ROOT ACTIVITY IN PINEAPPLE

(*Ananas comosus* (L.) Merr.)

By

DEEPA RAJ M. L.

THESIS

Submitted in partial fulfilment of the requirement for the degree of

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Department of Pomology and Floriculture

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DECLARATION

I hereby declare that the thesis entitled "**Root activity in pineapple [*Ananas comosus* (L.) Merr.]**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that the thesis entitled "**Root activity in pineapple (*Ananas comosus* (L.) Merr.)**" is a record of research work done independently by Ms. Deepa Raj M. L. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to her.

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Deepa Raj

Deepa Raj M.L.

Affectionately Dedicated

to

My Loving

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Introduction

INTRODUCTION

Pineapple [*Ananas comosus* (L.) Merr.] belonging to the family Bromeliaceae is a choice fruit of India. The unique fruit qualities and high productivity under marginal condition makes pineapple a commercially important fruit crop. It is having great demand both in fresh and processed forms in the international market. In India pineapple is mainly grown in the states of Assam, Kerala, West Bengal, Tripura, Meghalaya, Bihar and Karnataka because of the congenial humid tropical climate.

In Kerala this fruit crop occupies an area of 10692 ha with a production of 84599 tonnes (FIB, 2002). Suitable climate, product diversification and new avenues of marketing make pineapple cultivation in Kerala a profitable entrepreneurship. The two important varieties recommended for large scale commercial cultivation in Kerala are Kew and Mauritius. Of late the variety Mauritius has gained more importance in Kerala owing to its better keeping quality, short duration, better taste and flavour as compared to Kew.

Pineapple is planted in trenches, in beds and on flat land, depending upon the suitability of land, variety and desired number of crop cycles. Trench planting is recommended for Kew pineapple, whereas, surface planting is recommended for Mauritius by Kerala Agricultural University (KAU, 2002). The system of planting also decides the planting density and growth. Optimization of plant density by adopting suitable system of planting and spacing is necessary to achieve high production and productivity. Under well designed plant orientation by optimizing population, high yield and acceptable size and quality of fruits is achieved (Chadha *et al.*, 1977). The plant population followed by farmers is very low as compared to the recommendations of the Kerala Agricultural University (KAU, 2002).

For optimum plant population to be maintained a thorough knowledge of the root activity and root level interactions with reference to nutrient and water uptake is essential. Studies related to these aspects are lacking in pineapple.

A knowledge of the spread of active roots in the soil is useful in determining the exact site and time of fertilizer application for the effective and economic utilization of the nutrients. It is also important in understanding the extent of soil space explored by component species in poly culture in view of the competitive or complementary root level interactions. Despite the importance of the root system, studies on it have been very few and scattered, primarily because of the difficulties encountered in examining the roots in their natural environment.

Considerable amount of variations have also been observed in the rooting pattern of same variety as well as that of different varieties of the same crop under different systems of planting and planting densities. Hence it is necessary to study the variations in rooting pattern in the two cultivated varieties of pineapple with respect to method of planting as well as spacing. This in turn will help in modifying the cultural practices like method and location of fertilizer application, irrigation as well as optimum spacing, for high yield and productivity. Keeping in view of the above factors, the present study on the rooting pattern of pineapple was undertaken with the following objectives.

- To study the active root zone of two varieties of pineapple under different methods of planting by employing ^{32}P soil injection technique.
- To study the uptake as well as sharing of radio active phosphorus by two varieties of pineapple under different systems of planting.

Review of Literature

2. REVIEW OF LITERATURE

The knowledge of root system is of utmost importance for the proper and scientific management of a fruit crop. Root activity patterns have been studied in detail in a number of perennial crops like apple, citrus, banana, mango, coconut, rubber etc. However, informations on the above aspects are scanty in pineapple. The literature available on the root distribution pattern of important fruit crops and plantation crops are reviewed and presented in this chapter under the following headings.

- Root system studies
- Root distribution pattern of crops
- Use of radioisotopes in root activity studies
- Root activity pattern of crops
- Root activity as influenced by variety
- Root activity as influenced by planting density
- Root activity as influenced by method of planting
- Root competition

2.1 Root system studies

The interest in root studies in crop plants was started early in eighteenth century as reported by Bohm (1979). Sachs was the first who used this technique.

A scientific excavation technique to study the root system of crop plants was developed by Weaver (1926). The acceptance of the traditional profile wall method came when Oskamp and Batjer (1932) made intensive root studies on orchard trees by this method. Later the discovery of 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. One of the most common root study methods, which combined pictorial presentation with quantitative determination of the root system of the plants, is the needle board method (Schuurmann and Goedewagen, 1971). Subsequently modern techniques involving root cellars and underground root chamber (rhizotrones) were developed (Karnok and Kucharski, 1982). This facilitated more reliable and easy methods for studying root system.

2.1.1 Root distri n of important fruits and plantation crops

he direct methods of investigating root systems include excavation, needle board method, monolith method, profile wall method etc. They provide substantial information on root surface area, root biomass, length and thickness of roots, root volume, extent of vertical and lateral spread etc. depending on the way the experiment is designed. Despite the cumbersome and often time consuming nature of the methods, root systems of several fruit trees and plantation crops have been studied.

2.1.1.1 Fruit crops

Apple

Earlier studies made in apple by Oskamp (1932) and Sweet (1933) showed a rooting depth of 2.5 m for a matured 'Baldwin' apple in a well drained soil. Examination of a 26 year old tree of Jonathan apple in a sandy soil by Tamasi (1959) showed that the roots occupied an area of 134 square metre while the crown occupied an area of 44 square metre, thus 69 per cent of the roots occupying under the crown spread. Pasinova (1960) reported that in 14 to 40 year old apple trees about 30-60 per cent of the roots are within a depth of 20-40 cm.

According to Doll (1961) the roots of a 1 year old apple tree showed a horizontal and vertical spread of 75 cm while four year old tree showed 3.35 m vertical spread and 4.82 m lateral spread. Studies of Babuk (1971) indicated that most of the roots of older apple trees were present in 80-100 cm soil layer. Pavan (1995) found that the greatest root density was in the 10-20 cm soil layer.

Banana

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 (Fawcett, 1913). He also found the minimum penetration to a depth of 140 cm. A horizontal root growth of 3.0 to 3.6 m was noted by Swarbrick (1964). Godefroy (1969) stated that banana roots penetrated to a depth of 80-100 cm when grown in alluvial soils. The banana plant mainly utilizes nutrients from a very limited soil depth due to shallow root system as generalized by Bose (1985). According to Araya *et al.* (1998) root weight of banana cv. 'Valery' was found highest in the top 15 cm of soil. More than 65 per cent of the total root weight was found in the upper 30 cm of soil.

Citrus

Studies in Sicily on the roots of sour orange by Baldini (1957) revealed that most of the roots were confined between 10 and 20 cm laterally and at a depth of 40 to 70 cm. Cahoon *et al.* (1961) concluded that 0 to 10 cm depth of the soil contained majority of the roots and irrigation had a pronounced effect on the percentage of roots in each soil depth. Aiyappa and Srivastava (1965) observed that the highest concentration of all kinds of roots including thick roots was at 0-15 cm radial distance in Coorg mandarin, but the fibrous roots were more beyond 90 cm. It was also found that the root system extend 10.2 cm vertically and 160 cm horizontally in a one and a half year old Coorg mandarin. Roots of 2 ½ year old seedling mandarin plants grew vertically to about 224 cm and laterally to about 351 cm in healthy trees to 191 and 269 cm in less chlorotic trees and to 199 and 179 cm respectively in severely chlorotic trees (Aiyappa and Srivastava, 1968). The heaviest concentration of feeder roots in a three and a half year old mandarin was found in the top 60 cm soil column (Aiyappa *et al.*, 1968).

A study on eight year old Gandhraj lemon by Ghosh and Chatopadyay (1972) revealed that majority of the roots (78%) were confined in the top 25 cm soil. Excavations of 15 year old sweet orange trees in deep plain lands revealed it to be a surface feeder with about 66 per cent of the total roots concentrated in the surface soil upto 25 cm depth at a radial distance of 50-100 cm (Ghosh, 1974). Chandra and Singh (1979) reported that in six year old eureka lemon the highest root density zone was found to be at 0-60 cm radial distance to a depth of 0-20 cm. Chandra and Yamdagni (1983) concluded that 0-60 cm radial distance and 0-25 cm depth constituted majority of the roots of 12 year old pearl tanjelo during summer and post rainy season. In a study on root distribution of 'Cleopatra' mandarin with 'Pera' sweet orange scion (Oliveira *et al.*, 1998), the effective rooting depth and the effective rooting distance was found to be 0.6 m and 1.65 m respectively.

Grapes

Root excavation studies of 'Concord' vine by Doll (1958) on a terraced vineyard in Iowa showed that in fertile soil, the vines had a maximum root extension of 6.6 m with vertical spread of 5.9 m as against its lateral and vertical spread of 7.25 and 2.85 m respectively in a less fertile soil. Studies conducted by Chelam (1974) at the Agricultural College, Coimbatore on the root system of eleven year old grape vine. varieties Anab-e-Shahi, Kali Saheb, Pachadraksha, Bangalore Blue, Muscat and Humberg indicated that many of the growing roots were confined to a depth of 90 cm of which a greater part being in the 20-40 cm depth. Richards (1983) observed that while most of the roots of grapes occurred in the top 100 cm of the soil, the absorptive lateral roots were concentrated between 10-60 cm depth. Sawaf *et al.* (1985) shown that in Vinifera grapes on heavy soils under rainfed conditions, fibrous roots grew upto a depth of 1.5 m whereas, in shallow sandy soils under irrigation majority of the fibrous roots were found within a depth of 50 cm. In six year old Thompson seedless variety of grape the maximum root density was found at 0-50 cm radial distance and 15 cm soil depth (Prakash *et al.*, 1989).

Guava

Ghosh (1974) found that 48 per cent of the total roots were concentrated in the surface soil upto 25 cm depth. According to Purohit and Mukherjee (1974) feeder root density was much higher during rainy season as compared to summer season at a lateral distance of 120 cm and upto a depth of 15-30 cm during summer and 0-15 cm during rainy season. Bhutani *et al.* (1976) observed that tree growth and root development of Allahabad safeda were not affected by calcium carbonate layers and the intensity of roots at 60 cm depth was one and a half times more than that at 90 cm. Depth.

Mango

Singh (1960) reported that mango tree possess a very long tap root system, which continues to elongate till it reaches the water table and by that time few anchoring branches also develop. He also opined that the effective root system of an 18 year old mango tree grew to a depth of 1.2 m with lateral spread of 1.6 m. Root excavation studies by Ghosh (1974) showed that 44 per cent of the total roots of mango are concentrated in the surface soil upto 25 cm depth and to a lateral distance of 50 cm from the trunk. The feeder root distribution of mango was studied by Bojappa and Singh (1975) by soil auger sampling. They found the highest concentration of feeder roots in the zone close to the tree (60 cm) at the top 15 cm layer of soil. About 80-90 per cent of the feeder roots were within the peripheral 180 cm.

Pineapple

Collins (1960) reported that in pineapple variety 'Cayenne' the roots originating from the basal portion of stem eventually reach the soil within a radius of 30 cm. According to Inforzato et al. (1968), the roots of 12 month old pineapple grow to a depth of 1.3 m and 95 per cent of the roots were confined to the top 20 cm of soil. Purseglove (1975) reported that in pineapple there are two types of roots called axillary roots, which do not enter soil, and remains tightly wound around the stem at the leaf axils and are often flattened and the soil roots, growing from the underground portion of the stem. Samson (1980) opined that the roots of pineapple do not grow deeper than 50 cm. They rarely extend below 30 cm depth but the lateral spread may extend beyond the drip area of the plant. Chadha *et al* (1998) reported that the root system of pineapple is adventitious, dense and shallow and is concentrated mainly in the upper 15 cm of soil, and rarely extends to a depth of 30 cm.

2.1.1.2 Plantation crops

Arecanut

Bavappa and Murthy (1961) reported that the roots of areca palms radiate from all sides of the bole and most of them reside very close to the palms within 30-60 cm radius. Bhat and Leela (1969) observed that about 61-67 per cent of the roots of arecanut palm were found within a radius of 50 cm and few roots extended beyond 100 cm. They also found that 66-79 per cent of the roots met within a depth of 50 cm of the surface. According to Mohapatra *et al.* (1971) a four year old a palm had 96 per cent of its roots spread in a zone of 50 cm radius around the Bhat (1978) found that the areca roots penetrated to a depth of 2.6 m. Khader (1993) reviewed the root distribution of arecanut palm and reported that about cent of roots were found within a radius of 100 cm from the trunk and penet a depth of 2.6 m.

Cashew

Tsakiris and Northwood (1967) stu... ... ...

cashew trees growing on soils of loamy to sandy loam texture and found root of a three and a half year old tree extended to a depth of over 3.2 diameter of 8.8 cm at a soil depth of 46 cm. Khader (1986) observ seedling raised cashew tree, over 67 per cent of the thick roots and 26 p fine roots were confined to a radius of 50 cm from the base of the tree. year old cashew trees in a plantation at Thrissur showed that in a *shallc* cashews develop an extensive root system with the majority (89.3% within 300 cm of the plant laterally and within the top 100 cm of *soil* 1995).

Cocoa

The studies conducted by McCreary *et al*(1943) showed tree had an extensive spread of lateral roots, majority them lying in cm layer. The taproot grew to 50-120 cm length

Patarava (1968) reported that greatest co*ration* of feec at a depth of 10-30 cm and minimum roots in th-60 cm layer excavation studies by Bhat (1983) indicated verticaltration of roo m and a lateral extension to 1.75 m. He opined ter 67 per cer were seen in the 0-50 cm soil layer both horizontd *vertically*. W (1993) reviewed the root distribution pattern of and reported t surface feeder with majority of the roots lying in ace layer upto

Coconut

Root studies carried out at Veppankulam showed that a great majority of the roots were confined to the 16-60 cm layer of soil and that the number of roots produced by the palm increased with the increase in level of fertilizers applied (Anon, 1970).

Kushwah *et al.* (1973) from their studies on rooting pattern of coconut observed that the palms receiving regular cultivation and manuring produced the highest number of roots. They found that over 82 per cent of the roots resided in 31 to 120 cm soil depth and only 8.7 per cent of the roots went below 120 cm. About 74 per cent of the roots produced did not have lateral spread beyond two meter from the trunk. Jalil (1982) observed that upper most 50 cm soil layer constitute the highest root density in coastal clay soils of Malaysia. Louis and Balasubramanian (1983) found that as much as 60 per cent of the roots of eight year old palm lay in the 31-60 cm soil depth and only three per cent of the roots could be found in the top 15 cm layer. In an alluvial soil of northern Venezuela, the coconut roots were found to concentrate in the top 30 cm soil layer within an area of 1.5 m radius (Avilan *et al.*, 1984). According to Pomier and Bonneau (1987), under non-limiting conditions, the roots of coconut can reach a depth of four meter although about 50 per cent of the roots are found in the surface 0-50 cm soil layer. Studies on the root system distribution of dwarf coconuts by Cintra *et al.* (1992) shown that the greatest concentration of roots lies at a depth of 0.2-0.6 m. It was discovered that around 70 per cent of total roots and 65 per cent of the fine roots were found within one meter radius around the stem and 90 per cent of total roots within a radius of 1.5 m around the stem. Maheswarappa *et al.* (2000) reported that in coconut the effective root zone for agronomic management is within one meter radius of the trunk for six year old palms compared with a two meter radius for 26 year old palms.

Oil palm

Ruer (1967) reported that in adult palms, the total quantity of absorbing roots in surrounding circles increases at least to a radius of 3.5-4.5 m. The greatest quantity of roots is in the top 15-30 cm of soil. Nair (1993) reviewed the root distribution pattern of oil palm and reported that majority of the active root system lies at 5-35 cm depth. The total quantity of absorbing roots extends a radial distance of 3.5-4.5 m. The highest root activity is at the surface within 100 cm lateral distance from the palm. Beyond 300 cm there is a decrease in root activity.

Rubber

Soong (1976) on the evaluation of the vertical distribution of feeder roots of rubber found that the greatest root proliferation was in the topsoil and the proliferation decreased rapidly with depth. Kumar (1993) reviewed the root distribution pattern of rubber and reported that taproot was observed to be about 1.5 m and 2.4 m deep respectively, in trees of three and seven to eight year of age. The lateral roots were seen extending upto six to nine metre in the young plants and beyond 9 m in mature trees. 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 percentage of roots being in the surface soil layers, 0-10 cm and 10-20 cm in the region of 120 cm circle.

2.1.2 Use of radioisotopes in root activity studies

Many methods with radioactive isotopes have gained significance in root studies during last three decades. They have been used in recent times to determine the distribution pattern of active roots, both in terms of area around the individual trees and also its rooting depth. In contrast to the traditional methods, isotope technique is a non destructive and precise method which provide information on the underground parts more precisely, quickly and easily. The soil injection and plant injection techniques are now the common radioisotope aided methods employed in studying plant root system under field conditions. The development and activity of plant root system in natural profile was first measured with a radioactive tracer by Lott *et al.* (1950) and then by Hall *et al.* (1953). The soil injection techniques developed by Hall *et al.* (1953) employing ^{32}P radio isotope has been widely used for studying the root activity pattern of plants. Several workers like Fox and Lipps (1964) and Russel and Ellis (1968) have suggested that root distribution and root activity in different soil depths can be accurately and easily assessed by studying the uptake of radioisotopes placed at specified depths in the soil.

The ^{32}P plant injection technique for studying the root distribution of cereal roots was first described by Racz *et al.* (1964) and subsequently modified and improved by Rennie and Halstead (1965).

The most commonly used radioisotope in root activity studies is ^{32}P. Occasionally, ^{86}Rb and ^{33}P were also used (Saizdel Rio *et al.*, 1961; IAEA, 1975). ^{32}P is a high energy pure beta emitter with a half-life of 14.3 days. It is mostly preferred because of its safe handling characteristics, low price and relatively shorter half-life. It is relatively immobile in the soil to ensure its absorption by the plant from the point of its placement in the soil, at the same time mobile in the plant system to ensure rapid translocation in the plant. Root activity studies using radioisotope have been studied in a number of fruit crops and plantation crops.

2.1.2.1 Fruit crops

Apple

Atkinson (1974) observed that in a two year old apple tree the absorption of ^{32}P from 30 cm depth was greatest and in a 25 year old apple cultivar absorption was greatest from 90 cm.

Banana

Walmsly and Twyford (1968) studied the uptake of nutrients by 'Robusta' banana plant at two stages of growth and found that the active zone of nutrient uptake by two month and five month old plants were within a radius of 1.5-2.4 m respectively. It was also found that the feeding roots did not extend for more than a circle of 2.4 m radius in both heavy and light soils. Root activity studies in a two year old banana variety 'Naketengu' in dry and wet seasons at Makerere University in Uganda using ^{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 at 15 cm and 30 cm depths and sharply at 60 cm depth during the wet season. In the dry season, the highest root activity was noticed at a distance of 40 cm and 80 cm away from the plant. Moreover the roots were also found to be very active at 120 cm and 160 cm distances at depths of 30 and 15 cm respectively. Mohan and Rao (1985) recorded highest root activity within a radius of 30 cm in two month old plants. Sobhana *et al*

(1989) using ^{32}P showed that nendran banana has a shallow root system with most of the active roots seen at a depth of 30 cm, 20 cm away from the plant under rainfed condition. Maximum root activity under irrigated condition was observed at 30 cm depth and 20 cm lateral distance. In a crop geometry study conducted by Ashokan (1986), it was seen that in the cultivar Palayankodan (AAB), the active roots were distributed upto a radial distance of 30-35 cm and to a depth of 25-30 cm at the peak vegetative phase.

Citrus

Tripathi and Dutta (1967) found that in ten year old grape fruit trees at Saharanpur, active roots were maximum at 25 cm depth and 1.2 m radial distance from the trunk. The experiments carried out in orange trees grown under sandy loam soils in Spain using ^{32}P soil injection technique revealed that the root activity was highest at 30 cm depth and at 300 cm distance in the 30 year old trees and at 30 cm depth and 100 cm lateral distance in younger trees (IAEA, 1975). Feeding activity was confined mainly to the upper soil layer upto 30 cm or at the most 60 cm depth beyond which root activity was negligibly small. In an experiment on eight year old citrus trees in Tainean, highest root activity was observed at a distance of one meter and at a depth of 10 cm (IAEA, 1975). Chandra *et al.* (1979) observed that in six year old Eureka lemon, the maximum root activity was found at 60 cm radial distance and 20 cm depth. In Kagzi lime, the root activity was determined at IIHR, Bangalore by ^{32}P soil injection technique. It was found that about 75-80 per cent of the total root activity was confined to a radial distance of 120 cm. About 80-95 per cent of the feeder roots were located in the surface 10 cm soil layer (Iyengar and Murthy, 1987). Spatial distribution of root activity in Coorg Mandarin on a red sandy clay loam soil was studied using ^{32}P soil injection technique. In six year old tree, 78-88 per cent of the roots were located within the top 15 cm of soil. As much as 80-95 per cent of the activity confined to a radial distance of 120 cm (Iyengar *et al.*, 1988). Iyengar and Murthy (1989) reported greater absorption of fertilizer P from placement at 105 to 135 cm distance in 80 year old Coorg mandarin trees. Application during rainy season resulted in better absorption than during summer.

Dhander and Singh (1989) observed that the root activity of 20 year old grape fruit tree was highest at 120 cm radial distance and 20 cm depth followed by at 200 cm distance and 20 cm depth. Top 20 cm layer contributed 47-49 per cent of root activity and the remaining was distributed in the subsoil layers up to 60 cm depth. Iyengar and Shivananda (1990) reported that the 'Mosami' sweet orange budded on Rangpur lime is a surface feeder with 70-90 per cent of it's active roots located in the top 30 cm soil layer and 65-85 per cent root activity within a horizontal distance of 120 cm. Acid lime on Karna Khatta rootstock showed maximum root activity within 40 cm radius of the plant base (Kurian *et al.*, 1991). Most of the active roots (75-80%) were observed at 80 cm distance from the plant and to a depth of 16-24 cm. According to Kurian *et al.* (1992) Kinnow mandarin grafted on Karna Khatta rootstock showed active root spread up to 120 cm radially and between 16 and 24 cm vertically while that on Troyer citrange rootstock showed maximum root activity within 80 cm radial distance and to a depth of 24 cm.

Grapes

Ulrich *et al.* (1947) in a study on 25 year old grape vine grown under red loam soils of California using ^{32}P found that the roots were irregularly distributed around the vine and it was estimated that 90 per cent of the roots were within a radius of 2 feet around the base. Sathi *et al.* (1984) observed that about 70 per cent of the roots of 4 year old vine feed around the vine to a lateral distance of 1.5 m and within a depth of 30 cm. Brar *et al.* (1986) reported that about 77 to 84 per cent active roots of varieties Perlette and Anab-e-Shahi in a sandy loam soil were concentrated in the top 50 cm layer at a distance of 80 cm from the main stem. Perlette had maximum (52%) feeder roots at a depth of 50 cm but Anab-e-Shahi had 56 per cent of its active roots at a depth of only 20 cm from the surface. According to Iyengar *et al.* (1989) as much as 70 per cent of the root activity was located deeper in the soil between 45 and 75 cm depths. Nearly 80 per cent of the root activity was confined to a radial distance of 100-120 cm. Prakash *et al.* (1989) found that the maximum root activity zone of 7 year old Thompson seedless variety was at 40 cm radial distance and 15 cm depth.

Guava

Work conducted in India showed that the highest concentration of absorbing roots of guava trees was situated close to the soil surface and near the trunk (Purohit and Mukherjee, 1974). Nearly 71 per cent of the root activity was found within an area of 120 cm radius around the tree. During rainy season majority of the active roots were found at a depth of 15 cm and during summer it was upto 40 cm depth. Spatial distribution of active roots in 'Arka Mridula' guava was studied by Kotur *et al.* (1998). It was found that root activity was greatest during late rainy season (September-December) due to high soil moisture content and greater shoot activity during this season.

Jack

Root distribution of wild jack tree (*Artocarpus hirsutus*) was determined by ^{32}P placement (Jamaludheen *et al.*, 1997). They opined that most of the physiologically active roots were concentrated within a radius of 75 cm and 30 cm depth, although the taproot might reach even deeper.

Mango

Bojappa and Singh (1974) in their studies using ^{32}P in mango found that in 18 year old highest absorption of ^{32}P was from the zone close to the trunk at a distance of 120 cm and at a depth of 15 cm. Absorption rate decreased with increase in soil depth. About 77 per cent of the active roots were found in the upper 60 cm soil layer. Nearly 88 per cent of root activity was concentrated within an area of 300 cm around the tree. In studies carried out at IIHR, Bangalore during 1992-1993 spatial distribution of root activity was studied using ^{32}P soil injection technique in 8 year old trees of cv. Alphonso (Kotur *et al.*, 1997). It was observed that most of the active roots (80%) were confined to a 100 cm radial distance with about 41 per cent of the roots concentrating to a depth of 20 cm during late rainy season. About 46 per cent of the roots were found to a depth of 60 cm. During summer 52 per cent of the active roots were found at 150 cm radial distance. Root activity decreased with depth (50, 31 and 19% at 20, 40 and 60 cm respectively).

Papaya

An experiment was conducted in IIHR, Bangalore to study the spatial and temporal distribution of root activity in papaya (Kotur and Murthy, 2001). They observed that the active roots grew up to 60 cm radial distance and 30 cm depth of these 75-92 per cent of roots occurred up to 40 cm distance while 54-79 per cent found down to a depth of 15 cm.

2.1.2.2 Plantation crops

Cashew

Wahid *et al.* (1989a) studied the root activity pattern of active roots of 20 years old cashew trees growing in laterite soil. The results indicated that cashew tree is a surface feeder with about 50 per cent of the root activity confining to the top 15 cm of root layer. About 72 per cent of the root activity was found within a radial distance of 2m from the tree. Bhaskar *et al.* (1995) observed highest root activity during flushing and early flowering phase, which extended from September to December.

Cocoa

Experiments conducted at the Cocoa Research Institute, Ghana indicated that the most active root zone lay within 7.5 cm surface soil layer upto a lateral distance of 1.5 m (Ahenkorah, 1975). The wet and dry season experiments conducted at Ghana revealed considerable root activity in the surface 7.5 cm soil layer with maximum activity at 2.5 cm depth (IAEA, 1975). Root activity pattern of cocoa was studied by Wahid *et al.* (1989b) and found that 85 per cent of the feeder roots were found within an area of radius 150 cm around the tree. The vertical spread of the roots indicated the maximum number of active roots at 30 cm depth.

