of work in other plantation crops are also reviewed.

2.7.1 Height / age of the plant

In the first reported work in coconut, Nelliat *et al.* (1974) studied the sequential changes in the percentage of light infiltration from the age of 10 year onwards in adequately spaced coconut plantations. In general, there was a progressive increase in light infiltration from 20 per cent during the 10th year to as high as 70 per cent with advancing age. Abraham (1993) found that the turning point of quadratic model relating light infiltration with plant height was found to be 6.4 indicating that the light infiltration decreases with increase in plant height upto this height of 6.4 meters there being a reverse trend beyond this height. The approximate age corresponding to the turning point was estimated as nine years. The decrease in light infiltration with increase in height in the early years is explainable as there will be a corresponding increase in canopy size and density. The decrease in it, on the contrary, may be due to decrease in effective canopy size and increase in plant height. Sanker and Muthuswami (1986) in a trial with ginger as intercrop in two-year-old and six-year-old arecanut planted at a spacing of 2.75 m x 2.75 m observed that the highest total dry matter production of ginger and dry matter accumulation in rhizomes at all stages were obtained in six-year-old arecanut. The light intensity in the interspaces of this six-year-old arecanut plantation was found to be 15.3 k lux.

2.7.2 Canopy

Garrilova (1969) reported that the increase in canopy density by every one unit is accompanied by a simultaneous reduction of total light radiation by 8 per cent and heat radiation by 15 - 20 per cent under the canopy. Stoutjesdijk (1972) elucidated that dense leaf canopies transmitted very little radiation in the wave length of 400-700 nm and very much more in the longer wave lengths.

Norman and Jarvis (1974) made investigations on light interception in 22 year old *Picea sitchensis* stand and concluded that the distribution of transmitted radiation was strongly influenced by leaf area index, the inclination angle of the sun and the ratio of diffused/direct light.

Kellomaki *et al.* (1985) reported that crown shape had only a small influence on interception of solar radiation and that a dense, regularly spaced stand of trees with tall, narrow symmetrical crown was most efficient. Sampson and Smith (1993) simulated the effects of changing canopy architecture on light infiltration and the results showed that the order of importance of the characteristics of the canopy architecture on light penetration was leaf area index, foliage aggregation, average leaf inclination angle and vertical distribution of foliage. It was also suggested that increased leaf area index and increased crown foliage aggregation result in reduced light capture efficiency (light capture/unit LAI). Abraham (1993) observed in coconut that the mean crown diameter and mean number of leaves have a negative relation with light infiltration.

2.7.3 Spacing/plant density

Satheesan *et al.* (1982) measured photosynthetically active radiation (PAR) in the open and in fully foliated mature rubber plantations grown at two spacings of 4.26 m x 4.26 m and 5.7 m x 5.7 m and reported that fully foliated canopies transmitted five per cent of the incoming photosynthetically active radiation and that there was no marked difference in the total PAR transmitted by the two stands. The widely spaced stand at 5.7 m x 5.7 m had a broad canopy, the spread of which was significantly higher than that in 4.26 m x 4.26 m. Leaf area index showed little variation under these two levels of spacing. Vales and Bunnell (1988) studied the relationship between transmission of solar radiation and coniferous forest stand characteristics and it was revealed that the sum of tree diameters and Reineke's stand density index were best predictors of global and diffuse radiation. Proportion of radiation components transmitted differed among radiation components and among stand. Abraham (1993) reported that in coconut, the east-west distance of planting and area occupied by a palm, have positive relationship with the degree of light infiltration.

MATERIALS AND METHODS

MATERIALS AND METHODS

Two field experiments were conducted on young rubber (initial three years) with and without banana as intercrop to study their root activity and competition aspects using radio isotop technique. A third experiment was also carried out to assess the availability of filtered light under the canopy of rubber during immature phase. The experimental fields were located at Vellanikkara which is at 10° 32'N latitude and 76° 10'E longitude at an altitude of 22.25 m above mean sea level.

3.1 Radio tracer experiments

Two experiments were conducted employing ^{32}P. One experiment was to evaluate the root activity pattern of young rubber trees in the first three years. The other experiment was to evaluate the root-level competition between rubber and intercropped banana during the first three years after planting rubber. The weather data during the experimental period are given in Appendix I.

3.1.1 Cropping history and cultural practices

Rubber (clone RRII-105) poly bag plants planted during 1994, 1995 and 1996 at a spacing of 6 x 3.5 m were used for the study. In each category, a part of area was maintained as rubber sole crop and utilized for studying root activity of rubber. Another part of the area was intercropped with banana cv. Poovan in single row and double rows planted in between rows of rubber for the root competition studies. In all cropping systems, manures and fertilizers were applied regularly to both the crops as per approved recommendations. The field was maintained for three years for experimentation. The soil type was laterite (vertisol). The physical and chemical properties of the soil is given in Table 1.

Table 1 Physico-chemical characteristics of the soil in the experimental field

Sl. No.	Particulars	Value	Method employed
1. Mechanical analysis			
	Sand	40.6%	Robinson's International Pipette method (Piper, 1942)
	Silt	26.8%	
	Clay	32.6%	
Soil texture		**Sandy clay loam**	
2. CEC		7.4 Cmol m^{-2}	Jackson, 1958
3. Available N		211 kg ha^{-1}	Alkaline permanganate method (Subbiah and Asija, 1956)
4. Available P		23.36 kg ha^{-1}	Bray I extract, Ascorbic acid blue colour method (Watanabe and Olsen, 1965)
5. Available K		100.5 kg ha^{-1}	Neutral normal ammonium acetate extract, Flame photometry (Jackson, 1958)
6. Organic C		0.84%	Walkely - Black method (Jackson, 1958)
7. Total N		2206 kg ha^{-1}	Micro-Kjeldahl method (Jackson, 1958)
8. Soil pH		5.2	1 : 2.5 soil : water suspension, pH meter (Jackson, 1958)

3.1.2 Experiment I: *Root activity pattern of young rubber during the first three years of growth*

The rubber plants were spaced at 6 x 3.5 m. Root activity was studied employing ^{32}P soil-injection technique (IAEA, 1975). The treatments consisted of factorial combinationsof five lateral distances and five depths as mentioned below.

Lateral distances	:	5 (50,100,150,200 and 250 cm)
Depths	:	5 (10, 25, 50,75 and 100 cm)
No. of treatment combinations	:	25
No. of replications	:	3
Design	:	RBD
Plot size	:	Single tree with border rows

The details of the lay out of the field are given in Fig.1

Mode of treatment application

Plants of uniform growth were selected for this experiment and the basins were cleared of weeds. Sixteen equidistant holes were taken in the soil around the selected plants in a circle according to the treatments mentioned above. This is illustrated in Fig.2 and Plate 8.

Holes were dug using a soil auger at different lateral distances and depths and PVC access tubes of 2 cm diameter were inserted to the appropriate depths keeping about 10-15 cm gutting above the soil surface. The access tubes were closed at the open ends with polythene cover to prevent entry of foreign materials. At the time of ^{32}P application, the polythene cover was removed from the PVC tube and 2 ml of

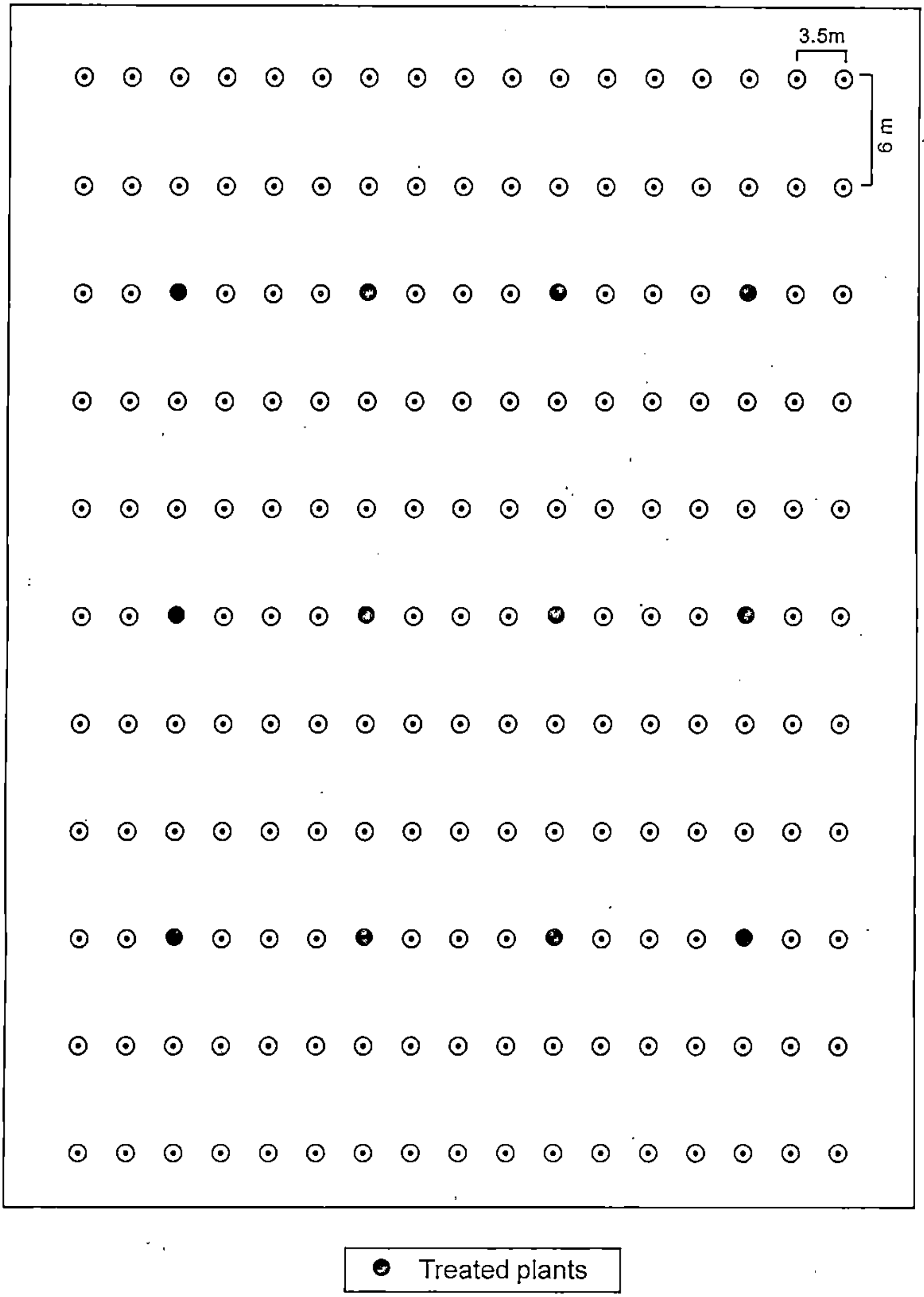


Fig. 1. Layout pattern of experimental field with pure stand of rubber

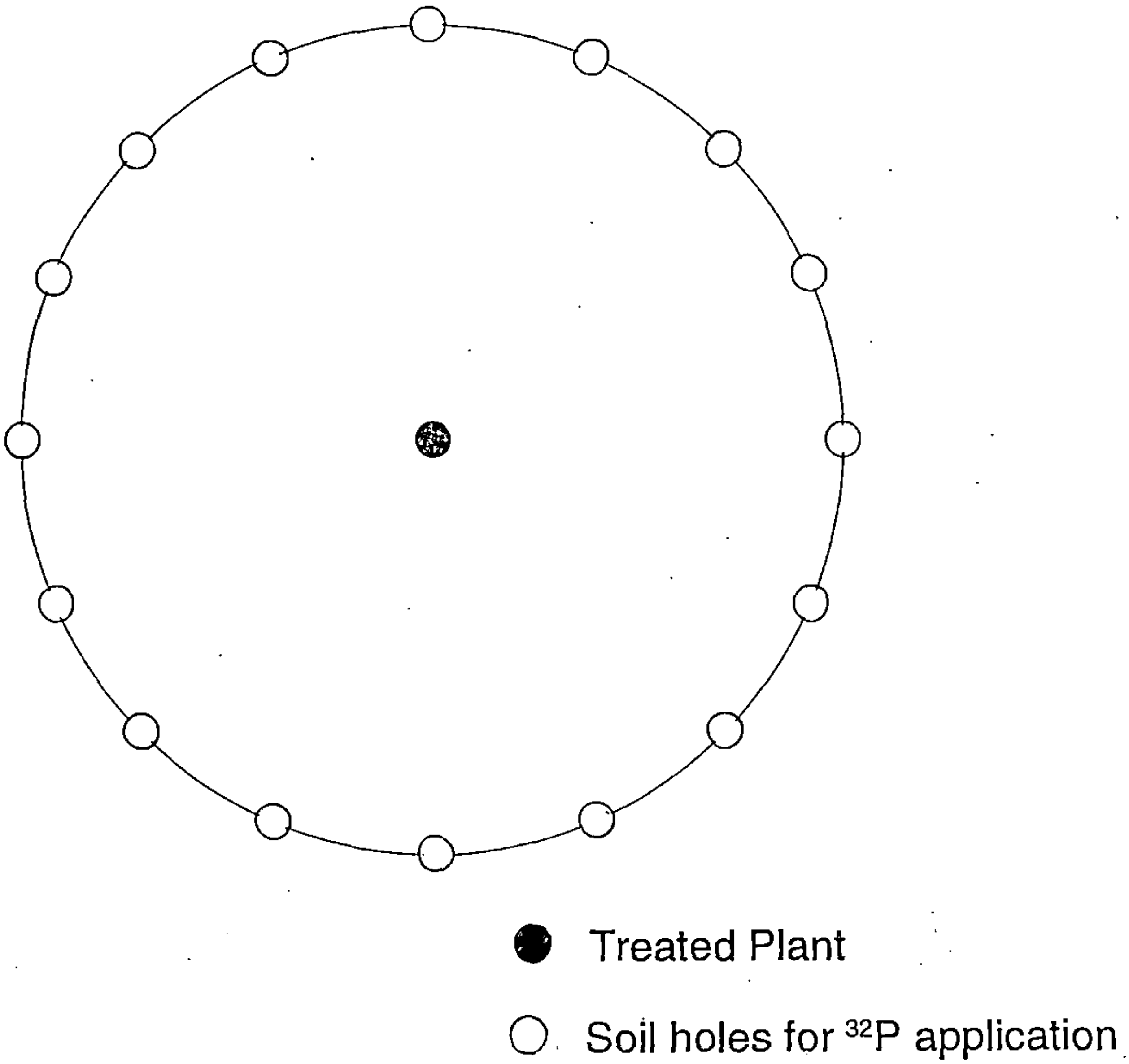


Fig. 2 Method of ^{32}P application in the experiment on root activity of rubber

radioactive solution at a carrier level of 1000 ppm P was applied into each tube using a laboratory dispenser (Plate 7) suitable for repeated delivery of fixed volume of solution (Wahid *et al.*, 1988). The total radioactivity applied per plant was 1 mCi (37 MBq). After dispensing, the solution remaining on the inner side of the access tube was washed down with a jet of water. The inclusion of carrier in the ^{32}P solution was to minimise the soil fixation of the applied label (IAEA, 1975).

3.2 Experiment II: *Root competition in mixed and pure stands of rubber and banana during the first three years of intercropping*

The lay out of the fields is given in Fig.3 to 7 and Plates 1 to 6.

After planting rubber during May 1995, part of the experimental area was interplanted with rainfed banana cv. Poovan using two different planting geometries. In one system, a single row of banana was planted 2 m apart along the inter row spaces of rubber, whereas in the other system, two rows of banana were planted along the inter rows of rubber. Simultaneously, two other fields were also planted with sole crop of banana under the two geometries of planting.

Root level interaction was studied employing ^{32}P soil injection technique. This experiment was continued for the first three years of planting of rubber and banana. The details of the treatments are as follows:

Cropping systems : 5

Rubber alone
Banana alone in single row system (SRS)
Banana alone in double row system (DRS)
Rubber + banana in SRS
Rubber + banana in DRS

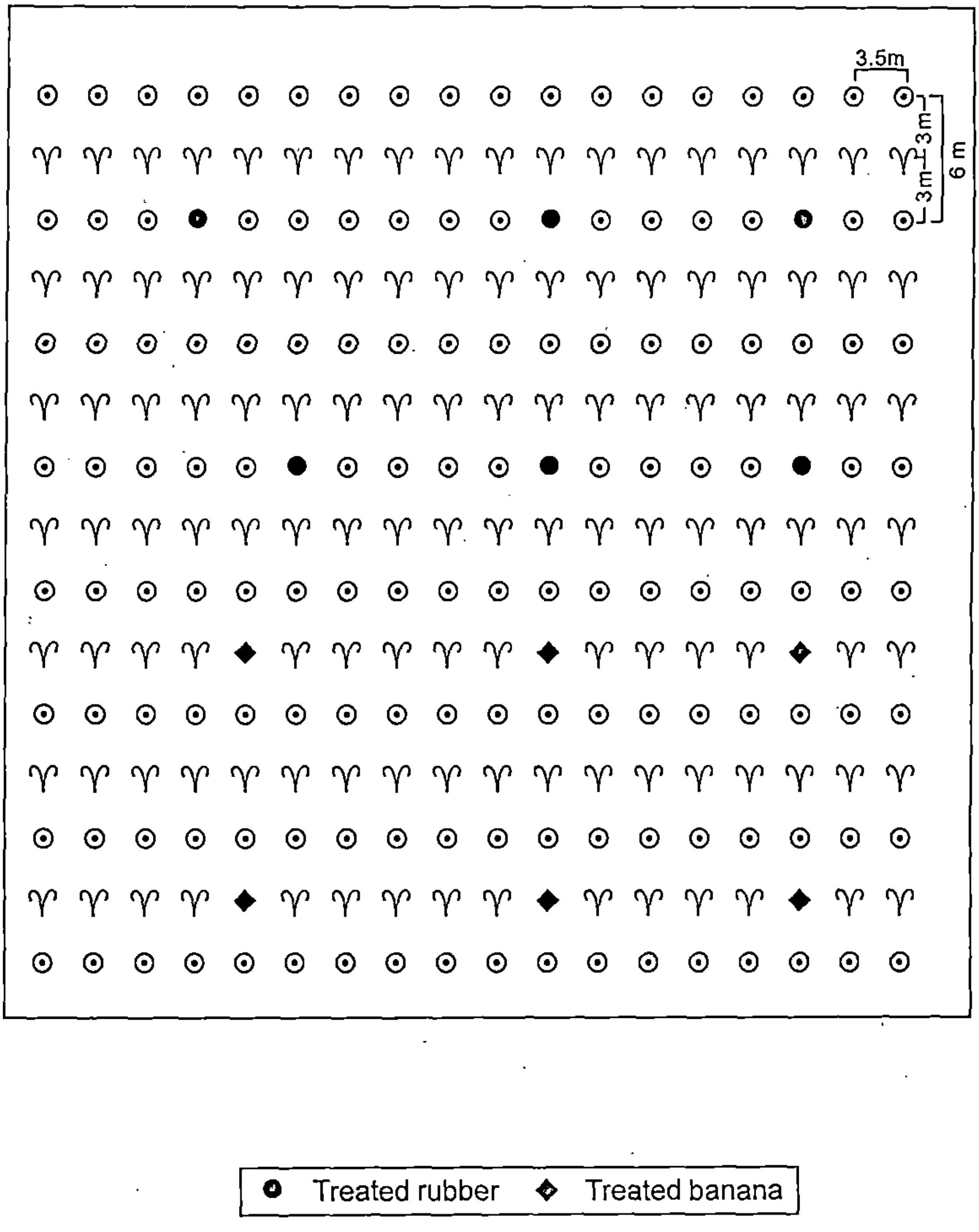


Fig. 3. Layout pattern of experimental field of rubber intercropped with banana in single row system

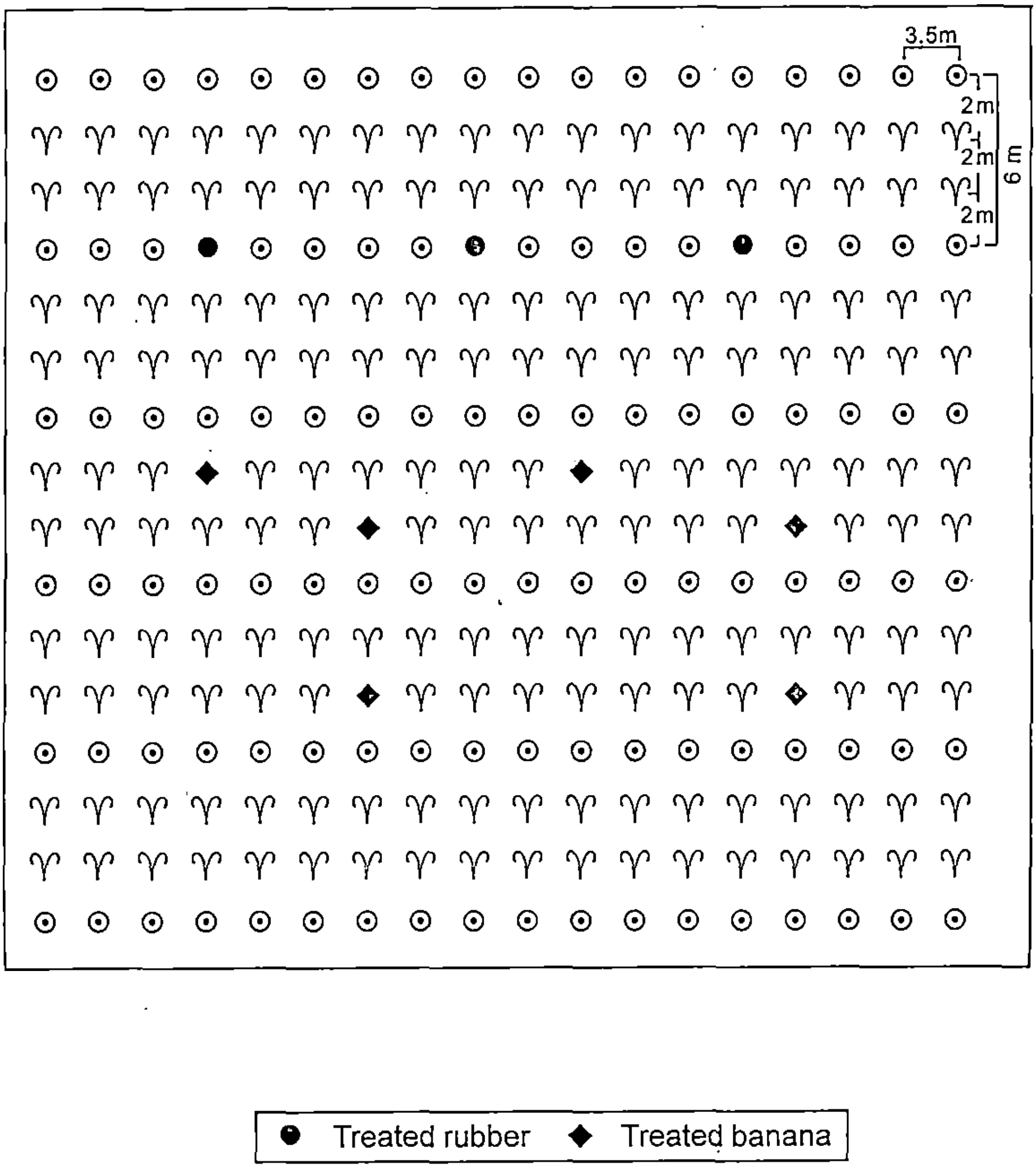


Fig. 4. Layout pattern of experimental field of rubber intercropped with banana in double row system