Coconut

Studies made in Ceylon using radioisotope technique to determine the efficiency of fertilization by coconut palms showed that the efficiency is greater when placed 10 cm or lower than on surface at a lateral distance of 50 cm (Anon, 1969). The root activity was found to be more within a radius of 2 m at a depth of 10-45 cm. Radioisotope studies conducted in Philippines indicated that the zone of highest root activity lay at 15 cm depth and within one to two metre area around the tree(IAEA,1975). Balakrishnamurthy (1977) opined that the roots of coconut were most active in the surface root to a depth of 10 cm. Anilkumar and Wahid (1988) observed that in 9 year old coconut palm the major portion of root activity (83%) lies within an area of 2 m radius around the palm. The vertical distribution of active roots (84.8%) was mainly confined to a depth of 60 cm below which root activity declined sharply.

Venugopal (1997) observed that over 60 per cent of the roots explored upto 30 cm soil depth in sole and mixed coconut. About 50 per cent of the root activity was found within a radial distance of 75 cm from the tree in both systems of coconut. Arachchi (1998) opined that 76-80 per cent of the roots of adult coconut palms were localized in a depth ranging from 20-100 cm with 15-20 per cent confined to the top layer (0-20 cm) of soil.

Oil palm

Experiments conducted in Malaysia on root activity pattern of young and bearing oil palm shown that the highest root activity was in the soil surface at 3 m lateral distance from the trunk (IAEA, 1975). About 70 to 80 per cent of active roots were in 0-20 cm depth with 50-60 per cent being concentrated near the soil surface. Studies conducted in Ivory Coast during dry season also revealed highest root activity within 0-20 cm soil layer and close to the tree (IAEA, 1975). Omoti (1982) showed that the active roots of oil palm were within the top 30 cm soil layer. The root activity profile of the palm showed that 70-90 per cent of active roots were located within 15-60 cm soil layer and 50-76 per cent within the 15-30 cm soil layer.

Rubber

Root activity studies conducted in Malaysia showed that the active roots of rubber were mainly located 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 (Soong *et al.,* 1971). According to Sing *et al.* (1972) root activity was less in top soil (0-15 cm) than in the subsoil (15-30 cm). Soong (1976) in the evaluation of the vertical distribution of feeder roots found that in most soils the greatest root proliferation was in the topsoil and the proliferation decreased rapidly with depth. The maximum root development was found to be in February-March corresponding to the period of active refoliation and peak uptake of moisture and nutrients by the tree. According to Chong-Qun Liu (1984), rubber seedlings showed highest root activity in 5-15 cm soil layer. 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 from the trunk up to a depth of 10-30 cm.

2.2 Root activity as influenced by variety/genetic make up

Varietal differences in root activity have been studied in many short duration crops such as wheat (Subbiah and Oza, 1971), rice (Kamath, 1971) using ^{32}P. Research work relating to this aspect in long duration crops is very limited. Varietal differences in root activity have been reported in cocoa (IAEA, 1975). The studies conducted with four cocoa varieties namely Amazon, Amelonado, Amelonado x Amazon and Amazon x Amelonado has shown that the pattern of root activity was similar for all the genotypes with highest root activity in the upper 7.5 cm soil layer. However the hybrid Amelonado x Amazon, the highest yielder among the genotype studied, exhibited more intense root activity than the other genotypes. IAEA (1975) observed that vegetatively propagated Arabica coffee in Kenya has highest wet season activity at 82.5 cm distance and 15 cm depth, whereas seeded Cattura coffee in Colombia showed highest activity at 30 cm distance to a depth of 15 cm. According to Avilan *et al.* (1984) cultivar Tall Criollo was found to produce more roots than the cultivar Yellow dwarf. The lateral spread was also found to be longer in the tall palms than in the Dwarf palms. Mohan and Rao (1985) reported that in banana, cultivar Monthan recorded the highest root activity followed by robusta and nendran.

Root activity was studied in two commercially grown grape varieties viz., Perlette and Anab-e-shahi by Brar *et al.* (1986). It was found that Perlette had maximum active roots at a depth of 50 cm while in case of Anab-e-shahi, the maximum active roots were present at a depth of 20 cm. Perlette variety was more efficient in the absorption of ^{32}P.

Rootstock can modify the root activity pattern of a plant. Kurien *et al.* (1992) showed that Kinnow mandarin grafted on Karna Khatta rootstock showed active root spread upto 120 cm laterally and to a depth of 16-24 cm, while that on Troyer citrange rootstock showed maximum root activity to a depth of 24 cm and 80 cm away from the plant. Kurien *et al.* (1993) studied the scionic influence on root activity in Kinnow mandarin and acid lime on Karna Khatta root stock. The greatest root activity of acid lime was found within a radial distance of 80 cm and to a depth of 16-24 cm whereas in Kinnow considerable radio activity was observed at a radial distance of 120 cm. Genetic variability was not observed in root activity patterns of four cashew genotypes, namely Anakkayam-1, H-1598, H-1600 and V-5 (Bhaskar *et al.*, 1995).

2.3 Root activity as influenced by planting densiy

Plant spacing is found to have effect on the root activity of some crops. Study on the root system of arecanut seedlings by Bavappa and Mathew (1960) showed that spacing of seedlings had a marked influence on root production. Although, the effect of spacing on root growth was not much conspicuous upto 30 cm x 30 cm, wider spacings of 37.5 cm x 37.5 cm and 45 cm x 45 cm improved root production and root growth considerably. Bhat and Leela (1969) studied the root distribution pattern in relation to density of planting using eight year old arecanut palms. It was found that 60-66 per cent of total roots were concentrated within 50 cm radius of the palm and more than 80 per cent of the total roots were within 1 to 1.25 m from the trunk. Though some roots extended laterally beyond 1.75 m, close planted palms (1.8 m x 1.8 m) appeared to have greater tendency to explore the lower soil strata than those planted wider apart (3.6 m x 3.6 m). The maximum depth of penetration of roots was 2.6 m with 66.79 per cent of total roots observed within the first 50 cm layer of soil. The quantity of roots per unit volume of the soil increased with increasing plant density whereas the calculated gross quantity of roots produced per tree decreased with the increased density of planting. Rahaman and Fareed (1977) reported that in tea the vertical growth of root was restricted with an increase in plant population.

Effect of plant density on banana root system was studied by Mohan and Rao (1984). It was found that the number of roots increased with increase in plant density. Irrespective of cultivars the total root length of the large roots decreased with increase in plant density while the length of fine roots increased with increase in plant density. The longest root of the medium sized roots were observed at the closest spacing (1.55 x 1.55 m).

2.4. Root activity as influenced by planting method

The development of the root system was found to be different for surface planted and pit planted trees (Tsakiris and Northwood, 1967). Surface planting favoured the development of a better root system. The pit planted trees on the other hand tended to put forth more roots in the planting hole, fully exploiting the topsoil in it. The surface roots of such trees extended beyond the hole and were thinner. However in both the cases, the taproots were strongly developed.

2.5 Root competition in monoculture system

IAEA (1975) studied the intra specific root competition in 8-9 year old orange trees by applying ^{32}P labelled fertilizer to the root zone of a tree followed. The absorbed radioactivity was assessed through radioassay of leaf samples collected separately from the treated tree and 8 adjacent non-treated trees. It was found that the tree treated with fertilizer has taken up about 50 per cent of the total fertilizer utilized by the nine trees together. The three adjacent trees account for about 25 per cent of the total fertilizer taken up and the remaining 25per cent of the fertilizer used is in the other five border trees. An experiment was conducted at Taiwan (IAEA, 1975) in 12 year old citrus tree to determine the extent to which root systems of neighbouring trees intermingle. The study shown that about 80-90 per cent of the total fertilizer utilized by the treated tree and the two adjacent trees is taken up by the treated tree. Similar studies were conducted by the IAEA (1975) with cocoa in Ghana and observed that both the treated tree and the eight contact trees surrounding it utilized the P labelled fertilizer maximally when applied at 120 cm or 170 cm distance from the treated tree. Only 10 to 12 per cent of the total fertilizer phosphate utilized is taken up by the treated tree. All border trees seem to benefit equally from the fertilizer applied.

Experiments conducted with coffee trees in Columbia and Kenya , with coconut palms in Srilanka, and with oilpalm in Ivory coast clearly indicated that P from labelled super phosphate applied in a strip near the tree was not only taken up by the treated tree but also by the trees surrounding it.(IAEA,1975)

Materials and Methods

3. MATERIALS AND METHODS

The present investigation carried out with a view to study the root activity in pineapple was conducted in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara, Thrissur during the year 1999-2001.

The experimental field is located at 10°32' N latitude and 76°16' E longitude at an altitude of 22-25 m above mean sea level. The location enjoys a warm humid tropical climate throughout the year. The soil type is lateritic.

In the present study, attempts have been made to study the root activity and to determine the uptake of ^{32}P by pineapple root system under two different systems of planting. The studies undertaken during the course of the investigation are as follows:

- Root activity studies in pineapple
- Uptake of the radioactive phosphorus by two varieties of pineapple under different systems of planting.

Details of the materials used and methodologies adopted are discussed below.

3.1 Experimental material

Kew and Mauritius, the two commercially grown pineapple varieties of Kerala formed the materials for the study. Healthy and uniform sized suckers of the variety Kew was procured from Pineapple Research Station, Vellanikkara and that of Mauritius from Vazhakkulam, the major pineapple growing tract of Kerala.

3.2 Experiment 1: Root activity studies in pineapple

In this experiment, the main objective was to determine the active root zone of pineapple.

3.2.1 Design and layout

The experiment was laid out in split plot design with three replications. Single plants were considered as experimental units. The layout plan is shown in Fig. 1. and a general view of the experimental plot is given in Plate 1.

3.2.2. Details of treatments

The treatments consisted of two varieties and two methods of planting in the main plot and sixteen combinations of ^{32}P placement in the sub plot.

Main plot treatments

a) Varieties

1. Kew (V_1)
2. Mauritius (V_2)

b) Method of planting

1. Surface method (M_1)
2. Trench method (M_2)

Main plot treatment combinations: 2 x 2 = 4

Sub plot treatments (Placement of ^{32}p)

a) Lateral distance (L)

1. 15 cm (L_1)
2. 30 cm (L_2)
3. 45 cm (L_3)
4. 60 cm (L_4)

b) Depth (D)

1. 15 cm (D_1)
2. 30 cm (D_2)
3. 45 cm (D_3)
4. 60 cm (D_4)

Sub plot treatment combinations: 4 x 4 = 16

Fig. 1. Lay out plan of Experiment I

BLOCK 1

Plot				
V_1M_2	L_2D_3	L_4D_3	L_3D_3	L_4D_1
	L_3D_1	L_1D_3	L_1D_4	L_3D_4
	L_1D_2	L_4D_4	L_4D_2	L_1D_1
	L_2D_4	L_4D_2	L_3D_2	L_2D_1
V_1M_1	L_3D_1	L_3D_4	L_1D_2	L_1D_3
	L_4D_1	L_2D_1	L_4D_3	L_1D_1
	L_4D_4	L_3D_2	L_2D_2	L_4D_2
	L_2D_4	L_1D_4	L_2D_3	L_3D_3
V_2M_2	L_1D_3	L_2D_2	L_4D_2	L_4D_1
	L_4D_3	L_3D_4	L_3D_3	L_2D_3
	L_4D_4	L_1D_2	L_1D_4	L_2D_1
	L_2D_4	L_3D_2	L_1D_1	L_3D_1
V_2M_1	L_1D_4	L_1D_1	L_3D_4	L_3D_2
	L_2D_4	L_4D_3	L_3D_3	L_1D_3
	L_4D_2	L_4D_4	L_4D_1	L_1D_2
	L_2D_2	L_2D_1	L_2D_3	L_3D_1

BLOCK 2

Plot				
V_2M_2	L_1D_2	L_4D_3	L_2D_4	L_3D_3
	L_3D_4	L_1D_4	L_2D_1	L_2D_3
	L_4D_2	L_1D_1	L_4D_4	L_1D_3
	L_3D_1	L_4D_1	L_2D_2	L_3D_2
V_2M_1	L_2D_2	L_4D_3	L_2D_1	L_1D_1
	L_1D_4	L_2D_3	L_4D_2	L_3D_3
	L_1D_3	L_2D_4	L_3D_1	L_3D_2
	L_4D_4	L_1D_2	L_4D_1	L_3D_4
V_1M_2	L_3D_4	L_1D_1	L_3D_3	L_1D_2
	L_2D_2	L_3D_2	L_4D_4	L_1D_4
	L_4D_3	L_1D_3	L_3D_1	L_2D_1
	L_2D_4	L_4D_1	L_2D_3	L_4D_2
V_1M_1	L_2D_3	L_3D_3	L_4D_4	L_2D_1
	L_4D_2	L_3D_2	L_1D_4	L_2D_4
	L_3D_1	L_4D_3	L_1D_1	L_2D_2
	L_1D_2	L_4D_1	L_3D_4	L_1D_3

BLOCK 3

				Plot
L_2D_4	L_4D_4	L_2D_1	L_2D_3	V_1M_2
L_3D_3	L_1D_1	L_4D_3	L_3D_4	
L_1D_2	L_4D_1	L_3D_2	L_1D_3	
L_1D_4	L_3D_1	L_4D_2	L_2D_2	
L_1D_1	L_4D_1	L_3D_4	L_2D_2	V_1M_1
L_2D_3	L_3D_3	L_4D_2	L_3D_1	
L_2D_4	L_4D_3	L_1D_2	L_1D_3	
L_1D_4	L_3D_2	L_4D_4	L_2D_1	
L_1D_2	L_4D_3	L_1D_4	L_3D_3	V_2M_2
L_3D_4	L_2D_1	L_4D_2	L_1D_1	
L_4D_1	L_2D_2	L_2D_3	L_1D_3	
L_3D_1	L_4D_4	L_2D_4	L_3D_2	
L_1D_4	L_4D_4	L_1D_2	L_3D_3	V_2M_1
L_2D_2	L_2D_1	L_4D_2	L_1D_3	
L_3D_2	L_4D_1	L_2D_3	L_1D_1	
L_2D_4	L_3D_4	L_4D_3	L_3D_1	

V_1 - Kew
V_2 - Mauritius

M_1 - Surface
M_2 - Trench

L_1 - 15 cm
L_2 - 30 cm
L_3 - 45 cm
L_4 - 60 cm

D_1 - 15 cm
D_2 - 30 cm
D_3 - 45 cm
D_4 - 60 cm

Plate 1. A general view of the experimental plot

The procedure followed for the allocation of various treatments to different plots was in accordance with random number table.

3.2.3 Land preparation and planting

The land was cleared, ploughed and levelled. Trenches of depth 15 cm, length 5 m and width 90 cm were prepared, aligned at a distance of 150 cm from centre to centre. Suckers of Kew and Mauritius were planted on surface (Plate.2.) and in trenches (Plate.3.) and also on surface in single rows. A wider spacing of 1.5 m x 1.5 m was given between plants to allow the growth of roots.

3.2.4 Cultural and management practices

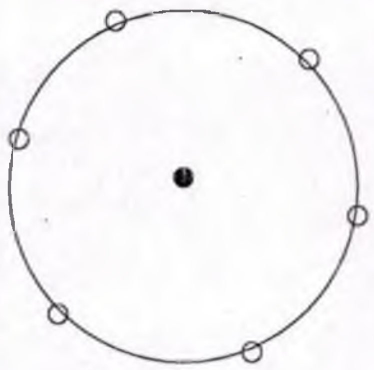
The cultural and management operations were done according to the Package of Practices Recommendations of the Kerala Agricultural University (KAU, 1996).

3.2.5 Mode of ^{32}P application

The soil injection of ^{32}P around the plants was given six months after planting at the peak vegetative stage. The area around the experimental plants was cleared off weeds. Six equidistant holes were dug around each plant in a circle according to the treatments mentioned above. The holes were then plugged by inserting suitable PVC tubes of slightly longer length, so that about 10 cm portion of the tube is above the ground level. This is illustrated in Fig.2 and Plate 4. The open end of the tube was covered with plastic cover to prevent filling up in the event of rain.

Injection of the desired volume of ^{32}P into the soil was done with a field dispenser fabricated exclusively for soil injection of ^{32}P (Wahid *et al.*, 1988). At the time of ^{32}P application, the plastic caps were removed from the tubes and 3 ml of the radioactive solution prepared in a carrier solution of 1000 ppm P as potassium dihydrogen orthophosphate was applied into each tube. The total activity applied per plant was 0.5 mCi (18.5 MBq), which necessitated a total of 96 mCi for 192 plants. The inclusion of carrier in the radioactive solution was to minimise the fixation of ^{32}P by soil through isotopic exchange (IAEA, 1975). The method of application

Fig. 2. Method of ^{32}P application in Experiment I



● Treated plant

○ Soil holes for ^{32}P application

Plate 4. Pineapple plant showing sites of application of ^{32}P along with PVC tubes and the soil injection device

Plate 5. Method of ^{32}P application in Experiment I

followed is shown in Plate 5. After application, the radioactivity remaining on the inner side of the tube was washed down with a jet of about 20 ml water.

3.2.6 Leaf sampling

The leaves were sampled from the treated plants. The 'D' leaf, which is the fourth leaf from the top, was taken for analysis (Rao *et al.*, 1977). The first sampling was done fifteen days after the application of ^{32}P and the subsequent samples were taken at 15 days interval for a period of 45 days.

3.2.7 Radio assay

The leaf samples collected were dried in hot air oven at 70-80°C. One gram of the finely powdered samples was digested in diacid mixture containing nitric acid and perchloric acid in 2:1 ratio. The digest was then transferred to a scintillation counting vial with distilled water upto a volume of 20 ml. They were then radio assayed by Cerenkov counting technique (Wahid *et al.*, 1985) in a liquid scintillation system. The count rates were corrected for decay to a common reference time after background correction. The percentage of active roots at different zones was also calculated.

$$\%\text{ of active roots at particular zone} = \frac{^{32}\text{P recovery from that zone}}{\text{Total }^{32}\text{P recovered from all the zones}} \times 100$$

3.2.8 Root excavation studies

Healthy plants from four main plot treatments were used for taking root observation. The whole plant was uprooted at vegetative stage without disturbing the root system. After digging out the plant the leaf portion was removed leaving a small portion of it on the stem. It was then washed in running water without injuring the roots. After removing all the soil particles and dirt adhering to it, observations were made on number, length and diameter of roots. The fresh and dry weights of the roots were also recorded.

3.3 Experiment II: Uptake of radio phosphorus by two varieties of pineapple under different systems of planting

The second experiment was carried out with a view to evaluate the root level competition of pineapple by studying the uptake of ^{32}P under two different systems of planting.

3.3.1 Design and layout

The experimental design was Factorial Randomised Block Design with eight treatments and three replications. The layout plan of the experiment is given in Fig.3 and a general view of the experimental plot is given in Plate.6.

3.3.2 Details of treatments

The details of treatments are given below.

Varieties	: 2 (Kew and Mauritius)
Planting density	: 2 (High density and low density)
Method of planting	: 2 (Surface planting and Trench planting)
Total number of treatments	: 2 x 2 x 2 = 8
Depth of ^{32}P application	: 15 cm and 30cm
Lateral distance	:15 cm and 30 cm

Treatment details

$V_1P_1M_1$ - Kew variety + High density planting + Surface method

$V_1P_2M_1$ - Kew variety + Low density planting + Surface method

$V_1P_1M_2$ - Kew variety + High density planting + Trench method

$V_1P_2M_2$ - Kew variety + Low density planting + Trench method

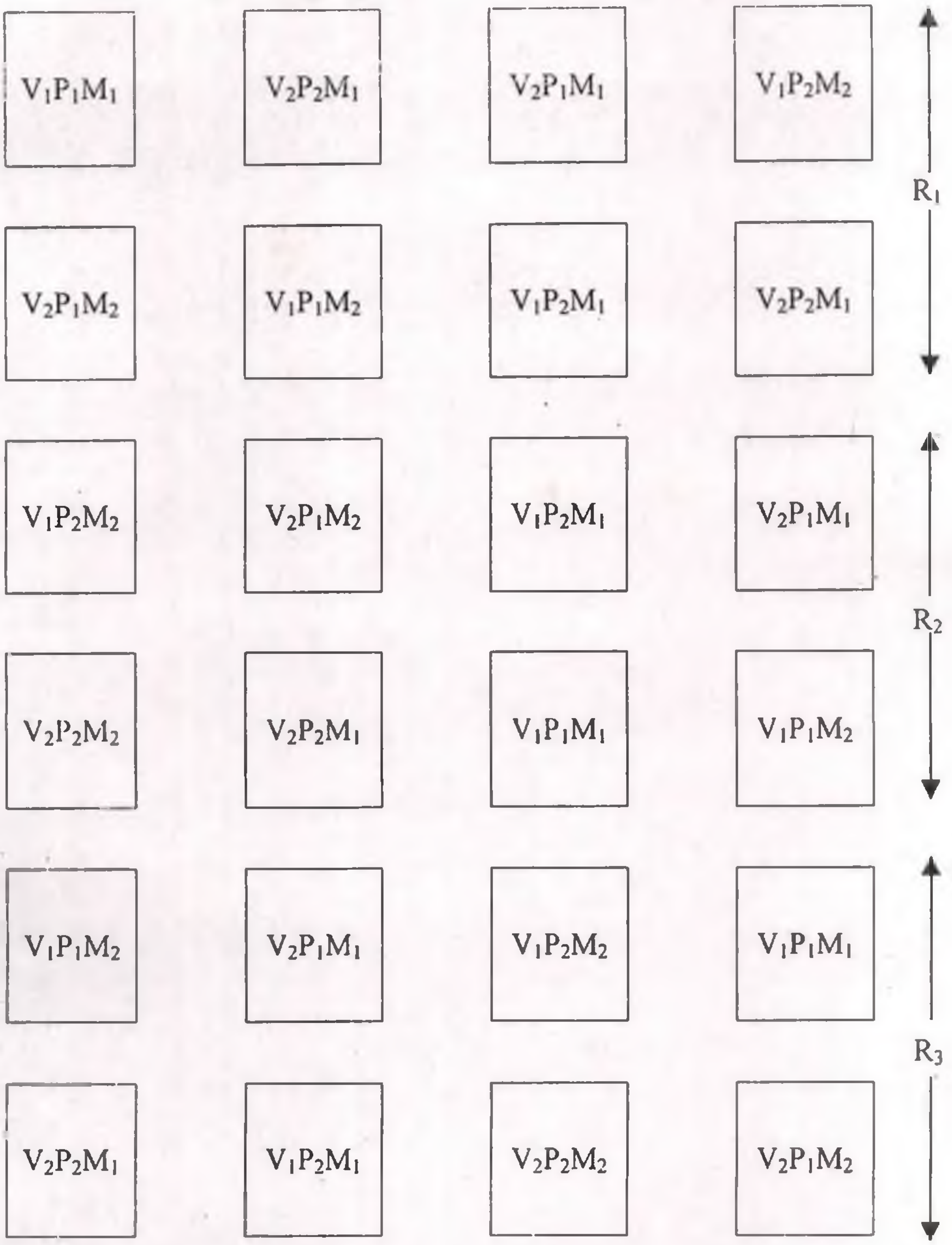
$V_2P_1M_1$ - Mauritius variety + High density planting + Surface method

$V_2P_2M_1$ - Mauritius variety + Low density planting + Surface method

$V_2P_1M_2$ - Mauritius variety + High density planting + Trench method

$V_2P_2M_2$ - Mauritius variety + Low density planting + Trench method

Fig. 3. Layout plan of Experiment 2



V_1 - Kew
V_2 - Mauritius

P_1 - High density planting
P_2 - Low density planting

M_1 - Surface planting
M_2 - Trench planting

Plate 6. A general view of the field in Experiment II

3.3.3 Land preparation and planting

The land was cleared, ploughed and levelled. Uniform suckers of Kew and Mauritius were planted on surface level and in trenches High density planting as per Package of Practices Recommendation of Kerala Agricultural University (KAU, 1996) as well as low density planting as per farmer's practice (20,000 plants per ha) were the systems of planting adopted.

Trenches of width 90 cm and length 2.8 m aligned at a distance of 165 cm from centre to centre were made for high density planting. In the case of low density planting trenches of same dimensions were made at a distance of 190cm from centre to centre. Double row system of planting was adopted. There were 80 plants per treatment under high density planting which were planted at a spacing of 30 cm between plants and 70 cm between the rows. Low density planting included 60 plants per treatment and they were planted at a spacing of 45 cm between plants and 70 cm between rows.

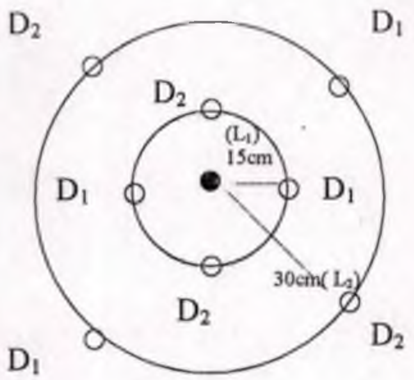
3.3.4 Cultural and management practices

The cultural and management practices including fertilizer application, irrigation, weeding, ethrel application etc. were done according to Package of Practices Recommendations of Kerala Agricultural University (KAU, 1996) as explained in Experiment 1.

3.3.5 Mode of ^{32}P application

In the second experiment, soil application of ^{32}P was done based on the results of Experiment 1. The ^{32}P was applied in two lateral distances of 15 and 30 cm and 2 depths of 15 and 30 cm, thus constituting four combinations of placement of ^{32}P for a single plant. In each treatment the central plant was given the soil injection of ^{32}P. For the application of ^{32}P, two circular rings of varying radii (15 and 30 cm) were made in the plant base. In each circle four equidistant holes of alternate depths (15 and 30 cm) were made as illustrated in Fig. 4. so that all the roots got equal chance of ^{32}P absorption (Plate.7). In the holes dug, PVC access tubes of suitable length were inserted with about 10-15 cm above the ground level and the open ends were closed with polythene cover. At the time of ^{32}P application, the

Fig.4. Method of ^{32}P application in Experiment II



D_1 - 15 cm depth
D_2 - 30 cm depth
L_1 - 15 cm lateral distance
L_2 - 30 cm lateral distance

● Treated plant
○ Soil holes for 32P application

Plate 7. Method of ^{32}P application in Experiment II

polythene cover was removed and 3 ml of radioactive solution prepared in a carrier solution of 1000 ppm P was applied into each tube as described earlier so that the total activity applied per plant was 0.5 mCi which necessitated a total of 12 mCi for the 24 treated plants.