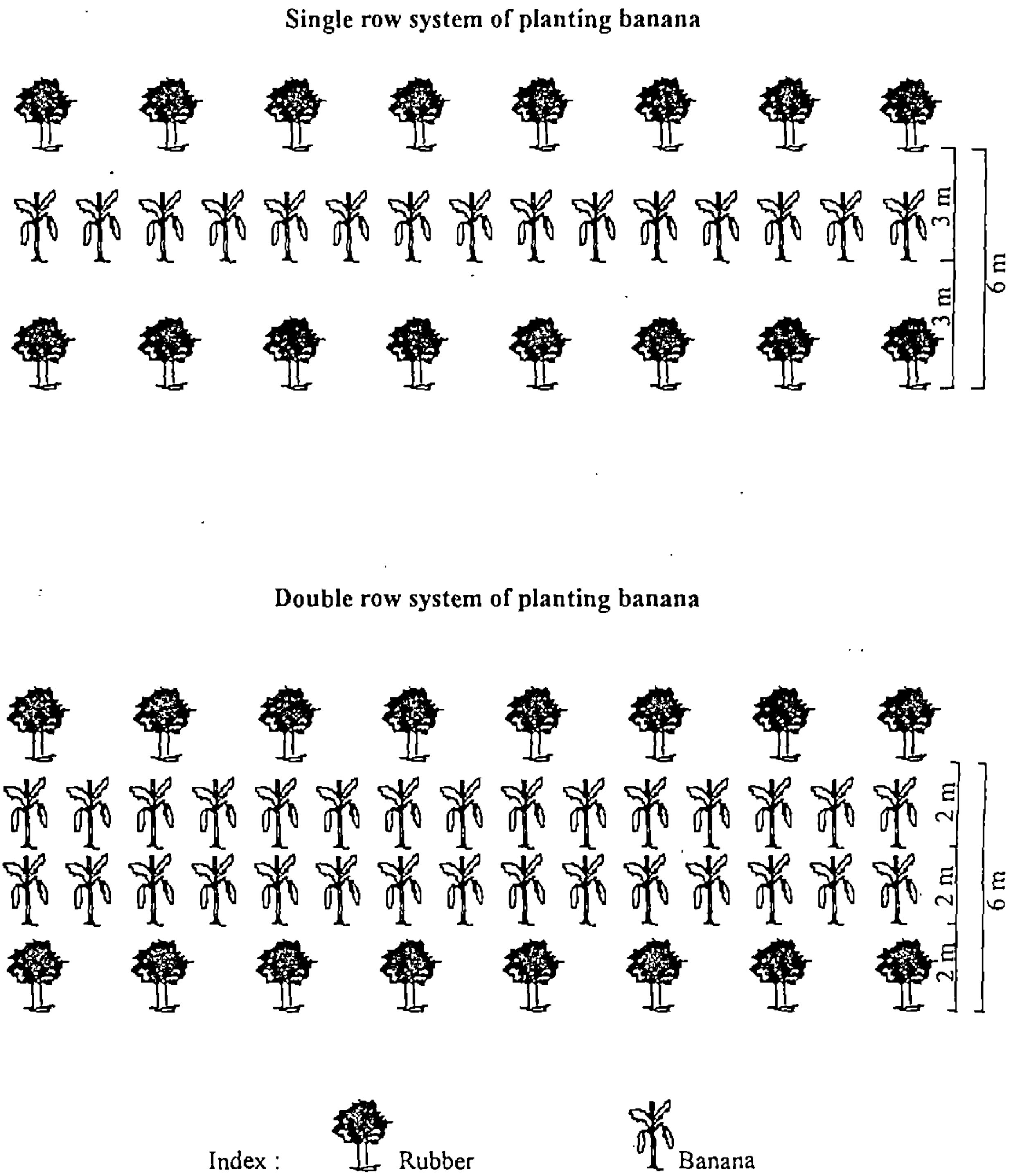


Fig. 5 Orientation of rubber and intercrop

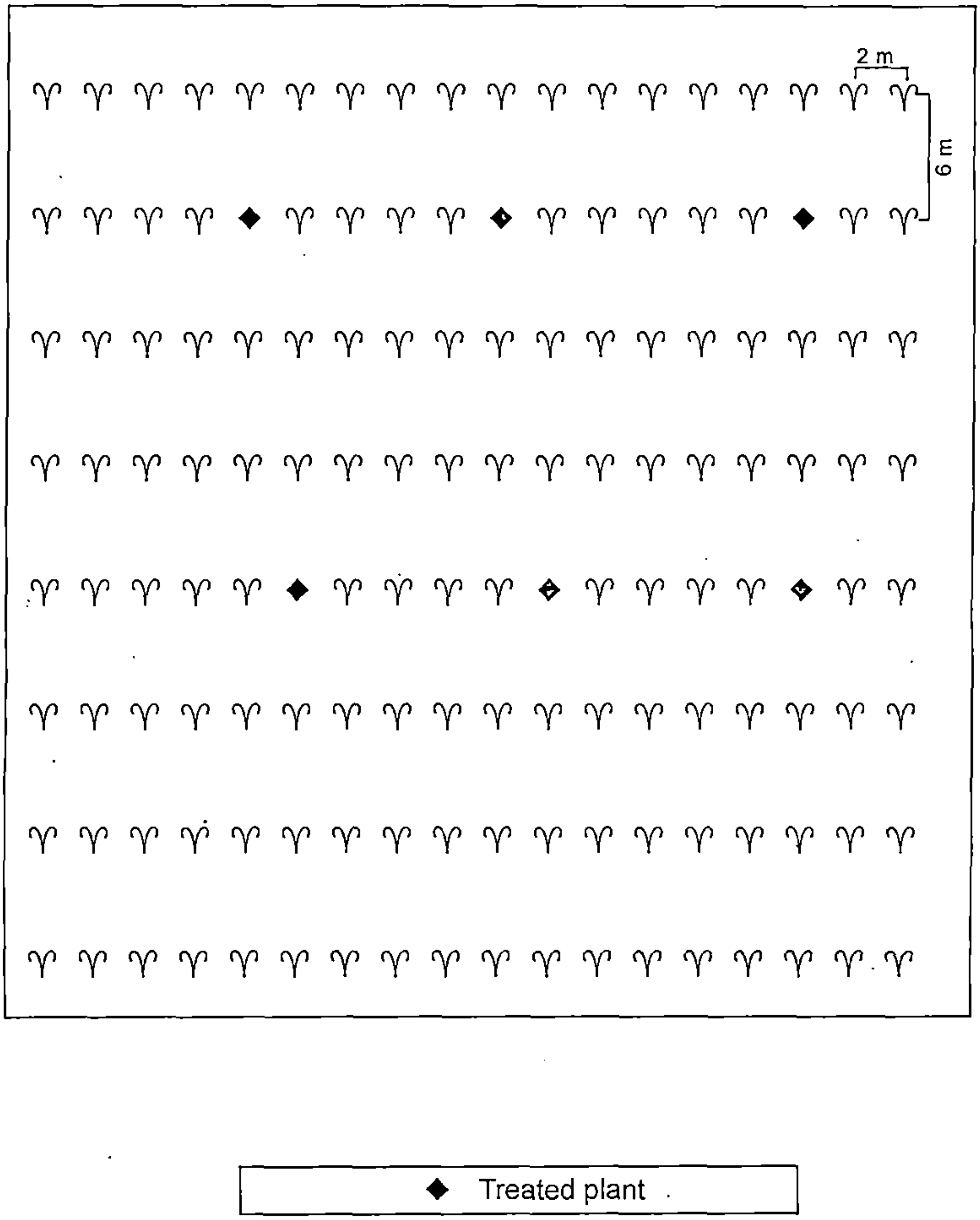
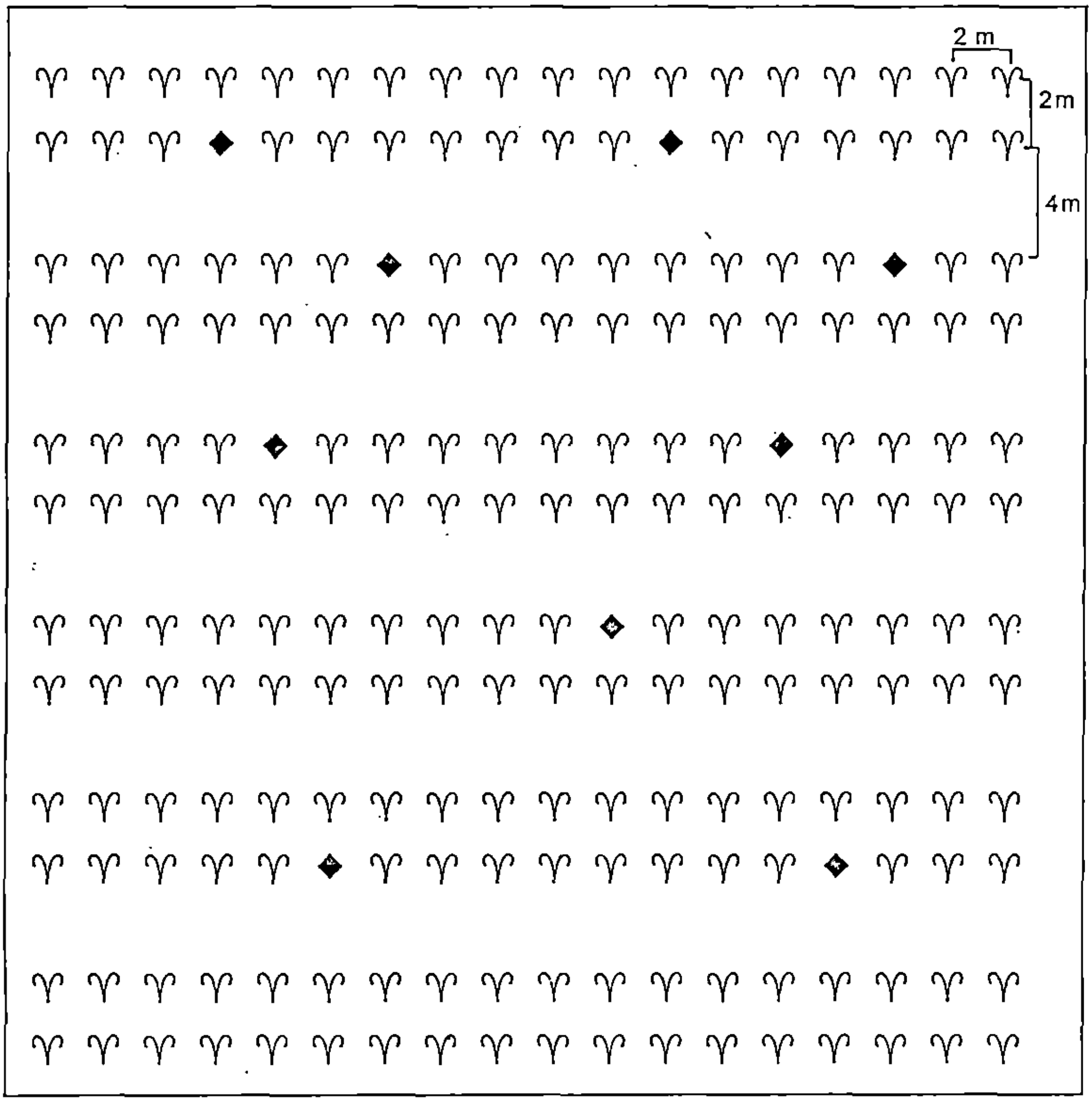


Fig. 6. Layout pattern of experimental field with pure stand of banana in single row system



Treated plant

Fig. 7. Layout pattern of experimental field with pure stand of banana in double row system

Method of application

Plants were selected randomly in such a way that root interaction between adjacent treated plants was avoided. The basins of the plants were cleared of weeds. Activity was applied to both rubber and banana in order to get a comparison between the root activity between these crops.

In this experiment, four circular rings of varying radii were made in the plant base. In each circle, nine equidistant holes of alternate depths at random were made as shown below and illustrated in Fig.8 and 9 so that all the roots got equal chance of ^{32}P absorption (Plate 9).

Lateral distance	:	4 (25,50,100 and 150 cm)
Depth	:	3 (25,50 and 75 cm)

The treatments were as mentioned below

(A) Application of activity to rubber

Treatments	:	3	Rubber alone
			Rubber + banana in SRS
			Rubber + banana in DRS
Design	:	CRD	
Number of replications	:	6	

(B) Application of activity to banana

Treatments	:	4	Banana alone in SRS
			Banana in SRS + rubber
			Banana alone in DRS
			Banana in DRS + rubber
Design	:	CRD	
No. of replication	:	5	

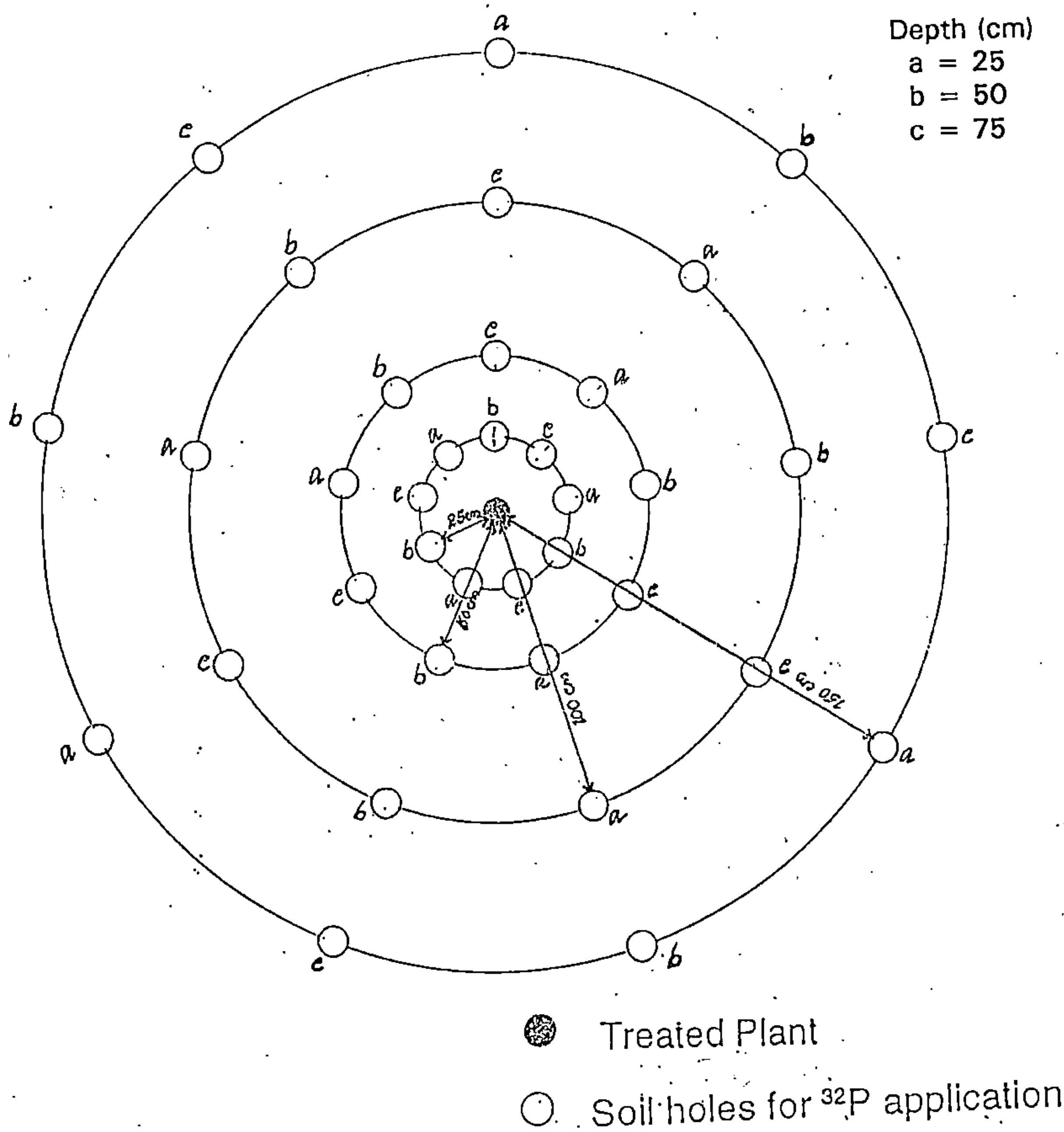


Fig. 8 Method of ^{32}P application in the experiment on root competition

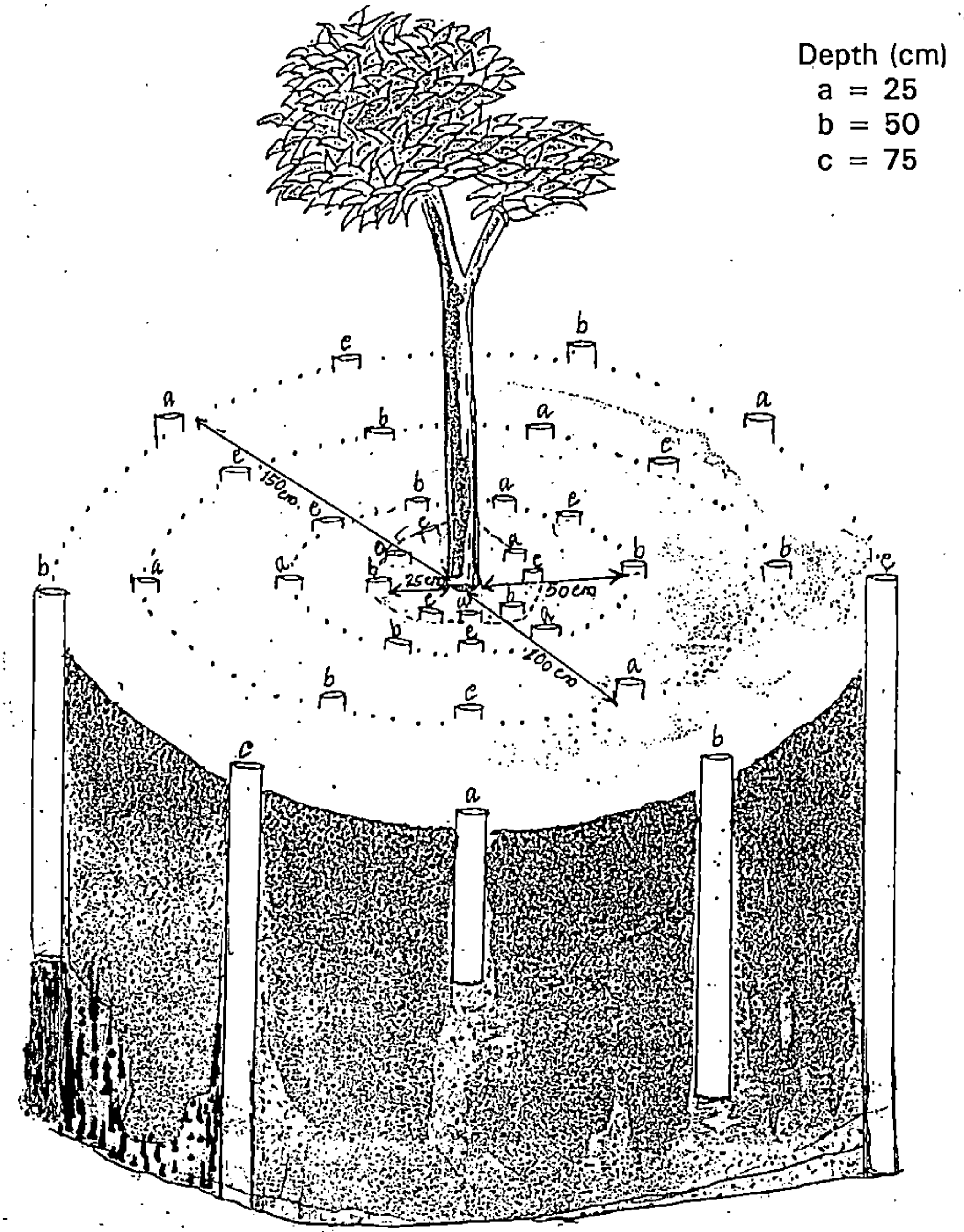


Fig. 9 Method of ^{32}P application in the experiment on root. competition-A field view

In the holes dug using a soil auger at different radial distances and depths, PVC access tubes (2 cm diameter) were inserted with about 10-15 cm gutting outside the hole. The access tubes were closed at the open ends with polythene cover to prevent entry of foreign materials. At the time of ^{32}P application, the polythene cover was removed from the PVC tube and 2 ml of radioactive solution at a carrier level of 1000 ppm P was applied into each tube as described earlier. The total radioactivity applied per tree was 2 mCi (74 MBq). The application of ^{32}P was done during the month of October in all the three years of experimentation.

3.3 Leaf sampling and radioassay

The extent of absorption of the soil applied radioactivity by the plant was measured by radioassay of leaf samples as follows: The leaves of both the crops were sampled at 15 day intervals for a period of one and a half months after ^{32}P application. The leaf samples were dried and radio assayed for ^{32}P content. In the case of rubber, leaflets from the recently matured whorl and in the case of banana, the third leaf from the top, were used for the radioassay. The leaf samples were dried at 65-70°C in a hot-air oven, powdered and acid-digested. They were then radioassayed by Wallac 1409, Finland, Cerenkov counting technique (Wahid *et al.*, 1985) in a liquid scintillation system.

The count rates (cpm) observed for the samples were corrected for the background and the decay.

3.4 Statistical analysis

The data were statistically analysed by applying analysis of variance. Assuming that the extent of absorption of applied ^{32}P from different depths and lateral distances by the plants is a function of relative root activity in the different soil zones, the percentage root activity at a particular depth and lateral distance was computed as follows:

$$\text{Root activity(\%)} = \frac{\text{Mean cpm values for the treatment}}{\text{Total cpm for all the treatments}} \times 100$$

In the root competition study under intercropped situation, the relative sharing of activity was compared between different treatments.

3.5 Light intensity studies in young rubber

This study aims at assessing the extent of light infiltration through rubber canopies of different ages planted at a common spacing of 6.0 x 3.5 m. This was conducted in Vaniyampara Rubber Estate, Thrissur, a location very near the present experimental site, during the summer season of 1997.

Measurement of light intensity

Measurements of light infiltration through rubber canopy were taken using line quantum sensor (LI 191 SA) (Plate 10) and point quantum sensor (LI 190 SA) (Plate 11) simultaneously. The component measured was photosynthetically active radiation (PAR) in units of micro moles/m^2/s. The line quantum sensor was placed in the centre of four rubber plants in the east-west direction and the point quantum sensor outside in an open area. A datalogger was attached to the two sensors to record the values from morning to evening at intervals of one minute. The data were later retrieved and hourly means were worked out. Thus, a single observation was taken from each age group. The location of the line quantum sensor, its direction and the duration of measurement were finalised based on earlier observations on such measurements and their standardisation (Abraham, 1993).

3.5.1 Observations

Percentage light infiltration

The hourly averages of PAR in the centre of four rubber plants and that in the open were obtained from the datalogger for each age group. From these values, per cent light infiltration was worked out as shown below for each years.

$$\text{Percentage light infiltration} = \frac{\text{Total PAR in the centre}}{\text{Total PAR in the open}} \times 100$$

Height of plants

The mean height of the plants for each age group was worked out from the height of the sample plants.

Girth of plants

The mean girth of plants at a height of 30 cm from the budunion was worked out from the girth of the sample plants.

Canopy diameter

Canopy diameter was measured as the distance between two points on the ground corresponding to the tips of the longest branches in the opposite direction. Such measurements were taken in the east-west and north-south directions for each canopy and the average worked out for a single plant. The mean canopy diameter of sample plants in each age group was then worked out.

3.5.2 Statistical analysis

Simple correlation coefficients relating all the parameters were worked out. Linear regression models were also fitted.

Plate 1
One-year-old rubber and banana in SRS

Plate 2
One-year-old rubber and banana in DRS

Plate 3
Two-year-old rubber and banana in SRS

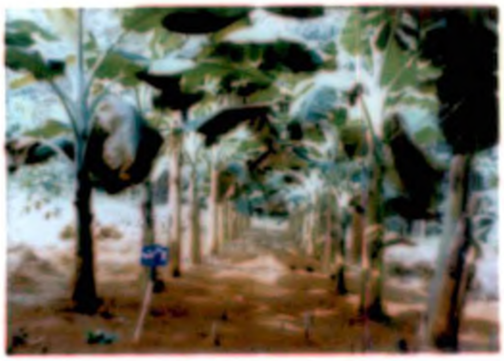


Plate 4
Two-year-old rubber and banana in DRS

Plate 5
Three-year-old rubber and banana in SRS

Plate 6
Three-year-old rubber and banana in DRS

Plate 7
Field dispenser for ^{32}P application

Plate 8
Application of ^{32}P in
root activity experiment

Plate 9
Application of ^{32}P in
root competition experiment

Plate 10
Line quantum sensor

Plate 11
Point quantum sensor

RESULTS

RESULTS

The following investigations were carried out during the course of this study and the results of the same are presented in this chapter.

1. Pattern of ^{32}P absorption by young rubber
2. Pattern of root activity in young rubber
3. Pattern of ^{32}P absorption by rubber and banana under intercropped situations
4. Pattern of root activity of rubber and banana under intercropped situations
5. Extent of root competition between the component crops in the intercropping system by sharing of applied radio activity
6. Extent of infiltration of light through the canopies of young rubber

4.1 Pattern of ^{32}P absorption by young rubber

In this experiment, radiophosphorus was applied employing soil injection technique (IAEA, 1975) around the rubber in circular rings of varying radii and depths. Leaves were sampled and radioassayed for ^{32}P 15, 30 and 45 days after application (DAA). In this study, comparisons were made of the uptake of radiolabel by the young rubber from varying lateral distances and depths.

4.1.1 Recovery of ^{32}P in the leaves as influenced by lateral distance and depth in the first year growth of rubber

The data on the recovery of radiolabel in the leaves of first year growth of rubber at 15, 30 and 45 DAA are given in Tables 2 to 5 and Fig.10 to 12 respectively. It is seen that the absorption of the radiolabel was significantly higher

Table 2 Uptake of soil applied ^{32}P (cpm/g leaf) at different lateral distances and depths by rubber (First year growth)

A. Lateral distance (cm)	Days after application		
	15 DAA	30 DAA	45 DAA
50	11806	23150	32696
100	14	100	225
150	7	18	331
200	5	28	157
250	3	20	198
SEm±	2266	5220	8129
CD (0.05)	6283	14469	22532
B. Depth (cm)			
10	3698	5163	5450
25	7911	17464	22613
50	211	572	4896
75	9	88	348
100	7	30	300
SEm±	2266	5220	8129
CD (0.05)	NS	NS	NS
AxB interaction CD (0.05)	14049	32353	NS

Table 3 ^{32}P activity (cpm/g leaf) recovered in the leaves of treated rubber (First year growth) at 15 DAA of ^{32}P to soil as affected by depth and lateral distances of application

Depth (cm)	Lateral distances (cm)				
	50	100	150	200	250
10	18456	15	1	12	7
25	39519	4	23	5	3
50	1011	36	1	5	1
75	21	10	8	3	1
100	26	5	1	2	1

SEm± : 5068
CD (0.05) : 14049

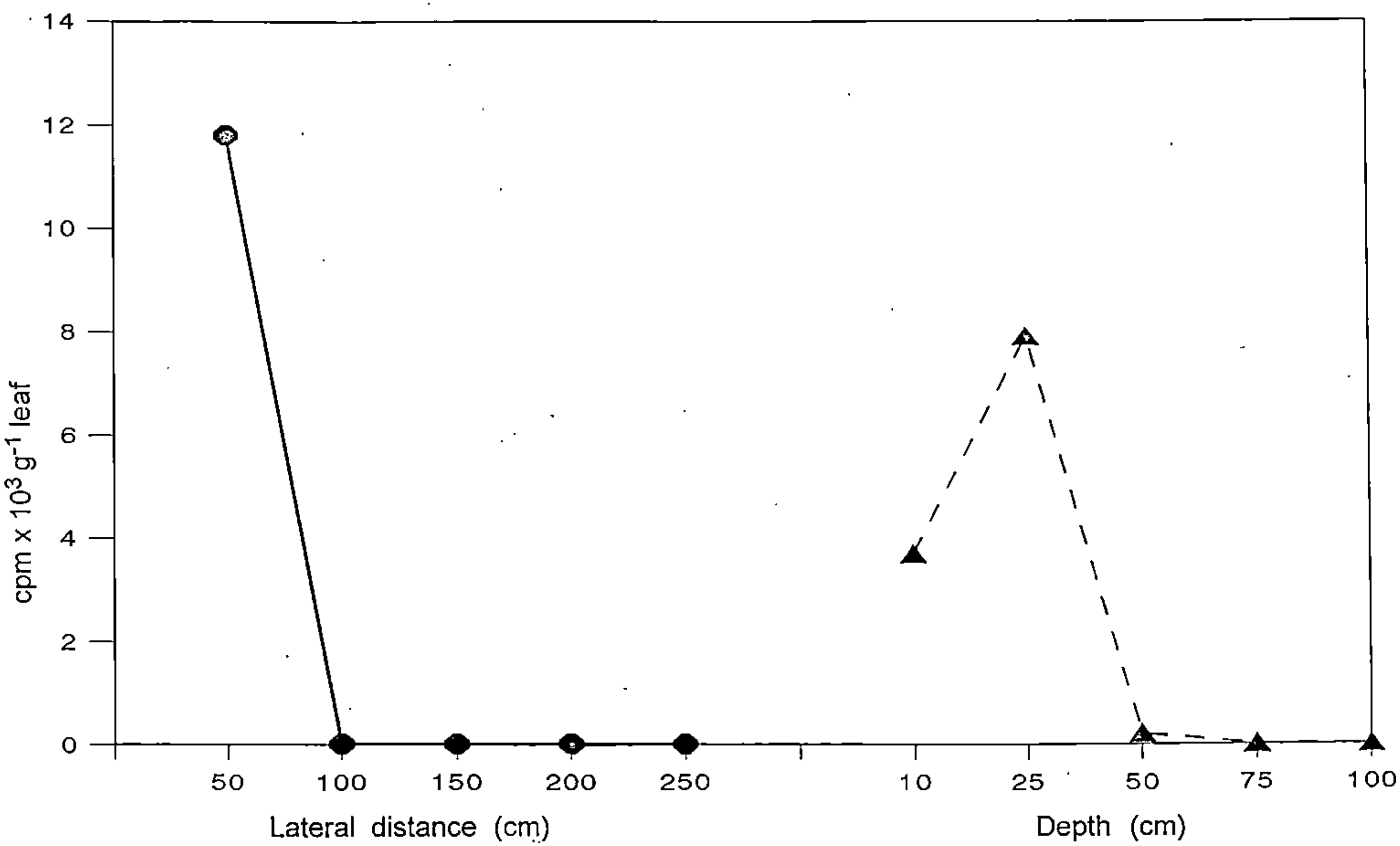


Fig. 10. Uptake of soil applied ^{32}P at different lateral distances and depths by one-year-old rubber at 15 DAA

Table 4 ^{32}P activity (cpm/g leaf) recovered in the leaves of treated rubber (First year growth) at 30 DAA of ^{32}P to soil as affected by depth and lateral distances of application

Depth (cm)	Lateral distances (cm)				
	50	100	150	200	250
10	25666	89	9	20	31
25	87215	27	23	45	9
50	2763	33	14	29	22
75	50	325	21	24	21
100	56	28	22	23	19

SEm± : 11672
CD (0.05) : 32353

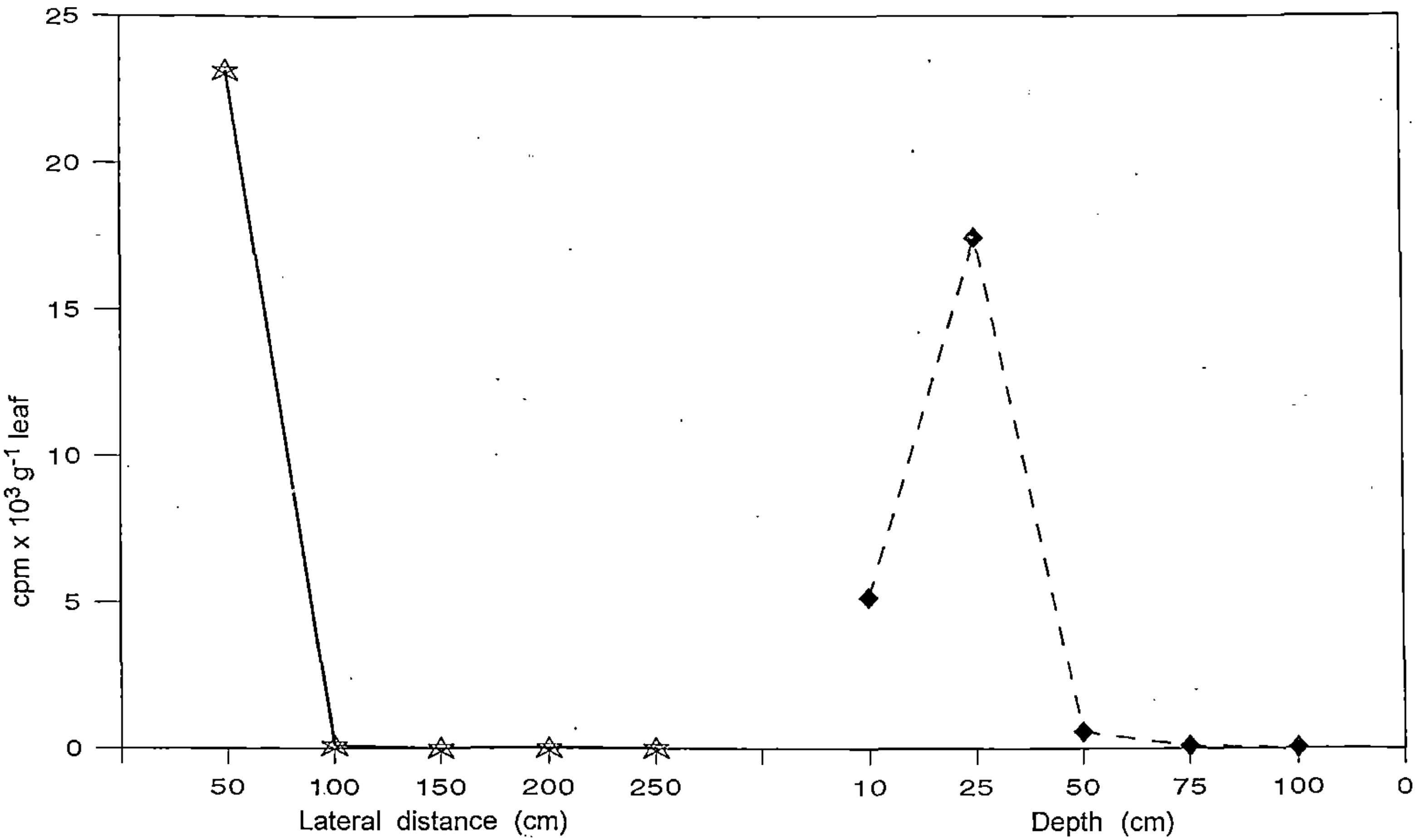


Fig. 11. Uptake of soil applied ^{32}P at different lateral distances and depths by one-year-old rubber at 30 DAA

Table 5 ^{32}P activity (cpm/g leaf) recovered in the leaves of treated rubber (First year growth) at 45 DAA of ^{32}P to soil as affected by depth and lateral distances of application

Depth (cm)	Lateral distance (cm)				
	50	100	150	200	250
10	26619	94	191	128	216
25	112368	144	212	155	189
50	23636	283	338	132	93
75	508	425	669	79	57
100	351	179	246	289	436

SEm± : 18177
CD (0.05) : NS

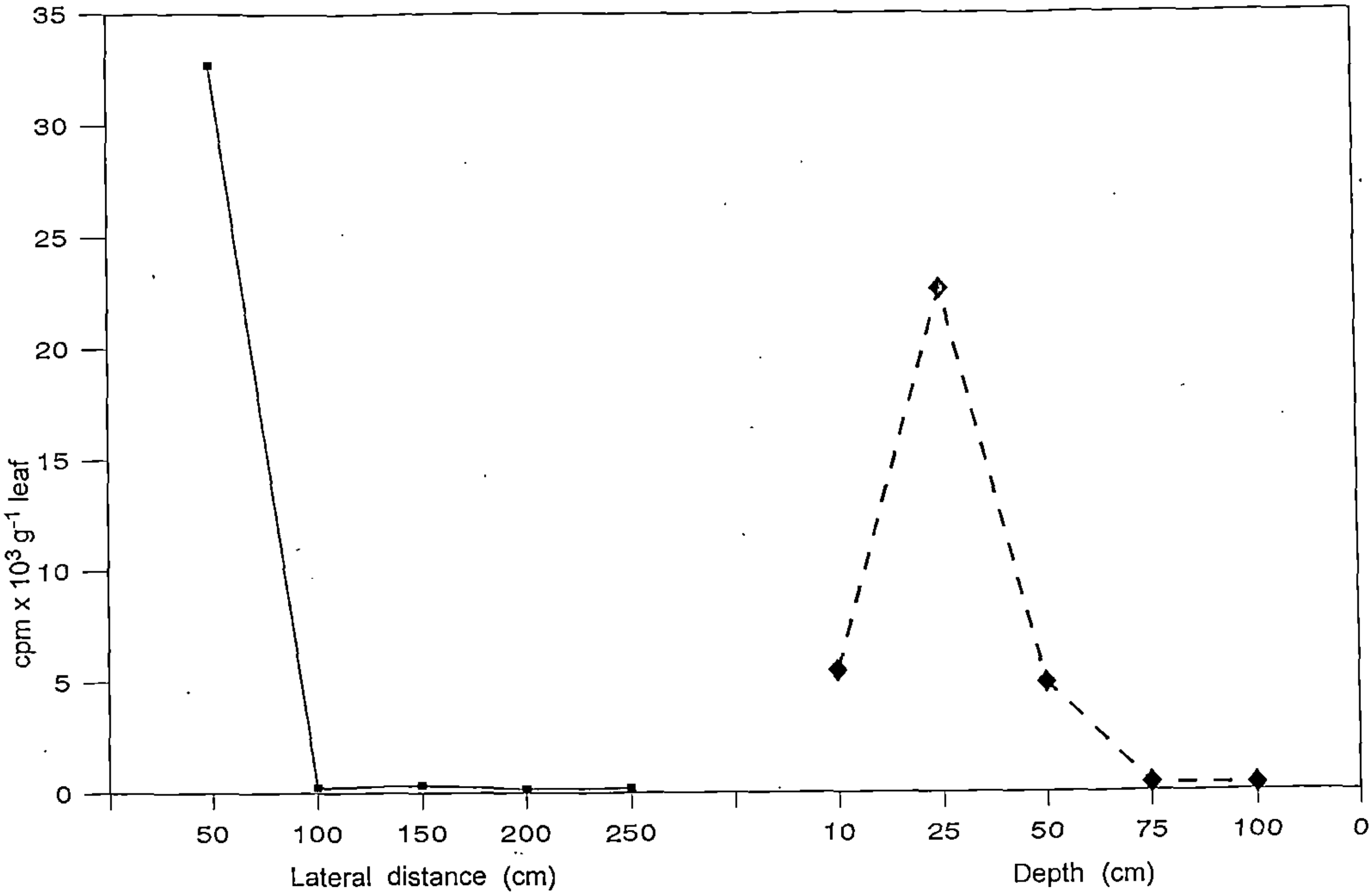


Fig. 12. Uptake of soil applied ^{32}P at different lateral distances and depths by one-year-old rubber at 45 DAA

at the lateral distance of 50 cm while the depth of application did not show any significant difference in recovery of ^{32}P.

The interaction effect was significant at 15 and 30 DAA. The treatment combination of 50 cm lateral distance and 25 cm depth recorded the highest absorption of ^{32}P in both cases. At 45 days after application, though the treatment effects were not significant, the same trend was noticed.

4.1.2 Recovery of ^{32}P in the leaves as influenced by lateral distances and depth in the second year growth of rubber

The data pertaining to the radio recovery by the two year old rubber trees are presented in Tables 6 to 12 and Fig.13 to 15. Among the main effects, the lateral distance of 50 cm was significantly the highest followed by the 100 cm distance (Table 6). The effect of depth of application was significant at 30 and 45 DAA and the ^{32}P applied at 50 cm depth gave the maximum recovery which was on par with 10 and 25 cm depths. Below 50 cm depth, the activity was reduced.

The interaction of lateral distance x depth was significant only at 30 DAA (Table 8). The highest activity was observed at 50 cm lateral distance upto a depth of 50 cm. It is seen that the activity is generally concentrated at all depths of 50 cm lateral distance and upto 50 cm depth at 100 cm lateral distance.

In the case of untreated neighbouring plants, substantial activity was observed beyond 200 cm distance from the treated plant which was more pronounced at 50 cm depth (Table 6).

Table 6 Uptake of soil applied ^{32}P (cpm/g leaf) at different lateral distances and depths by rubber (Second year growth)

A. Lateral distance (cm)	Treated rubber			Untreated rubber		
	15 DAA	30 DAA	45 DAA	15 DAA	30 DAA	45 DAA
50	18767	39258	45804	13	8	12
100	5641	11649	18582	12	70	37
150	40	676	817	10	13	1
200	17	1759	71	168	531	850
250	39	58	134	993	2593	3256
SEm±	2453	3027	3369	95	290	413
CD (0.05)	6801	8392	9340	265	805	1146
B. Depth (cm)						
10	3854	11985	11081	88	408	364
25	6059	15330	18153	188	943	1241
50	9970	16803	18956	852	1704	1819
75	851	5696	6000	38	84	636
100	3771	3588	11217	30	76	125
SEm±	2453	3027	3369	95	290	413
CD (0.05)	NS	8392	9340	265	805	1146
AxB interaction CD (0.05)	NS	18765	NS	592	1801	NS

Table 7 ^{32}P activity (cpm/g leaf) recovered in the leaves of treated rubber (Second year growth) at 15 DAA of ^{32}P to soil as affected by depth and lateral distances of application

Depth (cm)	Lateral distances (cm)				
	50	100	150	200	250
10	17394	1756	71	111	38
25	25630	4561	27	24	51
50	29323	20467	28	13	19
75	2723	1401	53	18	61
100	18766	20	22	18	29

SEm± : 5486
CD (0.05) : NS

NS - Not significant
DAA - Days after application

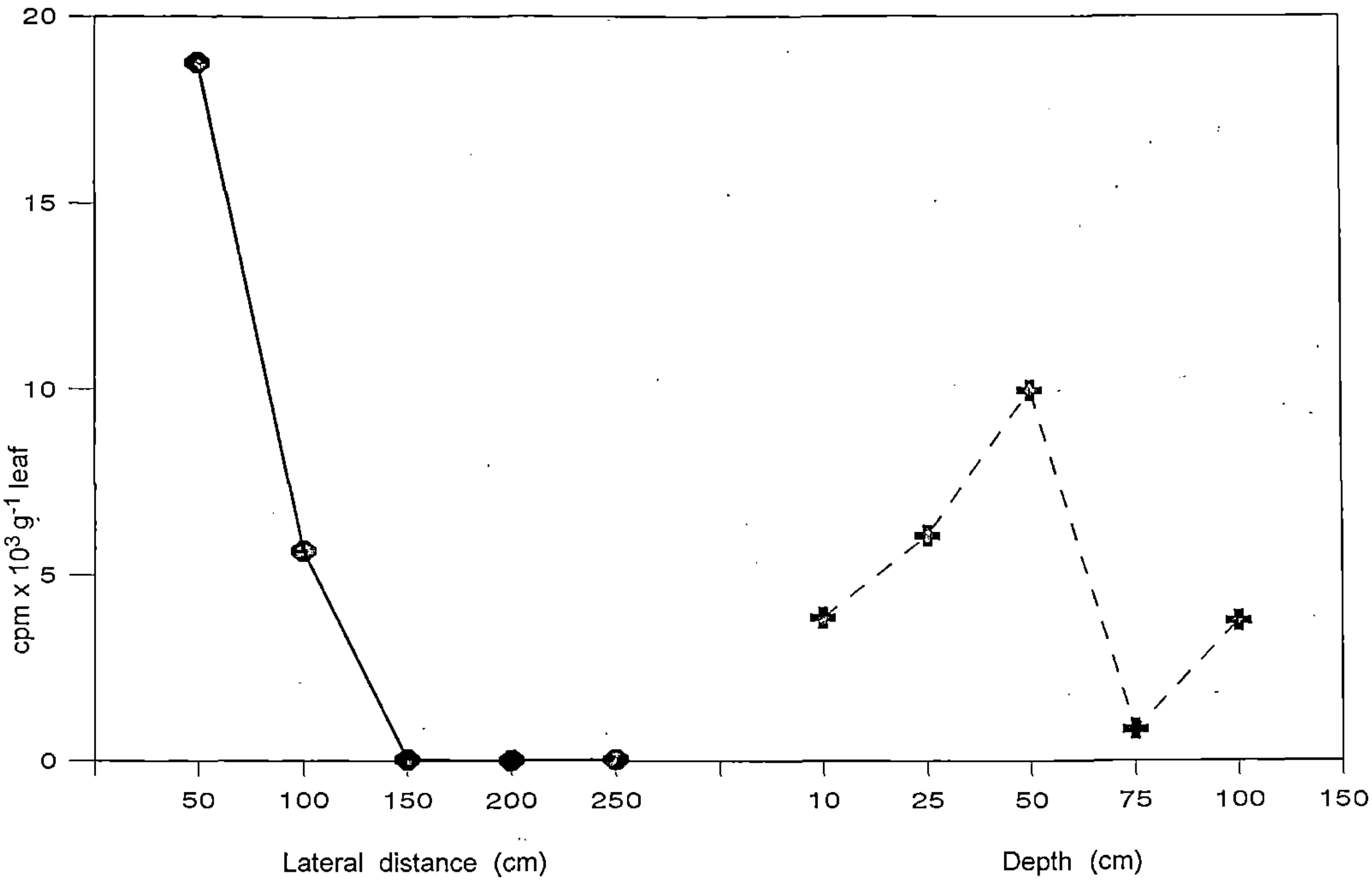


Fig. 13. Uptake of soil applied ^{32}P at different lateral distances and depths by two-year-old rubber at 15 DAA

Table 8 ^{32}P activity (cpm/g leaf) recovered in the leaves of treated rubber (Second year growth) at 30 DAA of ^{32}P to soil as affected by depth and lateral distances of application

Depth (cm)	Lateral distances (cm)				
	50	100	150	200	250
10	44068	15644	161	24	28
25	59672	16912	34	10	23
50	57824	22986	3156	16	31
75	16848	2694	15	8731	191
100	17880	12	12	16	21

SEm± : 6770
CD (0.05) : 18765

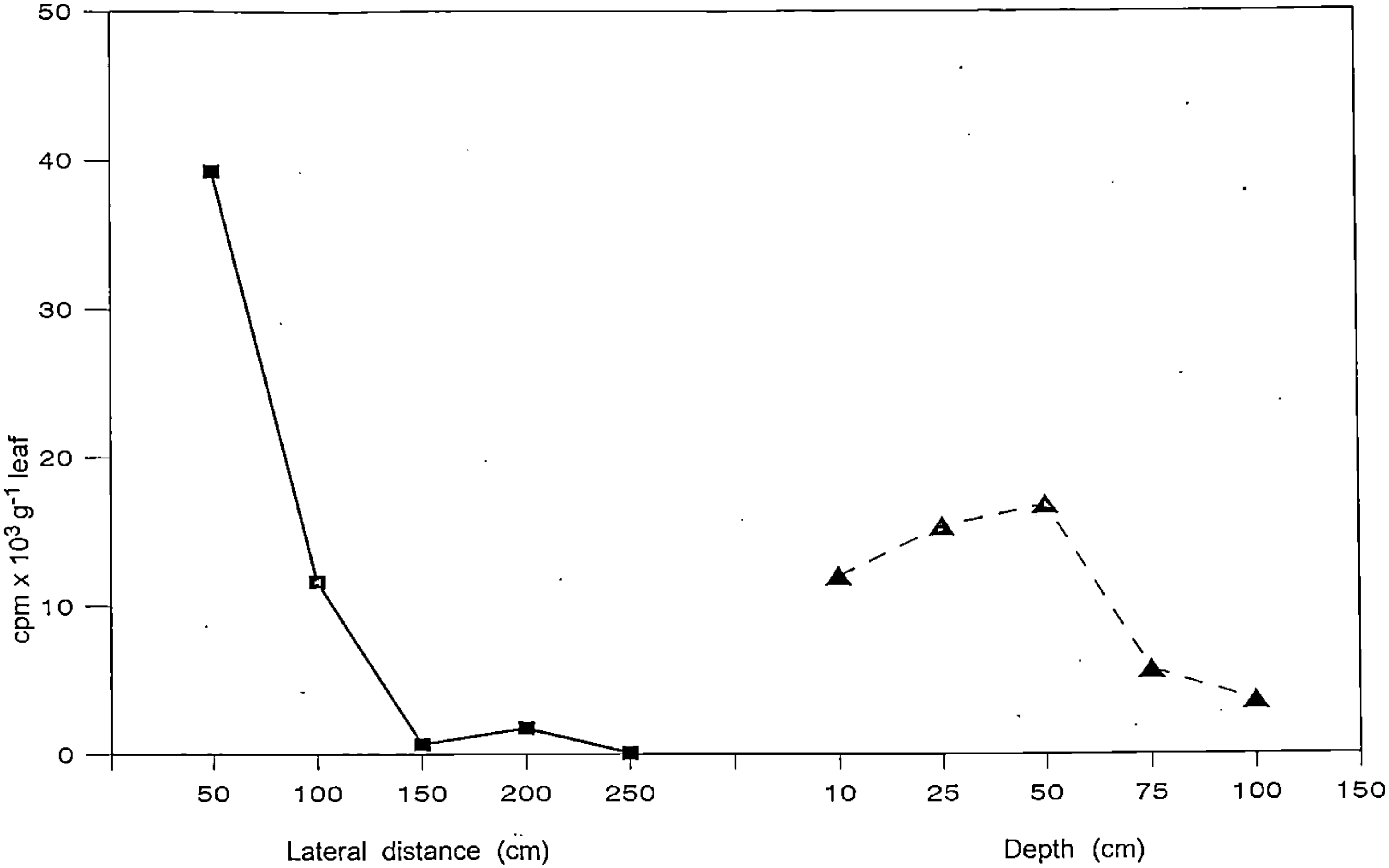


Fig. 14. Uptake of soil applied ^{32}P at different lateral distances and depths by two-year-old rubber at 30 DAA

Table 9 ^{32}P activity (cpm/g leaf) recovered in the leaves of treated rubber (Second year growth) at 45 DAA of ^{32}P to soil as affected by depth and lateral distances of application

Depth (cm)	Lateral distances (cm)				
	50	100	150	200	250
10	35398	18772	1029	103	104
25	62390	28049	189	64	73
50	56480	35414	2700	78	108
75	19067	10569	55	57	251
100	55684	103	111	53	136

SEm± : 7534
CD (0.05) : NS

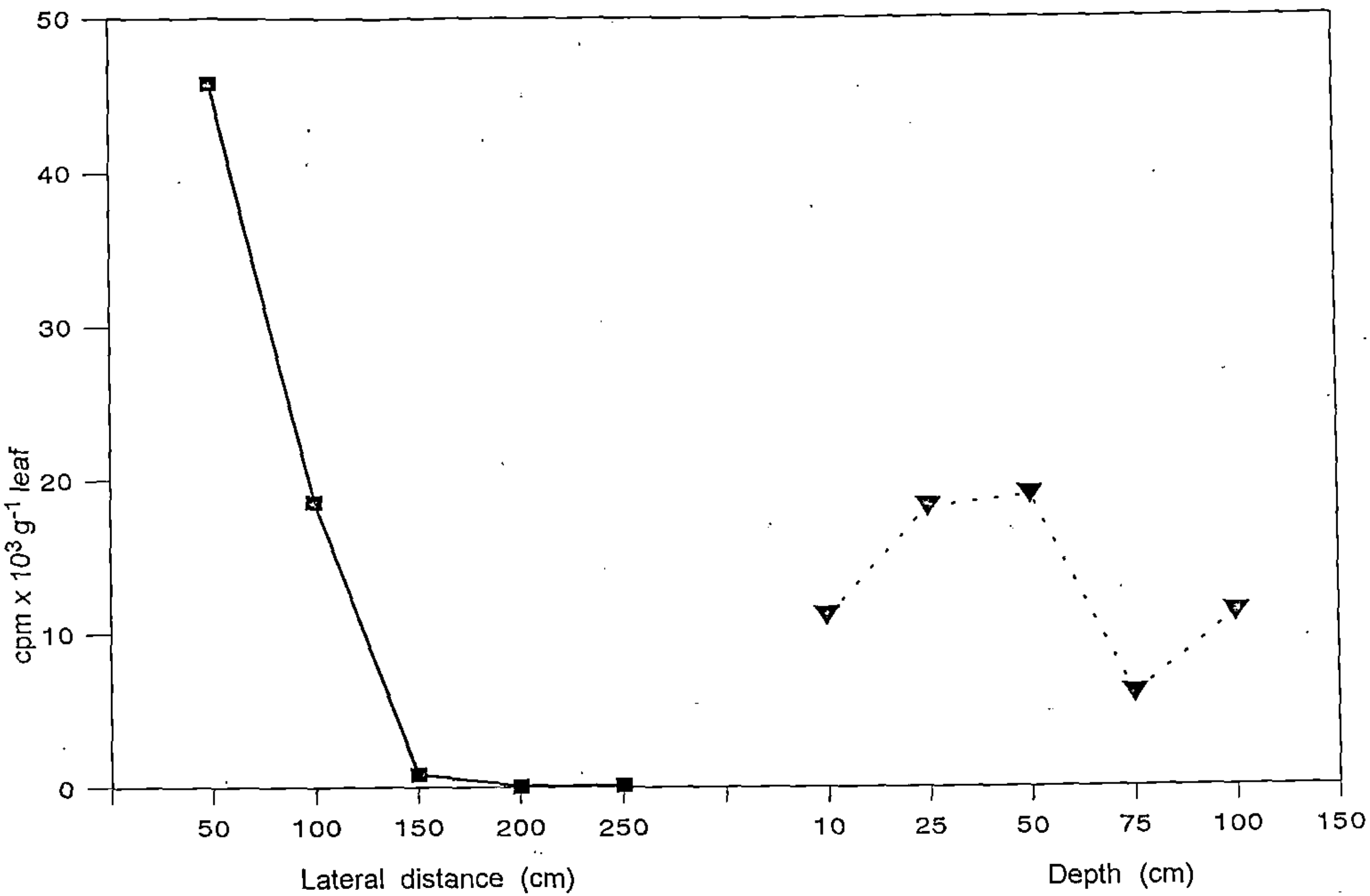


Fig. 15. Uptake of soil applied ^{32}P at different lateral distances and depths by two-year-old rubber at 45 DAA

Table 10 ^{32}P activity (cpm/g leaf) recovered in the leaves of untreated rubber (Second year growth) at 15 DAA of ^{32}P to soil as affected by depth and lateral distances of application

Depth (cm)	Lateral distances (cm)				
	50	100	150	200	250
10	20	12	2	226	180
25	17	20	16	25	862
50	14	15	17	557	3659
75	12	7	11	22	136
100	4	7	5	8	126

SEm± : 214
CD (0.05) : 592

Table 11 ^{32}P activity (cpm/g leaf) recovered in the leaves of untreated rubber (Second year growth) at 30 DAA of ^{32}P to soil as affected by depth and lateral distances of application

Depth (cm)	Lateral distances (cm)				
	50	100	150	200	250
10	13	9	28	513	1475
25	5	6	4	140	4558
50	5	305	10	1929	6269
75	1	15	7	70	327
100	17	15	14	2	335

SEm± : 650
CD (0.05) : 1801

Table 12 ^{32}P activity (cpm/g leaf) recovered in the leaves of untreated rubber (Second year growth) at 45 DAA of ^{32}P to soil as affected by depth and lateral distances of application

Depth (cm)	Lateral distances (cm)				
	50	100	150	200	250
10	3	8	1	611	1195
25	1	10	2	698	5358
50	24	143	1	2838	6088
75	32	25	1	101	3021
100	1	1	1	3	619

SEm± : 924
CD (0.05) : NS

4.1.3 Recovery of ^{32}P in the leaves as influenced by lateral distances and depth in the third year growth of rubber

The results are given in Tables 13 to 19 and Fig.16 to 18.