3.3.6 Leaf sampling

'D' leaf was used for analysis. It was taken from the treated plant and also from the surrounding non treated plants. In high density system of planting 'D' leaf was taken from the remaining 15 neighbouring plants in the same trench and in low density system there were only 11 plants. Sampling was done on 30th day of application of ^{32}P based on the observations made in Experiment1

3.3.7 Radioassay

For the determination of ^{32}P activity in the leaf sample, Cerenkov counting technique using liquid scintillation system was adopted. The procedure followed was same as explained in Experiment 1.The percentage of absorption by the treated plant and the surrounding plants were also calculated for each treatment to know the sharing of activity by the plants.

$$\text{\% of absorption of activity in a plant} = \frac{{}^{32}\text{P recovery from that plant}}{\text{Total } {}^{32}\text{P recovered from all the plants}} \times 100$$

3.4 Observations

3.4.1 Observations recorded for root excavation studies

The following observations regarding the root characters were taken for the main plot treatments in Experiment 1.

3.4.1.1 Length of the root: Mean length of all the roots were recorded for each treatment and expressed in centimeters.

3.4.1.2 Diameter of the root: Mean diameter of the roots were recorded for each treatment and expressed in centimetres.

3.4.1.3 Weight of the root: The mean fresh weight and dry weight of the roots were recorded for each treatment and expressed in grams.

3.4.1.4 Total number of roots: The total number of roots per plant was recorded for each treatment.

3.4.2 Vegetative characters

The following observations were recorded for Experiment II.

3.4.2.1 Total number of leaves: The total number of leaves were recorded at six months after planting

3.4.2.2 Plant height: The height of the plant from ground level to the longest leaf was measured at six months after planting and expressed in centimeters.

3.4.2.3 Length and breadth of 'D' leaf: The 'D' leaf (4^{th} leaf from the top) was taken out and length and breadth were recorded at six months after planting

3.4.3 Flowering characters

The following observations were recorded for Experiment II.

3.4.3.1 Days for initiation of flowering

The number of days taken for the appearance of reddish colour at the centre of the plant was recorded for each treatment.

3.4.3.2 Days for 50 per cent flowering

The mean number of days taken for the emergence of inflorescence in 50 per cent of the plants in each treatment was recorded.

3.4.3.3 Flowering phase

For each treatment, the number of days taken from the opening of the first flower to the opening of the last flower in an inflorescence was recorded.

3.5 Statistical analysis

Statistical analysis was done using Mstat-C package. The data were statistically analysed by applying the analysis of variance. In view of the wide variability in count rates, the data were subjected to log transformation prior to ANOVA.

Results

4. RESULTS

The results of the experiment conducted to study the root activity in pineapple and also the uptake of ^{32}P by two varieties of pineapple under different systems of planting are presented in this chapter.

4.1 Pattern of ^{32}P absorption by pineapple

4.1.1 Recovery of ^{32}P in the leaves of pineapple 15 days after application

The data on the recovery of ^{32}P in the leaves of pineapple 15 days after its application are furnished in Table 1. The data indicated that there was no significant difference between the main plot treatments (variety x method of planting). However, the variety Mauritius grown under surface method (V_2M_1) showed highest absorption of ^{32}P followed by variety Kew grown under surface method (V_1M_1) . When the lateral distance and depth were considered it was found that there was significant difference between the treatments. The maximum recovery of ^{32}P in the leaves was obtained from the treatment L_1D_1 (15 cm lateral distance and 15 cm depth) and was found to be significantly superior to all other treatments. The next best ^{32}P count was obtained from the treatment L_2D_1 (30 cm lateral distance and 15 cm depth) which was on par with the treatment L_1D_2 (15 cm lateral distance and 30 cm depth). The treatment L_4D_3 (60 cm lateral distance and 45 cm depth) recorded the lowest count and was on par with L_4D_4 (60 cm lateral distance and 60 cm depth).

The interaction effect was found to be non significant. However, out of 64 treatments maximum recovery of ^{32}P was obtained when it was applied to Mauritius grown under trench planting followed by Kew grown under trench planting at a lateral distance of 15 cm and a depth of 15 cm. When ^{32}P was applied to Kew grown under surface planting (V_1M_1) showed the highest uptake from a zone of 15 cm depth and 15 cm away from the plant followed by L_3D_1 (45 cm lateral distance and 15 cm depth). The lowest ^{32}P count was obtained from L_2D_4 (30 lateral distance and 60 cm depth). The variety Kew when grown under trench method (V_1M_2) showed the highest uptake of ^{32}P in L_1D_1 followed by L_1D_2 and the treatment L_4D_4 recorded the lowest recovery of ^{32}P. It was also found that when

Table 1. Recovery of ^{32}P (dpm/g) in the leaves of pineapple 15 days after application

*Recovery of ^{32}P (dpm/g leaf)					
Sub plot Treatments	Main plot treatments				
	V_1M_1	V_1M_2	V_2M_1	V_2M_2	Mean
L_1D_1	3.105 (1273.50)	3.192 (1555.966)	3.143 (1389.953)	3.207 (1610.646)	3.162
L_1D_2	2.124 (133.045)	2.669 (466.659)	2.536 (343.558)	2.586 (385.478)	2.479
L_1D_3	1.506 (32.062)	1.326 (21.184)	1.590 (38.905)	1.071 (11.776)	1.373
L_1D_4	1.083 (12.106)	1.267 (18.493)	2.095 (124.451)	1.302 (20.045)	1.437
L_2D_1	2.511 (324.339)	1.665 (46.238)	2.966 (924.698)	2.950 (891.251)	2.523
L_2D_2	1.587 (38.637)	1.575 (37.584)	0.913 (8.185)	1.657 (45.394)	1.433
L_2D_3	1.196 (15.704)	1.308 (20.324)	1.149 (14.093)	1.941 (87.297)	1.398
L_2D_4	0.581 (3.811)	0.771 (5.902)	1.526 (33.574)	0.589 (3.882)	0.867)
L_3D_1	2.593 (391.741)	1.806 (63.973)	2.524 (334.19)	1.708 (51.051)	2.173
L_3D_2	1.772 (59.156)	1.134 (13.614)	1.573 (37.411)	1.001 (10.02)	1.370
L_3D_3	0.938 (8.669)	1.834 (68.234)	1.028 (10.665)	1.477 (29.992)	1.319
L_3D_4	1.111 (12.912)	1.429 (26.853)	1.421 (26.363)	0.946 (8.831)	1.227
L_4D_1	1.286 (19.319)	1.577 (37.757)	0.927 (8.453)	1.283 (19.187)	1.268
L_4D_2	1.293 (19.634)	0.977 (9.484)	0.709 (5.116)	0.542 (3.483)	0.885
L_4D_3	0.908 (8.091)	0.418 (2.618)	0.276 (1.888)	0.488 (3.076)	0.523
L_4D_4	1.046 (11.117)	0.383 (2.415)	0.745 (5.559)	0.971 (9.354)	0.786
Mean	1.54	1.459	1.570	1.486	

CD (0.05) for comparison of
Main plot treatments (Variety (V) x Method of planting (M) - NS
Sub plot treatments (Lateral distance (L) x Depth (D) - 0.361
Interaction effect (VM x LD) - NS

*Log transformed values
Values in paranthesis indicate retransformed values

variety Mauritius grown under surface planting as well as trench planting the highest value of ^{32}P counts were observed in L_1D_1 followed by L_2D_1 and the least counts from L_4D_4.

The data presented in Table 2 and Fig. 5 shows the recovery of ^{32}P after 15 days of its application as influenced by lateral distance and depth. When lateral distance alone was considered irrespective of depth, variety and method of planting it was found that the maximum absorption of ^{32}P was from a lateral distance of 15 cm which was found to be significantly superior to all other lateral distances tried. The ^{32}P counts obtained from lateral distances of 30 cm and 45 cm were on par. It was also found that some absorption took place at 60 cm away from the plant. It was noticed from the table that there was significant difference between the various depth considered. The maximum ^{32}P count was obtained from 15 cm depth which was significantly superior to all other depths tried. The next best recovery of ^{32}P was from a depth of 30 cm. As the depth increased from 15 to 60 cm the recovery of ^{32}P was found to decrease with the least from a depth of 60 cm.

4.1.2 Recovery of ^{32}P in the leaves of pineapple 30 days after application

The mean ^{32}P counts obtained in the leaves of pineapple 30 days after its application are given in Table 3. It was seen that there was no significant difference between the main plot treatments V_1M_1 (Kew grown under surface planting), V_1M_2(Kew grown in trenches), V_2M_1(Mauritius grown under surface method), V_2M_2(Mauritius grown in trenches) with regard to ^{32}P uptake. However the highest value was shown by variety Mauritius grown under surface planting (V_2M_1). When combination of lateral distance and depth was considered it was observed that the highest value of ^{32}P count was obtained when ^{32}P was placed 15 cm away from the plant at a depth of 15 cm (L_1D_1) and was found to be significantly superior to all other treatments. The treatment L_1D_2 and L_2D_1 showed the next best counts of ^{32}P and were on par. The lowest value was recorded by the treatment L_4D_4 which was significantly inferior to all other treatments except L_2D_4.

The interaction effect was also found to be significant. Out of the 64 treatments highest absorption was obtained when ^{32}P was applied to a lateral distance of 15 cm at a depth of 15 cm, to the variety Kew grown under surface

Table 2. Recovery of ^{32}P(dpm/g) in the leaves of pineapple at 15 days after application as affected by lateral distance and depth

*Recovery of ^{32}P(dpm/g leaf)					
Depth(cm)	Lateral distance (cm)				
	15	30	45	60	Mean
15	3.162 (1452.112)	2.523 (333.426)	2.173 (148.936)	1.268 (18.535)	2.281
30	2.479 (301.30)	1.433 (27.102)	1.370 (23.442)	0.885 (7.674)	1.542
45	1.373 (23.605)	1.398 (25.003)	1.319 (20.845)	0.523 (3.334)	1.153
60	1.437 (27.353)	0.867 (7.362)	1.227 (16.866)	0.786 (6.109)	1.079
Mean	2.113	1.555	1.522	0.866	

CD(0.05) for comparison of

Lateral distance - 0.181
Depth - 0.181

*Log transformed values
Values in paranthesis indicate retransformed values

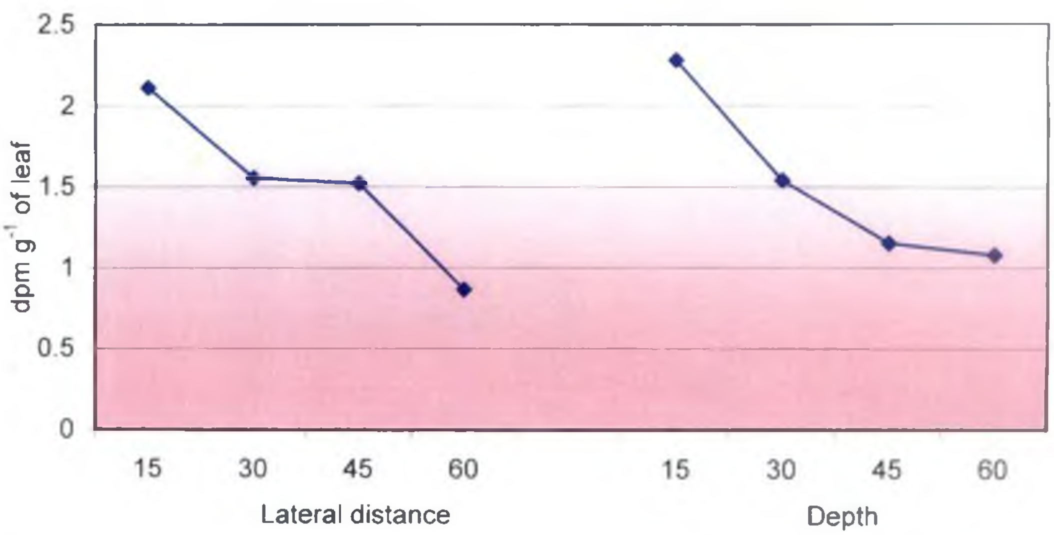


Fig. 5. Recovery of ^{32}P (dpm/g) in the leaves of pineapple 15 days after application as affected by lateral distance and depth

Table 3. Recovery of ^{32}P (dpm/g) in the leaves of pineapple 30 days after application

*Recovery of ^{32}P(dpm/g leaf)					
Sub plot Treatments	Main plot treatments				
	V_1M_1	V_1M_2	V_2M_1	V_2M_2	Mean
L_1D_1	3.338 (2117.709)	2.819 (659.174)	2.961 (914.113)	3.265 (1840.772)	3.096
L_1D_2	2.193 (155.955)	2.696 (496.592)	2.718 (522.396)	2.605 (402.717)	2.553
L_1D_3	0.774 (5.943)	1.326 (21.184)	1.504 (31.915)	1.672 (46.989)	1.319
L_1D_4	0.685 (4.842)	0.608 (4.055)	1.221 (16.634)	1.321 (20.941)	0.959
L_2D_1	2.702 (50.35)	1.638 (43.451)	2.666 (463.446)	2.961 (914.113)	2.492
L_2D_2	1.504 (31.915)	0.984 (9.638)	1.789 (61.518)	2.389 (244.906)	1.666
L_2D_3	0.613 (41.102)	1.625 (217)	2.342 (219.785)	1.878 (75.509)	1.615
L_2D_4	0.313 (2.056)	0.381 (2.404)	1.067 (11.668)	0.679 (4.775)	0.610
L_3D_1	2.971 (935.406)	2.248 (177.01)	2.449 (281.19)	1.660 (45.709)	2.332
L_3D_2	1.618 (41.495)	0.846 (7.015)	1.867 (73.621)	1.240 (17.378)	1.393
L_3D_3	1.010 (10.233)	1.746 (55.719)	1.209 (16.181)	1.681 (47.973)	1.412
L_3D_4	1.095 (12.445)	1.067 (11.668)	1.028 (10.666)	0.677 (4.753)	0.967
L_4D_1	1.151 (14.158)	1.361 (22.961)	1.689 (48.865)	1.057 (11.402)	1.315
L_4D_2	1.210 (16.22)	1.101 (12.618)	1.257 (18.072)	1.18 (15.136)	1.187
L_4D_3	1.011 (10.257)	1.051 (11.25)	1.059 (11.455)	1.041 (10.99)	1.040
L_4D_4	0.807 (6.412)	0.425 (2.661)	0.354 (2.259)	0.618 (4.149)	0.551
Mean	1.437	1.370	1.699	1.620	

CD (0.05) for comparison of

Main plot treatments (Variety (V) x Method of planting (M) - NS
Sub plot treatments (Lateral distance (L) x Depth (D) - 0.367
Interaction effect (VM x LD) - 0.735

*Log transformed values
Values in paranthesis indicate retransformed values

planting which was on par with Kew and Mauritius grown under trench planting and Mauritius grown under surface planting. The variety Kew, grown under surface planting (V_1M_1) showed highest recovery of the applied ^{32}P from L_1D_1. The next best counts were obtained from the treatments L_3D_1 (45 cm lateral distance and 15 cm depth) and L_2D_1 and were on par. The uptake of ^{32}P was found to be minimum at L_2D_4 and was on par with the treatments L_1D_4 and L_4D_4 (Table 3). The highest absorption of ^{32}P by the same variety when grown in trenches was observed to be for the treatment L_1D_1 followed by L_1D_2 and L_3D_1. The least counts of ^{32}P was obtained from a lateral distance of 30 cm at 60 cm depth (L_2D_4) and was on par with the treatments L_4D_4 and L_1D_4 (15 cm lateral distance and 60 cm depth). It was observed from the table that the variety Mauritius grown under surface method of planting (V_2M_1) showed the highest recovery of ^{32}P in a soil zone constituting 15 cm lateral distance and 15 cm depth. The next best counts were noticed at L_1D_2 and L_2D_1. The minimum amount of ^{32}P recovery was observed at L_4D_4 and was on par with the treatments L_3D_4 and L_4D_3. Mauritius variety grown under trench method produced the highest recovery of ^{32}P at L_1D_1 and was on par with the treatments L_2D_1 and L_1D_2. The lowest recovery of ^{32}P was noticed from L_4D_4 and was found to be on par with the treatments L_3D_4 and L_2D_4.

Data pertaining to the recovery of ^{32}P by pineapple 30 days after application as affected by lateral distance and depth is presented in Table 4 and Fig. 6. It was seen from the data that the lateral distance and depth differ significantly. When the lateral distance alone was considered it was observed that the highest recovery of ^{32}P was from 15 cm followed by 30 cm. At 60 cm lateral distance the absorption was found to be very less. The uptake of ^{32}P from 15 cm lateral distance was significantly superior to all other lateral distances tried. The absorption from 30 cm and 45 cm lateral distances were on par. Absorption of ^{32}P from 15 cm depth was found to be significantly superior and the least uptake was obtained from a depth of 60 cm (Table 4). The recovery of ^{32}P from 30 cm and 45 cm depth were found to be on par.

4.1.3 Recovery of ^{32}P in the leaves of pineapple 45 days after application

Data pertaining to the recovery of ^{32}P in the leaves of pineapple 45 days after its application are presented in Table 5. The data revealed that there was no

Table 4. Recovery of ^{32}P (dpm/g)in the leaves of pineapple at 30 days after application as affected by lateral distance

*Recovery of ^{32}P(dpm/g leaf)					
Depth(cm)	Lateral distance (cm)				
	15	30	45	60	Mean
15	3.096 (1247.383)	2.492 (310.456)	2.332 (214.783)	1.315 (20.654)	2.309
30	2.533 (341.193)	1.666 (46.345)	1.393 (24.717)	1.187 (15.382)	1.695
45	1.319 (20.845)	1.615 (41.209)	1.412 (25.823)	1.040 (10.965)	1.346
60	0.959 (9.099)	0.610 (4.074)	0.967 (9.268)	0.551 (3.556)	0.772
Mean	1.98	1.59	1.526	1.023	

CD (0.05) for comparison of

Lateral distance - 0.183
Depth - 0.183

*Log transformed values
Values in paranthsis indicate retransformed values

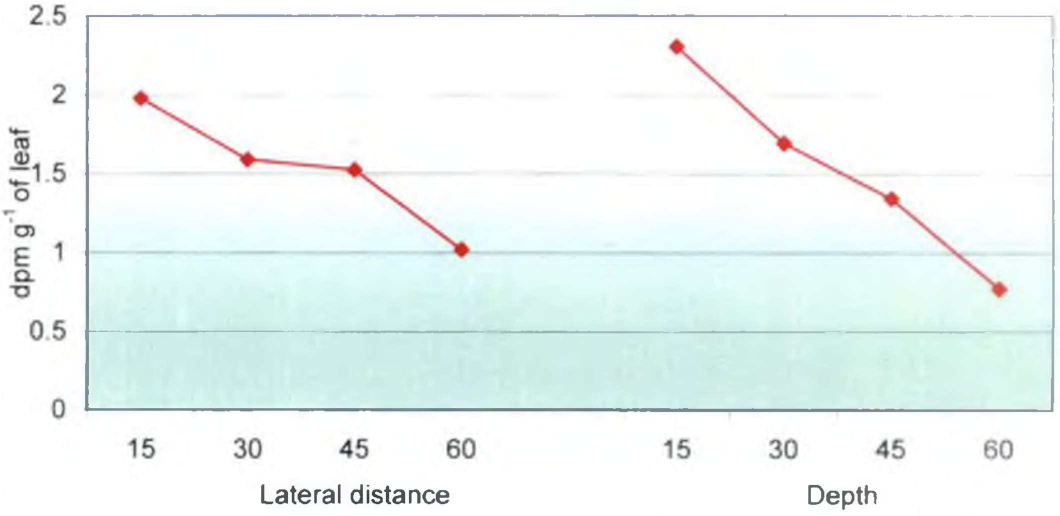


Fig. 6. Recovery of ^{32}P (dpm g^{-1}) in the leaves of pineapple 30 days after application as affected by lateral distance and depth

Table 5. Recovery of ^{32}P (dpm/g) in the leaves of pineapple 45 days after application

*Recovery of ^{32}P(dpm/g leaf)					
Sub plot Treatments	Main plot treatments				
	V_1M_1	V_1M_2	V_2M_1	V_2M_2	Mean
L_1D_1	2.365 (231.739)	2.378 (238.781)	2.776 (597.035)	2.973 (939.72)	2.623
L_1D_2	1.500 (31.623)	1.872 (74.473)	2.434 (271.64)	2.208 (161.44)	2.004
L_1D_3	1.440 (27.542)	1.212 (16.293)	0.929 (8.491)	1.368 (23.334)	1.238
L_1D_4	0.774 (5.943)	1.435 (27.227)	1.449 (28.119)	1.199 (15.812)	1.214
L_2D_1	2.321 (208.411)	1.644 (46.132)	2.553 (357.27)	2.470 (295.12)	2.247
L_2D_2	0.844 (6.982)	1.431 (26.977)	1.411 (25.763)	1.590 (38.905)	1.319
L_2D_3	0.459 (2.877)	1.303 (20.09)	1.752 (56.494)	1.557 (36.058)	1.268
L_2D_4	1.128 (13.428)	0.625 (4.217)	1.087 (12.218)	1.273 (18.749)	1.028
L_3D_1	2.082 (120.781)	1.621 (41.783)	2.127 (133.968)	1.702 (50.35)	1.883
L_3D_2	1.376 (23.768)	1.321 (20.94)	1.780 (60.256)	1.233 (17.1)	1.427
L_3D_3	1.300 (19.953)	1.583 (38.282)	1.408 (25.59)	1.766 (58.344)	1.514
L_3D_4	1.211 (16.255)	1.123 (13.274)	0.966 (9.247)	0.915 (8.222)	1.054
L_4D_1	1.009 (10.209)	0.850 (7.079)	1.762 (57.81)	0.641 (4.375)	1.065
L_4D_2	0.969 (9.311)	1.298 (19.86)	1.109 (12.853)	1.034 (10.814)	1.103
L_4D_3	1.247 (17.66)	1.170 (14.791)	1.086 (12.189)	1.265 (18.408)	1.192
L_4D_4	1.077 (11.939)	0.897 (7.889)	0.343 (2.203)	0.930 (8.511)	0.812
Mean	1.319	1.360	1.561	1.508	

CD (0.05) for comparison of
Main plot treatments (Variety (V) x Method of planting (M) - NS
Sub plot treatments (Lateral distance (L) x Depth (D) - 0.338
Interaction effect (VM x LD) - 0.676

*Log transformed values
Values in paranthesis indicate retransformed values

Table 5. Recovery of ^{32}P (dpm/g) in the leaves of pineapple 45 days after application

*Recovery of ^{32}P(dpm/g leaf)					
Sub plot Treatments	Main plot treatments				
	V_1M_1	V_1M_2	V_2M_1	V_2M_2	Mean
L_1D_1	2.365 (231.739)	2.378 (238.781)	2.776 (597.035)	2.973 (939.72)	2.623
L_1D_2	1.500 (31.623)	1.872 (74.473)	2.434 (271.64)	2.208 (161.44)	2.004
L_1D_3	1.440 (27.542)	1.212 (16.293)	0.929 (8.491)	1.368 (23.334)	1.238
L_1D_4	0.774 (5.943)	1.435 (27.227)	1.449 (28.119)	1.199 (15.812)	1.214
L_2D_1	2.321 (208.411)	1.644 (46.132)	2.553 (357.27)	2.470 (295.12)	2.247
L_2D_2	0.844 (6.982)	1.431 (26.977)	1.411 (25.763)	1.590 (38.905)	1.319
L_2D_3	0.459 (2.877)	1.303 (20.09)	1.752 (56.494)	1.557 (36.058)	1.268
L_2D_4	1.128 (13.428)	0.625 (4.217)	1.087 (12.218)	1.273 (18.749)	1.028
L_3D_1	2.082 (120.781)	1.621 (41.783)	2.127 (133.968)	1.702 (50.35)	1.883
L_3D_2	1.376 (23.768)	1.321 (20.94)	1.780 (60.256)	1.233 (17.1)	1.427
L_3D_3	1.300 (19.953)	1.583 (38.282)	1.408 (25.59)	1.766 (58.344)	1.514
L_3D_4	1.211 (16.255)	1.123 (13.274)	0.966 (9.247)	0.915 (8.222)	1.054
L_4D_1	1.009 (10.209)	0.850 (7.079)	1.762 (57.81)	0.641 (4.375)	1.065
L_4D_2	0.969 (9.311)	1.298 (19.86)	1.109 (12.853)	1.034 (10.814)	1.103
L_4D_3	1.247 (17.66)	1.170 (14.791)	1.086 (12.189)	1.265 (18.408)	1.192
L_4D_4	1.077 (11.939)	0.897 (7.889)	0.343 (2.203)	0.930 (8.511)	0.812
Mean	1.319	1.360	1.561	1.508	

CD (0.05) for comparison of
Main plot treatments (Variety (V) x Method of planting (M) - NS
Sub plot treatments (Lateral distance (L) x Depth (D) - 0.338
Interaction effect (VM x LD) - 0.676

*Log transformed values
Values in paranthesis indicate retransformed values

significant difference between the main plot treatments V_1M_1, V_1M_2, V_2M_1 and V_2M_2. However highest recovery was found in V_2M_1. Regarding lateral distance and depth there was significant difference between the treatments.

It was observed from Table 5 that the placement of ^{32}P at 15 cm depth and 15 cm away from the plant (L_1D_1) recorded the maximum ^{32}P count followed by L_2D_1 and L_1D_2 . The data indicated that the treatment L_1D_1 was significantly superior to all other treatments while L_1D_2 was on par with L_2D_1. The treatment L_4D_4 resulted in the lowest value which was on par with the treatment L_2D_4 and significantly inferior to all other treatments.