In the three-year-old rubber plants, the activity was the highest at 50 cm lateral distance followed by 100 cm and then by 150 cm. When the lateral distance was further increased, the activity was significantly reduced. The intensity of activity was found to be independent of the depth of application.

The interaction between lateral distance and depth was not significant indicating that these factors behave independently.

In the case of untreated plants, considerable activity was observed in the leaf samples at lateral distances beyond 150 cm from the treated plants which was more pronounced at 25 cm depth throughout the period of sampling (Tables 17 to 19).

4.1.4 Uptake of soil applied ^{32}P at different lateral distances and depths by rubber as a function of time

The absorption of ^{32}P by the young rubber at varying ages at different lateral distances and depths as a function of time is given in Tables 2, 6 and 13. In all the ages the absorption of ^{32}P increased with time from all lateral distances and depths of ^{32}P application. This might be the result of accumulation of ^{32}P in the leaves with time.

Table 13 Uptake of soil applied ^{32}P at different lateral distances and depths by rubber (Third year growth)

A. Lateral distance (cm)	Treated rubber			Untreated rubber		
	15 DAA	30 DAA	45 DAA	15 DAA	30 DAA	45 DAA
50	2200	4308	5633	20	16	11
100	1060	2094	2593	6	3	3
150	400	631	1110	80	37	305
200	150	168	263	114	467	220
250	33	71	86	134	230	449
SEm±	198	310	452	35	89	108
CD(0.05)	550	861	1257	98	248	301
B. Depth (cm)						
10	789	1344	1977	60	108	105
25	968	1934	1824	199	347	553
50	771	1431	2043	42	177	198
75	707	1128	1893	31	38	47
100	608	1437	1949	23	82	87
SEm±	198	310	453	35	89	108
CD (0.05)	NS	NS	NS	98	NS	301
AxB interaction CD (0.05)	NS	NS	NS	NS	NS	NS

Table 14 ^{32}P activity (cpm/g leaf) recovered in the leaves of treated rubber (Third year growth) at 15 DAA of ^{32}P to soil as affected by depth and lateral distances of application

Depth (cm)	Lateral distances (cm)				
	50	100	150	200	250
10	2387	1105	263	182	11
25	2117	1566	1047	91	18
50	2340	1089	253	169	5
75	1671	1233	314	301	14
100	2484	308	123	8	116

SEm± : 444
CD (0.05) : NS

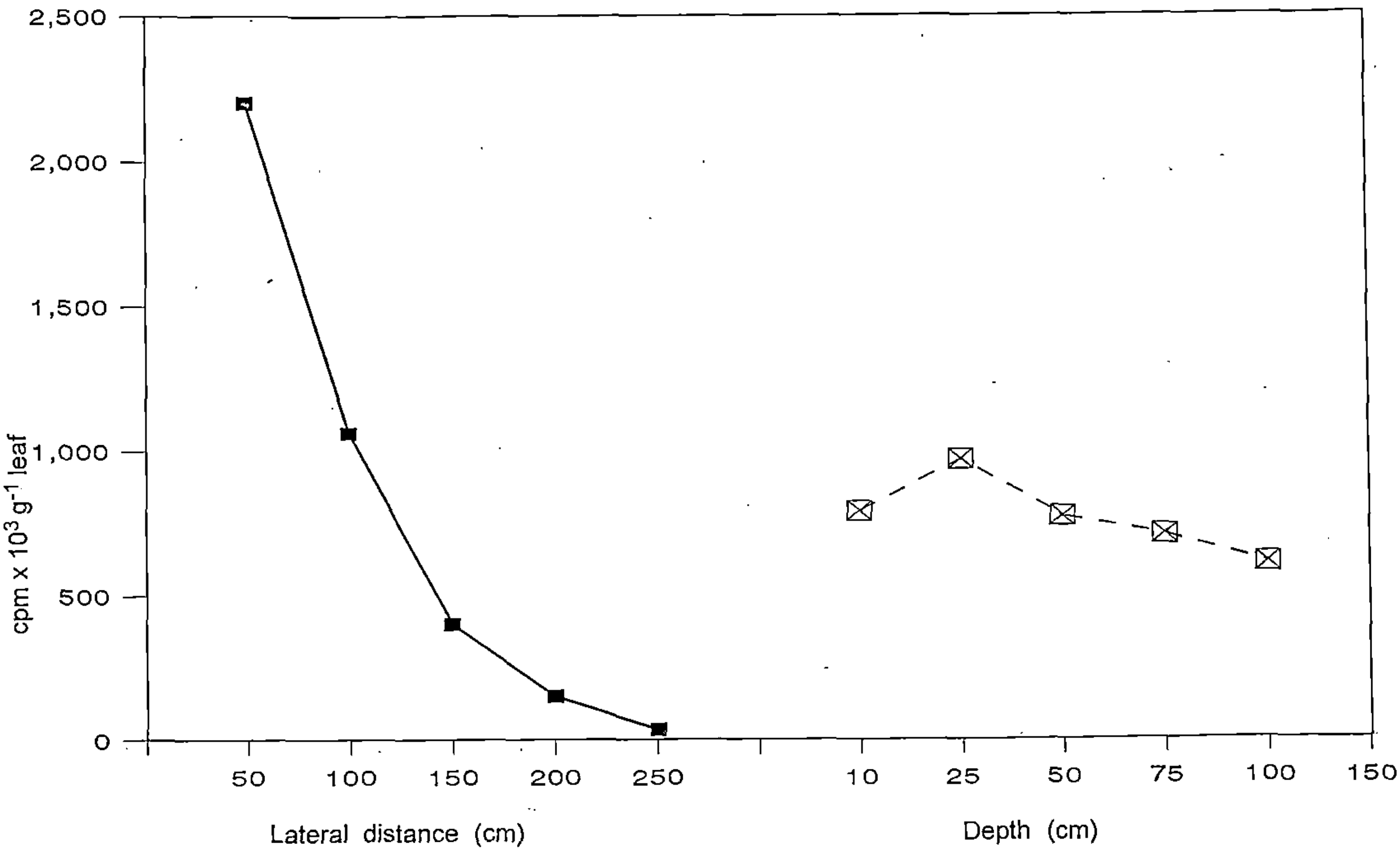


Fig. 16. Uptake of soil applied ^{32}P at different lateral distances and depths by three-year-old rubber at 15 DAA

Table 15 ^{32}P activity (cpm/g leaf) recovered in the leaves of treated rubber (Third year growth) at 30 DAA of ^{32}P to soil as affected by depth and lateral distances of application

Depth (cm)	Lateral distances (cm)				
	50	100	150	200	250
10	4190	2142	308	67	10
25	4536	3559	1374	78	121
50	3637	2740	329	436	10
75	3176	1407	811	241	2
100	5999	624	334	15	213

SEm± : 694
CD (0.05) : NS

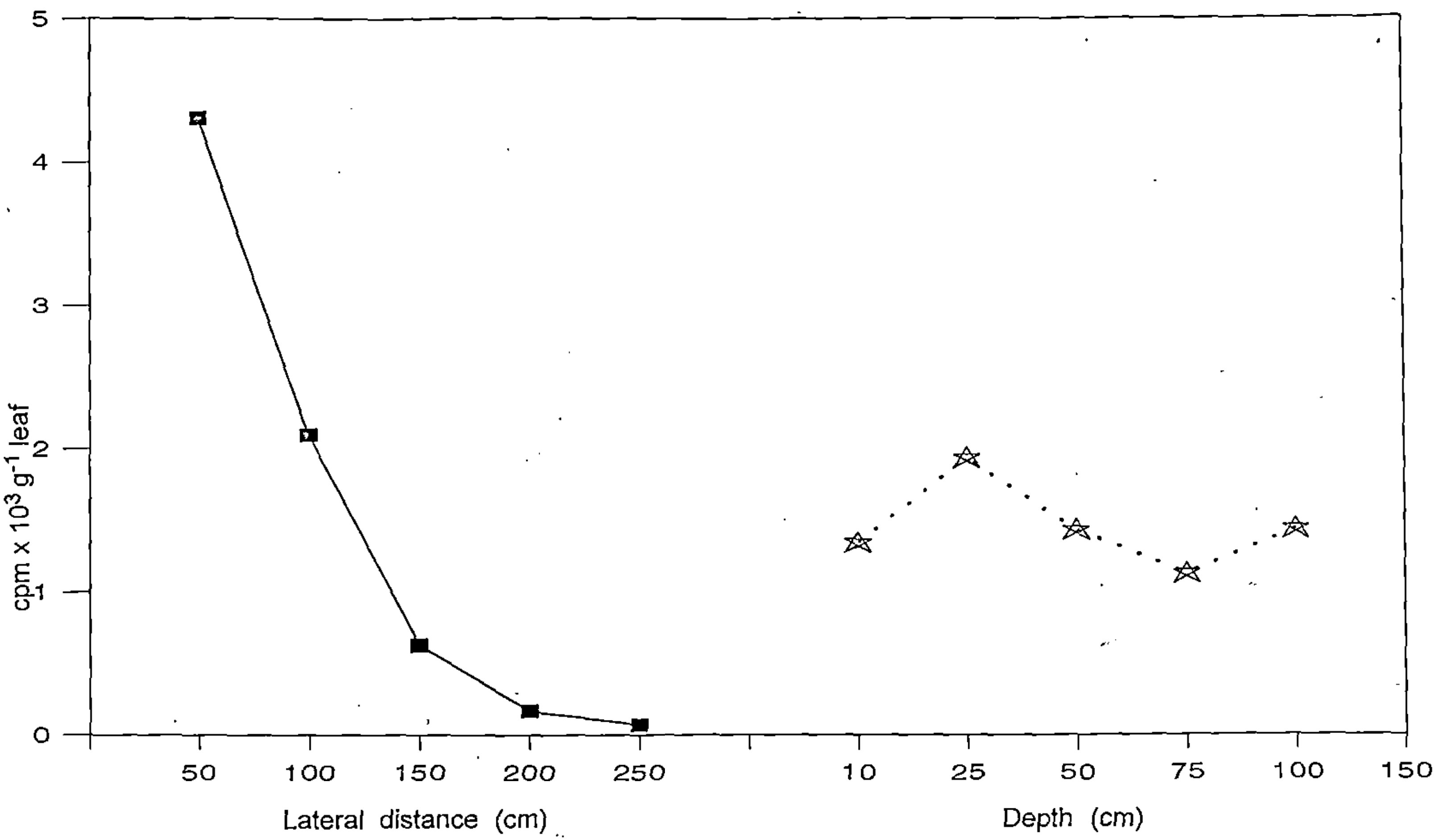


Fig. 17. Uptake of soil applied ^{32}P at different lateral distances and depths by three-year-old rubber at 30 DAA

Table 16 ^{32}P activity (cpm/g leaf) recovered in the leaves of treated rubber (Third year growth) at 45 DAA of ^{32}P to soil as affected by depth and lateral distances of application

Depth (cm)	Lateral distances (cm)				
	50	100	150	200	250
10	5764	2332	1316	448	25
25	4187	2799	1796	9	330
50	5046	4605	438	100	26
75	5444	2600	742	676	4
100	7724	632	1260	83	48

SEm± : 1014
CD (0.05) : NS

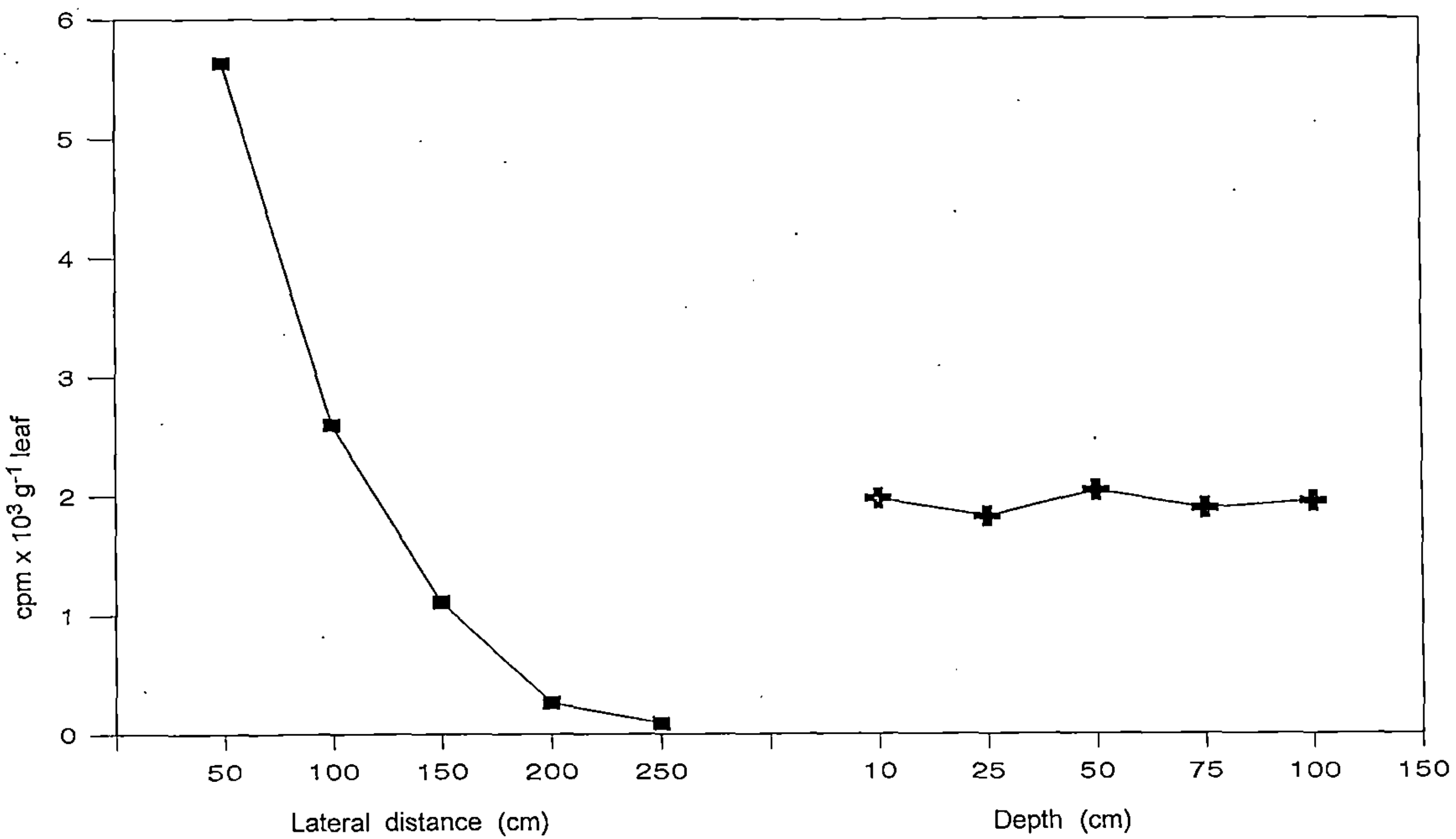


Fig. 18. Uptake of soil applied ^{32}P at different lateral distances and depths by three-year-old rubber at 45 DAA

Table 17 ^{32}P activity (cpm/g leaf) recovered in the leaves of untreated rubber (Third year growth) at 15 DAA of ^{32}P to soil as affected by depth and lateral distances of application

Depth (cm)	Lateral distances (cm)				
	50	100	150	200	250
10	1	1	1	96	201
25	90	2	337	198	366
50	8	16	35	127	22
75	1	9	9	110	24
100	1	1	15	38	58

SEm± : 79
CD (0.05) : NS

Table 18 ^{32}P activity (cpm/g leaf) recovered in the leaves of untreated rubber (Third year growth) at 30 DAA of ^{32}P to soil as affected by depth and lateral distances of application

Depth (cm)	Lateral distances (cm)				
	50	100	150	200	250
10	2	5	2	398	135
25	67	1	93	987	587
50	3	4	73	538	266
75	4	2	7	143	32
100	3	2	8	270	130

SEm± : 200
CD (0.05) : NS

Table 19 ^{32}P activity (cpm/g leaf) recovered in the leaves of untreated rubber (Third year growth) at 45 DAA of ^{32}P to soil as affected by depth and lateral distances of application

Depth (cm)	Lateral distances (cm)				
	50	100	150	200	250
10	1	3	10	183	324
25	51	2	1072	364	1274
50	1	4	319	230	434
75	3	3	22	137	70
100	1	5	105	183	143

SEm± : 243
CD (0.05) : NS

4.2 Pattern of root activity in young rubber

The percentage root activity at different lateral distances and depths were worked out from the corresponding mean cpm values of treatments using the formula

$$\text{Root activity (\%)} = \frac{\text{Radio activity (cpm) recovered in the leaf for the treatment}}{\text{Total radio activity (cpm) recovered for all the treatments}} \times 100$$

The radio activity recovered in the leaf by absorption of radio label from different soil zones reflects the relative density of active roots in these zones. Comparisons were made of the percentage root activity at the various zones for plants of the three different ages. Root activity pattern of rubber with various age group is important in getting an insight into the vertical and lateral spread of roots. This will help in identifying the zone of maximum nutrient absorption by rubber plants of different age groups. This information will also be useful in the selection and orientation of intercrops with minimum root competition.

4.2.1 Root activity pattern of one-year-old rubber

The percentages of root activity at 15, 30 and 45 DAA at different lateral distances and depths was worked out for first year growth of rubber and are given in Tables 20 to 24. The percentage root activity at 10, 25 and 50 cm depth confined only to 50 cm radial distance and the values were 23, 70 and 6 per cent (Table 24). This indicates that more than 90 per cent of the root activity is confined to a lateral distance of 50 cm and 25 cm depth (Fig.19 and 22).

Table 20 Root activity of rubber (First year growth) at different lateral distances and depths (%) at 15 DAA

Depth (cm)	Lateral distances (cm)				
	50	100	150	200	250
10	31	Tr	Tr	Tr	Tr
25	67	Tr	Tr	Tr	Tr
50	2	Tr	Tr	Tr	Tr
75	Tr	Tr	Tr	Tr	Tr
100	Tr	Tr	Tr	Tr	Tr
Total	100	Tr	Tr	Tr	Tr

Tr - in traces

Table 21 Root activity of rubber (First year growth) at different lateral distances and depths (%) at 30 DAA

Depth (cm)	Lateral distances (cm)				
	50	100	150	200	250
10	22	Tr	Tr	Tr	Tr
25	75	Tr	Tr	Tr	Tr
50	2	Tr	Tr	Tr	Tr
75	Tr	Tr	Tr	Tr	Tr
100	Tr	Tr	Tr	Tr	Tr
Total	9	Tr	Tr	Tr	Tr

Tr - in traces

Table 22 Root activity of rubber (First year growth) at different lateral distances and depths (%) at 45 DAA

Depth (cm)	Lateral distances (cm)				
	50	100	150	200	250
10	16	Tr	Tr	Tr	Tr
25	67	Tr	Tr	Tr	Tr
50	14	Tr	Tr	Tr	Tr
75	Tr	Tr	Tr	Tr	Tr
100	Tr	Tr	Tr	Tr	Tr
Total	97	Tr	Tr	Tr	Tr

Tr - in traces

Table 23 Percentage root activity of rubber at first year of growth at different sampling intervals

Days after ^{32}P application	Lateral distance (cm)					Depth (cm)				
	50	100	150	200	250	10	25	50	75	100
15	99	Tr	Tr	Tr	Tr	31	67	2	Tr	Tr
30	99	Tr	Tr	Tr	Tr	22	75	2	Tr	Tr
45	97	1	1	Tr	Tr	16	67	15	Tr	Tr

Tr - in traces

Table 24 Root activity of rubber at different lateral distances and depth (%) at first year of growth (Mean of the three sampling intervals)

Depth (cm)	Lateral distance (cm)					Total
	50	100	150	200	250	
10	23	Tr	Tr	Tr	Tr	23
25	70	Tr	Tr	Tr	Tr	70
50	6	Tr	Tr	Tr	Tr	6
75	Tr	Tr	Tr	Tr	Tr	Tr
100	Tr	Tr	Tr	Tr	Tr	Tr
Total	99	Tr	Tr	Tr	Tr	99

Tr - in traces

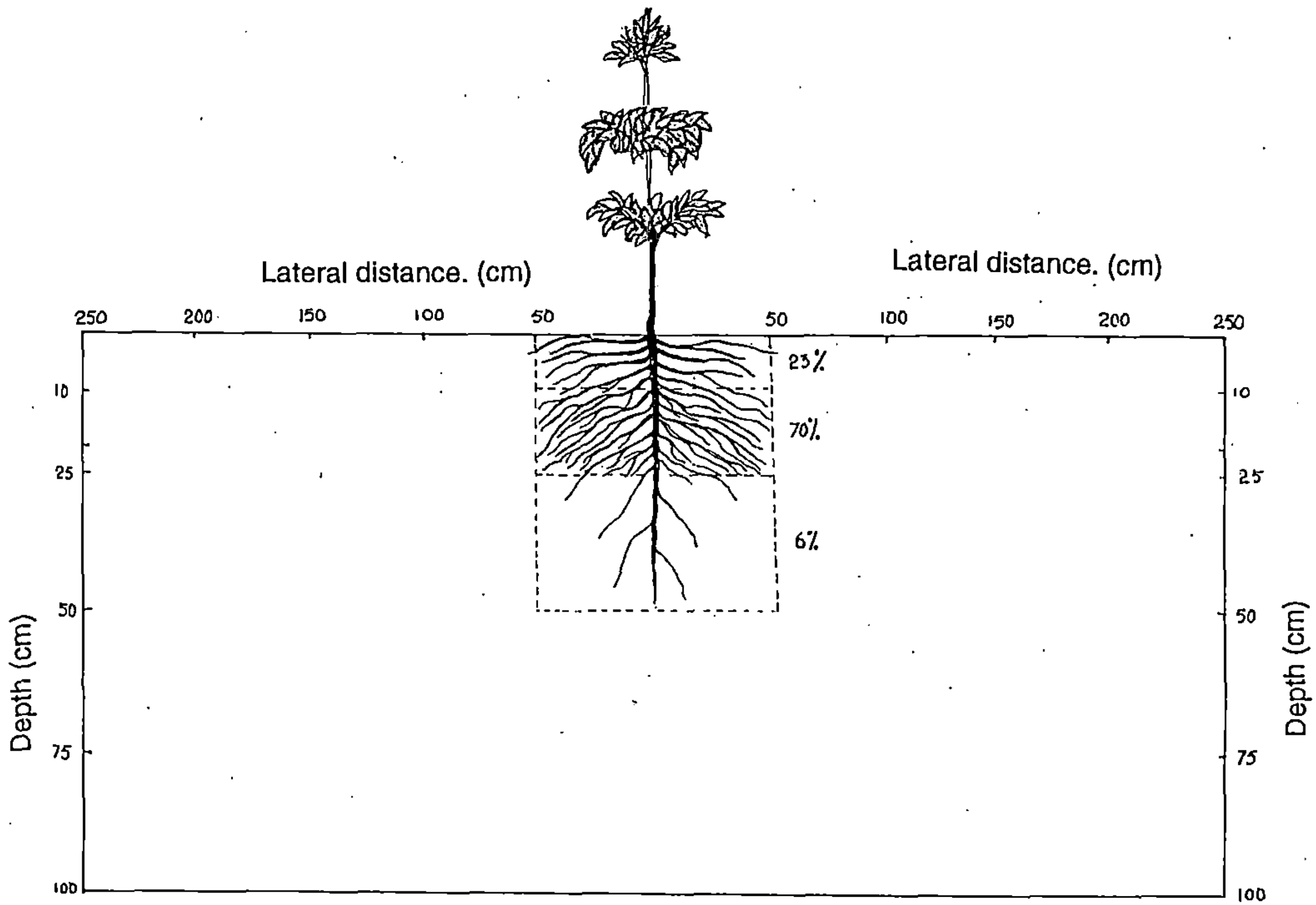


Fig. 19 Root distribution pattern in rubber (First Year) based on % radioactivity

4.2.2 Root activity pattern of two-year old rubber

The percentage root activity for the different sampling dates for second year growth of rubber is given in Tables 25 to 29. The root activity decreased with increased lateral distance at all depths (Table 29). Altogether, the activity was reduced to about one third when the lateral distance was increased from 50 to 100 cm. From the data, it is obvious that 80 per cent of the root activity was confined to a zone of 100 cm lateral distance and to a depth of 50 cm (Fig.20 and 22). The balance 20 per cent activity was distributed to a lateral distance of 50 cm and to 75 and 100 cm depths.