The interaction was also found to be significant. Out of the 64 treatments highest absorption was obtained when ^{32}P was applied to a lateral distance of 15 cm at a depth of 15 cm, to the variety Mauritius grown under trench planting which was on par with Kew grown under surface and trench planting and Mauritius grown under surface planting. In the main plot treatment V_1M_1, uptake of ^{32}P was found to be the highest at L_1D_1 followed by L_2D_1 and L_3D_1. All these treatments were found to be on par. The lowest ^{32}P count was obtained from L_2D_3 (60 cm lateral distance and 30 cm depth). The variety Kew when grown under trench method of planting (V_1M_2) the highest value of ^{32}P count was observed in L_1D_1 followed by L_1D_2 and L_2D_1 and were found to be on par. The placement of ^{32}P at L_2D_4 recorded the lowest count for V_1M_2, which was on par with L_4D_1 (60 cm lateral distance and 15 cm depth) and L_4D_4. In both the main plot treatments V_2M_1 and V_2M_2 the highest recovery of ^{32}P was from L_1D_1 followed by L_2D_1 and L_1D_2. These values were found to be on par. The main plot treatment V_2M_1 showed the lowest value of ^{32}P at L_4D_4 . While in V_2M_2 the lowest value of ^{32}P uptake was recorded by L_4D_1 and was on par with L_3D_4 and L_4D_4.

Data on the recovery of ^{32}P by pineapple as affected by lateral distance and depth is presented in Table 6 and Fig.7. When the lateral distance alone was considered it was found that the absorption of ^{32}P was significantly higher at a distance of 15 cm from the plant with the least at 60 cm away from the plant. The recovery of ^{32}P from 30 cm and 45 cm lateral distance were on par. With respect to various depths considered, 15 cm depth showed highest ^{32}P recovery followed by 30

Table 6. Recovery of ^{32}P (dpm/g)in the leaves of pineapple at 45 days after application as affected by lateral distance and depth

*Recovery of ^{32}P(dpm/g leaf)					
Depth(cm)	Lateral distance (cm)				
	15	30	45	60	Mean
15	2.623 (419.759)	2.247 (176.604)	1.883 (76.384)	1.065 (11.614)	1.955
30	2.004 (100.925)	1.319 (20.845)	1.427 (26.730)	1.103 (12.676)	1.463
45	1.238 (17.298)	1.268 (18.535)	1.514 (32.658)	1.192 (15.559)	1.303
60	1.214 (58.884)	1.028 (10.666)	1.054 (11.324)	0.812 (6.486)	1.027
Mean	1.77	1.466	1.469	1.043	

CD(0.05) for comparison of

Lateral distance - 0.169
Depth - 0.169

*Log transformed values
Values in paranthesis indicate retransformed values

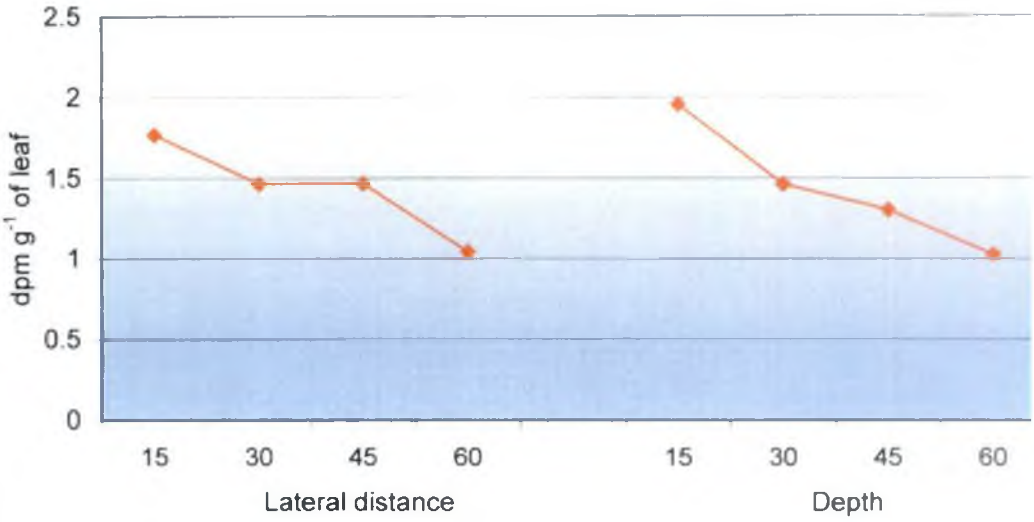


Fig. 7. Recovery of ^{32}P (dpm g^{-1}) in the leaves of pineapple 45 days after application as affected by lateral distance and depth

cm depth. The uptake of ^{32}P from 15 cm depth was found to be significantly superior to other depths tried. However some absorption took place at a depth of 60 cm.

4.1.4 Pattern of ^{32}P absorption as influenced by variety and method of planting

Recovery of ^{32}P as influenced by variety and method of planting at different sampling intervals is given in Table 7.

Data revealed that there was no significant difference between the two varieties or method of planting. However the variety Mauritius recorded the highest absorption of ^{32}P at all the sampling intervals. Eventhough maximum ^{32}P count was obtained in the surface method of planting, no significant difference was noticed between the method of planting .

4.2 Pattern of root activity

4.2.1 Pattern of root activity in pineapple 15 days after ^{32}P application

Data pertaining to the percentage distribution of active roots in pineapple irrespective of variety and method of planting 15 days after application of ^{32}P as influenced by lateral distance and depth are furnished in Table 8 and Fig. 8.

When the different lateral distances alone were considered 67.08 per cent of the active roots were seen 15 cm away from the plant followed by 30 cm distance, which contributed 20.67 per cent of the roots. The root activity at a lateral distance of 60 cm was found to be only 1.59 per cent. When depth alone was considered maximum root activity was observed from a soil depth of 15 cm (79.24%) followed by 30 cm depth (14.61%). Only 2.76 per cent of the root activity was seen at 60 cm depth. It was observed from the table that when the combination of lateral distance and depth was considered the most active root zone of pineapple was noticed to be 15 cm away from the plant reaching to a depth of 15 cm (52.82%) followed by the soil zone comprising 30 cm lateral distance and 15 cm depth (17.88%). The active roots were very less (0.15%) at a lateral distance of 60 cm and depth of 45 cm.

Table 7. Recovery of ^{32}P(dpm/g leaf) as influenced by variety and method of planting at different sampling intervals

	*Recovery of ^{32}P(dpm/g leaf)									
	15 days after application			30 days after application			45 days after application			Overall mean
	Kew	Mauritius	Mean	Kew	Mauritius	Mean	Kew	Mauritius	Mean	
Surface method	1.54 (34.674)	1.57 (37.154)	1.555 (35.892)	1.437 (27.353)	1.699 (50.003)	1.568 (36.983)	1.319 (20.845)	1.561 (36.392)	1.44 (27.542)	1.521
Trench method	1.459 (28.774)	1.486 (30.619)	1.473 (29.717)	1.370 (23.442)	1.620 (41.687)	1.495 (31.261)	1.360 (22.909)	1.508 (32.211)	1.434 (27.164)	1.467
Mean	1.50	1.528	1.514	1.404	1.659	1.532	1.339	1.534	1.437	1.494

CD(0.05) for comparison of

Variety (V) - NS
Method of planting (M) - NS
Interaction effect - NS

*Log transformed values
Values in paranthesis indicate retransformed values

Table 8. Root activity (%) of pineapple at 15 days after ^{32}P application as influenced by lateral distance and depth

Depth (cm)	Root activity (%)				
	Lateral distance (cm)				
	15	30	45	60	Total
15	52.82	17.88	7.73	0.81	79.24
30	11.89	1.22	1.13	0.37	14.61
45	0.95	1.17	1.12	0.15	3.39
60	1.42	0.40	0.68	0.26	2.76
Total	67.08	20.67	10.66	1.59	

Table 9. Root activity(%) of variety of Kew grown under surface method15 days after ^{32}P application

Depth (cm)	Root activity(%)				
	Lateral distance (cm)				
	15	30	45	60	Total
15	53.87	13.72	16.56	0.82	84.978
30	5.63	1.63	2.50	0.83	10.591
45	1.37	0.67	0.37	0.34	2.750
60	0.51	0.16	0.55	0.47	1.691
Total	61.38	16.18	19.98	2.46	

Table 10. Root activity (%) of variety Kew grown under trench method at 15 days after ^{32}P application

Depth (cm)	Root activity (%)				
	Lateral distance (cm)				
	15	30	45	60	Total
15	64.90	1.93	2.67	1.57	71.07
30	19.47	1.57	0.57	0.39	22.00
45	0.88	0.85	2.85	0.11	4.69
60	0.77	0.25	1.12	0.10	2.24
Total	86.02	4.60	7.21	2.17	

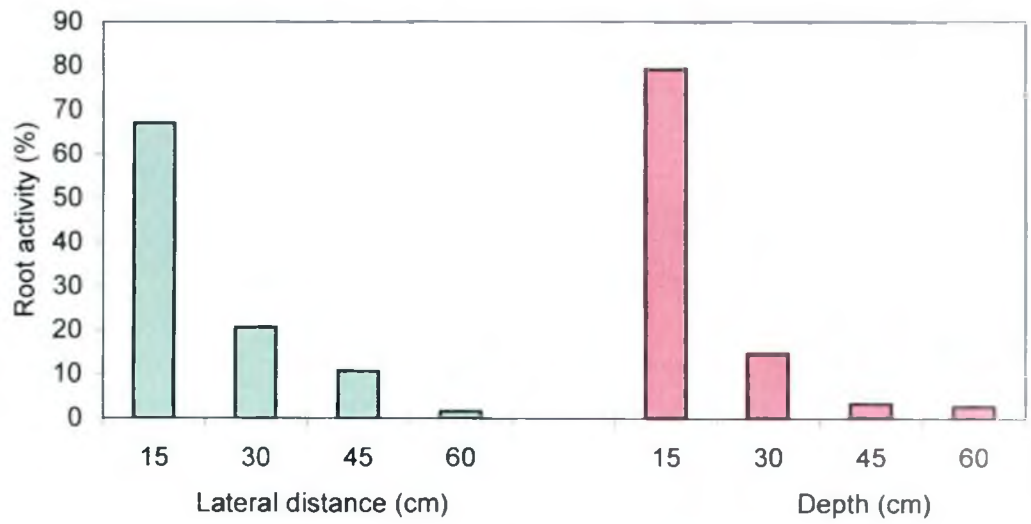


Fig. 8. Root activity (%) of pineapple 15 days after ^{32}P application as influenced by lateral distance and depth

4.2.1.1 Pattern of root activity in pineapple variety Kew grown under surface planting 15 days after ^{32}P application

The percentage distribution of active roots at various lateral distances and depths of variety Kew grown under surface planting is presented in Table 9. The data showed that the highest percentage of root activiy (61.38%) was observed 15 cm away from the plant and the least (2.46%) 60 cm away from the plant. The lateral distance of 30 cm contributed 16.18 per centage . With respect to depth, 84.97 per cent of the root activity was seen confined to a depth of 15 cm followed by 30 cm (10.59%). As the depth increased from 45 to 60 cm, the root activity decreased from 2.75 per cent to 1.69 per cent.

With respect to combination of lateral distance and depth the most active root zone was seen 15 cm away from the plant and to a depth of 15 cm with 53.87 per cent of the active roots concentrating there. This was followed by the soil zone constituting 45 cm lateral distance and 15 cm depth, which accommodated 16.56 per cent of the root activity. The minimum root activity (0.16%) was observed 30 cm away from the plant and at 60 cm depth.

4.2.1.2 Pattern of root activity in pineapple variety Kew grown under trench planting 15 days after ^{32}P application

The data related to the percentage distribution of active roots of variety Kew grown under trench system is furnished in Table 10. It was noticed that 86.02 per cent of the active roots of Kew planted in trenches were seen 15 cm away from the plant. As the lateral distance increased from 15 to 60 cm, the density of active roots decreased to 2.17 per cent. When depth alone was considered it was found that 71.07 per cent of the root activity confined to 15 cm. The zone of 30 cm depth also showed considerable amount of root activity (22.0%). The least activity was (2.24%) obtained from 60 cm depth.

When combination of lateral distance and depth was considered it was seen that about 64.9 per cent of the roots were seen 15 cm away from the plant at a depth of 15 cm. The least root activity was observed at a soil zone of 60 cm lateral distance and depth of 60 cm (0.10%).

4.2.1.3 Pattern of root activity in pineapple variety Mauritius grown under surface method 15 days after ^{32}P application

The data on the percentage root distribution of Mauritius grown under surface planting is given in Table 11. It was observed from the table that when lateral distance alone was considered maximum percentage of the active roots (57.36%) were confined to a lateral distance of 15 cm. The root distribution at 30 cm lateral distance was also appreciable with 29.66 per cent of the root activity concentrating there. Some amount of root activity (0.63%) was observed at 60 cm lateral distance also. When depth alone was considered the maximum percentage of active roots were observed 15 cm deep (80.36%) followed by 30 cm (11.92%). The soil layer of 45 cm contributed only 1.98 per cent of the roots.

With respect to combination of lateral distance and depth, the most active root zone of Mauritius grown under surface planting was found to be the zone constituting 15 cm radial distance and 15 cm depth which accommodated 42.03 per cent of the active roots. A lateral distance of 30 cm and depth of 15 cm contributed 27.96 per cent of the roots. The least concentration of root activity was seen 60 cm away from the plant up to a depth of 45 cm (0.05%).

4.2.1.4 Pattern of root activity in pineapple variety Mauritius grown under trench method of planting 15 days after ^{32}P application

The percentage distribution of active roots of Mauritius grown under trench planting is presented in Table 12. It was seen from the data that when lateral distance alone was considered the highest amount of root activity (63.56%) was obtained 15 cm away from the plant. considerable amount of root activity (32.2%) was seen at 30 cm lateral distance and the least (1.11%) from a distance of 60 cm from the plant. With respect to depth 80.61 per cent of the root activity was seen confined to 15 cm followed by 30 cm depth (13.92%). The vertical distance of 60 cm contributed only 1.33 per cent of the roots.

With respect to combination of lateral distance and depth maximum amount of active roots were seen at a treatment site 15 cm deep and 15 cm away from the plant (50.48%). The soil zone constituting of 30 cm radial distance and 15

Table 11. Root activity(%) of variety Mauritius grown under surface method 15 days after ^{32}P application

Root activity(%)					
Depth (cm)	Lateral distance (cm)				
	15	30	45	60	Total
15	42.03	27.96	10.11	0.26	80.36
30	10.39	0.25	1.13	0.15	11.92
45	1.18	0.43	0.32	0.05	1.98
60	3.76	1.02	0.79	0.17	5.74
Total	57.36	29.66	12.35	0.63	

Table 12. Root activity (%) root activity of variety Mauritius grown under trench method at 15 days after ^{32}P application

Root activity (%)					
Depth (cm)	Lateral distance (cm)				
	15	30	45	60	Total
15	50.48	27.93	1.60	0.60	80.61
30	12.08	1.42	0.31	0.11	13.92
45	0.37	2.73	0.94	0.10	4.14
60	0.63	0.12	0.28	0.30	1.33
Total	63.56	32.20	3.13	1.11	

Table 13. Root activity (%) of pineapple 30 days after ^{32}P application as influenced by lateral distance and depth

Root activity (%)					
Depth (cm)	Lateral distance (cm)				
	15	30	45	60	Total
15	44.90	14.35	11.73	0.99	71.97
30	16.38	2.57	1.25	0.57	20.77
45	1.00	3.22	1.42	0.42	6.05
60	0.39	0.19	0.40	0.13	1.11
Total	62.67	20.33	14.80	2.11	

cm depth contributed 27.93 per cent of the roots with the minimum from a distance of 60 cm and depth of 45 cm (0.10%).

4.2.2 Pattern of root activity in pineapple 30 days after application of ^{32}P

Data on percentage distribution of active roots in pineapple 30 days after application as influenced by lateral distance and depth are presented in Table 13 and Fig. 9.

It was observed from the data that among the various lateral distances tried 62.67 per cent of the active roots were concentrated 15 cm away from the plant base. The horizontal distances of 30 cm and 45 cm also contributed considerable amount of root activity of 20.33 per cent and 14.80 per cent respectively. The least amount of active roots (2.11%) were seen 60 cm away from the plant. When depth alone was considered it was found that the highest distribution of active roots (71.97%) were in the surface soil layer of 15 cm followed by 30 cm (20.77%). The zone of 45 cm and 60 cm depth showed active roots of 6.06 and 1.11 per cent respectively.

When the combination of lateral distance and depth was considered it was seen that the treatment combination of 15 cm lateral distance and 15 cm depth recorded the highest percentage of active roots (44.9%). The treatment site of 15 cm lateral distance and 30 cm depth contributed 16.38 per cent of the root activity. The soil zone of 60 cm depth and 60 cm lateral distance amounts to the least root activity of 0.13 per cent.

4.2.2.1 Pattern of root activity in pineapple variety Kew grown under surface method of planting 30 days after ^{32}P application

Data relating to the percentage distribution of active roots of Kew grown under surface method is presented in Table 14.

The data indicated that the lateral distances of 15 cm accommodated 58.93 per cent of the active roots followed by 30 cm (13.98%). The lateral distance of 45 cm accommodated 25.80 per cent of the roots with the least (1.29%) from 60 cm. The vertical spread of roots indicated that 92.21 per cent of the roots concentrated at 15 cm

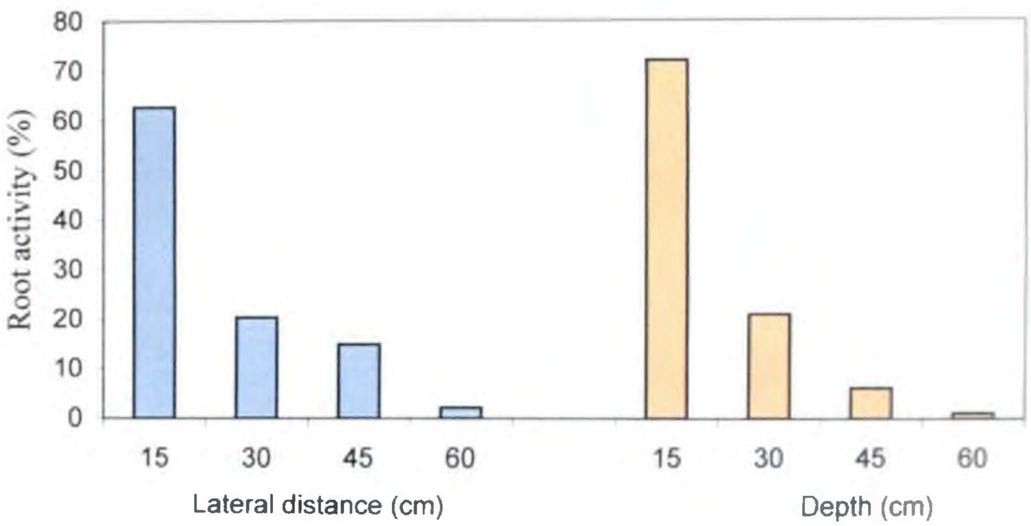


Fig. 9. Root activity (%) of pineapple 30 days after ^{32}P application as influenced by lateral distance and depth

Table 14. Root activity (%) of variety Kew grown under surface method at 30 days

Depth (Cm)	Root activity (%)				
	Lateral distance (cm)				
	15	30	45	60	Total
15	54.68	13.00	24.15	0.38	92.21
30	4.03	0.82	1.07	0.42	6.34
45	0.15	0.11	0.26	0.26	0.78
60	0.13	0.05	0.32	0.17	0.67
Total	58.93	13.98	25.80	1.29	

Table 15. Root activity (%) of variety of Kew grown under trench method 30 days after ^{32}P application

Depth (cm)	Root activity (%)				
	Lateral distance (cm)				
	15	30	45	60	Total
15	41.73	2.75	11.21	1.45	57.14
30	31.44	0.61	0.44	0.80	33.29
45	1.34	2.67	3.53	0.71	8.25
60	0.26	0.15	0.74	0.17	1.32
Total	74.77	6.18	15.92	3.13	

Table 16. Root activity (%) of variety Mauritius grown under surface method at 30 days after ^{32}P application

Depth (cm)	Root activity (%)				
	Lateral distance (cm)				
	15	30	45	60	Total
15	33.56	17.01	10.32	1.80	62.69
30	19.20	2.26	3.00	0.66	25.12
45	1.20	8.07	0.60	0.42	10.29
60	0.61	0.43	0.40	0.08	1.52
Total	54.57	27.77	14.32	2.96	

depth. The root activity was found to decrease with increase in depth. The minimum amount (0.67%) of root activity was seen at a depth of 60 cm

When the combination of lateral distance and depth was considered it was found that 54.68 per cent of the active roots of Kew grown on surface reside 15 cm away from the plant and at a depth of 15 cm followed by the treatment site of 45 cm lateral distance and 15 cm depth (24.15%). The least amount of active roots were seen at a depth of 60 cm and 30 cm around the plant (0.05%).

4.2.2.2 Pattern of root activity in pineapple variety Kew grown under trench planting 30 days after ^{32}P application

The data depicting the percentage distribution of active roots of Kew grown under trench planting is furnished in Table 15.

It was observed that in variety Kew 74.77 per cent of the active roots were found 15 cm away from the plant when planted in trenches. The least amount (3.13%) of the active roots were seen at a horizontal distance of 60 cm from the plant. When depth alone was considered it was noticed that 57.14 per cent of the roots reside in the 15 cm soil layer. The percentage of active roots showed a decreasing trend with increase in depth. The soil layer of 30 cm contributed 33.29 per cent of active roots followed by 45 cm (8.25%) and 60 cm (1.320%) depth.

When combination of lateral distance and depth was considered, it was found that the most active root zone of Kew grown in trenches was found to be 15 cm laterally around the plant and 15 cm vertically from the soil surface constituting 41.73 per cent of the roots (Table 15). The soil zone of 30 cm lateral distance and 60 cm depth contributed the lowest amount of roots (0.15%).

4.2.2.3 Pattern of root activity in pineapple variety Mauritius grown under surface planting 30 days after ^{32}P application

Data on the percentage distribution of active roots of Mauritius grown under surface planting is presented in Table 16.

It was seen from the data that under surface planting the highest percentage of active roots (54.57%) of Mauritius were located 15 cm laterally around the plant followed by 30 cm (27.77%). The percentage of root activity decreased from 54.57 per cent to 2.96 per cent as the lateral distance increased from 15 to 60 cm. Root activity declined with increase in lateral distance and depth. When depth alone was considered it was found that 62.69 per cent of the roots explored a vertical space of 15 cm. About 25.12 per cent of the roots were seen at 30 cm depth and was considerably less at 60 cm depth (1.52%).

With respect to combination of lateral distance and depth, it was seen that most of the active roots (33.56%) of Mauritius lay within 15 cm surface soil layer and 15 cm around the plant followed by a soil zone comprising of 15 cm lateral distance and 30 cm depth (19.2%). The minimum percentage of active roots (0.08%) was seen 60 cm away and 60 cm deep from the plant base.

4.2.2.4 Pattern of root activity in pineapple variety Mauritius grown under trench planting 30 days after ^{32}P application

Percentage distribution of active roots of variety Mauritius grown under trench planting is presented in Table 17.

The data revealed that 62.33 per cent of the active roots confined to a lateral distance of 15 cm followed by 30 cm (33.42%). The minimum percentage of active roots (1.13%) was seen 60 cm away from the plant. The vertical distance was mainly confined to a depth of 15 cm (75.83%). The soil layer of 30 cm contributed 18.34 per cent of the active roots below which root activity declined sharply with 0.93 per cent at 60 cm depth.

When the combination of lateral distance and depth was considered it was found that 49.64 per cent of the active roots of Mauritius grown in trenches concentrated in a soil zone constituting 15 cm lateral distance and 15 cm depth. The least root activity was observed 60 cm away from the plant and at a depth of 60 cm with only 0.11 per cent of the roots concentrating there.

Table 17. Root activity (%)of variety Mauritius grown under trench method 30 days after ^{32}P application

Depth (cm)	Root activity (%)				
	Lateral distance (cm)				
	15	30	45	60	Total
15	49.64	24.65	1.23	0.31	75.83
30	10.86	6.60	0.47	0.41	18.34
45	1.27	2.04	1.29	0.30	4.90
60	0.56	0.13	0.13	0.11	0.93
Total	62.33	33.42	3.12	1.13	

Table 18. Root activity (%) of pineapple at 45 days after ^{32}P application as influenced by lateral distance and depth

Depth (cm)	Lateral distance (cm)				
	15	30	45	60	Total
15	39.99	18.43	8.41	1.55	68.38
30	10.48	2.27	2.78	1.46	16.99
45	2.04	2.28	3.45	1.63	9.40
60	1.95	1.07	1.33	0.88	5.23
Total	54.46	24.05	15.97	5.52	

Table 19. Root activity (%) of variety of Kew grown under surface method 45 days after ^{32}P application

Depth (cm)	Root activity (%)				
	Lateral distance (cm)				
	15	30	45	60	Total
15	30.52	27.58	15.90	1.34	75.34
30	4.16	0.92	3.13	1.22	9.43
45	3.63	0.38	2.63	2.33	8.97
60	0.78	1.77	2.14	1.57	6.26
Total	39.09	30.65	23.80	6.46	

4.2.3 Pattern of root activity in pineapple 45 days after application of ^{32}P

The data on percentage distribution of active roots in pineapple 45 days after application of ^{32}P as influenced by lateral distance and depth are presented in Table 18 and Fig. 10.

It was noticed from the data that among the various lateral distances tried 15 cm showed highest percentage of active roots (54.46%) followed by 30 cm (24.05%). The percentage root activity was only 5.52 per cent 60 cm away from the plant. The vertical spread of the roots indicated that 68.38 per cent of the roots explored the surface soil layer of 15 cm followed by 16.99 of the roots at 30 cm. The root activity was least at 60 cm depth (5.23 %).

When combination of lateral distance and depth was considered it was found that the most active root zone of pineapple 45 days after application of ^{32}P was found to be 15 cm away from the plant and reaching to a depth of 15 cm with 39.99 per cent of the roots concentrating there. The soil zone comprising 60 cm radial distance and 60 cm depth accounted the lowest percentage (0.88%) of active roots.

4.2.3.1 Pattern root activity in pineapple variety Kew grown under surface planting 45 days after ^{32}P application

Data pertaining to the percentage root distribution of Kew under surface planting is shown in Table 19.

It was observed from the data that ^{32}P when placed 15 cm away from the plant accommodated 39.09 per cent of the roots. When depth alone was considered it was noticed that there is a concentration of active roots at shallow depth of 15 cm (75.34%). The percentage of active roots at 60 cm depth was only 6.26 per cent.