4.2.3 Root activity pattern of three-year old rubber

The results are given in Tables 30 to 34. More or less uniform distribution of radio activity was noticed at all depths of application and it ranged from 18 to 23 per cent (Table 34). The data show that the root activity was concentrated to lateral and vertical spreads of 150 and 100 cm, respectively (Fig.21 and 22).

4.3 Pattern of ^{32}P absorption by rubber and banana in pure and intercropped situations

In this experiment, radiophosphorus was applied employing soil injection technique in points along circles of various radii around rubber and/or banana. Leaves were sampled and radioassayed for ^{32}P at 15, 30 and 45 DAA. Comparisons were made on the uptake of the radiolabel between rubber plants in sole crop and mixed crop situations and between banana plants in sole and mixed crop situations under two systems of planting viz. single row and double row systems of planting.

Table 25 Root activity of rubber (Second year growth) at different lateral distances and depths (%) at 15 DAA

Depth (cm)	Lateral distances (cm)				
	50	100	150	200	250
10	14	1	Tr	Tr	Tr
25	21	4	Tr	Tr	Tr
50	24	17	Tr	Tr	Tr
75	2	1	Tr	Tr	Tr
100	15	Tr	Tr	Tr	Tr
Total	76	24	Tr	Tr	Tr

Tr - in traces

Table 26 Root activity of rubber (Second year growth) at different lateral distances and depths (%) at 30 DAA

Depth (cm)	Lateral distances (cm)				
	50	100	150	200	250
10	17	6	Tr	Tr	Tr
25	22	6	Tr	Tr	Tr
50	22	9	1	Tr	Tr
75	6	1	Tr	3	Tr
100	7	Tr	Tr	Tr	Tr
Total	74	22	1	3	Tr

Tr - in traces

Table 27 Root activity of rubber (Second year growth) at different lateral distances and depths (%) at 45 DAA

Depth (cm)	Lateral distances (cm)				
	50	100	150	200	250
10	11	6	Tr	Tr	Tr
25	19	9	Tr	Tr	Tr
50	17	11	1	Tr	Tr
75	6	3	Tr	Tr	Tr
100	17	Tr	Tr	Tr	Tr
Total	70	29	1	Tr	Tr

Tr - in traces

Table 28 Percentage root activity of rubber at second year of growth on different sampling intervals

Days after ^{32}P application	Lateral distance (cm)					Depth (cm				
	50	100	150	200	250	10	25	50	75	100
15	77	23	Tr	Tr	Tr	16	25	41	3	15
30	74	22	1	3	Tr	22	29	31	11	7
45	70	28	1	Tr	Tr	17	28	29	9	17

Tr - in traces

Table 29 Root activity of rubber at different lateral distances and depth (%) at second year of growth (Mean of the three sampling intervals)

Depth (cm)	Lateral distance (cm)					Total
	50	100	150	200	250	
10	14	4	Tr	Tr	Tr	18
25	21	6	Tr	Tr	Tr	27
50	21	12	Tr	Tr	Tr	33
75	5	2	Tr	Tr	Tr	7
100	13	Tr	Tr	Tr	Tr	13
Total	74	24	Tr	Tr	Tr	98

Tr - in traces

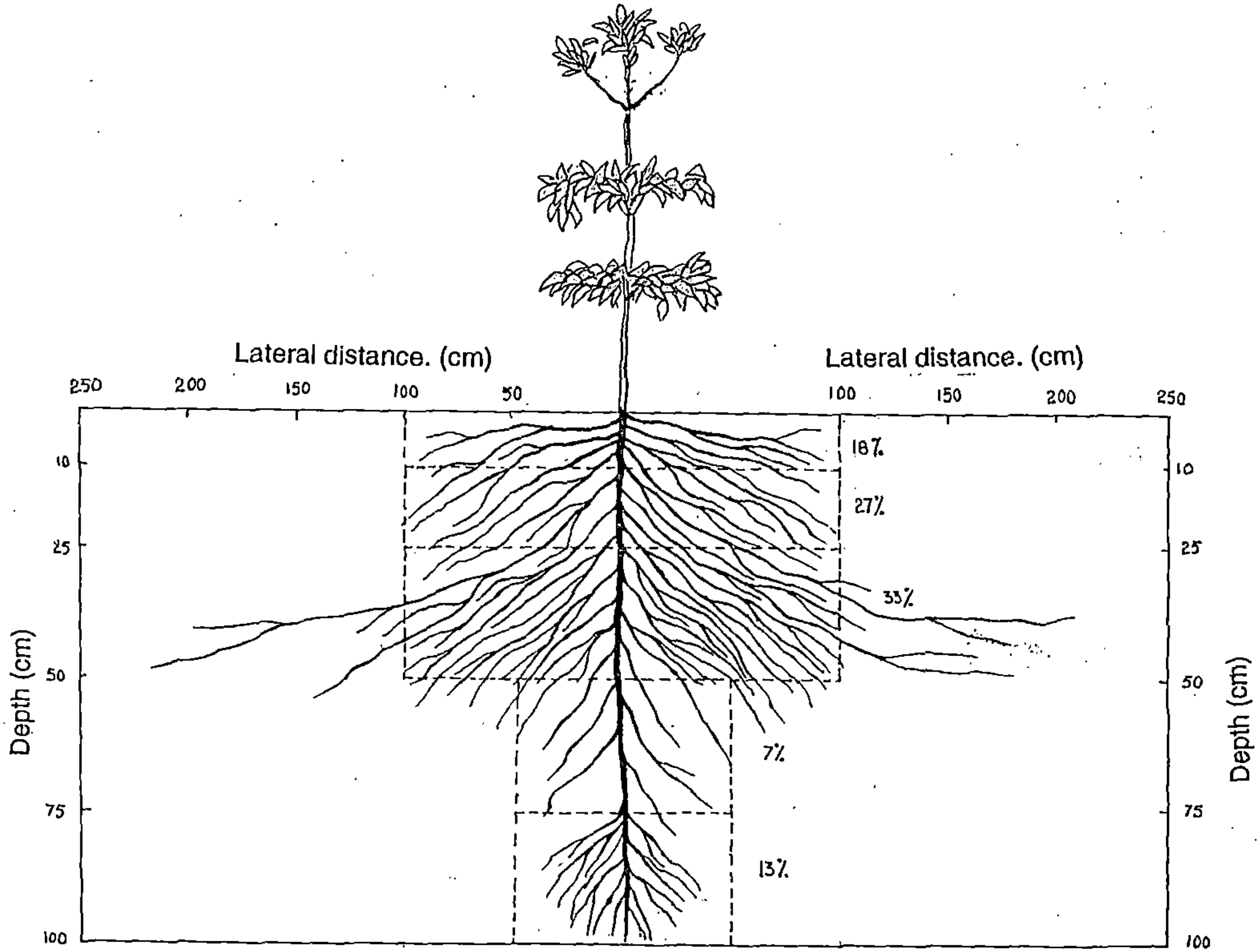


Fig. 20 Root distribution pattern in rubber (second Year) based on % radioactivity

Table 30 Root activity of rubber (Third year growth) at different lateral distances and depths (%) at 15 DAA

Depth (cm)	Lateral distances (cm)				
	50	100	150	200	250
10	12	6	1	1	Tr
25	11	8	5	Tr	Tr
50	12	6	1	1	Tr
75	9	6	2	2	Tr
100	13	2	Tr	Tr	Tr
Total	57	28	9	4	Tr

Tr - in traces

Table 31 Root activity of rubber (Third year growth) at different lateral distances and depths (%) at 30 DAA

Depth (cm)	Lateral distances (cm)				
	50	100	150	200	250
10	12	6	1	Tr	Tr
25	12	10	4	Tr	Tr
50	10	8	1	2	Tr
75	9	4	2	Tr	Tr
100	16	2	1	Tr	Tr
Total	59	30	9	2	Tr

Tr - in traces

Table 32 Root activity of rubber (Third year growth) at different lateral distances and depths (%) at 45 DAA

Depth (cm)	Lateral distances (cm)				
	50	100	150	200	250
10	12	5	3	1	Tr
25	9	6	4	Tr	Tr
50	10	10	1	Tr	Tr
75	11	5	2	1	Tr
100	16	1	3	Tr	Tr
Total	58	27	13	2	Tr

Tr - in traces

Table 33 Percentage root activity of rubber at third year of growth on different sampling intervals

Days after ^{32}P application	Lateral distance (cm)					Depth (cm)				
	50	100	150	200	250	10	25	50	75	100
15	57	28	10	Tr	Tr	21	25	20	18	16
30	59	29	9	2	Tr	18	27	20	16	19
45	58	27	11	3	1	20	19	21	20	20

Tr - in traces

Table 34 Root activity of rubber at different lateral distances and depth (%) at third year of growth (Mean of the three sampling intervals)

Depth (cm)	Lateral distance (cm)					Total
	50	100	150	200	250	
10	12	6	1	1	Tr	20
25	11	8	4	Tr	Tr	23
50	11	8	1	1	Tr	21
75	10	5	2	1	Tr	18
100	15	2	1	Tr	Tr	18
Total	59	29	9	3	Tr	100

Tr - in traces

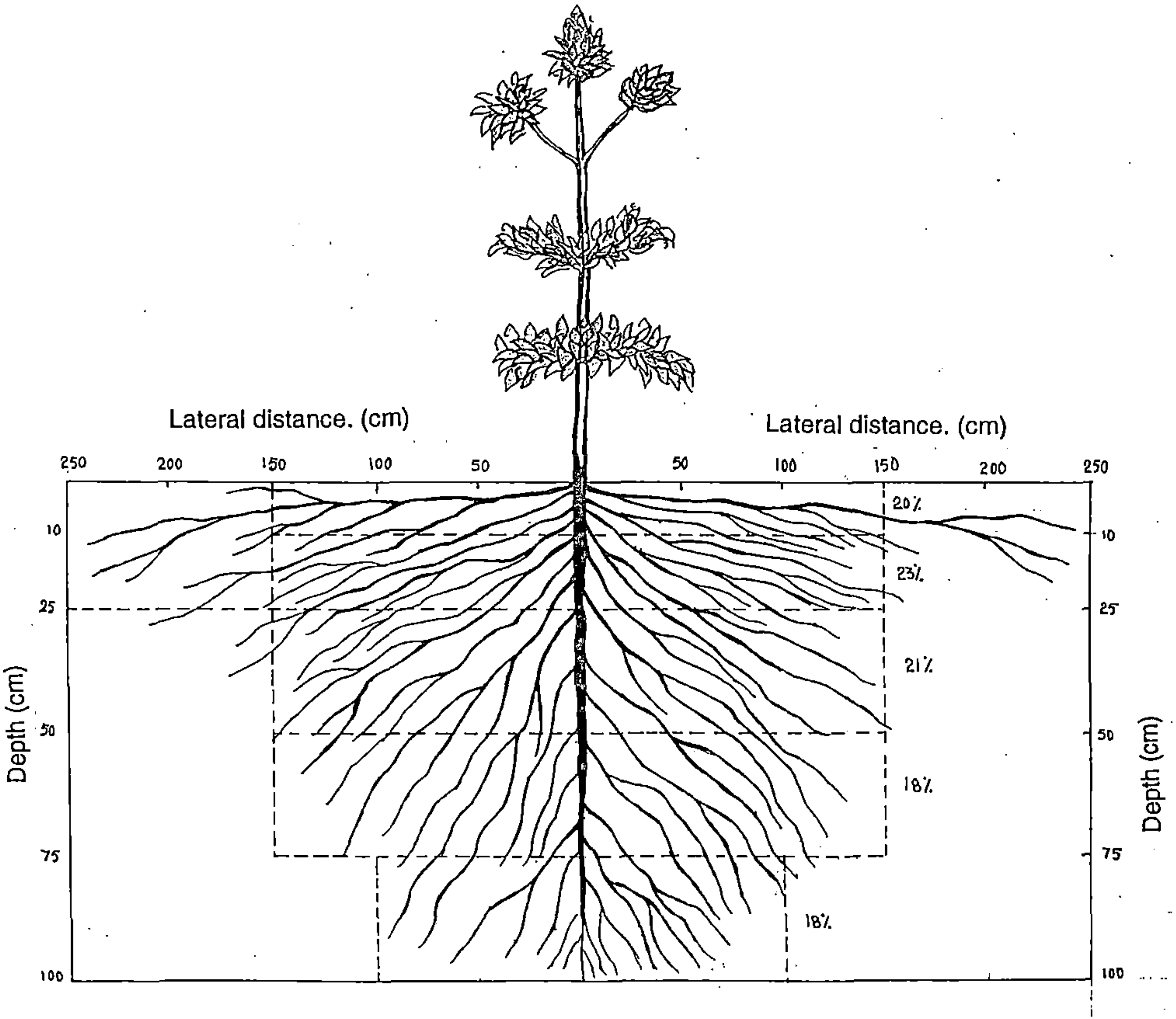


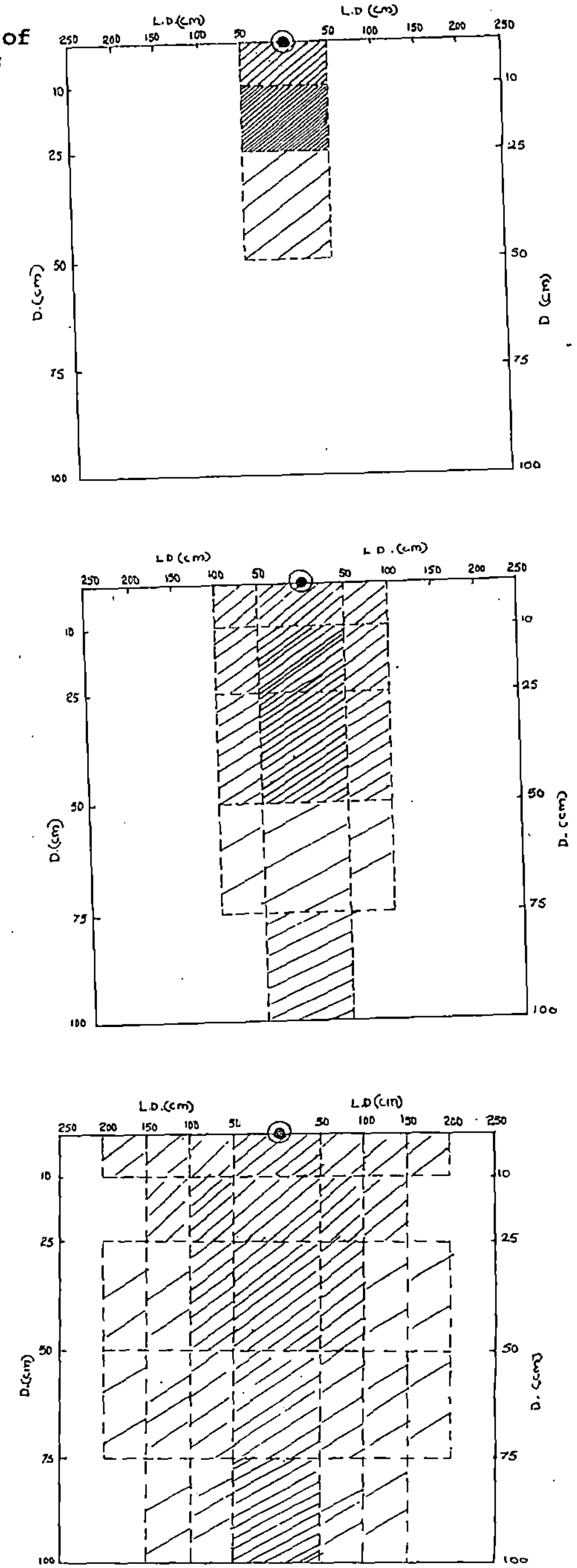
Fig. 21 Root distribution pattern in rubber (Third Year) based on % radioactivity

Fig.22 Active root zone of rubber at varying ages

One-year-old rubber

Two-year-old rubber

Three-year-old rubber



4.3.1 Recovery of ^{32}P in the leaf as influenced by crop stand in the first year of intercropping rubber with banana

The data relating to the absorption of ^{32}P by rubber and banana in sole and mixed stands in the first year of intercropping are furnished in Tables 35 and 36 and Fig.23 and 24. It was observed that the uptake of ^{32}P by both rubber and banana was significantly different in pure and mixed crop situations (Table 35). In general, the absorption of ^{32}P was higher when these crops were grown alone. Sole rubber was found to absorb significantly more ^{32}P than when it was intercropped with banana either in single row or double row system of planting (Fig.23).

The radio activity of banana leaf was more in sole double row system of planting as compared to all other systems under sole and mixed crop stands (Fig.24). The least activity was noticed in single row banana under intercropped situation giving the maximum chance for sharing the applied activity by the neighbouring rubber (Fig.24). There was a progressive increase in activity from 15 DAA to 45 DAA for rubber and banana under all situations.

Table 36 shows that the uptake of activity by the untreated rubber plants neighbouring the treated rubber was not significant indicating the absence of overlapped roots in the first year growth of rubber.

An examination of Tables 35 and 36 indicates that in the case of banana, there was presence of overlapped roots and hence resulted in sharing of activity by the neighbouring plants. The maximum sharing of the activity was shown in the double row system of planting banana.

Table 35 Absorption of ^{32}P by sole and mixed stand of rubber and banana at 15, 30 and 45 DAA of ^{32}P to the soil (cpm/g leaf) during the first year of intercropping

	Days after ^{32}P application		
	15	30	45
Rubber sole	20108	52665	78192
Rubber mixed (SRS)	6542	17415	22616
Rubber mixed (DRS)	4403	9362	20801
SEm±	3066	7936	9384
CD (0.05)	7602	19675	23266
Banana sole (SRS)	5179	15264	20797
Banana mixed (SRS)	4240	10866	17561
Banana sole (DRS)	15384	31438	42162
Banana mixed (DRS)	5721	12066	30267
SEm±	1932	4746	5047
CD (0.05)	4770	11719	12463

DAA - Days after application
SRS - Single row system
DRS - Double row system

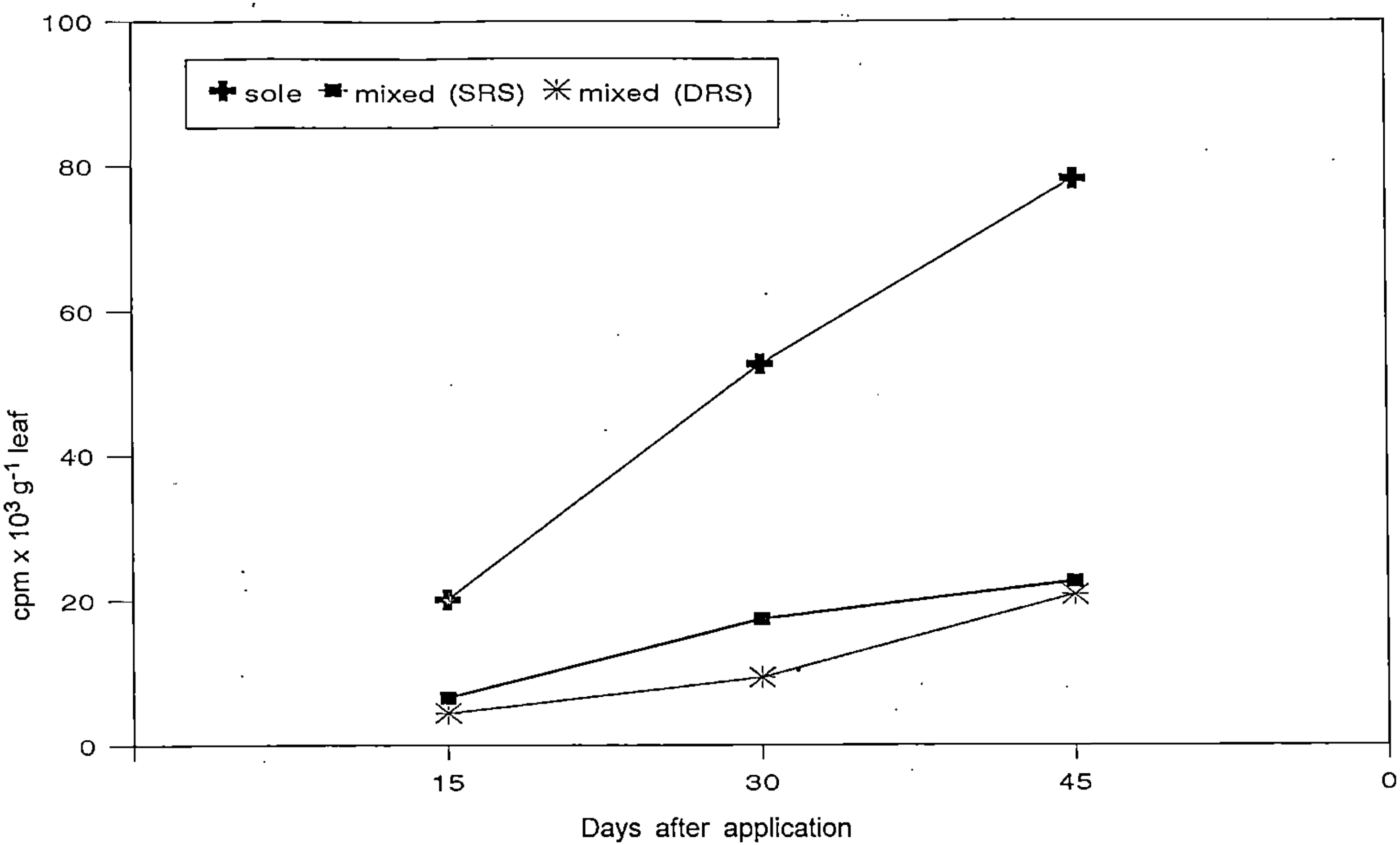


Fig. 23. Uptake of soil applied ^{32}P in sole and mixed rubber as a function of time during first year of intercropping

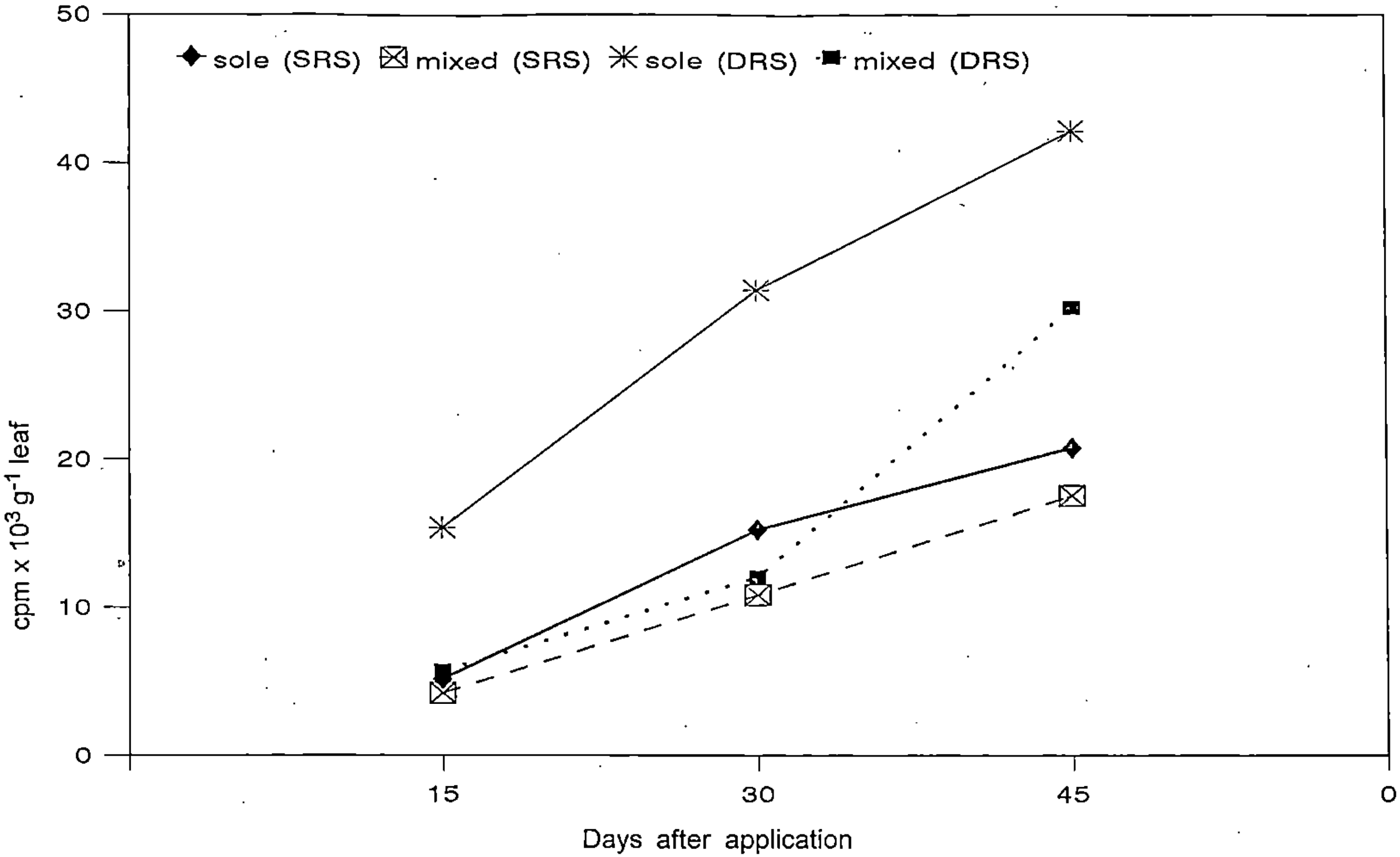


Fig. 24. Uptake of soil applied ^{32}P in sole and mixed banana as a function of time during first year of intercropping

Table 36 Absorption of ^{32}P by the untreated neighbouring plants under sole and mixed stands of rubber and banana at 15, 30 and 45 DAA (cpm/g leaf) during first year of intercropping

	Days after ^{32}P application		
	15	30	45
Rubber sole	5	42	157
Rubber mixed (SRS)	5	92	189
Rubber mixed (DRS)	6	270	75
SEm±	2	75	52
CD (0.05)	NS	NS	NS
Banana sole (SRS)	2649	6283	7199
Banana mixed (SRS)	498	1994	2716
Banana sole (DRS)	270	858	4417
Banana mixed (DRS)	2476	5234	6318
SEm±	277	789	1409
CD (0.05)	685	1949	NS

NS - Not Significant
DAA - Days after application
SRS - Single row system
DRS - Double row system

4.3.2 Recovery of ^{32}P in the leaf as influenced by crop stand in the second year of intercropping rubber with banana

The data relating to the absorption of ^{32}P by rubber and banana in sole and mixed stands in the second year of intercropping are furnished in Tables 37 and 38 and Fig.25 and 26. It was observed that the uptake of ^{32}P was significantly higher in sole stands of rubber and banana in all the sampling days. The radio uptake by rubber was numerically higher when it was intercropped with single row of banana than with double row (Fig.25).