When the combinations of lateral distances and depth were considered it was observed that the density of active roots of Kew planted on surface was more confined to 15 cm radial distance at a depth of 15 cm (30.52%) and was found to be negligible (0.38%) at a zone of 30 cm lateral distance and 45 cm depth.

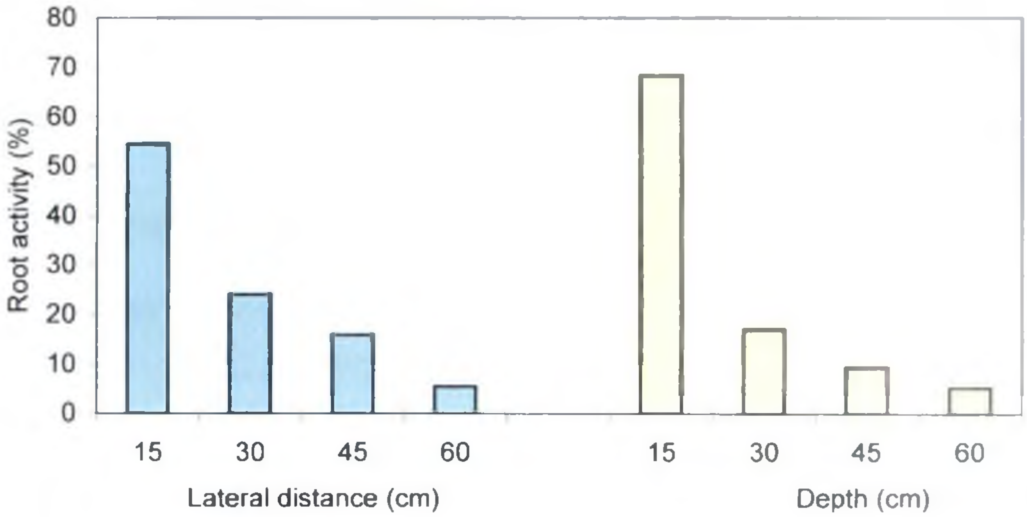


Fig. 10. Root activity (%) of pineapple 45 days after ^{32}P application as influenced by lateral distance and depth

4.2.3.2 Pattern of root activity in pineapple variety Kew grown under trench planting 45 days after ^{32}P application

Table 20 represent the percentage distribution of active roots of variety Kew grown under trench planting.

It was seen from the data that 57.73 per cent of the roots confined to a lateral distance of 15 cm followed by 45 cm (18.5%). The root activity was least at 60 cm away from the plant base (8.02 %). With respect to depth, the soil layer of 15 cm contributed 53.99 per cent of the root activity. Appreciable amount of active roots (23.01%) were seen at 30 cm depth with the least (8.52%) from a depth of 60 cm.

When lateral distance and depth combination was considered it was observed that 38.63 per cent of the active roots were seen 15 cm laterally around the plant at 15 cm depth. The least active root zone (0.68%) was found to be 30 cm radially at a depth of 60 cm.

4.2.3.3 Pattern of root activity in pineapple variety Mauritius grown under surface planting 45 days after ^{32}P application

The data on the percentage distribution of active roots of Mauritius grown under surface planting is furnished in Table 21.

The data indicated that 54.17 per cent of the active roots were seen 15 cm away from the plant. The minimum percentage of active roots (5.09%) were seen 60 cm away from the plant. When depth alone was considered 68.59 per cent of the roots were seen on the surface soil layer of 15 cm. The soil layer of 30 cm contributed 22.17 per cent of active roots. The least root activity (3.09%) was observed at 60 cm depth.

When the combination of lateral distance and depth was considered it was found that the most active root zone of Mauritius grown in trenches was the soil zone constituting 15 cm laterally and vertically (35.73%). The least activity was observed from the treatment 60 cm away from the plant at a depth of 60 cm (0.13%).

Table 20. Root activity (%) of variety Kew grown under trench method at 45 days after ^{32}P application

Depth (cm)	Root activity (%)				
	Lateral distance (cm)				
	15	30	45	60	Total
15	38.63	7.46	6.76	1.14	53.99
30	12.05	4.36	3.39	3.21	23.01
45	2.64	3.25	6.20	2.39	14.48
60	4.41	0.68	2.15	1.28	8.52
Total	57.73	15.75	18.50	8.02	

Table 21. Root activity (%) of variety Mauritius grown under surface method 45 days after ^{32}P application

Depth (cm)	Root activity (%)				
	Lateral distance (cm)				
	15	30	45	60	Total
15	35.73	21.38	8.02	3.46	68.59
30	16.25	1.54	3.61	0.77	22.17
45	0.51	3.38	1.53	0.73	6.15
60	1.68	0.73	0.55	0.13	3.09
Total	54.17	27.03	13.71	5.09	

Table 22. Root activity (%) of variety Mauritius grown under trench method 15 days after ^{32}P application

Depth (cm)	Root activity (%)				
	Lateral distance (cm)				
	15	30	45	60	Total
15	55.11	17.31	2.95	0.26	75.63
30	9.47	2.28	1.00	0.63	13.38
45	1.37	2.11	3.42	1.08	7.98
60	0.93	1.10	0.48	0.50	3.01
Total	66.88	22.80	7.85	2.47	

4.2.3.4 Percentage distribution of root activity of variety Mauritius grown under trench planting 45 days after ^{32}P application

The data related to the percentage distribution of active roots of pineapple grown under trench planting is presented in Table 22.

With respect to lateral distances, 66.88 per cent of the root activity was seen 15 cm away from the plant with only 2.47 per cent of the root activity at 60 cm distance. When the vertical spread was considered it was found that 75.63 per cent of the active roots concentrated in a layer of 15 cm. The root activity at 30 cm depth was found to be 13.38 per cent with the least (3.01) at 60 cm soil layer.

When combination of lateral distance and depth was considered it was found that Mauritius grown in trenches showed the highest percentage of roots (55.11%) at 15 cm lateral distance and 15 cm depth. The least root activity (0.26%) was observed 60 cm laterally and at 15 cm depth.

4.2.4 Mean root activity pattern of pineapple for three sampling dates

The mean root activity of pineapple for all the 3 sampling dates at different lateral distance and depth is furnished in Table 23.and Fig.11

Among the various lateral distances considered irrespective of the sampling dates, 61.38 per cent of the root activity was seen 15 cm away from the plant followed by 30 cm (21.68%). Root activity was found to be very low (3.16%) at 60 cm lateral distance. When depth alone was considered it was found that 73.21 per cent of the active roots concentrate at a depth of 15 cm. The soil layer of 30 cm accommodated 17.41 per cent of the root activity with the least from a depth of 60 cm (3.09%).

When combination of lateral distance and depth was considered, it was seen that the most active root zone was 15 cm away from the plant and at a depth of 15 cm with 45.91 per cent of the roots concentrating there (Fig.12.) The zone of 30 cm lateral distance and 15 cm depth contributed 16.89% of the active roots. The least root activity was observed at a lateral and vertical distance of 60 cm (0.49%).

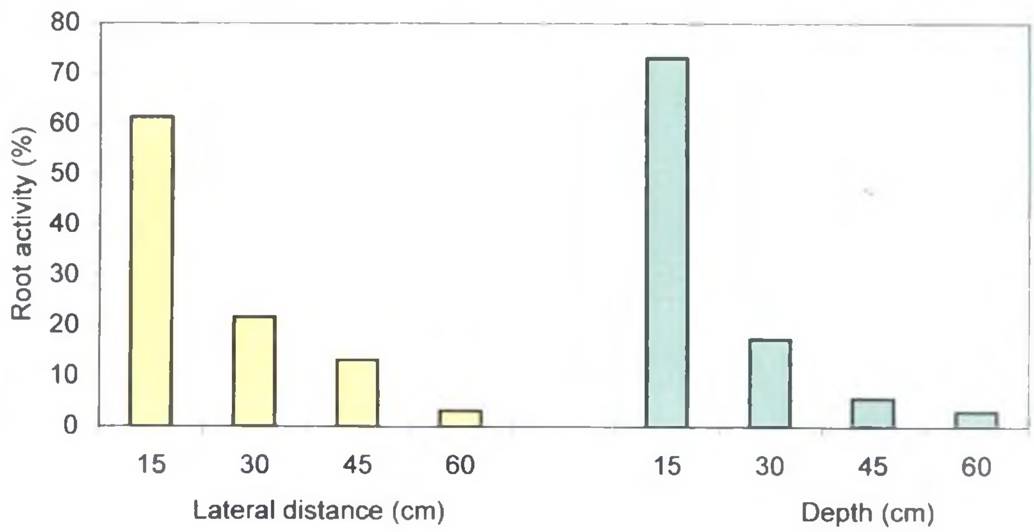


Fig. 11. Root activity (%) of pineapple at different lateral distances and depth (Mean of three sampling intervals)

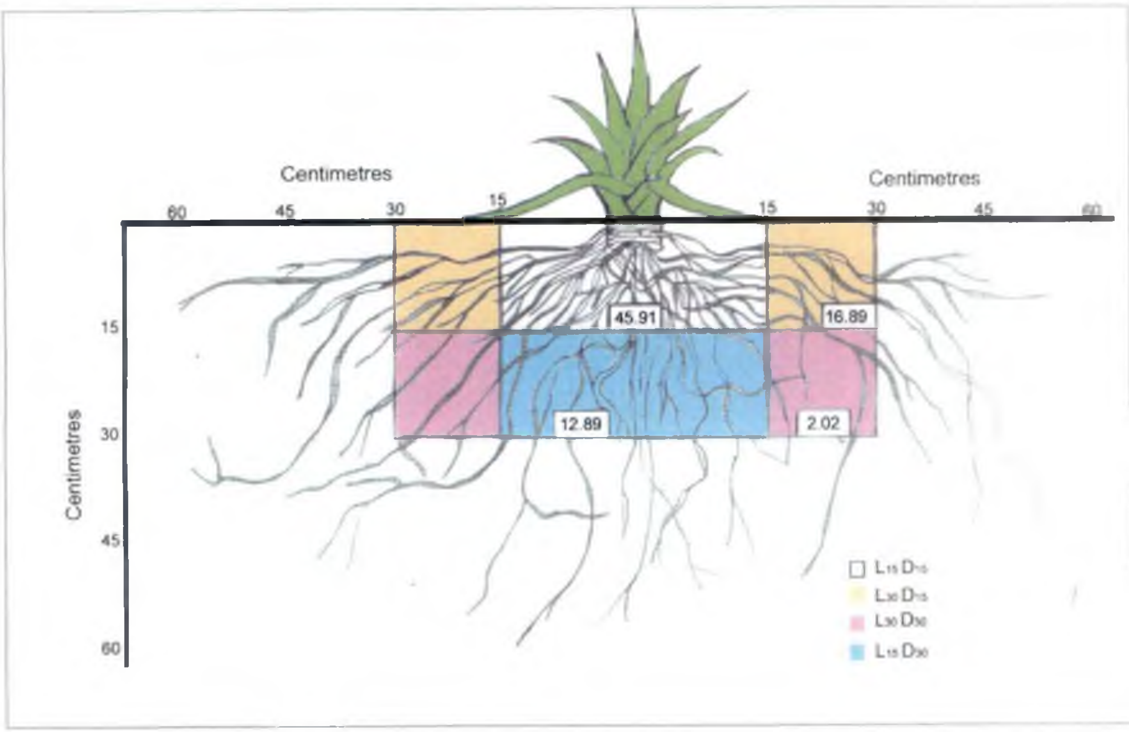


Fig. 12. Root activity pattern of pineapple [*Ananas comosus* (L.) Merr.]

Table 23. Root activity (%) of pineapple at different lateral distances and depth (Mean of three sampling intervals)

Depth (cm)	Root activity (%)				
	Lateral distance (cm)				
	15	30	45	60	Total
15	45.91	16.89	9.29	1.12	73.21
30	12.89	2.02	1.69	0.81	17.41
45	1.33	2.22	1.36	0.74	5.65
60	1.25	0.55	0.80	0.49	3.09
Total	61.38	21.68	13.14	3.16	

Table 24. Root activity (%) of pineapple at $L_{30}D_{30}$

	Root activity (%)								
	15 DAA		30 DAA		45 DAA		Mean		Overall mean
	Surface	Trench	Surface	Trench	Surface	Trench	Surface	Trench	
Kew	74.85	87.87	72.53	76.53	63.18	62.50	70.19	75.63	72.91
Mauritius	80.63	91.91	72.03	91.75	74.90	84.17	75.85	89.28	82.57
Mean	77.74	89.89	72.28	84.14	69.04	73.30	73.02	82.46	

Table 25. Root growth of pineapple under different methods of planting

Treatment	Number of roots	Length of roots (cm)	Diameter (cm)	Fresh weight (g)	Dry weight (g)
V_1M_1	47	23.56	0.52	59.5	16.08
V_1M_2	62	25.62	0.57	63.83	20.10
V_2M_1	71	25.33	0.55	66.33	25.41
V_2M_2	55	23.76	0.55	61.33	18.20

V_1 - Kew　　M_1 - Surface planting
V_2 - Mauritius　　M_2 - Trench planting

4.2.5 Root activity (%) of pineapple at $L_{30}D_{30}$

The data on Table 24 represent the root activity of the two pineapple varieties Kew and Mauritius at the active root zone where more than 80 per cent of the active roots were seen. From the table it was observed that variety Mauritius showed highest root activity at all the sampling intervals. When the different planting systems were considered it was found that trench method of planting showed highest root activity.

4.3 Root Excavation Studies

Data on root growth of pineapple estimated by root excavation technique is presented in Table 25 and in Plates 8 to 11. The data indicated that there was difference in the number of roots of two varieties of pineapple grown under different systems of planting. The highest number of roots (71) was obtained from the treatment V_2M_1 (Mauritius grown under surface method) followed by V_1M_2 (Kew grown under trench method) with a value of 61. The least value (47) was showed by the treatment V_1M_1 (Kew grown on surface).

With respect to length of roots, it was observed that length varied between 23.56 cm and 25.62 cm. When diameter of roots was considered it was found that the diameter varied between 0.52 cm and 0.57 cm.

When the fresh weight and dry weight of the roots were considered it was found that Mauritius grown under surface method recorded the highest value of 56.33g and 25.41g respectively. The least value was recorded by variety Kew grown under surface method with a fresh weight of 49.5 and dry weight of 16.08.

4.4 Vegetative and Flowering Characters

The vegetative characters as well as the flowering characters of pineapple variety Kew and Mauritius grown under two methods of planting and under two planting densities are presented here under.

Plate 8. Root distribution pattern of pineapple variety Kew grown under surface planting

Plate 9. Root distribution pattern of pineapple variety Kew grown under trench planting

Plate 10. Root distribution pattern of pineapple variety Mauritius grown under surface planting

Plate 11. Root distribution pattern of pineapple variety Mauritius grown under trench planting

4.4.1 Plant characters

Plant characters namely the vegetative characters as influenced by variety, method of planting and planting densities adopted are given below.

4.4.1.1 Plant height

Data pertaining to the mean plant height at six months after planting is presented in Table 26.

It was observed from the data that there was no significant difference in treatment means between the varieties Kew and Mauritius and also the two planting densities adopted. However method of planting showed significant difference. Trench planting was found to be superior to surface planting. The interaction of all the factors (variety, method of planting, planting density) did not show any significant difference.

4.4.1.2 Number of leaves

Data on the mean number of leaves per plant at six months after planting as influenced by variety, method of planting and planting density are given in Table 27.

The data indicated that the maximum number of leaves was produced by variety mauritius (40.17) than Kew (32.67) eventhough no significant difference was noticed. The interaction effect of different factors were also observed to be non significant.

4.4.1.3 'D' Leaf length

Data depicting the effect of treatments on length of 'D' leaf at six months after planting are presented in Table 28.

Data indicated that there existed no significant difference between the two varieties in the length of 'D' leaf. Planting density also did not show any significant difference. However method of planting was found to differ significantly. Trench planting showed maximum 'D' leaf length (70.18 cm).

Table 26. Effect of treatments on plant height of pineapple six months after planting

Plant height(cm)							
	Kew (V_1)		Mean	Mauritius (V_2)		Mean	Overall mean
	High density (P_1)	Low density (P_2)		High density (P_1)	Low density (P_2)		
Surface (M_1)	83.53	84.40	83.93	94.83	99.90	97.37	90.67
Trench (M_2)	89.17	88.63	88.90	96.83	100.20	98.52	93.71
Mean	86.35	86.52	86.44	95.83	100.05	97.95	92.19

Variety (V) - NS
Planting density (P) - NS
Method of planting (M) - Significant
Interaction effect (V x P x M) - NS

Table 27. Effect of treatments on number of leaves of pineapple at six months after planting

Number of leaves							
	Kew (V_1)		Mean	Mauritius (V_2)		Mean	Overall mean
	High density (P_1)	Low density (P_2)		High density (P_1)	Low density (P_2)		
Surface (M_1)	30.33	31.67	31.00	39.67	39.67	39.67	35.34
Trench (M_2)	35.00	33.67	34.34	42.67	38.67	40.67	37.51
Mean	32.67	32.67	32.67	41.17	39.17	40.17	36.42

Variety (V) - NS
Planting density (P) - NS
Method of planting (M) - NS
Interaction effect (V x P x M) - NS

Table 28. Effect of treatments on 'D' leaf length of pineapple 6 months after planting

'D' leaf length(cm)							
	Kew (V_1)		Mean	Mauritius (V_2)		Mean	Overall mean
	High density (P_1)	Low density (P_2)		High density (P_1)	Low density (P_2)		
Surface (M_1)	62.82	64.68	63.75	72.08	72.72	72.40	68.08
Trench (M_2)	65.90	66.27	66.09	75.47	73.04	74.26	70.18
Mean	64.36	65.48	64.92	73.78	72.88	73.33	69.13

Variety (V) - NS
Planting density (P) - NS
Method of planting (M) - Significant
Interaction effect (V x P x M) - NS

Table 29. Effect of treatments on 'D' leaf breadth of pineapple 6 months after planting

'D' leaf breadth(cm)							
	Kew (V_1)		Mean	Mauritius (V_2)		Mean	Overall mean
	High density (P_1)	Low density (P_2)		High density (P_1)	Low density (P_2)		
Surface (M_1)	3.92	3.81	3.87	4.76	5.01	4.89	4.38
Trench (M_2)	4.29	4.00	4.15	5.52	5.30	5.41	4.78
Mean	4.11	3.91	4.01	5.14	5.16	5.15	4.58

Variety (V) - Significant
Planting density (P) - NS
Method of planting (M) - Significant
Interaction effect (V x P x M) - NS

4.4.1.4 'D' leaf breadth

Data pertaining to the width of 'D' leaf as influenced by the various treatments are shown in Table 29.

It was observed that the width of 'D' leaf varied from 3.92 cm ($V_1P_1M_1$) to 5.52 cm. ($V_2P_1M_2$). When variety was taken into consideration it was found that there exist significant difference between Kew and Mauritius in 'D' leaf breadth. Kew recorded maximum value (5.15cm). Planting density showed no significant difference. However method of planting exhibited significant difference in 'D' leaf breadth. It was found to be higher in trench planting. The interaction effect was found to be non significant.

4.4.2 Flowering characters

Data on the influence of various treatments on the flowering characters are presented here under.

4.4.2.1 Days for initiation of flowering

Data on the days for initiation of flowering as influenced by different varieties, planting methods and density of planting are furnished in Table 30.

From the table it was noticed that the varieties Kew and Mauritius differed significantly in the days taken for initiation of flowering. In Kew it was found to be 44.25 days while Mauritius took only 32.13 days for initiation of flowering. Interaction effect was found to be non significant.

4.4.2.2 Days for 50 per cent flowering in pineapple

Data on the effect of various treatments on the days taken for 50 per cent flowering are presented in Table 31.

From the data it was found that only varieties showed significant difference. Kew took 49.25 days while Mauritius took only 37.00 days. Planting density, method of planting and interaction of all the factors were found to be non significant.

Table 30. Effect of treatments on days for initiation of flowering in pineapple

Days for initiation of flowering							
	Kew (V_1)		Mean	Mauritius (V_2)		Mean	Overall mean
	High density (P_1)	Low density (P_2)		High density (P_1)	Low density (P_2)		
Surface (M_1)	44.33	44.33	44.33	31.00	32.00	31.50	37.92
Trench (M_2)	41.00	47.33	44.17	31.33	34.17	32.75	38.46
Mean	42.67	45.83	44.25	31.17	33.09	32.13	38.19

Variety (V) - Significant
Planting density (P) - NS
Method of planting (M) - NS
Interaction effect (V x P x M) - NS

Table 31. Effect of treatments on days for 50 per cent flowering in pineapple

Days for 50 per cent flowering							
	Kew (V_1)		Mean	Mauritius (V_2)		Mean	Overall mean
	High density (P_1)	Low density (P_2)		High density (P_1)	Low density (P_2)		
Surface (M_1)	49.33	51.10	50.17	36.33	37.67	37.00	37.33
Trench (M_2)	48.67	48.00	48.33	35.33	38.67	37.00	37.83
Mean	49.00	49.50	49.25	35.83	38.17	37.00	37.58

Variety (V) - Significant
Planting density (P) - NS
Method of planting (M) - NS
Interaction effect (V x P x M) - NS

Table 32. Effect of treatments on flowering phase of pineapple

Flowering phase							
	Kew (V_1)		Mean	Mauritius (V_2)		Mean	Overall mean
	High density (P_1)	Low. density (P_2)		High density (P_1)	Low density (P_2)		
Surface (M_1)	17.33	17.67	17.50	11.33	11.67	11.50	14.50
Trench (M_2)	16.00	17.67	16.84	13.33	13.33	13.33	15.09
Mean	16.67	17.67	17.17	12.33	12.50	12.42	14.79

Variety (V) - Significant
Planting density (P) - NS
Method of planting (M) - NS
Interaction effect (V x P x M) - NS

4.4.2.3 Flowering phase

Data on flowering phase as affected by various treatments are given in Table 32.

The data revealed that there exist significant difference in the flowering phase of Kew and Mauritius. In Kew the flowering phase lasted for 17.17 days while in Mauritius it was 12.42 days. Method of planting and planting density did not show any significant difference. The interaction effect was also found to be non significant.

4.5 Uptake of ^{32}P by two varieties of pineapple under different systems of planting

Data pertaining to the uptake of ^{32}P by Kew and Mauritius grown in trenches as well as at ground level under high density planting and low density planting is furnished in Table 33 and Fig. 13.

It was seen from the data that there was no significant difference between the two varieties with respect to ^{32}P uptake. However variety Mauritius recorded highest absorption of ^{32}P. When the different methods of planting was considered irrespective of variety and planting density, it was found that the trench method of planting was significantly superior to surface method of planting in ^{32}P uptake. It was also observed that there was no significant difference between the two planting densities adopted. Regarding interaction effect there was no significant difference between the treatment means.

4.5.1 Uptake of ^{32}P by treated and non treated plants of pineapple

Absorption of ^{32}P by treated as well as untreated pineapple plants grown under high density system of planting is presented in Table 34 and Fig. 14-17. When uptake of ^{32}P by the treated plants were considered, Mauritius grown under surface planting recorded the highest absorption followed by Mauritius grown under trench method.The least absorption was by the variety Kew grown in trenches. It was observed from the data that the applied ^{32}P was absorbed not only by the plant which received the treatment but also by the neighbouring plants.