Again, it was found that the uptake of ^{32}P by banana was generally higher in the single row system of intercropping with rubber than the double row system (Fig.26). Table 38 reveals that the effect of sharing of activity by neighbouring rubber plants was negligible under both sole and intercropped situations. It was also seen that the sharing of activity between the applied and neighbouring banana plant was greater in the double row system of intercropping than in the single row system. An overall evaluation of the results indicates that the single row system of intercropping is more feasible than the double row system.

4.3.3 Recovery of ^{32}P in the leaf as influenced by crop stand in the third year of intercropping rubber with banana

The data relating to the uptake of ^{32}P by rubber and banana in sole and mixed stands in the third year of intercropping are furnished in the Tables 39 and 40 and illustrated in Fig.27 and 28.

Table 37 Absorption of ^{32}P by sole and mixed stand of rubber and banana at 15, 30 and 45 DAA of ^{32}P to the soil (cpm/g leaf) during the second year of intercropping

	Days after ^{32}P application		
	15	30	45
Rubber sole	28950	102750	123779
Rubber mixed (SRS)	5660	63630	59897
Rubber mixed (DRS)	2545	26500	69260
SEm±	7400	20414	13110
CD (0.05)	18346	50609	32501
Banana sole (SRS)	5995	16260	28831
Banana mixed (SRS)	2254	10281	18307
Banana sole (DRS)	6525	25298	46569
Banana mixed (DRS)	930	5724	14794
SEm±	613	1553	2218
CD (0.05)	1513	3834	5477

DAA - Days after application
SRS - Single row system
DRS - Double row system

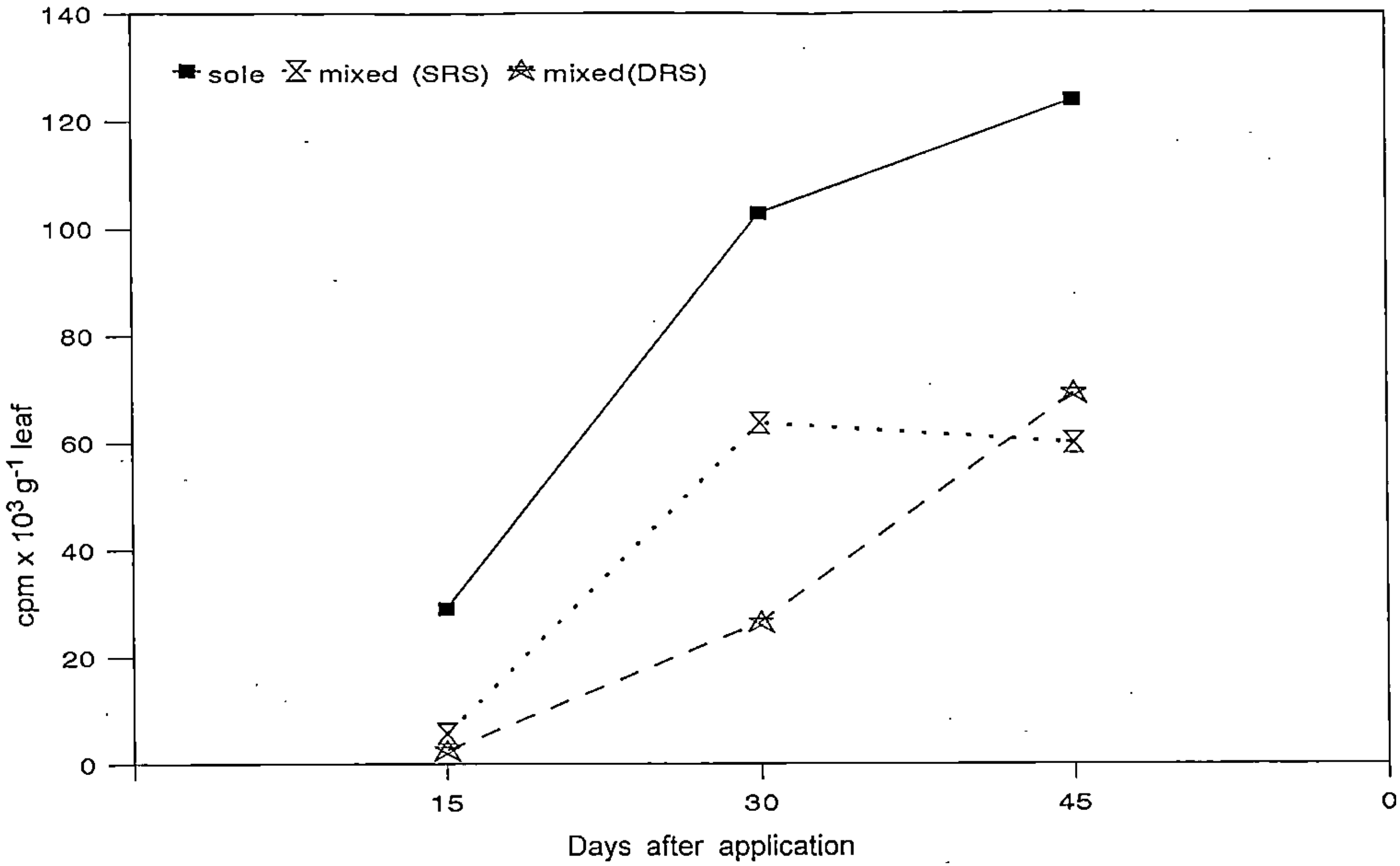


Fig. 25. Uptake of soil applied ^{32}P in sole and mixed rubber as a function of time during second year of intercropping

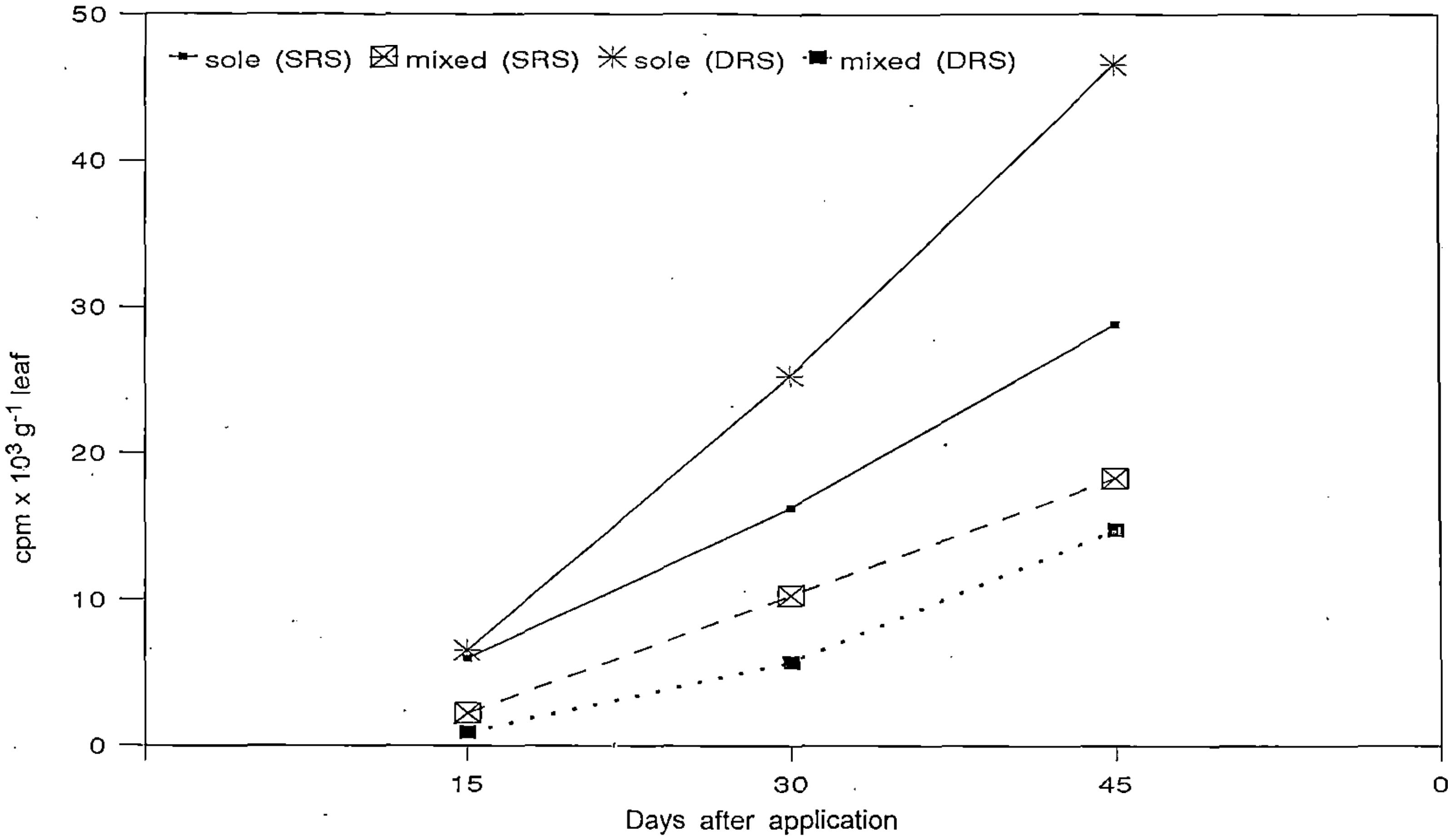


Fig. 26. Uptake of soil applied ^{32}P in sole and mixed banana as a function of time during second year of intercropping

Table 38 Absorption of ^{32}P by the untreated neighbouring plants under sole and mixed stands of rubber and banana at 15, 30 and 45 DAA (cpm/g leaf) during second year of intercropping

	Days after ^{32}P application		
	15	30	45
Rubber sole	3	49	58
Rubber mixed (SRS)	8	27	81
Rubber mixed (DRS)	4	419	121
SEm±	4	85	54
CD (0.05)	NS	211	NS
Banana sole (SRS)	3066	7278	10129
Banana mixed (SRS)	243	1147	2667
Banana sole (DRS)	283	994	7319
Banana mixed (DRS)	358	2849	4845
SEm±	178	764	1208
CD (0.05)	441	1887	NS

NS - Not significant
DAA - Days after application
SRS - Single row system
DRS - Double row system

Table 39 Absorption of ^{32}P by sole and mixed stand of rubber and banana at 15, 30 and 45 DAA of ^{32}P to the soil (cpm/g leaf) during the third year of intercropping

	Days after ^{32}P application		
	15	30	45
Rubber sole	18829	34356	56301
Rubber mixed (SRS)	7212	20479	26844
Rubber mixed (DRS)	3848	11415	22680
SEm±	1762	2850	6356
CD (0.05)	4368	7065	15758
Banana sole (SRS)	11626	19435	28047
Banana mixed (SRS)	7944	11215	13067
Banana sole (DRS)	4320	6873	10985
Banana mixed (DRS)	1035	3490	5957
SEm±	878	1898	3178
CD (0.05)	2168	4688	7847

DAA - Days after application
SRS - Single row system
DRS - Double row system

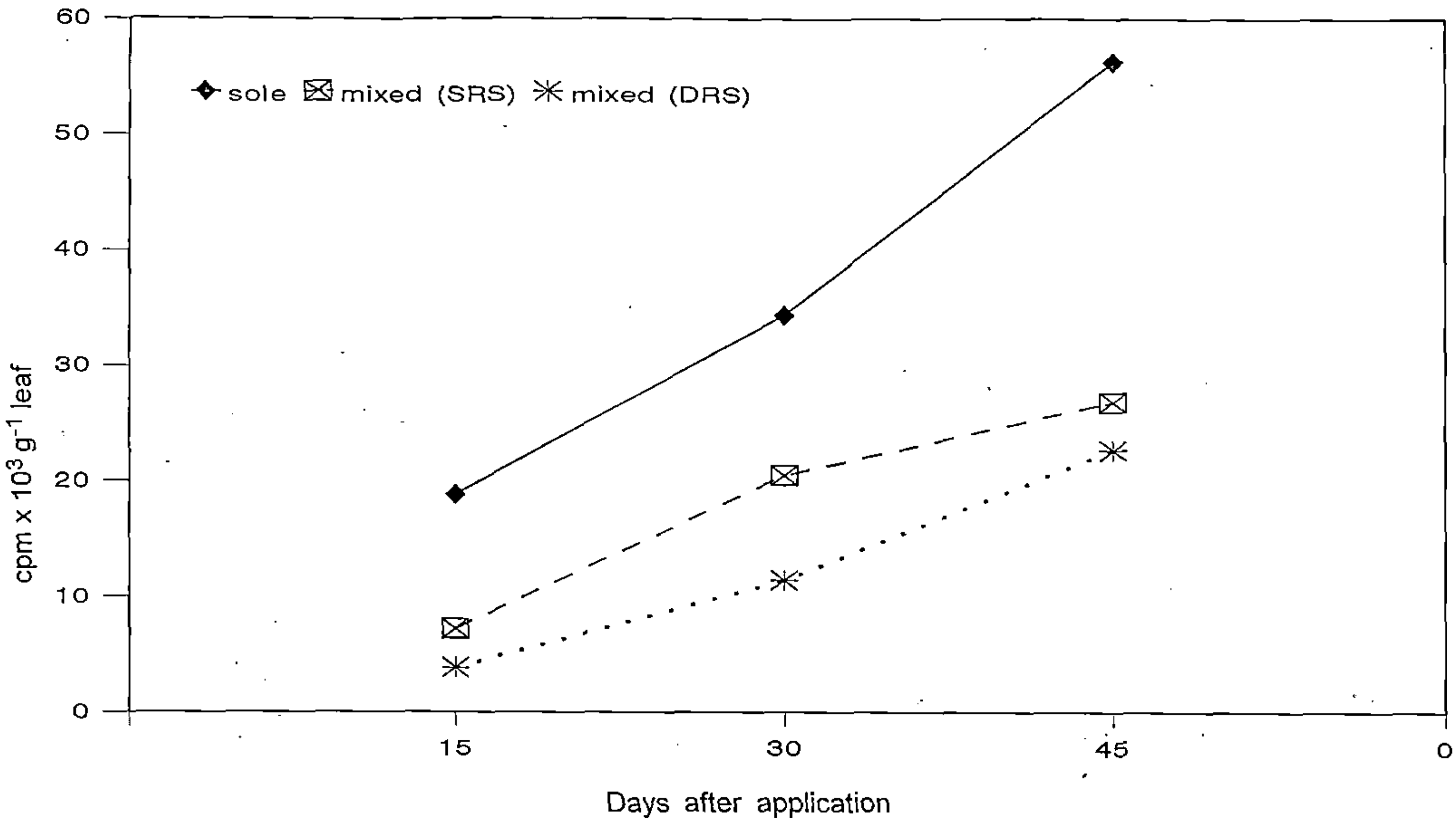


Fig. 27. Uptake of soil applied ^{32}P in sole and mixed rubber as a function of time during third year of intercropping

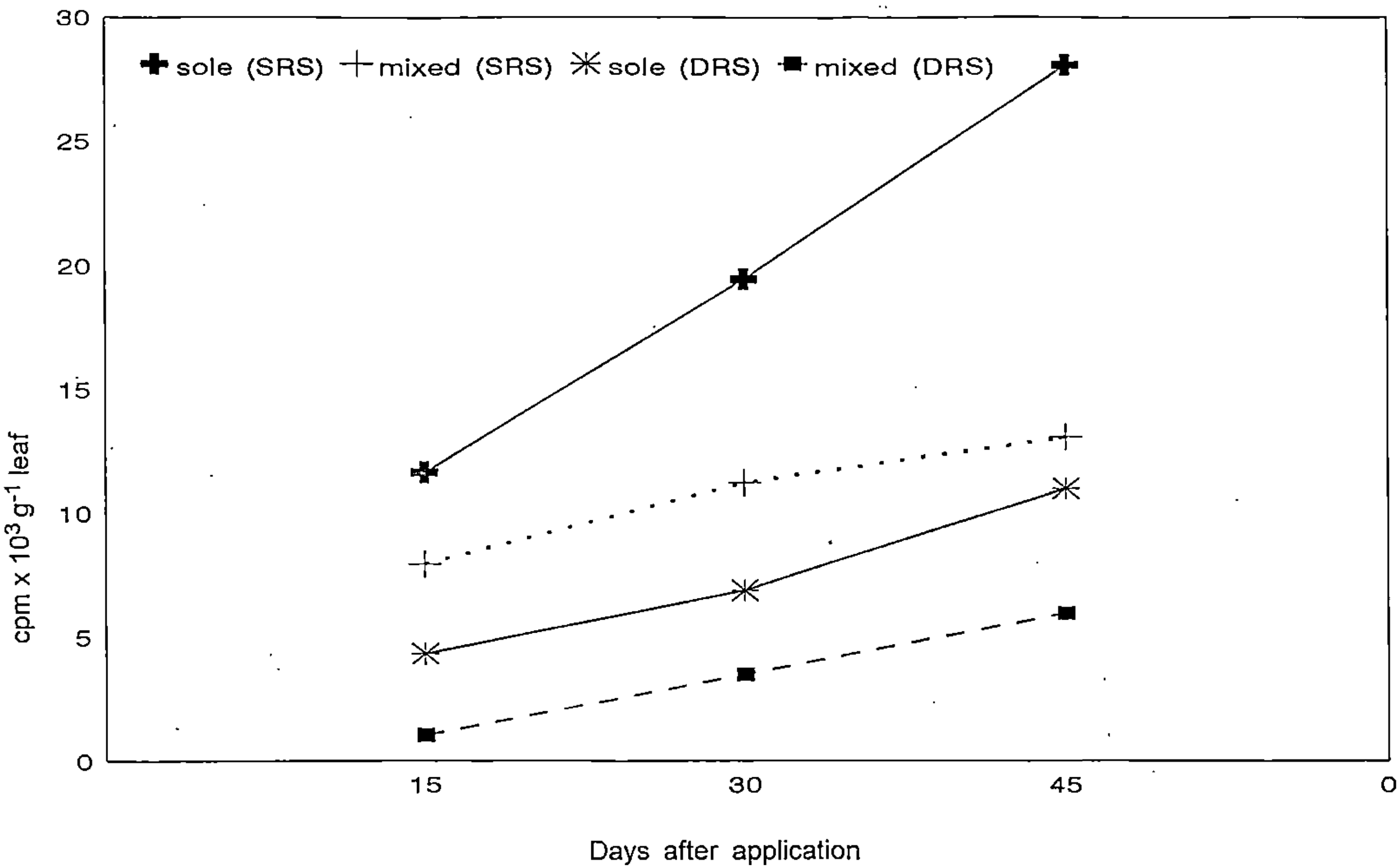


Fig. 28. Uptake of soil applied ^{32}P in sole and mixed banana as a function of time during third year of intercropping

Table 40 Absorption of ^{32}P by the untreated neighbouring plants under sole and mixed stands of rubber and banana at 15, 30 and 45 DAA (cpm/g leaf) during third year of intercropping

	Days after ^{32}P application		
	15	30	45
Rubber sole	43	22	75
Rubber mixed (SRS)	52	50	159
Rubber mixed (DRS)	42	377	95
SEm±	42	113	85
CD (0.05)	NS	NS	NS
Banana sole (SRS)	4146	6135	8499
Banana mixed (SRS)	1533	3515	5500
Banana sole (DRS)	600	1430	1729
Banana mixed (DRS)	282	756	1220
SEm±	357	545	841
CD (0.05)	882	1346	2076

NS - Not significant
DAA - Days after application
SRS - Single row system
DRS - Double row system

As in the previous years, the uptake of radioactivity was higher in sole crop of rubber and banana compared to the intercropped situations. The activity absorbed by rubber plants under intercropped situations was higher in the single row system than in the double row system of planting banana.

Similarly, the absorption of radio isotope by banana when intercropped with rubber was higher in the single row system than in the double row system. These results favour the intercropping of rubber with single row banana during the third year.

An examination of Tables 39 and 40 indicated that the sharing of activity between treated and untreated neighbouring rubber plants was negligible.

4.3.4 Uptake of soil applied ^{32}P in sole and mixed rubber and banana with time

The uptake of activity by rubber increased from the first year to the second year and then decreased during the third year under the sole crop and intercropped situations (Table 41 and Fig.29).

The uptake of activity by banana was maintained more or less uniformily during the three years of intercropping under the single row system. But in the double row system, the activity was drastically reduced with age of intercropping. This favours single row system of intercropping banana (Table 41 and Fig.30).

4.4 Pattern of root activity of rubber and banana under intercropped situations

In this study the root activity in mixed as well as pure stands of rubber and banana was examined. The percentage root activity at different situations was worked

Table 41 Uptake of soil applied ^{32}P in sole and mixed rubber and banana with time

	Period of intercropping		
	First year	Second year	Third year
Rubber sole	50322	85160	36495
Rubber mixed (SRS)	15524	43062	27409
Rubber mixed (DRS)	11522	32768	12648
Banana sole (SRS)	13747	17029	19703
Banana mixed (SRS)	10889	10281	10742
Banana sole (DRS)	29661	26131	7393
Banana mixed (DRS)	16018	7149	3494

SRS - Single row system
DRS - Double row system

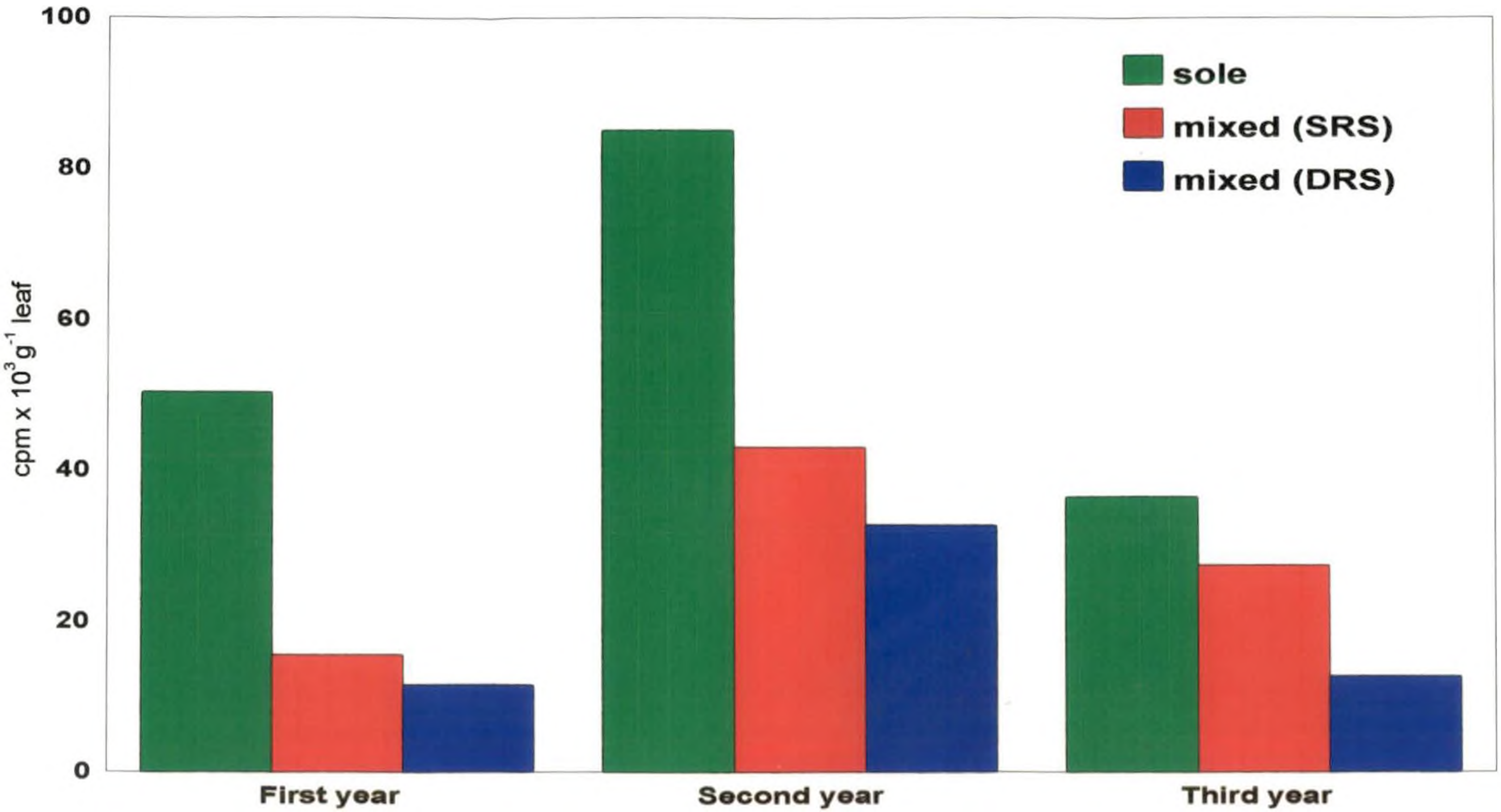


Fig. 29. Uptake of soil applied ^{32}P in sole and mixed rubber during three years of intercropping

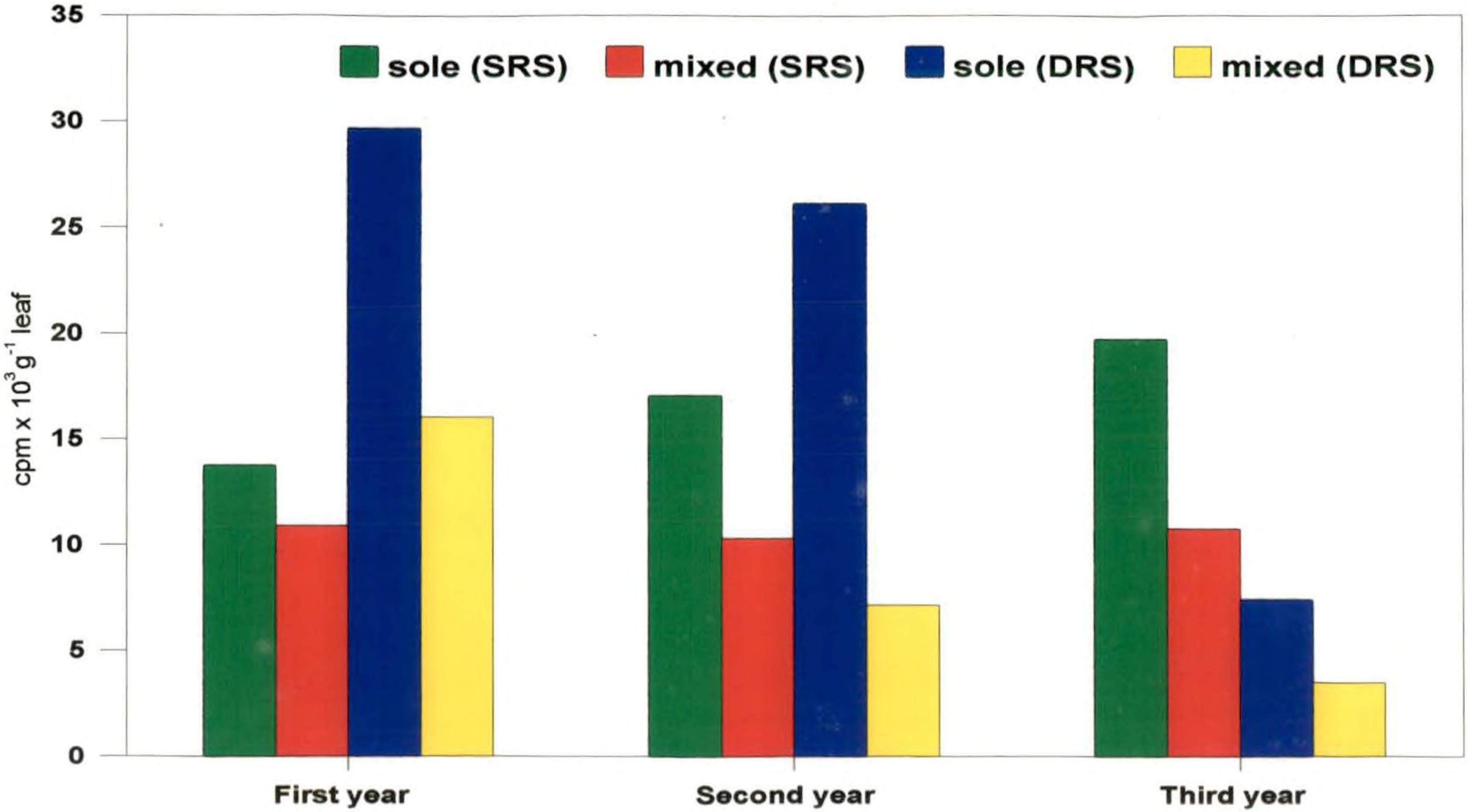


Fig. 30. Uptake of soil applied ^{32}P in sole and mixed banana during three years of intercropping

out from the corresponding mean cpm values of the previous experiment (4.3) using the formula:

$$\text{Root activity (\%)} = \frac{\text{Radio activity (cpm) recovered in the leaf for the treatment}}{\text{Total radio activity (cpm) recovered for all the treatments}} \times 100$$

The radioactivity recovered in the leaf by absorption of radio label from the soil by the component crops under each situation reflects the relative activity of roots and hence sharing of activity by the component crops,if any. In this study,comparisons are made on the percentage root activity of sole and mixed crop of rubber and between sole and mixed crop of banana. Root activity patterns of rubber and banana in mixed stand in comparison with that of pure stands of rubber and banana are important in getting an idea about the degree of competition between rubber and banana, the age upto which intercropping is possible and the pattern of sharing of nutrients by these crops.

4.4.1 Root activity pattern of sole and mixed stand of rubber and banana during the first year of intercropping

The percentage root activity at various sampling intervals were worked out for rubber and banana during the first year of intercropping and is given in Table 42 and Fig.31. Percentage root activity was greater for the sole crop than mixed crops. Root activity of rubber was reduced to approximately one third by intercropping with banana in single row system and was further reduced to about $1/5^{th}$ when intercropped with double row banana.

Table 42 Percentage root activity of sole and mixed stand of rubber and banana during the first year of intercropping

	Days after ^{32}P application			Mean
	15	30	45	
Rubber sole	65	66	64	65
Rubber mixed (SRS)	21	22	19	21
Rubber mixed (DRS)	14	12	17	14
Banana sole (SRS)	17	22	19	19
Banana mixed (SRS)	14	16	16	15
Banana sole (DRS)	50	45	38	44
Banana mixed (DRS)	19	17	27	21

SRS - Single row system
DRS - Double row system

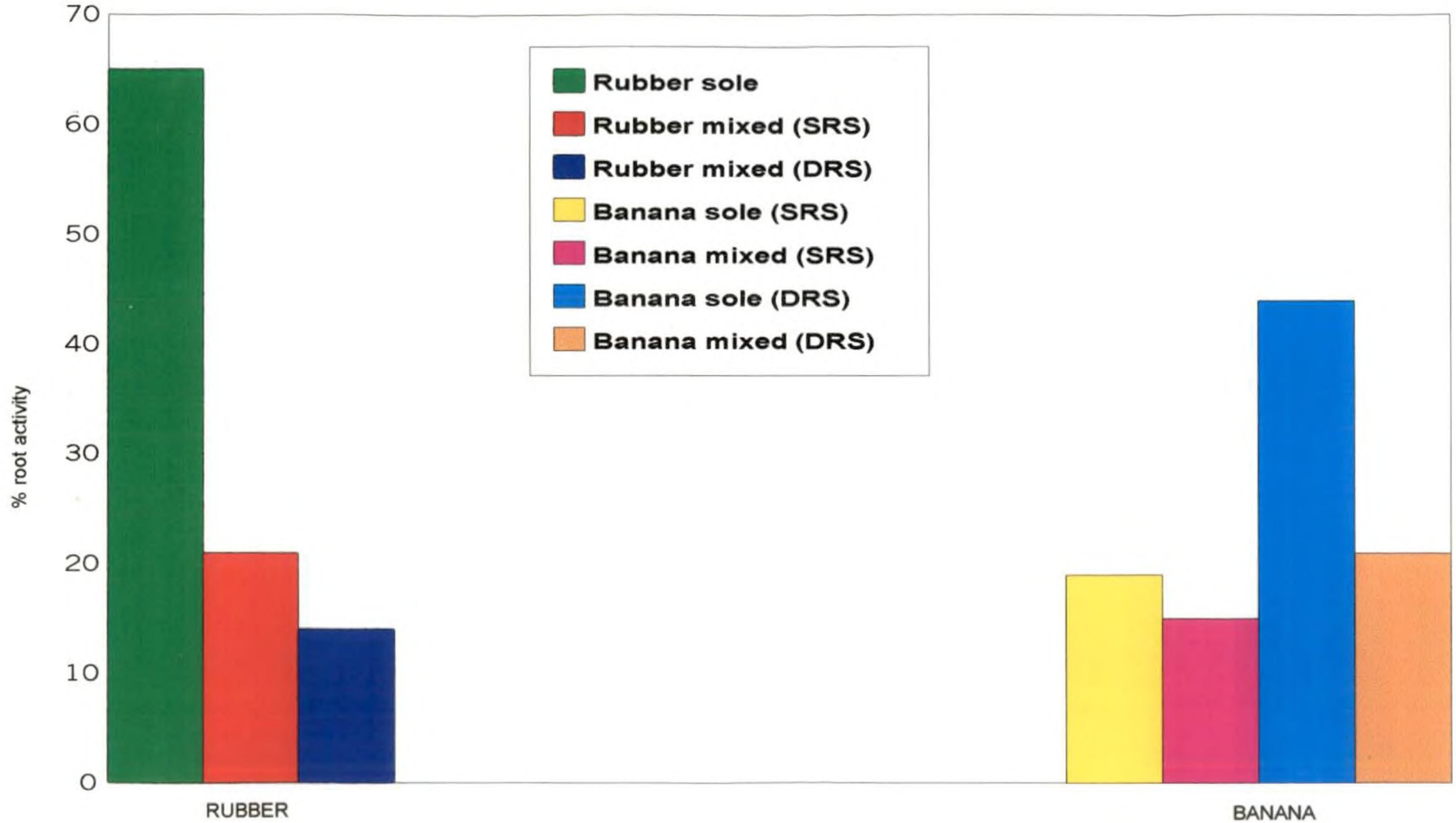


Fig. 31. Percentage root activity of sole and mixed stand of rubber and banana during first year of intercropping

When banana was grown alone, the activity was more (44%) in the double row system than in the single row system (19%). In mixed situation also, the double row banana showed higher percentage of root activity. The above results indicate that competition for rubber in the intercropped situation is minimum in the single row system of banana during the first year.

4.4.2 Root activity pattern of sole and mixed stand of rubber and banana during the second year of intercropping

The data on the percentage root activity during the second year of intercropping are presented in Table 43 and Fig.32. The percentage root activity was more for sole rubber and banana as compared to their mixed stands as it was during the first year also. The reduction in root activity was more severe when intercropped with two rows of banana.

Root activity in banana also decreased because of intercropping in rubber and it decreased further from 16 per cent in single row banana to 10 per cent in double row system of planting (Fig.32).

4.4.3 Root activity pattern of sole and mixed stand of rubber and banana during the third year of intercropping

Data on the percentage root activity during the third year of intercropping are given in Table 44 and Fig.33. As in the previous two years of intercropping, percentage root activity was greater for the sole crop than the mixed crops during the third year of intercropping also. Root activity of rubber which was 56 per cent in

Table 43 Percentage root activity of sole and mixed stand of rubber and banana during the second year of intercropping

	Days after ^{32}P application			Mean
	15	30	45	
Rubber sole	78	53	49	60
Rubber mixed (SRS)	15	33	24	24
Rubber mixed (DRS)	7	14	27	16
Banana sole (SRS)	38	28	27	31
Banana mixed (SRS)	14	18	17	16
Banana sole (DRS)	42	44	43	43
Banana mixed (DRS)	6	10	13	10

SRS - Single row system
DRS - Double row system

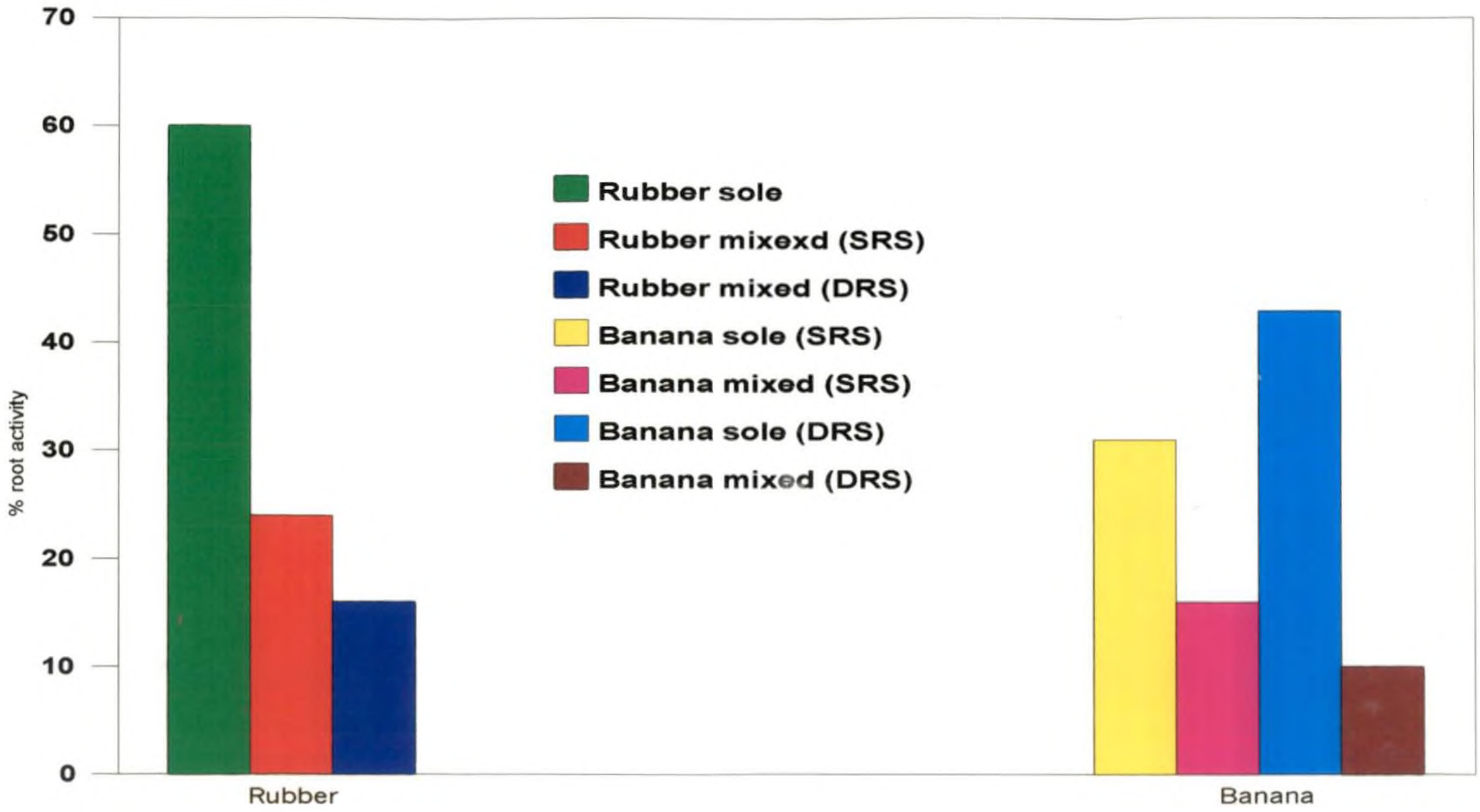


Fig. 32. Percentage root activity of sole and mixed stand of rubber and banana during second year of intercropping

Table 44 Root activity (%) of sole and mixed crop of rubber and banana during the third year of intercropping

	Days after ^{32}P application			Mean
	15	30	45	
Rubber sole	63	52	53	56
Rubber mixed (SRS)	24	31	25	27
Rubber mixed (DRS)	13	17	21	17
Banana sole (SRS)	47	47	48	47
Banana mixed (SRS)	32	27	23	27
Banana sole (DRS)	17	17	19	18
Banana mixed (DRS)	4	9	10	8

SRS - Single row system
DRS - Double row system

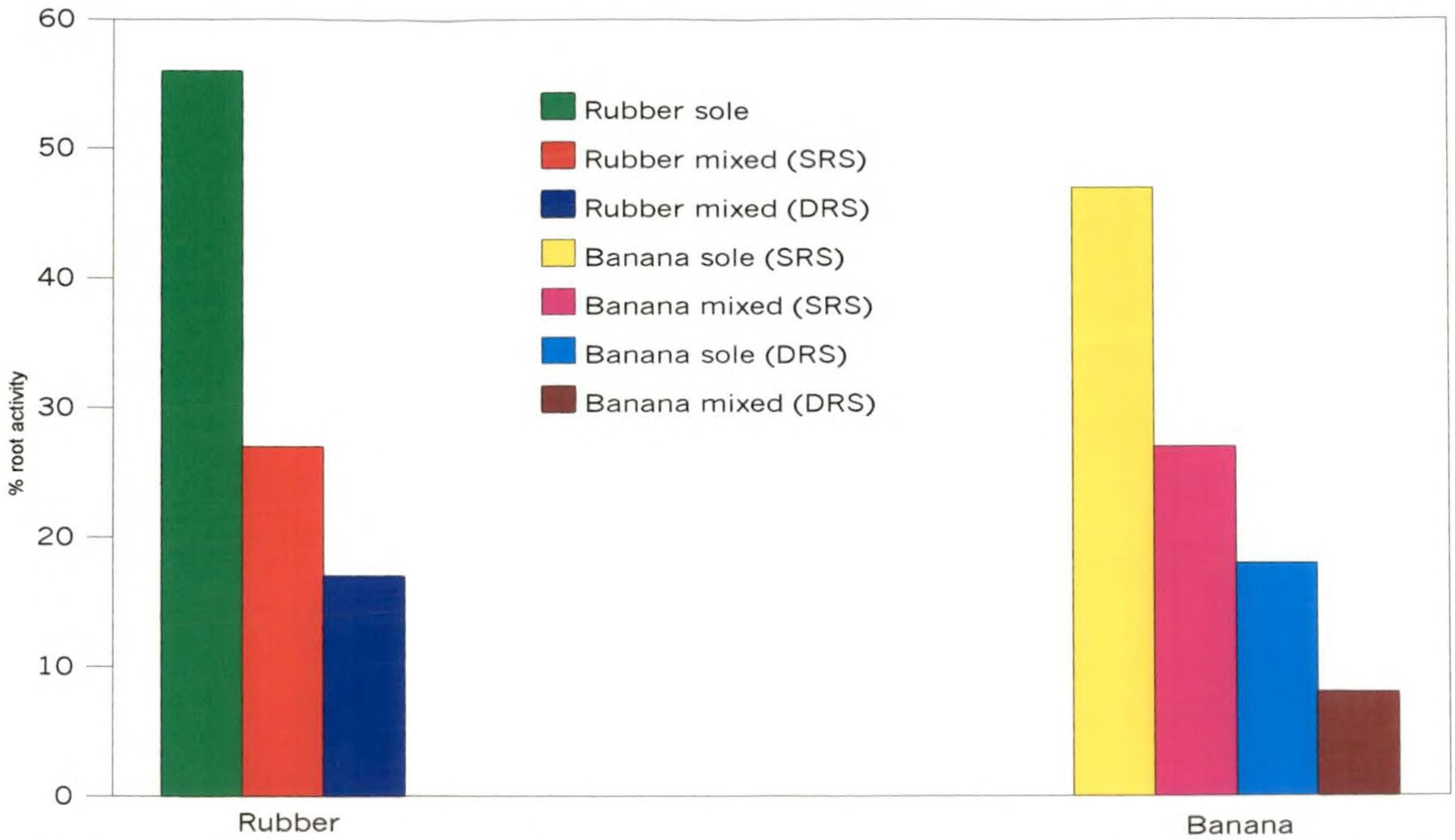


Fig. 33. Percentage root activity of sole and mixed stand of rubber and banana during third year of intercropping

sole situation was reduced to 27 and 17 per cent respectively, under the single and double row systems of intercropping banana.

There was greater reduction in the root activity of banana in the double row system of intercropping than in the single row system indicating that single row system is more feasible during the third year.

4.5 Extent of root competition between rubber and banana in the intercropping systems

The extent of root competition between rubber and banana over different years of intercropping is presented in Table 45 and Fig.34. In all the three years of intercropping, sole crops had the maximum root activity which was suppressed by intercropping due to competition between component crops.

Under the intercropped situations, root activity of rubber was consistently higher in the single row system of planting as compared to double row system.

When intercropped, single row banana registered greater root activity than banana in the double row system in all the years except in first year.

In general, root competition between rubber and banana was minimum when rubber was intercropped with a single row of banana during the initial three years.

4.6 Extent of light infiltration through the canopies of young rubber

The pattern of progressive vegetative development of the rubber plant from first year after planting to seventh year as represented by height, girth and canopy

Table 45 Percentage root activity of sole and mixed rubber and banana during three years of intercropping

	Period of intercropping		
	First year	Second year	Third year
Rubber sole	65	60	56
Rubber mixed (SRS)	21	24	27
Rubber mixed (DRS)	14	16	17
Banana sole (SRS)	19	31	47
Banana mixed (SRS)	15	16	27
Banana sole (DRS)	44	43	18
Banana mixed (DRS)	21	10	8

SRS - Single row system
DRS - Double row system

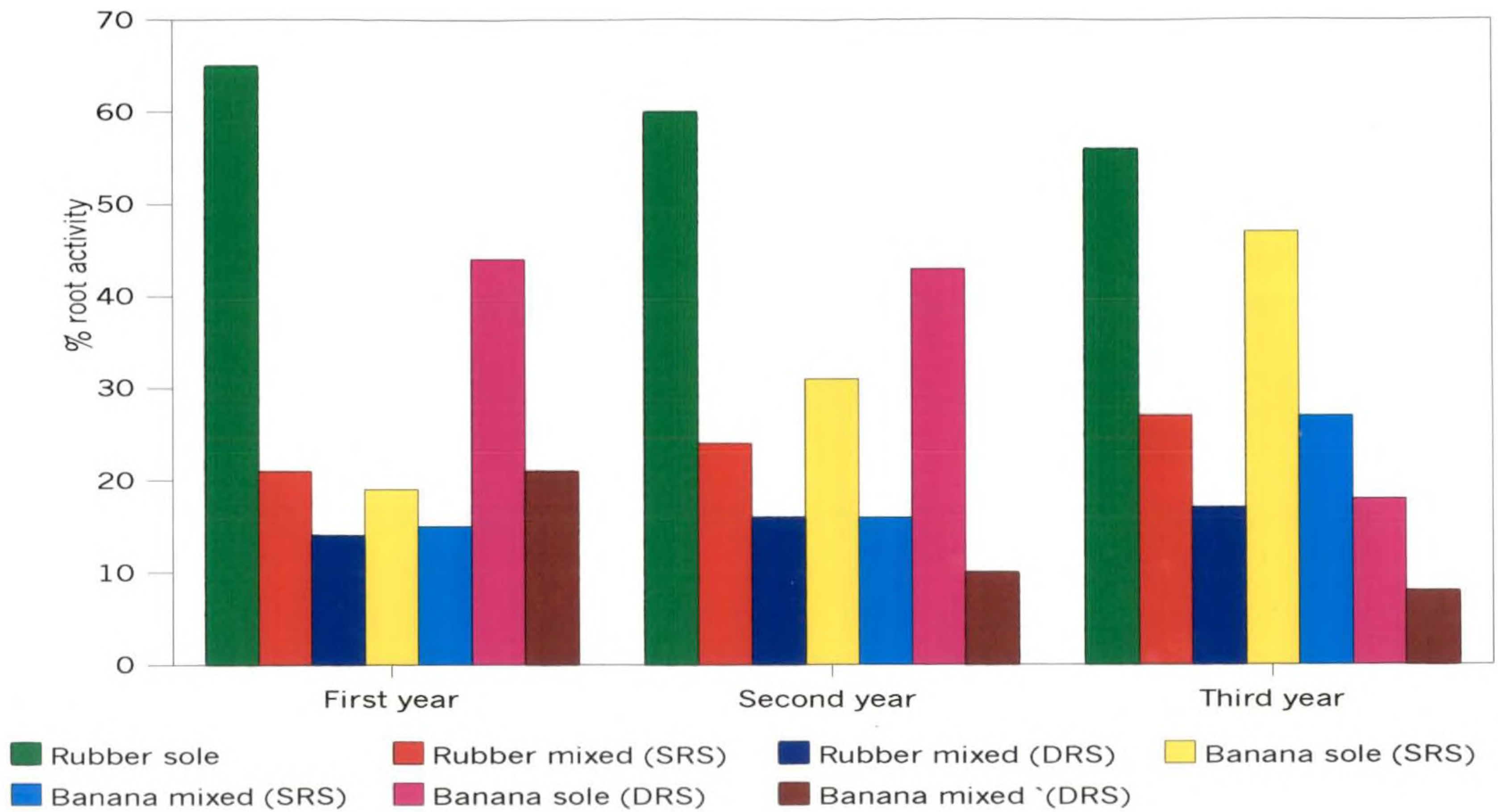


Fig. 34. Degree of competition between rubber and banana under intercropped situation over time

diameter observed in the present study is presented in Table 46. The data show that the growth of the rubber tree was closely associated with a steady increase in all the growth parameters. The mean girth of 6.5 cm and height of 2.4 m in the first year planting increased to 50.2 cm and 11.2 m respectively, after seven years of growth. Canopy diameter during the corresponding period increased from 0.79 m to 7 m. The increase in canopy development progressively reduced the light infiltration from 97 per cent at the end of first year to a meagre 7 per cent at the end of seventh year. Light infiltration showed a steady decrease with increasing levels of the other growth parameters also (Fig.35).

Correlation matrix of the various growth parameters is presented in Table 47. It can be seen that all the growth parameters observed were significantly related among themselves. They also had a significant negative relation with percentage of light infiltration.

Data on individual and multiple regression analysis are presented in Table 48. The equation indicates the possibility for reasonably accurate prediction of degree of light infiltration, if any one parameter of growth is known.