Table 33. Uptake of ^{32}P (dpm/g leaf) by treated plants of pineapple grown under different systems of planting

	*Uptake of ^{32}P (dpm/g leaf)						
	Kew (V_1)			Mauritius (V_2			Overall mean
	High density planting (P_1)	Low density of planting (P_2)	Mean	High density planting (P_1)	Low density of planting (P_2)	Mean	
Surface planting (M_1)	4.424 (26546.055)	4.016 (10375.284)	4.22 (16595.87)	4.576 (37670.379)	3.622 (4187.936)	4.099 (51951.3005)	4.1595 (14437.766)
Trench planting (M_2)	5.287 (193642.196)	4.387 (24378.108)	4.837 (68706.844)	5.298 (198609.492)	4.952 (89536.477)	5.125 (133352.143)	4.981 (95719.41)
Mean	4.855 (71696.837)	4.202 (15903.767)	4.528 (33767.585)	4.937 (86496.792)	4.287 (19364.219)	4.612 (40926.066)	

CD(0.05) for comparison of

- Variety (V) - NS
- Method of planting (M) - 0.4709
- Planting density (P) - NS
- Interaction effect - NS

*Log transformed values

Values in Paranthesis indicate retransformed values

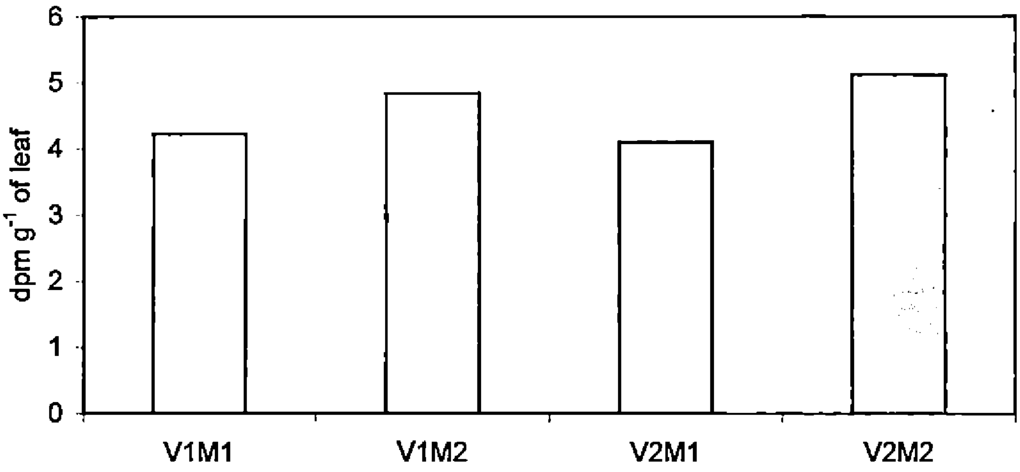


Fig. 13. Uptake of P^{32} (dpm g^{-1} of leaf) by treated plants of pineapple grown under different systems of planting

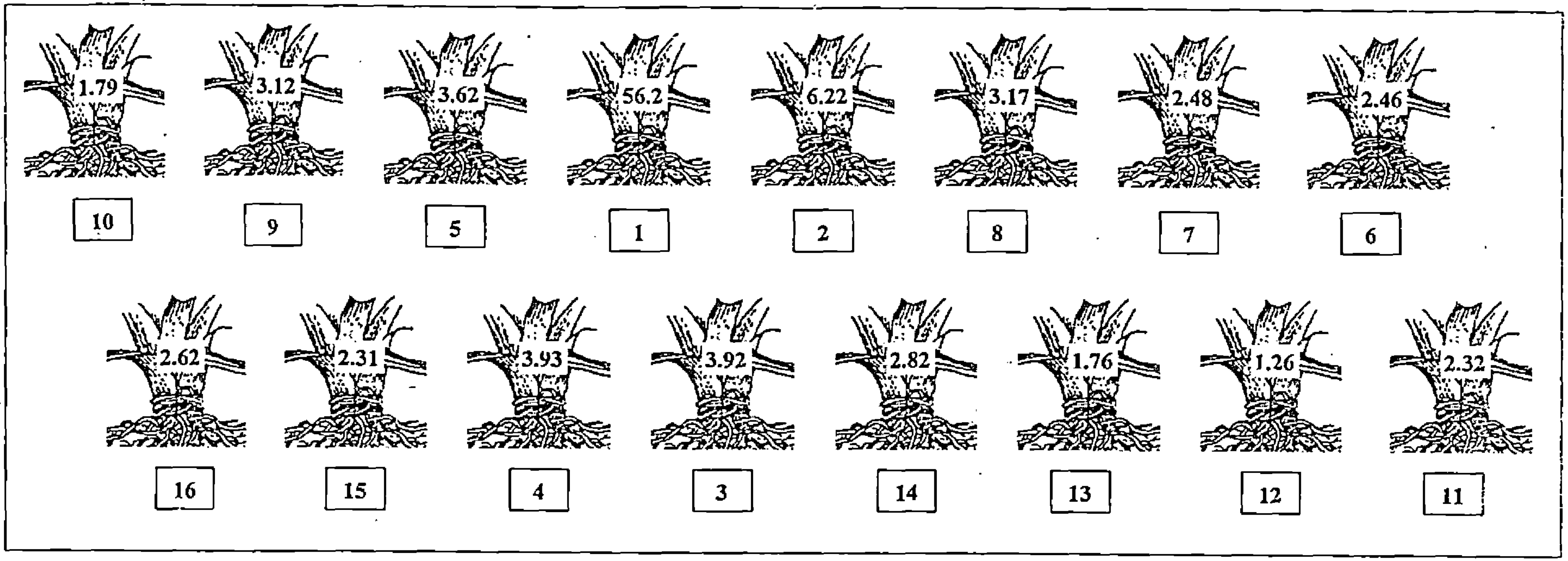
Table 34. Uptake of ^{32}P (dpm/g leaf) by treated and non treated plants of pineapple grown under high density system of planting

Uptake of ^{32}P (dpm/g leaf)																		
Treat-ments	Treated plant	Contact plants				Total 2+3+4 +5	Neighbouring plants											Total 6+7+8+ 9+10+11+ 12+13+14+ 15+16	Total
	1	2	3	4	5		6	7	8	9	10	11	12	13	14	15	16		
$V_1P_1M_1$	28658 (56.2)	3173 (6.22)	2000 (3.92)	2005 (3.93)	1847 (3.62)	9025 (17.69)	1256 (2.46)	1266 (2.48)	1614 (3.17)	1590 (3.12)	916 (1.79)	1184 (2.32)	643 (1.26)	898 (1.76)	1437 (2.82)	1180 (2.31)	1335 (2.62)	13319 (26.11)	51002
$V_1P_1M_2$	262287 (34.56)	90020 (11.86)	139994 (18.45)	27788 (3.66)	114616 (15.1)	372418 (49.07)	962 (0.13)	1487 (0.2)	13268 (1.75)	8518 (1.12)	1538 (0.20)	1098 (0.14)	1223 (0.16)	7129 (0.94)	51111 (6.74)	36720 (4.84)	1052 (0.14)	124106 (16.36)	758811
$V_2P_1M_1$	99072 (68.35)	18805 (12.97)	3225 (2.22)	2052 (1.41)	8128 (5.61)	32210 (22.21)	1155 (0.79)	694 (0.50)	1565 (1.08)	2265 (1.56)	1283 (0.88)	897 (0.62)	836 (0.58)	1001 (0.69)	1443 (0.99)	1563 (1.08)	974 (0.67)	13676 (9.44)	144958
$V_2P_1M_2$	268311 (59.41)	72698 (16.07)	34440 (7.62)	20265 (4.50)	23008 (5.10)	150411 (33.31)	692 (0.15)	771 (0.17)	16417 (3.64)	1871 (0.41)	898 (0.20)	557 (0.12)	1052 (0.23)	896 (0.20)	7308 (1.62)	1586 (0.35)	844 (0.18)	32892 (7.27)	451614

V_1 - Kew M_1 – Surface P_1-High density
V_2 - Mauritius M_2 – Trench P_2-Low density

Values in Paranthesis indicate percentage absorption of ^{32}P

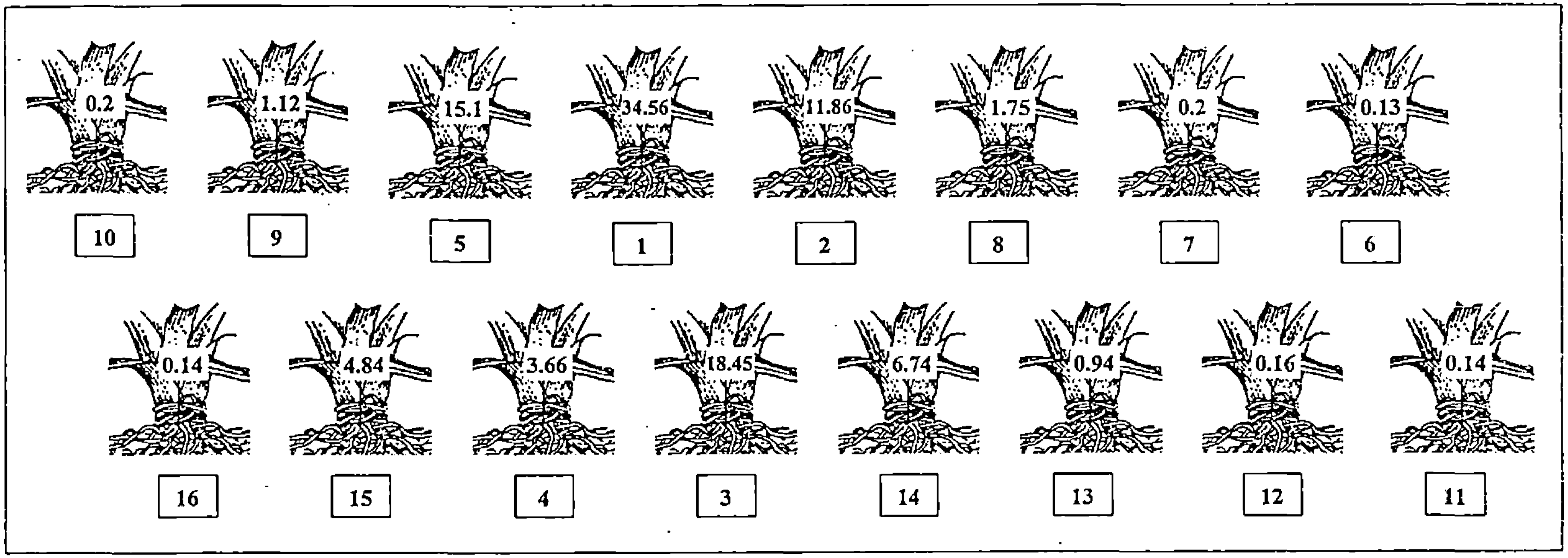
Fig. 14. Percentage absorption of applied ^{32}P among treated and neighbouring plants in Kew (V_1) at high density (P_1) surface planting (M_1)



Values given on the plant indicate percentage absorption of ^{32}P.
Values given in boxes indicate the plant number.

Plant No.I : Treated plant
Plant No.2 – 5 : Contact plants
Plant No.6 – 16 : Neighbouring plants

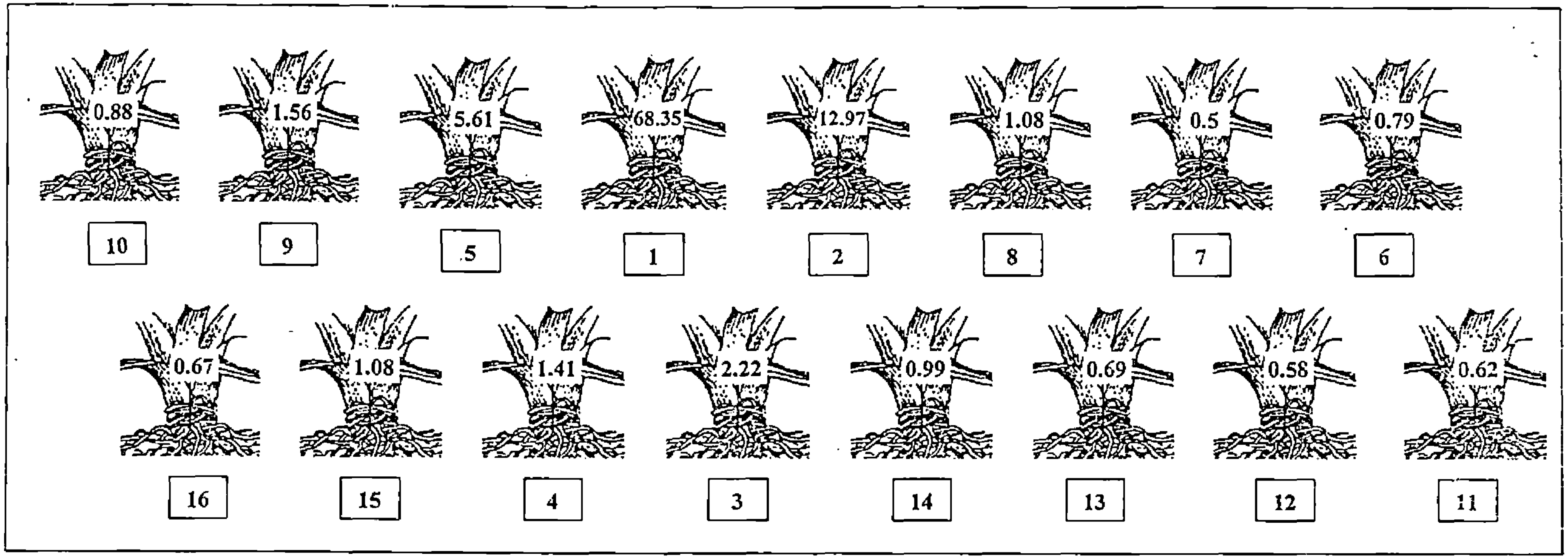
Fig. 15. Percentage absorption of applied ^{32}P among treated and neighbouring plants in Kew (V_1) at high density (P_1) trench planting (M_2)



Values given on the plant indicate percentage absorption of ^{32}P.
Values given in boxes indicate the plant number.

Plant No.I : Treated plant
Plant No.2 – 5 : Contact plants
Plant No.6 – 16 : Neighbouring plants

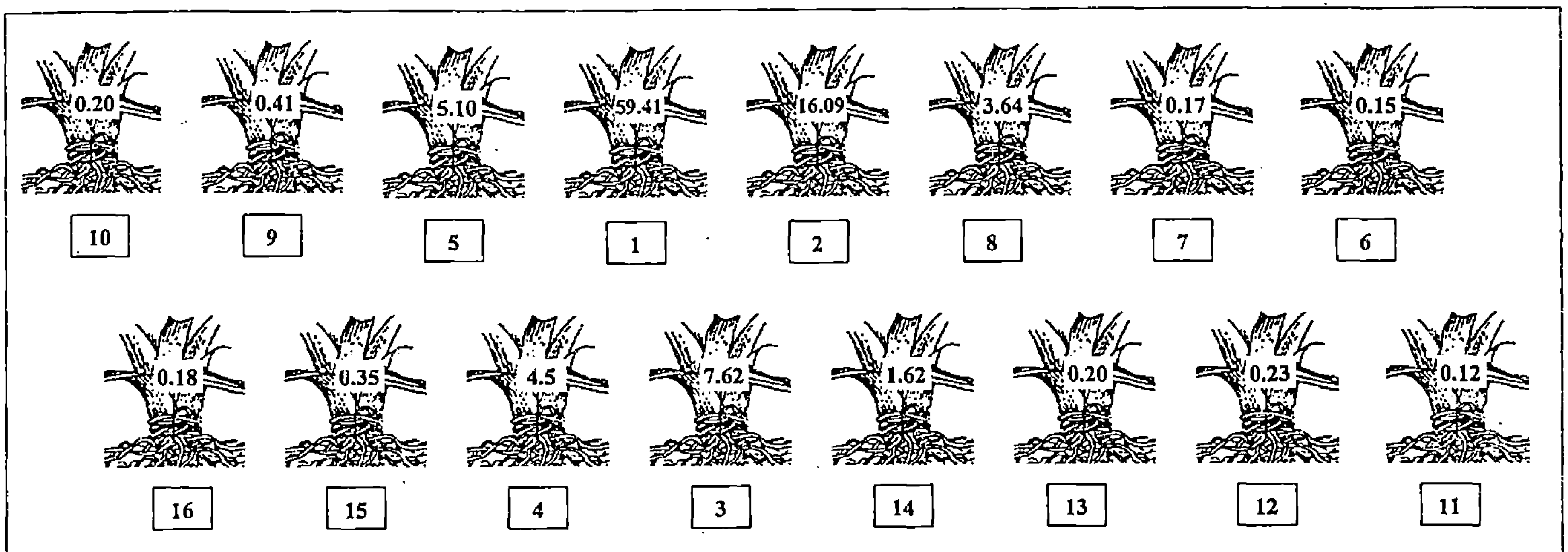
Fig. 16. Percentage absorption of applied ^{32}P among treated and neighbouring plants in Mauritius (V_2) at high density (P_1) surface planting (M_1)



Values given on the plant indicate percentage absorption of ^{32}P.
Values given in boxes indicate the plant number.

Plant No.1 : Treated plant
Plant No.2 – 5 : Contact plants
Plant No.6 – 16 : Neighbouring plants

Fig. 17. Percentage absorption of applied ^{32}P among treated and neighbouring plants in Mauritius (V_2) at high density (P_1) trench planting (M_2)



Values given on the plant indicate percentage absorption of ^{32}P.
Values given in boxes indicate the plant number.

Plant No.I : Treated plant
Plant No.2 – 5 : Contact plants
Plant No.6 – 16 : Neighbouring plants

The data showed that in variety Kew grown under surface planting, the highest absorption of ^{32}P was by the treated plant which accounted 56.2 per cent of the total absorbed ^{32}P. The next highest counts were obtained for the 4 contact plants, which together contributed 17.69 per cent of the activity. The least count was obtained from Plant No.12 which accounted only 1.26 per cent of the total absorbed ^{32}P. The eleven neighbouring plants (6-16) together contributed 26.11 per cent of the total ^{32}P recovered.

The extent of absorption of ^{32}P by the treated plant of Kew grown in trenches was found to be 34.56 per cent followed by the plants numbered 3, 5 and 2, which were the contact plants. These four contact plants together contributed 49.07 per cent of the total recovery. Other neighbouring plants together accounted 16.36 per cent of the total activity, with very less activity from plants numbered 6, 11 and 16 which were the farthest plants.

When applied to Mauritius grown under surface planting, 68.35 per cent of the radio activity absorbed in the system was recovered in the treated plant and 22.21 per cent in the four contact plants. Among the contact plants, Plant No.2 showed highest counts of ^{32}P with 12.97 per cent of the total activity concentrating there. The other eleven neighbouring plants together accounted for only 9.44 per cent of the total ^{32}p absorbed .

Application of ^{32}P to Mauritius grown in trenches resulted in highest counts of ^{32}P with 59.41 per cent of the total recovery in the applied plant itself. The next best counts were obtained from plant No.2 and accounted for 16.09 per cent of the applied ^{32}P followed by the plants numbered 3, 5 and 4 which were the 4 contact plants. They together contributed 33.31 per cent of the total ^{32}P recovered and the other eleven plants in the same trench accounted only 7.27 per cent.

Data on the relative uptake of applied ^{32}P by the treated and non treated plants of pineapple grown under low density system of planting is presented in Table 35 and Fig. 18-21.

It was observed from the table that when uptake of ^{32}P by the treated plant was considered, the highest absorption of the applied activity was by the

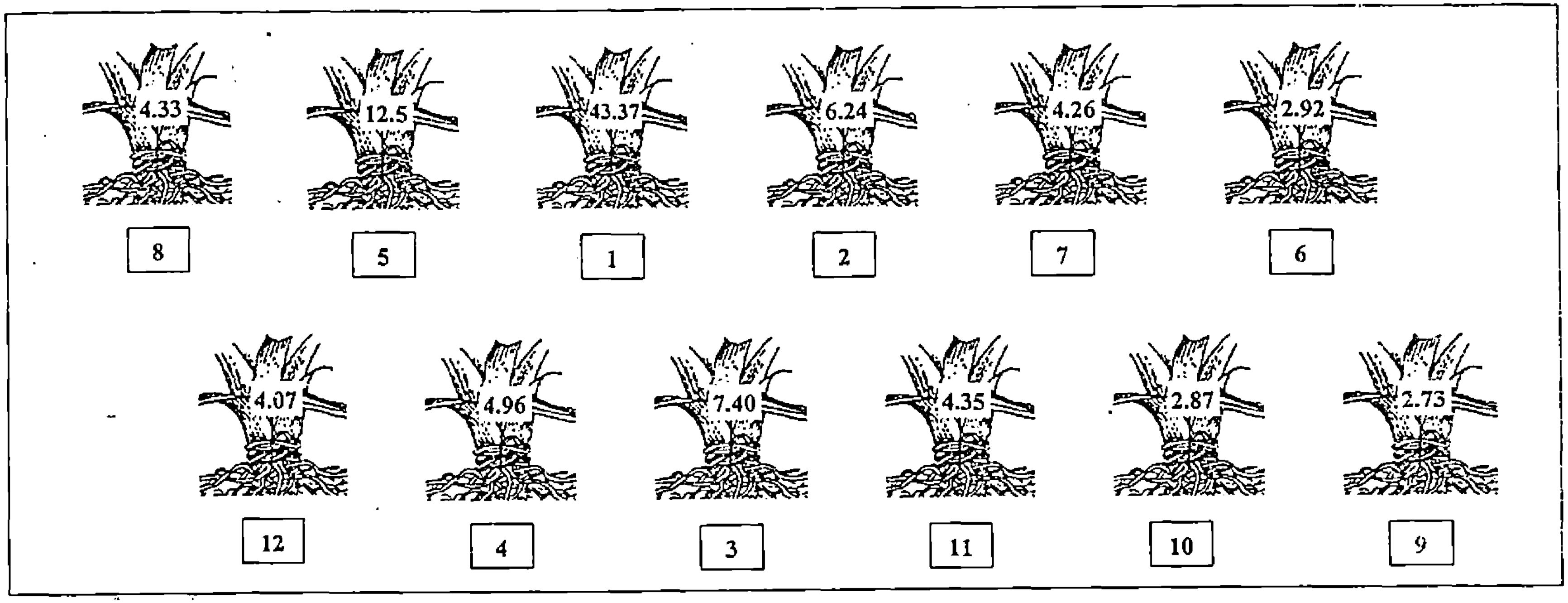
Table 35. Uptake of ^{32}P (dpm/g leaf) by treated and nontreated plants of pineapple grown under low density system of planting

Uptake of ^{32}P (dpm/g leaf)															
Treat-ments	Treated plant	Contact plant				Total 2+3+4+5	Neighbouring plants							Total 6+7+9+10+11+12	Total
	1	2	3	4	5	5	6	7	8	9	10	11	12		
$V_1P_2M_1$	12011 (43.37)	1729 (6.24)	2043 (7.40)	1374 (4.96)	3462 (12.5)	8608 (31.10)	809 (2.92)	1180 (4.26)	1201 (4.33)	756 (2.73)	795 (2.87)	1205 (4.35)	1128 (4.07)	7074 (25.53)	27693
$V_1P_2M_2$	73720 (57.58)	7055 (5.51)	9237 (7.21)	15017 (11.73)	13544 (10.58)	44853 (35.03)	1003 (0.78)	2357 (1.84)	1690 (1.32)	575 (0.45)	898 (0.70)	1549 (1.21)	1384 (1.08)	9456 (7.38)	128029
$V_2P_2M_1$	4831 (24.39)	3192 (16.11)	1128 (5.69)	1513 (7.64)	1842 (9.3)	7675 (38.75)	1018 (5.14)	1182 (6.00)	642 (3.24)	975 (4.92)	1430 (7.22)	923 (4.66)	1128 (5.69)	7298 (36.85)	19804
$V_2P_2M_2$	118272 (79.91)	1421 (0.96)	3315 (2.24)	3443 (2.33)	14111 (9.53)	22290 (15.06)	1129 (0.76)	1178 (0.79)	1077 (0.73)	1175 (0.79)	898 (0.61)	880 (0.59)	1114 (0.75)	7451 (5.03)	148013

V_1 - Kew M_1 – Surface P_1-High density
V_2 - Mauritius M_2 – Trench P_2-Low density

Values in Paranthesis indicate percentage absorption of ^{32}P

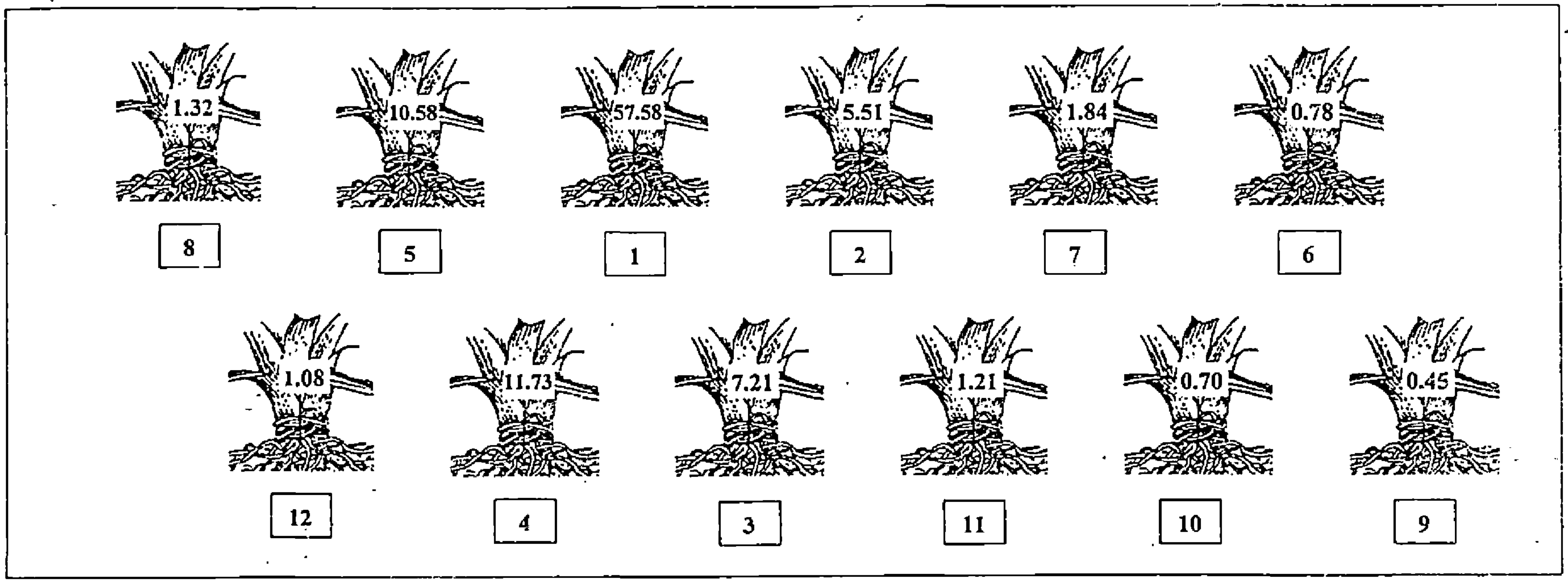
Fig. 18. Percentage absorption of applied ^{32}P among treated and neighbouring plants in Kew (V_1) at low density (P_2) surface planting (M_1)



Values given on the plant indicate percentage absorption of ^{32}P.
Values given in boxes indicate the plant number.

Plant No.I : Treated plant
Plant No.2 – 5 : Contact plants
Plant No.6 – 12 : Neighbouring plants

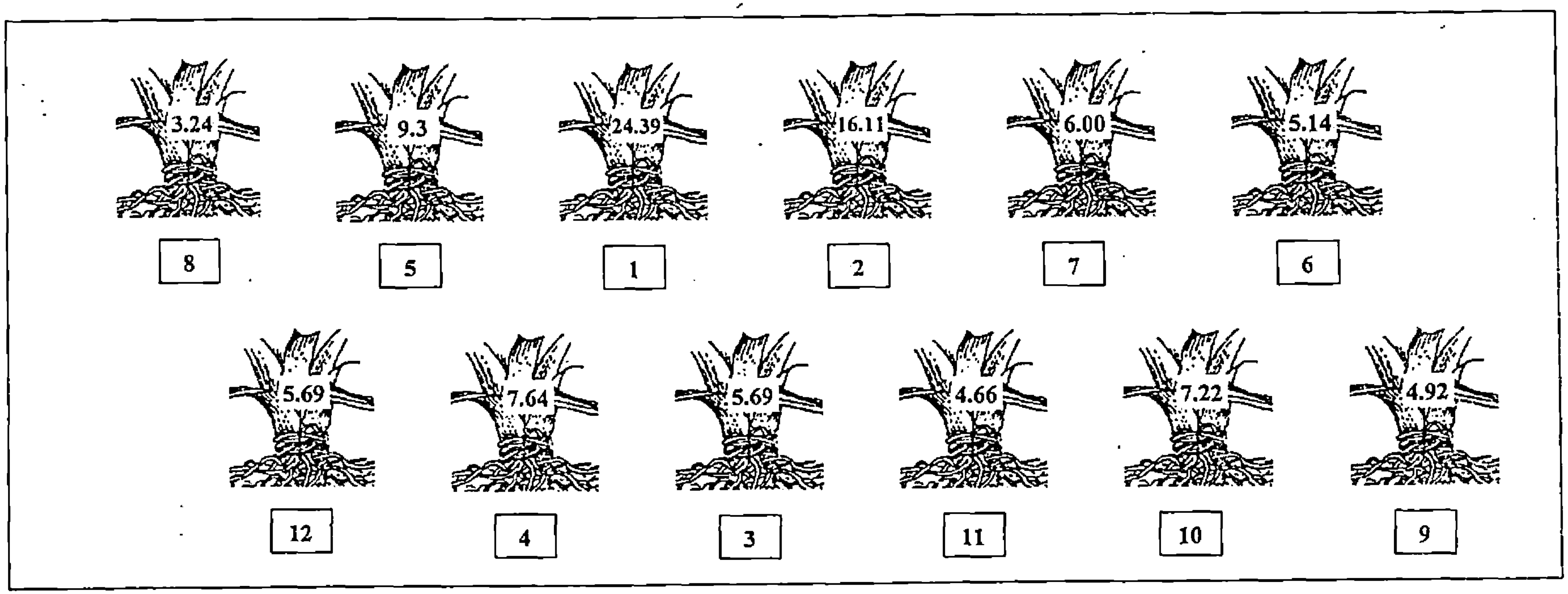
Fig. 19. Percentage absorption of applied ^{32}P among treated and neighbouring plants in Kew (V_1) at low density (P_2) trench planting (M_2)



Values given on the plant indicate percentage absorption of ^{32}P.
Values given in boxes indicate the plant number.

Plant No.I : Treated plant
Plant No.2 – 5 : Contact plants
Plant No.6 – 12 : Neighbouring plants

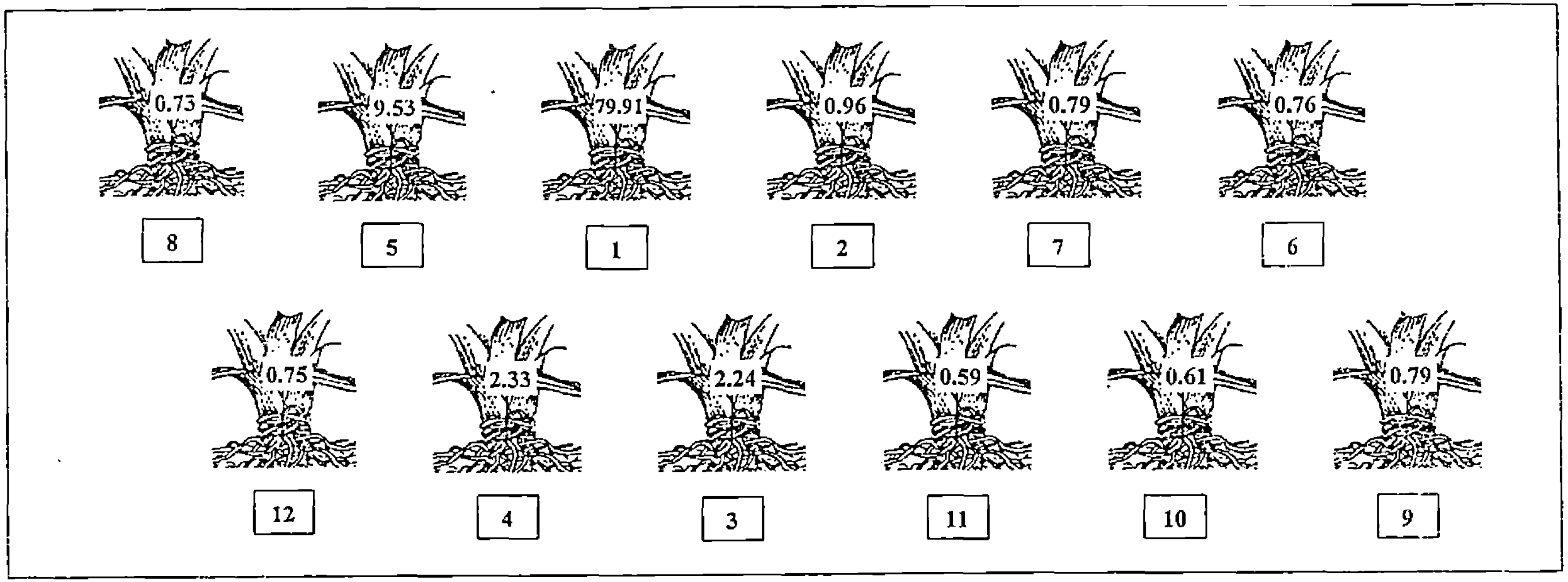
Fig. 20. Percentage absorption of applied ^{32}P among treated and neighbouring plants in Mauritius (V_2) at low density (P_2) surface planting (M_1)



Values given on the plant indicate percentage absorption of ^{32}P.
Values given in boxes indicate the plant number.

Plant No.I : Treated plant
Plant No.2 – 5 : Contact plants
Plant No.6 – 12 : Neighbouring plants

Fig. 21. Percentage absorption of applied ^{32}P among treated and neighbouring plants in Mauritius (V_2) at low density (P_2) trench planting (M_2)



Values given on the plant indicate percentage absorption of ^{32}P.
Values given in boxes indicate the plant number.

Plant No.I : Treated plant
Plant No.2 – 5 : Contact plants
Plant No.6 – 12 : Neighbouring plants

variety Mauritius grown in trenches followed by Kew grown in trenches. The least absorption was by Mauritius grown under surface method of planting.

In Kew grown under surface planting, the highest counts of ^{32}P were obtained by the treated plant itself with 43.37 per cent of the total activity absorbed. The next best counts were obtained from the four contact plants, which together contributed 31.1 per cent of the activity. The least activity was found to occur from a plant numbered 9, which is far away from the treated plant. The seven neighbouring plants together contributed 25.53 per cent of the active roots.

In trench system of planting of Kew, 57.58 per cent of the total radio activity absorbed was recovered in the treated plant followed by plant No.4 (11.73%) which is a contact plant. All the four contact plants showed highest uptake of ^{32}P than other 7 neighbouring plants and together they contributed 35.03 per cent of the activity. The least absorption was by plant No.9 (0.45%). The recovery of ^{32}P by the neighbouring plants (6-12) was found to be less and together they accounted for only 7.38 per cent.

When Mauritius grown on surface was treated with ^{32}P, the treated plant absorbed 24.39 per cent of the activity. The surrounding four plants together accounted for 38.75 per cent of the total recovery while the other seven plants together accounted for 36.85 per cent of the total ^{32}P uptake.

Application of ^{32}P to Mauritius grown in trenches resulted in the accumulation of 79.91 per cent of the total activity recovered, in the treated plant alone followed by plant No.5 which is a contact plant and accounted 9.53 per cent of the applied ^{32}P. The uptake of ^{32}P was found to be higher in the 4 contact plants than in other neighbouring plants. The contact plants together contributed 15.06 per cent and the remaining seven plants together accounted only 5.02 per cent of the total ^{32}P recovered.

Discussion

5. DISCUSSION

A knowledge of rooting pattern is an essential pre-requisite for increasing fertilizer use efficiency by proper placement, for determining optimum spacing between plants, for choosing the most suitable crop combination for a given land use system and also helpful in irrigation management. Inspite of its importance work on the extent and distribution of root system in pineapple is meagre.

The present investigations were carried out in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during 1999-2001 in order to study the root activity pattern of pineapple under surface and trench method of planting employing ^{32}P soil injection technique. It was also aimed to know the nutrient sharing between plants under different systems of planting. The salient results of the study are discussed hereunder.

5.1 Pattern of ^{32}P absorption by pineapple

In this experiment, root activity of pineapple was determined by studying the absorption of ^{32}P by Kew and Mauritius varieties grown under surface and trench method of planting at a wider spacing. The data on the recovery of ^{32}P in the leaves of pineapple showed no significant difference between the main plot treatments V_1M_1 (Kew grown under surface planting), V_1M_2 (Kew grown in trenches), V_2M_1 (Mauritius grown under surface method) and V_2M_2 (Mauritius grown under trench planting). The interaction of lateral distance and depth was found to be significant. The highest value of ^{32}P count was obtained when ^{32}P was placed 15 cm away from the plant at a depth of 15 cm (L_1D_1) at all the sampling intervals of 15, 30 and 45 days after application and it was found to be significantly superior. This indicates that most of the active roots are present in this zone. The least value of ^{32}P count was observed at L_4D_4 (60 cm lateral distance and 45 cm depth). This may be due to the less number of active roots in this region.

When the interaction of all the four factors (variety, method of planting, lateral distance and depth) was considered it was found that Mauritius grown in trenches (V_2M_2) recorded the highest absorption of ^{32}P, 15 cm away from the plant at a depth of 15 cm except in the second sampling. However, the effect was non significant.

The data on the recovery of ^{32}P 15 days after application as influenced by lateral distance and depth, irrespective of variety and method of planting revealed that the differences in the absorption of ^{32}P from different lateral distances, namely 15, 30, 45 and 60 cm were statistically significant (Table 2). The maximum absorption was observed from a lateral distance of 15 cm, which was significantly superior. The next best absorption was from 30 cm lateral distance and the least from a distance of 60 cm. Similar trend was noticed in 30 DAA (Table 4) and 45 DAA (Table 6) in the absorption of ^{32}P. This is in confirmity with the result of Collins (1960) who reported that the roots of pineapple originating from the basal portion of the stem reach the soil within a radius of 30 cm. When depth alone was considered, the highest ^{32}P activity was recorded in the nearest placement treatment of 15 cm and decreased sharply with increase in depth. This was probably due to the higher root density near the plant base. The least absorption was noticed from 60 cm depth. The same trend was noticed with all dates of sampling. These results point to the fact that pineapple is a shallow rooted crop. This could be supported by the findings of Inforzato *et al.* (1968) who observed that 95 per cent of the roots of pineapple were confined to the top 20 cm of soil. Samson (1980) opined that the roots of pineapple do not grow deeper than 50 cm and rarely extend below 30 cm depth.

Thus from the present investigation it was inferred that the soil zone constituting 15 cm lateral distance and 15 cm depth is the most active root zone of pineapple irrespective of varieties and method of planting. So this can be considered as the possible zone of maximum nutrient uptake. Bose (1985) opined that banana plant utilizes nutrient from a very limited soil depth due to shallow root system. Similar results were obtained in Nendran banana in which most of the active roots were confined to a depth of 30 cm and laterally to 20 cm. (Sobhana, 1985).

A scrutiny of the results revealed that the varieties Kew and Mauritius did not exhibit any significant difference in terms of ^{32}P uptake. However variety Mauritius recorded higher absorption of ^{32}P. The ^{32}P was applied uniformly to both Kew and Mauritius at 6 months after planting. At the time of application of ^{32}P, Mauritius was at it's maximum vegetative growth. The root system may also be very vigorous at this stage. Since Kew is a long duration variety it might not have reached its maximum vegetative and root growth at the time of ^{32}P application. This may be the reason for higher absorption of ^{32}P observed in Mauritius variety as compared to Kew.

Root activity has been studied in different varieties in other crops also. Absence of genetic variability was observed in root activity patterns of four cashew genotypes as reported by Bhaskar *et al.* (1995). Contrary to this, varietal difference in root activity was reported by many workers in different crops. Brar (1986) reported that Perlette variety of grapes was more efficient in the absorption of ^{32}P than Anab-e-Shahi.

The results generated revealed that there was no significant difference in root activity between surface and trench method of planting. Chadha and Singh (1993) pointed out that trials conducted with Kew in different agroclimatic regions have revealed the superiority of trench planting for three crop cycles, while for one crop cycle flat planting was found equally good. Bindu (1998) reported that there was no significant difference between surface and trench planting with respect to growth and yield of Mauritius pineapple.

5.2 Pattern of root activity in pineapple

The percentage distribution of active roots of pineapple varieties Kew and Mauritius irrespective of method of planting showed that the highest root activity was from a lateral distance of 15 cm followed by 30 cm and the least from 60 cm depth. The same trend was noticed with depth also. This was same for all the sampling dates. The percentage root activity decreased with increasing radial distance from the plant irrespective of variety and planting method (Table 23). The total root activity at 15 cm lateral distance was observed to be the highest with 61.38 per cent of the roots concentrating there followed by 30 cm lateral distance (21.68%). The active roots were only 3.16 per cent at 60 cm away from the plant indicating that the amounts of active roots were very negligible at this distance.

The vertical spread of roots indicated that there was a marked difference in the absorption of ^{32}P from different depths. The absorption from surface layer was considerably more than from lower depths with 73.21 per cent of the active roots exploring the 15 cm soil layer. There was appreciable contribution from 30 cm depth also (17.4%). The active roots were found to be very less (3.16%) at 60 cm depth, which clearly indicates low activity of roots at deeper layers. These findings are in agreement with the result of Samson (1980) who reported that the roots of pineapple rarely extend below 30 cm depth. Similar results were obtained in other crops also. Iyengar and Murthy (1987) reported that in Kagzi lime about 80-95 per cent of the feeder roots were seen located in the surface 10 cm soil layer. Wahid *et al* (1989a) opined that cashew tree is a surface feeder with about 50 per cent of the root activity confining to the top 15 cm of soil layer. In another study Iyengar and Shivananda (1990) reported that sweet orange budded on rangpur lime is a surface feeder with 70-90 per cent of its active roots located in the top 30 cm soil layer.

Considering that the absorption of applied ^{32}P as a function of active root density in different soil zones, it is apparent from the data (Table 23 and Fig.12.) that maximum concentration of the active roots (45.91%) was confined to the surface 15 cm soil layer at 15 cm away from the plant. The soil zone constituting 30 cm lateral distance and 15 cm depth contributed 16.89 per cent of the root activity. The percentage of root activity at 60 cm lateral distance and 60 cm depth was found to be negligible with only 0.49 per cent of the roots concentrating there. This clearly indicates that the root system of pineapple is very shallow and compact with maximum concentration of active roots seen 15 cm away from the plant at 15 cm depth even at wider spacing of 120 cm. Application of fertilizer to this zone of maximum root activity will result in efficient utilization of the applied nutrients. According to Salam and Wahid (1993) root system of crop plants especially those of field crops have been described in qualitative terms such as deep, spreading, compact, shallow etc.

Maximum concentration of active roots in the top layer of soil at a lateral distance of about 30-50 cm has been reported in Guava (Purohit and Mukherjee, 1974), Palayankodan banana (Ashokan, 1986) and in Thompson Seedless grape (Prakash *et. al.*, 1989). Study conducted in papaya (Kotur and Murthy, 2001) revealed that 75-92 per cent of the active roots occurred up to 40 cm distance while 54-79 per cent found down to a depth of 15 cm.

A concept of effective foraging space (EFS) has been proposed to delineate the lateral and vertical soil space of intense root activity around a plant (Wahid, 2000). The EFS of a plant is the soil cylinder around the plant that accounts for 80 per cent or more root activity. Based on that the EFS of pineapple can be calculated. When lateral distance was considered it was found that 15 cm (61.38%) and 30 cm (21.68%) distance together contribute 83.06 per cent of the root activity and regarding depth, 15 cm (73.21%) and 30 cm depth (17.41%) together accommodate 90.62 per cent of the active roots. From this it is evident that the area upto 30 cm lateral distance and depth contribute more than 80 per cent of the root activity. So the dimensions of the EFS of pineapple was found to be L_{30}/D_{30} eventhough the active root zone was $L_{15}D_{15}$. When the percentage of active roots in the EFS of pineapple (L_{30}/D_{30}) was observed it was noticed that the highest percentage of root activity was in trench planting compared to surface planting. This may be due to the vigorous root system in trenches as compared to surface method. Delineation of EFS is helpful in developing the most efficient method of fertilizer application and irrigation to crops (Wahid, 2001). Both spacing of plants and geometry of planting in a production system can be decided upon in relation to the EFS of the associated species Which will minimize root competition for nutrients and water.

5.3 Root excavation studies

The root distribution pattern of pineapple was also studied directly by excavation of the root system. In the present study distinction could not be made between vertically and horizontally oriented roots. The highest number of roots (71) was obtained from variety Mauritius grown on surface. Mean length of roots was found to be the highest for variety Kew grown in trench. The average length of roots irrespective of variety and method of planting was found to be about 24 cm. This is confirmatory with the result of the study conducted with ^{32}P where about 90 per cent of the roots were seen at a depth of 0-30 cm. This could be supported by the studies conducted by Inforzato *et al.* (1968) and Samson (1980) in pineapple. Similar results were obtained with other crops also. A root excavation study on 8 year old Gandhraj lemon by Ghosh and Chatopadyay (1972) revealed that majority of roots (78%) was confined in the top 25 cm soil.

5.4 Vegetative and flowering characters

Growth in pineapple is determined by the height, number of leaves and 'D' leaf characters (Singh *et al.*, 1978). In the present study it was observed that variety and planting density did not influence plant height or leaf number. When the method of planting was considered it was found that trench planting produced more number of leaves compared to surface planting. However plant height was not affected by method of planting. This was in confirmation with the findings of Bindu (1998) who noticed that the method of planting did not influence the plant height in Mauritius pineapple.

In pineapple, the most important leaf is 'D' leaf which is defined as the most recently matured leaf with maximum physiological activity (Chadha *et al.*, 1998). The study revealed that method of planting showed significant difference in 'D' leaf length and breadth. Trench method of planting was found to be superior to surface method. Similar results were obtained by Radha *et al.* (1990) in variety Kew, that the length of D leaf increased with the depth of trenches six months after planting.

The results generated revealed that there was significant difference between the varieties Kew and Mauritius in the days taken for initiation of flowering and days for 50 per cent flowering. In all the characters studied the number of days taken for Kew was more than Mauritius. This might be due to the long duration character of Kew.

5.5 Uptake of ^{32}P by two varieties of pineapple under different systems of planting

In this experiment the uptake and sharing of ^{32}P by the treated and neighbouring plants of two varieties of pineapple grown under different systems of planting was studied. Based on the results of the experiment conducted to study the root activity of pineapple, application of ^{32}P was given both at 15 cm and 30 cm depth and 15 cm and 30 cm away from the plant. Data on the uptake of ^{32}P by treated plants of Kew and Mauritius grown under different systems of planting revealed that the two varieties did not differ significantly in ^{32}P absorption. However, Mauritius recorded highest absorption of ^{32}P. This is in confirmation with the results of Experiment 1 where Mauritius recorded highest absorption of ^{32}P eventhough no significant difference was noticed. This is in confirmation with the findings of IAEA (1975). The study showed that the pattern of root activity was similar for all the four genotypes of cocoa with the highest root activity in the upper 7.5 cm soil layer. However, hybrid Amelonado x Amazon exhibited more intense root activity than others. A similar report was given by Bhaskar *et al.* (1995) in cashew where genetic variability was not observed in root activity patterns of four cashew genotypes.

When the different methods of planting were considered irrespective of varieties and planting densities trench method of planting was found to be significantly superior to surface method in ^{32}P uptake. This means that the treated plants grown in trenches have absorbed more of the applied ^{32}P than the plants grown on surface. This may be due to the strong and healthy root system of plants grown in trenches which might have helped in absorbing more ^{32}P.Trenches also checks soil erosion which might have helped in reducing the runoff soil containing ^{32}P thus increasing absorption in trench. The superiority of trench planting for pineapple has been reported by different workers (Aiyappa and Nanjappa, 1965; Radha *et al.*, 1990; Chadha and Singh, 1993).

From the present study it was also observed that the absorption of ^{32}P did not show any significant difference between low density and high density system of planting. Chadha *et al* (1998) reported that adoption of high density planting does not hamper fruit size, quality and canning recovery in pineapple.

The data on the relative uptake of applied ^{32}P by the treated and the other plants surrounding it indicate that though a considerable portion of the applied label was taken up by the applied plant, the remaining being absorbed by the neighbouring plants. Absorption of applied ^{32}P by plants around the treated ones points to the possibility of intraspecific competition in nutrient absorption. The percentage of sharing of the applied ^{32}P irrespective of variety planting method and density of planting showed that majority of the applied ^{32}P was absorbed by the treated plant and the four contact plants. It was interesting to observe that the distant plants were also benefited by the application of ^{32}P even though in smaller amounts. This may be due to the intermingling of roots or by the runoff of soil containing ^{32}P to the plants situated at the end of the row by irrigation or rain.

Under high density planting system in surface planted Kew pineapple, the treated plant (56.2%) and the four neighbouring plants (17.69%) together accounted 73.89 per cent of the total ^{32}P absorption where as in trench planting the treated plant (34.56%) and the contact plants (49.07%) together contributed 83.63 per cent of the total ^{32}P uptake. The remaining was shared by the other eleven plants. In variety Mauritius grown on surface the treated plant (68.35%) and the four contact plants (22.21%) together accounted for 90.56 per cent. In trench planting, treated plant (59.41%) and contact plants (33.31%) contributed 92.72 per cent of the total ^{32}P absorbed in the whole system. A similar report was given by IAEA (1975) in orange, in which the uptake of ^{32}P was about 50 per cent by the treated tree, 25 per cent by the border trees and the remaining 25 per cent by the five neighbouring plants.

The sharing of applied ^{32}P by the treated and non treated plants of pineapple grown under low density system of planting revealed that the treated plant absorbed maximum quantity of ^{32}P followed by the four contact plants which also contributed an appreciable amount. The neighbouring plants also showed some amount of ^{32}P absorption. In variety Kew grown under surface planting the treated plant (43.37%) and the four contact plants (31.10%) together accounted for 74.47 per cent of the total ^{32}P uptake. While in trench planting it was 92.61 per cent by the absorption of the applied plant (57.58) and contact plants (35.03).

In variety Mauritius grown on surface, the treated plant (24.39%) and the contact plants (38.75%) together contributed 63.14 per cent of the total ^{32}P uptake. The remaining was by the eleven neighbouring plants. When Mauritius was planted in trench it was found that the treated plant absorbed 79.91 per cent of the total activity followed by the four contact plants (15.06%) which together accounted for 94.97 per cent of the total ^{32}P absorbed in the system. Here also only 5 per cent of the total ^{32}P was absorbed by the other seven neighbouring plants.

Experiments with cocoa trees by IAEA (1975) revealed that both the treated tree and eight neighbouring trees surrounding it utilized the labelled superphosphate maximally when applied at 120 or 180 cm distance from the tree and the utilization by the treated tree was only 10-12 per cent. The border trees were also benefitted from the applied fertilizer.

Thus from the present investigation it was inferred that the uptake of ^{32}P by the treated plant was the maximum followed by the four contact plants irrespective of variety, planting method and density of planting system. Absorption of applied ^{32}P by the plants around the treated ones points to the possibility of intraspecific competition in nutrient absorption. The sharing of activity by the contact plant was found to be more, may be because of the intermingling of roots. Double row system of planting also contributed to more sharing of activity. Joseph (1995) noticed maximum sharing of activity in the double row system of planting in banana than in single row system.

The results revealed that in the case of Kew grown both under high density and low density system of planting, the sharing by the contact plants (35-49%) was found to be more under trench planting compared to surface planting where it was about 17-31 per cent. This may be due to low run off compared to surface planting and also due to well developed root system in trenches. In Mauritius the sharing by the contact plants was found to be 15-33 per cent in trench planting and 22-38 per cent in surface planting. This indicates that there was not much difference between the two methods of planting. This could be supported by the findings of Bindu (1998) who reported that most of the characters related to growth and yield of Mauritius were seen unaffected by the method of planting.

Thus the present study could give a basic idea about the rooting pattern in pineapple varieties. The results generated reveal that pineapple is a shallow rooted crop with majority of roots concentrated in the top 15 cm layer at a distance of 15 cm away from the plant. Regarding the sharing of ^{32}P it was inferred that the uptake of ^{32}P by the treated plant was the maximum followed by four contact plants irrespective of variety, planting method and density of planting system. Specific research on the rooting pattern of pineapple with respect to planting systems and variety, at normal spacing is a topic for further investigation.

Summary

SUMMARY

The present study was undertaken in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during 1999-2001. The main objective of the trial was to study the root activity pattern of pineapple varieties Kew and Mauritius grown under surface and trench method of planting employing ^{32}P soil injection technique. It was also aimed to study the uptake of ^{32}P by the two varieties of pineapple grown in trenches and at surface level under high density and low density system of planting. The salient results of the investigation are summarized below.

1. There was no significant difference between the main plot treatments V_1M_1 (Kew grown under surface planting), V_1M_2 (Kew grown in trenches), V_2M_1 (Mauritius grown under surface method) and V_2M_2 (Mauritius grown in trenches) with respect to recovery of ^{32}P in the leaves.

2. The interaction effect of lateral distance and depth was significant and the most active root zone of pineapple was observed to be the zone consisting of 15 cm lateral distance and 15 cm depth (L_1D_1) irrespective of variety and method of planting. The least active root zone was found to be L_4D_4 (60 cm lateral distance and 60 cm depth) except at the first sampling where it was L_4D_3 (60 cm lateral distance and 45 cm depth).

3. When lateral distance alone was considered irrespective of depth, variety and method of planting, the highest absorption of ^{32}P was obtained from 15 cm lateral distance and was seen significantly superior to other lateral distances. This was followed by 30 cm and 45 cm. The least absorption was noticed 60 cm away from the plant. The same trend was noticed at all the sampling intervals.

4. When depth alone was considered, application of ^{32}P at 15 cm depth showed highest absorption of ^{32}P. The next best recovery was from 30 cm depth. The lowest recovery of the applied ^{32}P was observed at 60 cm depth.

5. Variety Mauritius recorded the highest absorption of ^{32}P at all the sampling intervals even though there was no significant difference noticed between the two varieties.

6. There was no significant difference between the two methods of planting systems adopted with respect to ^{32}P absorption at all the sampling dates.

7. The percentage distribution of active roots of pineapple at different lateral distance and depth irrespective of variety and method of planting showed that about 45.9 per cent of the active roots were seen in a soil zone consisting of 15 cm lateral distance and 15 cm depth. The least active root zone was found to be 60 cm away from the plant and at a depth of 60 cm, which contributed only 0.49 per cent of the active roots.

8. When lateral distance alone was considered, the percentage distribution of active roots was observed to be 61.38 per cent at 15 cm away from the plant followed by 30 cm which accommodated 21.68 per cent of the total active roots. The least concentration was seen 60 cm away from the plant with 3.16 per cent of the roots concentrating there.