Table 46 Light infiltration and biological parameters of rubber

Parameters				Light infiltration(%)
Age of the plant (years)	Girth (cm)	Height (cm)	Canopy diameter (m)	
1	6.5	2.4	0.79	97
2	8.5	4.4	2.1	76
3	23.3	6.1	3.3	43
4	35.9	7.6	4.0	22
5	38.1	8.3	4.5	15
6	49.7	9.5	5.5	8
7	50.2	11.2	7.0	7

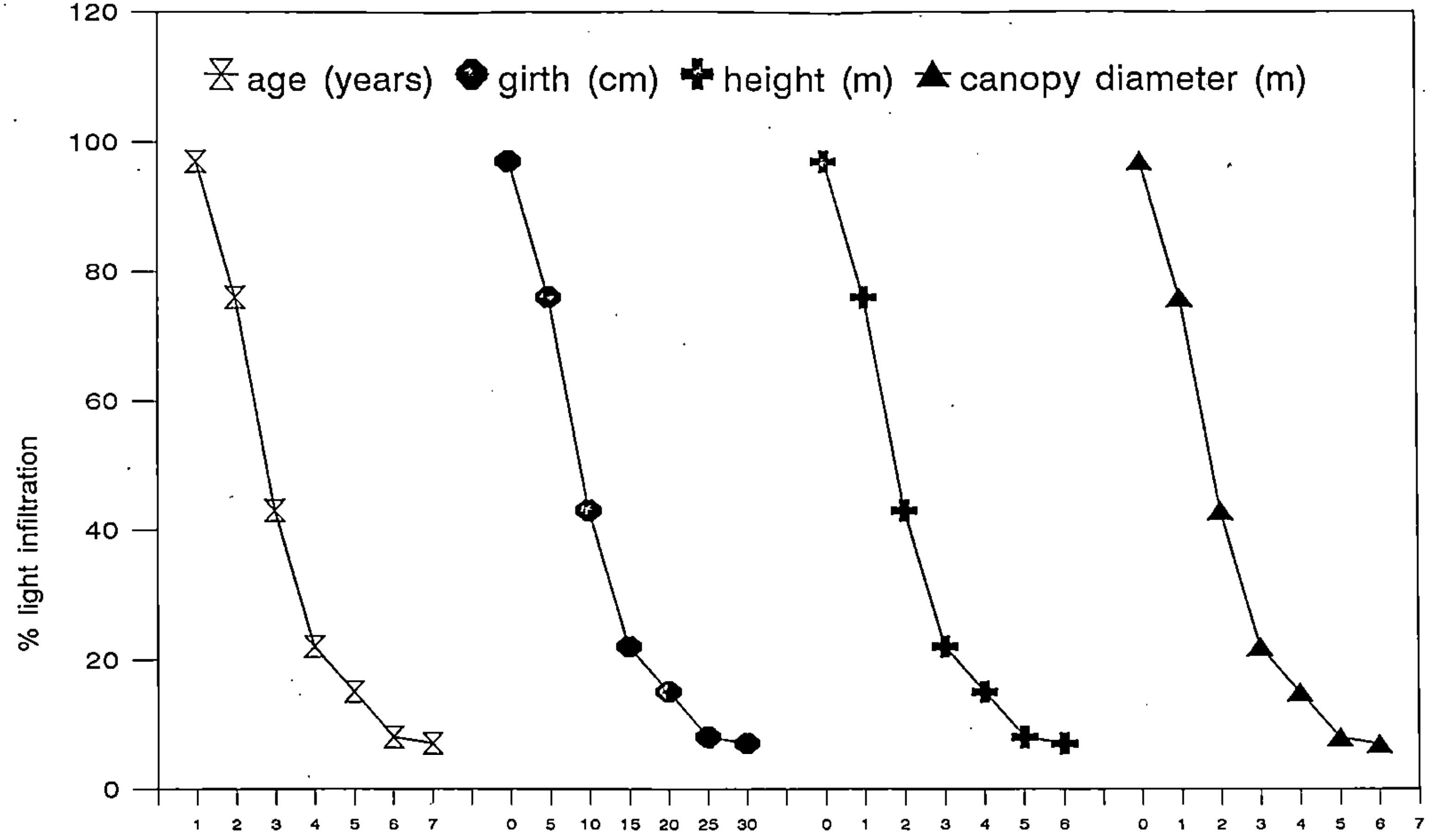


Fig. 35. Percentage light infiltration in relation to various biological parameters of rubber

Table 47 Correlation matrix of light infiltration with different biological parameters

	Age	Girth	Height	Canopy diameter	% light infiltered
Age	1.000				
Girth	0.976	1.000			
Height	0.992	0.973	1.000		
Canopy diameter	0.991	0.959	0.996	1.000	
% light infiltered	-0.941	-0.969	-0.962	-0.936	1.000

Table 48 Individual and multiple regression analysis of light infiltration with different biological parameters

Parameter	Equation	Predictability (%)
Age	$Y = 169.6 \times 0.6187^x$	98
Girth	$Y = 142.1 \times 0.9441^x$	98.5
Height	$Y = 316.1 \times 0.7055^x$	90
Canopy diameter	$Y = 166.4 \times 0.6130^x$	94

x = observed parameter in cm/m
Y = percentage light infiltration

DISCUSSION

DISCUSSION

5.1 Root activity pattern of young rubber

5.1.1 Root activity pattern of one-year-old rubber

Tables 3 and 4 showed that in the first year of growth of rubber, the absorption of the radiolabel was maximum from the root zone area of 50 cm lateral distance and 25 cm depth. This indicates that the active roots confine to this soil area during the first year of planting. Chong-Qun Liu (1984) also reported similar results in rubber. He observed that the ^{32}P absorption was low when phosphate fertilizer was applied at the soil surface or at soil depths below 25 cm. He also found that the root activity was maximum within a radius of 30 cm around the plant. So the possible zone of maximum nutrient uptake is 50 cm lateral distance and a depth of 25 cm.

It is also evident that the uptake of radiolabel is dependent on lateral distance and depth of application in the first year of growth. This emphasises the importance of pitmanuring at the time of planting, particularly when the initial fertility status is inadequate.

In the first year growth of rubber, 90 per cent of the total root activity confined to a lateral distance of 50 cm and to a depth of 25 cm (Table 24 and Fig.19). Cheng-Wen, Xu (1960) also reported that 66-91 per cent of the total amount of roots are distributed in the 0 - 30 cm soil layer.

The present recommendation on method of fertilizer application is to apply fertilizers in a circular band of radius 30 cm leaving 7 cm around the plant base and to fork into 5 to 8 cm top soil (Rubber Research Institute of India, 1999). Based on the results of the present study, fertilizers can be probably more effectively applied to the active root zone area of 50 cm circular band around the plant leaving 7 cm from the plant base (Table 24). It also appears that there is scope for modifying the present recommendation on the depth of placement also.

5.1.2 Root activity pattern of two-year-old rubber

From the results obtained from the data (Table 29 and Fig.20) it is obvious that about 80 per cent of the root activity was confined to a zone of 100 cm lateral distance and to a depth of 50 cm. Active roots are also noted beyond 50 cm upto a depth of 100 cm (20%). Chong-Qun, Liu (1984) also reported a similar trend of increasing spread of roots with increase in age/tree girth.

The abundance of feeder roots in the area of 100 cm lateral distance and 50 cm depth emphasises the need for application of fertilizers to this zone to get maximum nutrient absorption. The present recommendation by Rubber Research Institute of India is to apply fertilizers in a circular band of 45 cm leaving 15 cm around the base of the tree and to fork into the top soil to a depth of 5 - 8 cm. Based on the results obtained from the present study it is suggested that the zone of fertilizer application may be increased further in second year of growth of rubber to ensure the fullest utilization of applied nutrients. Similarly, about 80 per cent of root activity was noticed within a depth of 50 cm. This indicates that fertilizer placement in this region, rather than forking in, will be more advantageous (Table 29).

In the second year growth also, the rubber plants probably get the advantages of pit manuring done at the time of pit filling as evidenced from the data given in

Table 29. In second year also the lateral distance and depth of application are important in deciding nutrient availability. The ideal method of application at this time may be either pit manuring or placement in circular bands of 20 to 30 cm depth within a radius of 100 cm.

5.1.3 Root activity pattern of three-year-old rubber

The data (Table 34 and Fig.21) showed that about 80 per cent of root activity was concentrated in the lateral and vertical zones of 150 cm and 75 cm, respectively, in the third year growth of rubber. So during the third year, the zone of fertilizer application shall be in a circular band within 150 cm leaving 25 cm around the plant base and the fertilizer may be placed in the soil to any convenient depth.

5.2 Pattern of root activity in pure and mixed stand of rubber and banana

The root activity pattern of rubber and banana grown alone and in mixture was studied using ^{32}P soil injection technique. The study was carried out during the monsoon season when soil moisture availability was not limiting and the extent of absorption of ^{32}P could then be considered to reflect the amount of root activity (Wahid *et al.*, 1988). Therefore, root activity characterisation at this time may probably represent root interactions of the largest possible magnitude.

5.2.1 Root activity pattern of pure and mixed stand of rubber and banana in the first year of intercropping

The data (Table 35) indicated that the uptake of ^{32}P was higher when the component crops were grown alone. The percentage root activity was also more for sole crop than in mixed situation (Table 42).

George *et al.* (1995) reported similar results that the crops in sole situations absorbed more ^{32}P than in mixed systems. Rubber was found to be the most dominant species as compared to banana in single row or in double row system. Under the intercropped situation, the root activity of rubber was high with single row banana when planted in between two rows of rubber. Ashokan *et al.* (1988) also reported such a dominance by a component crop in a cassava-banana-elephant foot yam intercropping system. It was also found that radiophosphorus applied to the root zone of one of the component species was absorbed not only by the treated plant but also by neighbouring plants.

Similarly in banana also the least root activity was registered by single row banana under intercropped situation giving the maximum chance for sharing nutrients to the neighbouring rubber or banana. Hence single row system of planting banana in the first year of rubber is found to be better for both the component crops. In double row system of planting banana with rubber the extent of mutual competition is found to be very high.

5.2.2 Root activity pattern of pure and mixed stand of rubber and banana in the second year of intercropping

In the second year of intercropping also, sole crops of rubber and banana registered a higher root activity than in the mixed situation indicating consistency of the results obtained in first year also (Table 37). Among the intercropped situations, single row banana in between two rows of rubber offered much less competition than banana in double row. In the case of banana also, when it was planted in single row as intercrop, it showed higher root activity than when planted in double rows. The advantage of maintaining single row of banana as intercrop in rubber was thus indicated during second year also.

The double row system of planting banana resulted in severe competition between banana and rubber. As rubber grows, the space and light availability in the inter rows become gradually reduced and hence planting banana in double row system may lead to severe competition within and between plant species.

The root activity of rubber was also reduced by double row system of planting banana in second year of intercropping by competition and sharing of available resources. At the same time, the root activity of banana under single row system of planting was fairly high (Table 43) thus emphasising the preference for planting banana as single row in the second year.

5.2.3 Root activity pattern of pure and mixed stands of rubber and banana in the third year of intercropping

In the third year of intercropping also the same pattern of root activity was noted as in the first and second year of intercropping when the sole crop registered a higher root activity than the crops in a mixed situation (Table 39). This may be the result of sharing of applied activity by the component crops as reported by Ashokan *et al.* (1988). When banana was grown in single row in the inter spaces of rubber, the root activity of rubber was fairly high as compared to when it was intercropped with double row banana.

Similarly, single row banana also showed better root activity as compared to double row banana under intercropped situation. When banana was grown as intercrop in double row in the third year rubber, there was greater competition between these crops. Therefore, single row banana appears to be better during the third year also.

In the case of percentage root activity, the same trend was followed (Table 44). This again confirms the relevance of intercropping rubber with single row of banana during the third year in order to reduce mutual competition within and between crop species.

5.3 Extent of root competition between rubber and banana under intercropped situation

The extent of root competition for nutrients between component crops viz., rubber and banana in the intercropping system was evaluated by studying the pattern of sharing of applied radio activity (Table 45). In all the years, sole crops of rubber and banana were superior in root activity. Their root activity was suppressed to a great extent under intercropped situations due to competition.

Rubber was the dominant species in terms of root activity in all the three years of intercropping with banana. In mixed banana also, single row banana registered maximum root activity as compared to double row system in all the years except for the first year of intercropping.

In short, the root activity of both rubber and banana under intercropped situation was maintained at substantially lower levels when single row of banana between two rows of rubber was maintained during the initial three years of planting.

5.4 Light infiltration with advancing age of rubber

Light infiltration through rubber canopy was dependent on age of the plant during the immature phase. As the age increases, the biological parameters of the tree also increase. It was observed from Table 46 and Fig.35 that as age increased from first year to seventh year, percentage light infiltration decreased from 97 to 7 per cent. Satheesan *et al.* (1982) also reported that the extent of filtered light in a mature rubber plantation was 5 per cent of the incoming total PAR irrespective of spacing. From the third year onwards, availability of filtered light was reduced to levels below 22 per cent thus making it difficult to go in for any sort of intercropping in this crop. It also appears that availability of light is the main factor for restricting intercropping in rubber to the initial three years only.

Root level competition, which sets in from the very first year of planting of rubber and goes on increasing with advancing age, may not be as strong a competing factor as solar radiation is. Such a root level competition is substantially more when double row system is followed for planting banana. It is, therefore, concluded that single row system should be preferred for planting banana if factors related to productivity are not significantly in favour of the double row system.

SUMMARY

SUMMARY

Field experiments were conducted at Kerala Agricultural University during 1994-97 to study the extent of involvement of root level competition and competition for light in the early years of growth of rubber.

Rooting pattern of rubber was studied employing ^{32}P soil injection technique. The required activity was applied at varying lateral distances of 50, 100, 150, 200 and 250 cm from the plant and at varying depths of 10, 25, 50, 75 and 100 cm. This experiment was laid out in randomised block design and was replicated thrice.

In another experiment, rubber was intercropped with banana cv. Poovan under two systems of planting. In this experiment, the extent of root competition was evaluated using ^{32}P soil injection technique. Both rubber as well as banana were treated with radio activity of ^{32}P applied in four circular rings of varying radii of 25, 50, 100 and 150 cm around the plant. Along each circle, nine equi-distant soil holes were made and activity was applied at alternate depths of 25, 50 and 75 cm. This experiment was laid out in CRD.

In a third field experiment, the intensity of light infiltration through rubber canopies of varying ages was studied. For this study, fields with one to 7 year-old rubber were selected and in each age group, the extent of light infiltration was measured which was again related with the biological parameters of rubber plant viz., girth, height and canopy diameter.

The results of the investigations are summarised below.

1. Uptake of soil applied ^{32}P by one-year-old rubber was maximum when the radio chemical was applied in a lateral distance of 50 cm and depth of 25 cm. The interaction between lateral distance and depth of application of ^{32}P was significant indicating that lateral distance and depth were dependent during the first year.

2. More than 90 per cent of root activity in one-year-old rubber is confined to a lateral distance of 50 cm and a depth of 25 cm.

3. In two-year-old rubber, uptake of soil applied ^{32}P was significant with respect to lateral distance and the highest activity was noticed at 50 cm followed by 100 cm distance. The effect of depth of application was also significant and 50 cm depth recorded maximum recovery of the radio label. The interaction effect was also significant.

4. Regarding the root activity pattern of two-year-old rubber, about 80 per cent activity was confined to a zone of 100 cm lateral distance and 50 cm depth.

5. During the third year, maximum recovery of soil applied ^{32}P was obtained from a lateral distance of 50 cm followed by 100 and then by 150 cm. Uptake of activity was found to be independent of the depth of application.

6. At all the stages, absorption of ^{32}P from all lateral distances and depths of application increased with time of sampling as a result of accumulation of ^{32}P in leaves of rubber.

7. Uptake of ^{32}P by both rubber and banana was higher when these crops were grown alone during the first year of planting.

8. Under intercropped situation, lower activity of banana was noticed in single row

9. Root activity of rubber was reduced to approximately one third by intercropping with a single row of banana. This was further reduced when intercropping was done with banana in double row during first year of intercropping. The desirability of planting banana in a single row during the first year of rubber is thus indicated.

10. Uptake ^{32}P by two-year-old rubber was higher when intercropped with single row banana than with double row.

11. Uptake of radio activity by banana was generally higher in the single row system of intercropping than the double row system during second year.

12. In second year also, percentage root activity was more for sole rubber and banana as compared to their mixed stand. Root activity of rubber was reduced to approximately 24 and 16 per cent when mixed with single and double rows of banana, respectively. This favours planting of single row banana during second year also.

13. In the third year, sole crops of rubber and banana registered higher uptake rate of radioactivity compared to the intercropped situations.

14. Radio uptake by three-year-old rubber plants under intercropped situation was higher in the single row system of planting banana than the double row.

15. Absorption of ^{32}P by banana when intercropped with three-year-old rubber was also higher in the single row system than in the double row system of banana.

16. Root activity of three-year-old rubber was reduced to 27 and 17 per cent under single row and double row systems of intercropping banana, respectively.

17. In banana also double row system of planting registered much lower root activity (8%) than the single row system.

18. In banana, uptake of activity was maintained more or less uniformly during the three years of intercropping under single row system. But in the double row system, activity was drastically reduced with age.

19. In all the years of intercropping, sole crops had the maximum root activity which was suppressed by intercropping due to competition between component crops.

20. Under the intercropped situations, percentage root activity of rubber was higher in the single row system of planting as compared to double row system during all the years under study.

21. The degree of root competition between rubber and banana was minimum when banana was intercropped in single row in the inter row spaces of rubber during the initial three years of planting rubber.

22. Growth of rubber tree was closely associated with a steady increase in all the growth parameters during the immature phase.

23. The progressive development of canopy proportionately reduced the light infiltration from 97 per cent at the close of first year to a meagre 7 per cent at the end of seventh year.

24. All the growth parameters observed were significantly related among themselves and had a negative correlation with the percentage of light infiltration.

25. A reasonably accurate prediction of available infiltered light is possible using the equation $y = ab^x$, if only any one parameter of growth is known.

Conclusion

Based on the results of the present investigation, it is concluded that active roots of rubber are concentrated in radial distances of 50, 100 and 150 cm from the plant during the first, second and third year of growth, respectively.

Such a pattern indicates that fertilizers may be applied in zones extending to these lateral distances to get maximum fertilizer use efficiency in the early years of growth of rubber. Vertically, the roots of rubber are found to concentrate to depths in the range of 20-30 cm during the intial three years of growth rather than concentrating on the surface. Fertilizers are, therefore, to be placed to this zone instead of forking in after surface application. This will also reduce nutrient losses through volatilisation and run off. The study also indicated the importance of pit manuring prior to planting rubber.

Rubber plantations can be intercropped using banana during the initial three years. The planting geometry of banana should be preferably a single row along the interrow spaces of rubber if root competition only is considered as the factor.

The insufficiency of filtered light through rubber canopy is an important limiting factor for intercropping in this crop. However, this will assume importance only from second year onwards. From fourth year onwards, light infiltration will be so low that practically no crop can come up under the shade of rubber.

Future line of work

1. Root activity studies in rubber from fourth year to maturity so that we may get a clear picture of rooting pattern of rubber with advancing age and at maturity. This will help in taking the right decision where to apply the fertilizers according to the age of the tree to increase the fertilizer use efficiency.
2. Study further the scope of pit manuring in detail based on the results obtained in this study.
3. Conduct field trials on method of fertilizer application based on the results obtained from this study to affirm the findings for practical utility.
4. Intercropping trials are to be laid out using different varieties of banana to choose the most preferable variety for intercropping.
5. Screening of intercrops suitable for various intensities of infiltered light and then testing their field performance in rubber plantations of varying ages.

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* Originals not seen

APPENDICES

APPENDIX I

Weather data at monthly intervals during the experimental period
(May 1994 to May 1997)

Months	Air Temperature Mean		Mean relative humidity (%)	Rainfall (mm)	Rainy days	Mean sunshine hours	Mean wind speed (km)
	Max. (°C)	Min. (°C)					
1994							
May	33.6	24.7	75	124.2	7	8.0	4.5
June	28.9	22.9	90	955.1	27	2.1	4.2
July	28.6	22.4	91	1002.1	29	1.4	5.0
August	30.0	22.8	85	509.2	20	3.6	5.0
September	31.8	23.2	78	240.5	8	7.3	3.5
October	32.3	22.7	80	358.2	20	6.7	3.4
November	31.8	23.3	68	125.3	5	8.1	7.9
December	32.2	22.2	58	0.0	0	10.6	10.1
1995							
January	32.9	22.4	59	0.0	0	9.6	9.1
February	35.4	23.4	60	0.5	0	10.0	6.4
March	37.6	23.8	60	2.8	0	9.3	4.4
April	36.6	24.9	71	118.7	5	9.1	4.0
May	33.5	23.9	78	370.5	13	6.5	3.8
June	31.6	23.1	86	500.4	19	3.7	10.1
July	29.9	23.2	89	884.7	26	2.1	1.7
August	30.6	23.7	86	448.7	22	3.7	2.0
September	30.1	23.5	82	282.5	13	6.1	2.0
October	33.2	23.2	78	118.4	8	8.3	1.8
November	31.3	22.5	80	88.4	5	6.5	1.1
December	32.5	21.3	57	0.0	0	10.3	6.7

Contd....

Appendix I contd...

1996							
January	33.1	22.4	53	0.0	0	9.4	7.1
February	34.7	23.4	53	0.0	0	9.9	5.9
March	36.4	24.3	60	0.0	0	9.3	3.6
April	34.6	25.0	73	152.0	7	8.3	3.0
May	32.8	25.2	77	95.4	4	7.7	2.4
June	30.5	23.8	85	400.3	16	4.7	3.0
July	28.8	23.1	90	580.7	25	2.7	2.7
August	29.1	23.6	87	310.0	20	3.7	3.0
September	29.2	23.7	84	391.6	17	4.3	2.7
October	30.1	22.9	82	219.3	12	6.0	2.0
November	31.5	23.6	72	22.1	2	9.1	3.7
December	30.5	21.5	68	60.4	2	6.8	6.4
1997							
January	32.0	22.9	62	0.0	0	9.6	6.9
February	33.9	21.8	61	0.0	0	9.3	3.9
March	35.7	24.0	60	0.0	0	9.6	4.0
April	35.2	24.5	67	8.2	1	9.4	3.3
May	34.4	24.5	72	63.0	4	6.7	3.3

STUDIES ON SOME COMPETING FACTORS IN THE INTERCROPPING SYSTEMS OF RUBBER (*Hevea brasiliensis* Muell. Arg.)

By

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ABSTRACT OF THE THESIS

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ABSTRACT

Field experiments were conducted at the Kerala Agricultural University during 1994-97 to study the extent of involvement of root level competition and competition for light in the early years of growth of rubber. Rooting pattern of rubber was studied employing ^{32}P soil injection technique. Activity was applied at varying lateral distances of 50, 100, 150, 200 and 250 cm from the plant and varying depths of 10, 25, 50, 75 and 100 cm. This experiment was laid out in randomised block design and was replicated thrice. In another experiment, rubber was intercropped with banana cv. Poovan under two systems of planting. The extent of root competition was evaluated using ^{32}P soil injection technique. Both rubber as well as banana were treated with the radio label ^{32}P. It was applied in four circles of varying radii of 25, 50, 100 and 150 cm around the plant. Along each circle, nine equidistant holes were made and required activity was applied in alternate holes at depths of 25, 50 and 75 cm. This experiment was laid out in CRD. In a third field experiment, the intensity of light infiltration through rubber canopies of varying ages was studied. For this, fields with one to seven-year-old rubber were selected and in each age group the extent of filtered light was measured. These were related with the biological parameters of rubber plant viz., girth, height and canopy diameter. The most important findings of the investigation are abstracted below.

Uptake of soil applied ^{32}P by one-year-old rubber is maximum when the radio chemical was applied in a lateral distance of 50 cm and depth of 25 cm. The interaction between lateral distance and depth of application of ^{32}P was significant. The extent of root activity in one-year-old rubber was confined to a lateral distance of 50 cm and a vertical distance of 25 cm was over 90 per cent.

In two-year-old rubber, uptake of soil applied ^{32}P was significant with respect to lateral distance and the highest activity was noticed at 50 cm followed by 100 cm distance. The effect of depth of application was also significant and 50 cm depth recorded maximum recovery of the radio label. The interaction effect was also significant. Regarding the root activity pattern of two-year-old rubber, about 80 per cent activity was confined to a zone of 100 cm lateral distance and 50 cm depth.

During the third year, maximum recovery of soil applied ^{32}P was obtained from a lateral distance of 50 cm followed by 100 and 150 cm. Uptake of activity was found to be independent of the depth of application. More than 90 per cent of root activity was concentrated to a lateral distance of 150 cm from the plant.

Uptake of ^{32}P by both rubber and banana was higher when these crops were grown alone during the first year of planting. Among the intercropped situations,there was more of sharing of applied activity during first year in the case of the double row system of intercropping banana.

Root activity of rubber was reduced to approximately one third by intercropping with a single row of banana and this was further reduced in the double row system.

Uptake of ^{32}P by two-year-old rubber was higher when intercropped with single row banana than double row.

In the second year also, percentage root activity was more for sole rubber and banana as compared to their mixed stand. The root activity of rubber was reduced to approximately 24 and 16 per cent in rubber mixed with single and double row banana, respectively.

In the third year also, sole crops of rubber and banana registered higher uptake rate of radioactivity compared to the intercropped situations.

Radio uptake by three-year-old rubber plants under intercropped situation was higher in the single row system of planting banana. Root activity was reduced to 27 and 17 per cent under single row and double row systems of intercropping banana, respectively.

Absorption of ^{32}P by banana when intercropped with three-year-old rubber was higher in the single row system than in the double row system of banana. The percentage values were 27 and 8 per cent, respectively.

Uptake of activity by banana was maintained at much higher levels during the three years of intercropping under single row system (60 to 27 per cent). But in the double row system the activity was drastically reduced with age.

The degree of root competition between rubber and banana was minimum when rubber was intercropped with single row of banana during the initial three years of planting rubber.

The growth of rubber tree is closely associated with the steady increase in all the growth parameters during the immature phase.

Progressive development of rubber canopy proportionately reduced the light infiltration from 97 per cent at the close of first year to a meagre 7 per cent at the end of the seventh year.

All the growth parameters observed were significantly related among themselves and had a negative correlation with the percentage of light infiltration.

Reasonably accurate prediction on available infiltered light is possible using the equation $y = ab^x$, if only any one parameter of growth observed is known.

It is concluded that the active roots of rubber are concentrated in radial distances of 50, 100 and 150 cm from the plant during the first, second and third years of growth respectively. Majority of roots are found below soil surface to a range of 20-30 cm during the initial three years. Based on these, it can be tentatively recommended that fertilisers for rubber may preferably be placed in basins of proportionate radius and at a depth of 20-30 cm during the first, second and third years respectively. Banana can be grown in the inter row spaces of rubber as a rainfed crop during the initial three years. Insufficiency of filtered light through the rubber canopy will limit the scope for intercropping beyond the third year of growth of rubber.