9. When depth alone was considered, about 73.2 per cent of the roots were seen closer to the plant at 15 cm depth followed by 30 cm (17.4%). The least concentration was noticed at 60 cm depth, which contributed only 3.09 per cent.

10. The root excavation studies revealed that Mauritius grown under surface method produced more number of roots. When the length of roots was considered it was found that the average length of roots irrespective of variety

and planting method was about 24cm. Regarding fresh weight and dry weight of roots, Mauritius grown under surface method recorded the highest value.

1. When the vegetative and flowering characters were considered it was found that the vegetative characters like plant height and leaf number were not influenced by variety and planting density. However trench method of planting was superior to surface method, when number of leaves was considered. D leaf length and breadth showed significant difference when planting method was taken into account and trench planting was found to be significantly superior. When the flowering characters were observed, significant difference was noticed between the two varieties.

2. The study undertaken to know the uptake of ^{32}P by the treated and surrounding plants of pineapple showed that there was no significant difference between the varieties Kew and Mauritius in ^{32}P uptake. However variety Mauritius recorded highest absorption of the applied label. When the different systems of planting were considered it was also observed that there was no significant difference between high density and low density system of planting in ^{32}P absorption.

3. When different methods of planting was considered it was noticed that trench planting is significantly superior to surface planting in the absorption of ^{32}P by the treated plant.

4. Uptake of ^{32}P by treated plants of pineapple varieties Kew and Mauritius grown under high density and low density system of planting showed that Mauritius grown under trench planting recorded highest absorption. However, the effect was non significant.

15. Under high density planting of the surface planted Kew, treated plant absorbed 56.2 per cent and the four contact plants together absorbed 17.69 per cent of the total ^{32}P absorbed. When grown in trenches, the treated plant

absorbed 34.56 per cent whereas the four contact plants together absorbed 49.07 per cent.

In variety Mauritius grown under surface planting, about 68 per cent of the total absorption of ^{32}P was by the treated plant and the contact plants contributed 22.2 per cent. Under trench method of planting of Mauritius the treated plant absorbed 59.4 per cent and the contact plants together absorbed 33.31 per cent.

6. In variety Kew grown on surface under low density planting, the treated plant absorbed 43.37 per cent and the four contact plants together absorbed 31.5 per cent of the total 32P applied. Under trench system of planting of Kew, the treated plant absorbed 57.58 per cent and the contact plants together contributed 35.03 per cent.

   Mauritius when grown on surface it was found that 24.39 per cent of the total ^{32}P absorbed was by the treated plant. The four contact plants together contributed 38.75 per cent. When grown in trenches the treated plant of Mauritius absorbed 79.91 per cent of the activity. The contact plants accounted for 15.06 per cent.

References

REFERENCES

Ahenkorah, Y. 1975. Use of radioactive phosphorus in determining the efficiency of fertilizer utilization by Cocoa plantation. *Pl. Soil* 42: 429-439

*Aiyappa, K.M. and Nanjappa, P.P. 1965. And now why not pineapple? *Lal Baugh J.* 12(2): 1-10

Aiyappa, K.M. and Srivastava, K.C. 1965. Studies on root system of Coorg mandarin seedling trees. *Indian J. Hort.* 22: 122-130

Aiyappa, K.M. and Srivastava, K.C. 1968. Studies on different aspects of root system II with healthy and chlorotic *Citrus reticulata* Swingle. *Indian J. Hort.* 25: 31-35

Aiyappa, K.M., Srivastava, K.C. and Sulladmath, U.V. 1968. Studies on citrus root system III. Lateral spread and depth of penetration, relationship between top and root position, dry matter content of various non-chlorotic and chlorotic *Citrus reticulata* Blanco. *Indian J. Hort.* 25: 126-139

Anilkumar, K.S. and Wahid, P.A. 1988. Rootactivity pattern of coconut palm. *Oleagineux.* 43: 337-342

Anon. 1969. Report of the soil chemist. *Ceylon Coconut Q.* 20(1&2): 58

*Anon. 1970. Annual progress report for 1969-70. Scheme for the establishment of a Regional Coconut Research Station in Tanjavore district, Tamil Nadu . pp : 47-48

Arachchi, L.P.V., Yapa, P.A.J., Mapa, R.B. and Somapala, H. 1998. Soil water extraction pattern of coconut (*Cocos nucifera* L.) in relation to soil compaction. *Cocos.* 13: 66-80

Araya, M., Vargas, A. and Chevez, A. 1998. Changes in distribution of roots of banana (Musa AAA cv. 'Valery') with plant height, distance from the pseudostem and soil depth. CORBANA 23(50): 167-176

Ashokan, 1986. Production potential of cassava based cropping system. M.Sc. thesis, Kerala Agricultural University, Vellanikkara, Thrissur. p. 180

Atkinson, D. 1974. Some observations on the distribution of root activity in apple trees. *Pl. Soil* 40: 333-341

Avilan, L., Rivas, N. and Sucre, R. 1984. Estudio del Sistema radical del cocotero (*Cocos nucifera*). *Oleagineux.* 39: 13-23

*Babuk, V.I. 1971. The effect of tree age on the development of root system, growth, productivity of apple trees. Trudy Kishinev. Sel'kokh Inst. 81: 70-76

Balakrishnamurthy, T.S. 1977. Studies on the root activity of coconut using radioactive phosphorus. *International Symposium on Increasing Crop and*

Animal Productivity by Nuclear and Allied Techniques. Indian Agricultural Research Institute, New Delhi, Abstract: 63-64

*Baldini, E. 1957. Work and observations on citrus root system. *Riv. Agrum.* 2: 11-30

Bavappa, K.V.A. and Mathew, T. 1960. Effect of different spacings on the quality of arecanut seedlings. *Arecanut J.* 11: 3-8

Bavappa, K.V.A. and Murthy, K.N. 1961. Morphology of arecanut palm, the root. *Arecanut J.* pp.65-71

Bhaskar, B., Salam, M.A. and Wahid, P.A. 1995. Root activity of cashew (*Anacardium occidentale* L.) varieties in relation to phonological phases. *J. Plantation Crops* 23(1): 35-39

Bhat, K.S. 1978. Agronomic research in arecanut - a review. *J. Plantation Crops* 6: 67-80

Bhat, K.S. 1983. Plant interactions in a mixed crop community of arecanut (*Areca catechu* L.) and cocoa (*Theobroma cacac* L.) Ph.D. thesis, University of Mysore, Mysore. p. 172

Bhat, K.S. and Leela, M. 1969. Effect of density of planting on distribution of arecanut roots. *Trop. Agric. Trin.* 46(1): 55-61

Bhutani, V.P., Singh, J.D. and Khera, A.P. 1976. Influence of calcium carbonate layer on tree growth and root development as measured by radioactive phosphorus in guava. *Punjab Hort. J.* 16: 125-130

Bindu,v.1998.Influence of size of sucker and method of planting on the growth and yield of pineapple variety Mauritius.M.Sc.Thesis.Kerala Agricultural University,Vellanikkara,Thrissur. p: 63

*Bohm, W. 1979. Methods of studying root systems. *Ecological studies.* 33, Springer Verlag Berlin Heidlbery., New York, p. 188

Bojappa, K.M. and Singh, R.N. 1974. Root activity of mango by radio tracer technique using ^{32}P. *Indian J. agric. Sci.* 44: 175-180

Bojappa, K.M. and Singh, R.N. 1975. The feeder root distribution pattern of young and old mango (*Mangifera indica* L.) trees. *Indian J. agric. Sci.* 32(3): 123-127

Bose, T.K. 1985. Fruits of India, *Tropical and Subtropical.* Naya Prakash, Calcutta, pp.124-61

Brar, S.S., Dhillon, K.S., Dhillon, S.K. and Bindra, A.S. 1986. Rooting pattern of Grapevines in a sandy loam soil using ^{32}P. *J. Nuclear agric. Biol.* 15: 40-45

Cahoon, G.A., Huberty, M.R. and Garber, M.J. 1961. Irrigation frequency effects on citrus root distribution. *Proc. Am. Soc. Hort. Sci.* 77: 167-172

Chadha, K.L., Reddy, B.M.C. and Shikhamany, S.D. 1998. Pineapple. Indian Council of Agricultural Research, New Delhi, p.115

Chadha,K.L. and Singh,H.P.1993.High density planting in pineapple.*Advances in Horticulture Vol.2 .Fruit crops:Part 2* (eds.Chadha,K.L. and Pareek,O.P. Malhotra Publishing Home,New Delhi.pp:663-673

Chadha,K.L.,Shikhamany,S.D.,Rao,G.G and Rao,J.V.1977.Ratoon cropping in high density pineapple plantation.*Indian Hort.*,22:3-4

Chandra, A. and Singh, R. 1979. Determination of root distribution in Eureka lemon by root excavation. *Phil. agric.* 62: 232-237

Chandra, A. and Yamadagni, R. 1983. Determination of root distribution in tangelo cv. Pearl by root excavation. Phil. agric. 66: 190-97

Chandra, A., Singh, R. and Rathore, V.S. 1979. ^{32}P study on root distribution in Eureka Round Lemon in the submontane Himalayan region. *Indian J. agric. Sci.* 49: 958-961

Chelam, G.V. 1974. Studies on certain aspects of the root system in some grape cultivars (*Vitis* sp.). Ph.D. thesis, Tamil Nadu Agricultural University, Coimbatore. p. 146

Chong-Qun Liu. 1984. Radiotracer studies on root activity and foliar uptake by rubber trees (*Hevea brasiliensis*). *Proceedings of the International Conference on Soils and Nutrition of Perennial Crops.* Malaysian Society of Soil Science ..Kuala Lumpur. pp.245-257

Cintra, F.L.D., Passos, M. and Leal, S. 1992. Root system distribution in dwarf coconuts. *Oleagineux.* 47(5): 225-234

Collins, J.L. 1960. The pineapple. Leonard Hill Books Ltd., New York, pp.216-217

Dhandar, A.G. and Singh, R.N. 1989. Root studies in grapefruit (*Citrus paradisi* Macf) using a radiotracer technique. *Scientia Hort.* 40: 113-118

*Doll, C.C. 1958. Grapes looking underground. *Am. Fruit Gr.*, 78(5): 16

Doll, C.C. 1961. Apple tree root development in terraced loess soil. *Proc. Am. Soc. Hort. Sci.* 78: 1-7

Fawcett, W. 1913. The banana. West Indian Committee, London, p.341

FIB, 2002. Farm Guide. Farm Information Bureau, Government of Kerala. p. 104

Fox, R.L. and Lipps, R.C. 1964. A comparison of stable strontium and ^{32}P as tracers for estimating alfalfa root activity. *Pl. Soil* 20: 337-350

Ghosh, S.P. 1974. Some aspects of root systems of sweet orange, guava and mango. *Punjab Hort. J.* 14: 34-38

Ghosh, S.P. and Chattopadhay, R.K. 1972. Studies on root system of lemon (*Citrus limon* L.). I. Growth and development of roots and their anatomy. *Indian Ag.* 16: 333-337

Godefroy, J. 1969. The developments of banana roots in various soils - relationship with fertility. *Fruits* . 24: 101-104

Hall, N.S., Chandlier, W.F., Van Bavel, C.H.M., Ried, P.H. and Anderson, J.H. 1953. A tracer technique to measure growth and activity of plant root system. *Nuclear Agric. Exp. Stn. tech. Bull.* 101: 40

IAEA. 1975. *Root activity patterns of some tree crops.* Technical Report Series No.170. International Atomic Energy Agency, Vienna, p.154

*Inforzato, R., Giacomelli, E.J. and Rochelle, L.A. 1968. Pineapple root system 4, 8 and 12 month after planting at the beginning of the dry season in a red latersol soil. *Bragantia* 27: 135-141

Iyengar, B.R.V. and Murthy, S.V.K. 1987. Spatial distribution of root activity in Kagzi lime (*Citrus aurantifolia* Swingle). *Indian J. Hort* 44: 41-44

Iyengar, B.R.V. and Murthy, S.V.K. 1989. Effect of time and method of placement on the absorption of fertilizer P by mandarin (*Citrus reticulata* Blanco). *Indian J. Hort.* 46: 453-457

Iyengar, B.R.V. and Shivananda, T.N. 1990. Root activity pattern in sweet orange during different seasons. *Indian J. agric. Sci.* 60(9): 605-608

Iyengar, B.R.V., Murthy, S.V.K. and Shivananda, T.N. 1988. Seasonal variation in root activity in mandarin (*Citrus reticulata* Blanco). *J. Nuclear agric. Biol.* 17: 67-71

Iyengar, B.R.V., Murthy, S.V.K. and Shivananda, T.N. 1989. Root activity studies in grape (*Vitis vinifera* L.) using radioactive ^{32}P. *Indian J. Hort.* 46: 148-153

Jalil, M.H.A. 1982. Studies on root distribution in coconuts. *Abstr. Coconis Newsl.* 4:6

Jamaludheen, V., Kumar, B.M., Wahid, P.A. and Kamalam, N.V. 1997. Root distribution pattern of the wild jack tree (*Artocarpus hirsutus* Lamk.) as studied by ^{32}P soil injection method. *Agroforestry Systems.* 35: 329-336

Joseph, M. 1999. Studies on some competing factors in the intercropping systems of rubber (*Hevea brasiliensis*). Ph.D. thesis, Kerala Agricultural University, Trichur, p.143

Kamath, M.B. 1971. Classification of some wheat and paddy varieties according to root distribution pattern. *Proceedings of the Symposium on Use of Radioisotopes in Agriculture and Animal Husbandry Research*, Indian Agricultural Research Institute, New Delhi, pp.629-637

Karnok, K.J. and Kucharaki, R.T. 1982. Design and construction of a rhizotron lysimeter facility at the Ohio State University. *Agron. J.* 74(1): 152-156

KAU. 1996. Package of Practices Recommendations Crops 96. Kerala Agricultural University, Vellanikkara, Thrissur, pp.199-202

KAU. 2002. Package of Practices Recommendations Crops. Kerala Agricultural University, Vellanikkara, Thrissur, pp.180-184

Khader, K.B.A. 1986. Distribution of cashew roots in the laterite soils of West Coast of India. *Indian Cashew J.* 17: 9-15

Khader, K.B.A., Bhat, K.S. and Venugopal, K. 1993. Oil Palm. *Rooting patterns of Tropical Crops.* (eds. Salam, M.A. and Wahid, P.A.). Tata Mc Graw Hill Publishing Co. Ltd., New Delhi, pp.204-216

Kotur, S.C. and Murthy, S.V.K. 2001. Spatial and temporal root activity distribution in papaya (*Carica papaya*) determined by isotopic technique. *Indian J. agric. Sci.* 71(9): 571-575

Kotur, S.C., Iyengar, B.R. and Shivananda, T.N. 1997. Distribution of root activity in young 'Alphonso' mango (*Mangifera indica*) trees as influenced by season and growth. *Indian J. agric. Sci.* 67(3): 113-116

Kotur, S.C., Murthy, S.V.K. and Iyengar, B.R.V. 1998. Spatial distribution of active roots in 'Arka Mridula' guava (*Psidium guajava*) as influenced by seasons, soil moisture and growth. *Indian J. agric. Sci.* 68(11): 744-746

Kumar, V.K. 1993. Rubber. *Rooting Pattern of Tropical Crops* (eds. Salam, M.A. and Wahid, P.A.). Tata Mc Graw Hill Publishing Co. Ltd., New Delhi, pp.235-241

Kurien, S., Goswami, A.M. and Deb, D.L. 1991. The distribution of root activity in acid lime (*Citrus aurantifolia*). *Exp. Ag.* 27: 431-434

Kurien, S., Goswami, A.M. and Deb, D.L. 1992. Root activity of two citrus rootstocks assessed using radiotracer techniques. *J. Hort. Sci.* 67: 87-94

Kurien, S., Goswami, A.M. and Deb, D.L. 1993. Scionic influence on root activity in citrus using a radio tracer technique. *Fruits.* 49(4): 261-267

Kushwah, B.L., Nelliat, E.V., Markose, V.T. and Sunny, A.F. 1973. Rooting pattern of coconut. (*Cocos nucifera* L.). *Indian J. Agron.* 18: 71-74

Lott, W.L., Satcheli, D.P. and Hall, N.S. 1950. A tracer element technique in the study of root extension. *Proc. Am. Soc. Hort. Sci.* 55: 27-34

Louis, I.H. and Balasubramanian, K. 1983. Effect of cultural practices, irrigation and manuring on the development of root systems in the coconut palm. *In Coconut Research and Development* (ed. N.M. Nayar), Wiley Eastern Limited, New Delhi, pp.293-295

Maheswarappa, H.P., Subramanian, P. and Dhanapal, R. 2000. Root distribution pattern of coconut (*Cocos nucifera* L.) in littoral sandy soil. *J. Plantation Crops.* 28(2): 164-166

Mc Creary, C.W.R., Mc Donald, J.A., Mulloon, V.I. and Hardy, F. 1943. The root system of cocoa. *Trop. Agric. Trin.*, 20(11): 207-220

Mohan, N.K. and Rao, V.N.M. 1984. The effect of plant density on the banana root system. *S. Indian Hort.* 32(5): 254-257

Mohan, N.K. and Rao, V.N.M. 1985. Determination of active root zone in banana using radioactive phosphorus. *S. Indian Hort.* 33(4): 217-220

Mohapatra, A.R., Bhat, N.T. and Khader, K.B.A. 1971. *Principles and practices of fertilizer use in arecanut.* Arecanut and Spices Bulletin, 11(4): 1-3

Nair, M.A. 1993. Oil palm. *Rooting patterns of Tropical Crops* (eds. Salam, M.A. and Wahid, P.A.). Tata Mc Graw Hill Publishing Co. Ltd., New Delhi, pp.217-222

*Oliveira, L.F.C. de., Vieira, D.B. and Souza, I.S.de. 1998. Root distribution of 'Cleopatra' mandarin with 'Pera' sweet orange scion. *Laranja.* 19(1): 117-131

*Omoti, U. 1982. Studies using ^{32}P to determine the distribution and activity patterns of the oil palm root system in Nigeria. *Proceedings of the Consultants Meeting on the Use of Nuclear Techniques in Improving Fertilizer and Water Management Practices for Tree Crops.* International Atomic Energy Agency, Vienna, pp.37-60

Oskamp, J. 1932. Rooting habit of deciduous fruits on different soils. *Proc. Am. Soc. Hort. Sci.*, 29: 213-219

Oskamp, J. and Batjer, L.P. 1932. Soils in relation to fruit growing in New York. Part II. Size, production and rooting habit of apple trees on different soil types in the Hilton and Morton areas. Monroe country. *Cornell Univ. Agric. Exp. Stn. Bull. Ilbaca,* New York, 550: 45

*Pasinova, G.B. 1960. A study of the root system of fruit trees grown along high ways. *Ved. Praco Ovocn Csazvy.* Huolorousich 1: 171-188

Patarava, D.T. 1968. On the problems of correlations between productivity and the development of the root system in tea plants. *Subtrop. Kul'tury.* 2: 3-28

*Pavan, A. 1995. Effect of mineral fertilization on apple root system distribution. *Revista Brasileira de Ciencia do Solo*. 19(3): 477-480

Pavlynehenko, T.K. 1937. The soil block washing method in quantitative root study. *Can. J. Res. Sect. C.*, 15: 33-57

*Pomier, M. and Bonneau, X. 1987. "Development du systeme racinarie du cocotier en fonction du milieu en cote d'Ivoire". *Oleagineux*. 42: 409-22

Prakash, G.S., Chadha, K.L., Iyengar, B.R.V. and Reddy, B.M.C. 1989. Root distribution and activity in grape cv. Thompson seedless as influenced by systems of training. *Indian J. Hort.* 46: 417-421

Purohit, A.G. and Mukherjee, S.K. 1974. Characterising root activity of guava trees by radiotracer technique. *Indian J. agric. Sci.* 44: 575-581

Purseglove, J.W. 1975. *Tropical crops - Monocotyledons*, Longman group Ltd. p.325

Racz, G.J., Rennie, D.A. and Hutcheon, W.L. 1964. The ^{32}P injection method for studying the root system of wheat. *Can. J. Soil Sci.* 44: 100-108

Radha, T., Baby, L.M. and Rajamony, L. 1990. Effect of depth of trenches on high density planting of Kew pineapple. *S. Indian Hort.* 38: 183-88

Rahaman, F. and Fareed, M. 1977. Studies on spacing of tea. *Proceedings Twenty eighth Tocklai Conference*, Tea Research Association, Jorhat, pp.8-15

Rao,M.H.P.,Subramanian,T.R.,Murthy,S.H.K.,Sinh,H.P.,Dass,H.C.and Ganapathy,K.M.1977.Leaf nitrogen status as influenced by varying levels of nitrogen application and it's relationship with yield in Kew pineapple.Scientia Hort.7:137-42

Rennie, D.A. and Halstead, E.H. 1965. A ^{32}P injection method for quantitative estimation of the distribution and extent of cereal grain roots. *Isotopes and Radiation in Soil Plant Nutrition Studies.* International Atomic Agency, Vienna, pp.489-504

Richards, D. 1983. The grape root system. *Hort. Review*. 5: 127-168

*Ruer, P. 1967. "Repartition on surface due systeme radiculaire du palmiera huile". *Oleagineux*, 22: 535-37

Russel, S.R. and Ellis, F.B. 1968. Estimation of the distribution of plant roots in soil. *Nature*. 27: 582-583

Saiz Del Rio, J.F., Fernandez, C.E. and Bellavita, O. 1961. Distribution of absorbing capacity of coffee roots determined by radioactive tracers. *Proc. Am. Soc. Hort. Sci.*. 77: 240-244

Salam, M.A., Puspalatha, P.B. and Suma, A. 1995. Root distribution pattern of seedling raised cashew tree. *J. Plantation Crops* 23(1): 59-61

Salam,M.A.,Wahid,P.A.1993.*Rooting Patterns Of Tropical Crops.*Tata Mc Graw Hill Publishing Co. Ltd. New Delhi.pp:331

Samarappuli, L., Yogaratnam, N., Karunadasa, P., Mitrasena, U. 1996. Root development in *Hevea brasiliensis* in relation to management practices. *J. Rubber Res. Inst. Sri Lanka* 77: 93-11

Samson, J.A. 1980. *Tropical Fruits.* Longman group Ltd., New York p.208-245

Sathe, A., Rao, A.P., Seethambaram, Y., Sathyanarayan, G. and Rao, M.B. 1984. Root distribution pattern of Anab-e-Shahi grape. *S. Indian Hort.* 32: 39-40

Sawaf, H.M., Senfaz, S., Adam, S.O., Azaga, A.K. and Ansari, M.A. 1985. Vine root distribution under irrigated and rainfed conditions with supplementary underground irrigation. *Acta Horticulturae.* 158: 187-195

*Schurmann, J.J. and Goedewagen, M.A.J. 1971. *Methods for the Examination of Root systems and Roots.* Wageninger pudoc, p.250

Singh, H.P., Ganapathy, K.M. and Dass, H.C. 1978. Evaluation of physiological constant for estimation of leaf area in pineapple(*Ananas comosus* (L.) Merr.). *Sci. Cult.* 44: 409-10.

Singh, L.B. 1960. *The Mango: Botany, Cultivation and Utilization.* Leonard Hill, London, p.182

*Singh, M.M., Pushparajah, E., Soong, N.K., Talibudeen, O. 1972. Radiotracer studies on phosphorus uptake by *Hevea brasiliensis* from Malayan soils for determining "active" root distribution. IAEA-SM-151/61 pp.465-479

Sobhana, A. 1985. Pattern of root activity in banana under irrigated and rainfed conditions. M.Sc. (Hort.) thesis, Kerala Agricultural University, Thrissur, India.p.89

Sobhana, A., Aravindakshan, M. and Wahid, P.A. 1989. Root activity pattern of banana under irrigated and rainfed conditions. *J. Nuclear agric. Biol.* 18: 117-123

Soong, N.K. 1976. Feeder root development of *Hevea brasiliensis* in relation to clones and environment. *J. Rubber Res. Inst. Malaysia* 24(5): 283-298

Soong, N.K., Pushparaj, E.J., Singh, M.M. and Tabibudeen, O. 1971. Determination of active root distribution of *Hevea brasiliensis* using radio active phosphorus. *Proceedings of International Symposium on Soil Fertility Evaluation,* Indian Agricultural Research Institute,New Delhi.pp:309-315

Subbiah, B.V., Oza, A.M. 1971. Root studies: Some practical basic considerations in relation to nutrient supply of high yielding varieties. *Proceedings of International symposium on Use of Radioisotopes in Research.* Indian Agricultural Research Institute, New Delhi, pp.616-623

Swarbrick, J.T. 1964. Growth and root distribution of shade plants. *Trop. Agric. Trin.* 41: 313-315

*Sweet, A.T. 1933. Soil Profie and root penetration as indication of apple production in lake shone district of Western New York. *U.S. Agric. Circ.,*: 303

*Tamasi, J. 1959. The root system of a Jonathan apple tree grafted on *Malus sylvestris* root stock growing in a vineyard on sandy soil. *Magyar. tud. Akad. Agrartud. Oszt. Kozl.*, 16(1): 89-106

Tripathi, R.D. and Dutta, N.P. 1967. To determine root activity of grape fruit (*Citrus paradisi*) by ^{32}P injection technique. Proceedings of the International Symposium on Subtropical and Tropical Horticulture , Indian Agricultural Research Institute,New Delhi.pp.659-74

Tsakiris, A. and Northwood, P.J. 1967. Cashewnut production in Southern Tanzania-IV. The root system of cashewnut tree. *East Afr. Agric. Forestry J.* 33: 83-87

Ulrich, A., Jacobson, L. and Overstreet, R. 1947. Use of radioactive phosphorus in a study of the availability of phosphorus to grape vines under field condition. *Soil Sci.*, 64: 17-18

Venugopal, V. 1997. Root level interaction in coconut-cocoa system. M.Sc. thesis, Kerala Agricultural University, Vellanikkara, Thrissur.p.84

Wahid, P.A. 2000. A system of classification of woody perennials based on their root activity patterns. Agroforestry systems 49: 123-130

Wahid, P.A. 2001. Radioisotope studies of root activity and root level interactions in tree based production systems: a review. Applied radiation and Isotopes 54 (2001) 715-736

Wahid, P.A., Kamalam, N.V. and Sankar, S.J. 1985. Determintion of ^{32}P in wet digested plant leaves by cerenkov counting. *Int. J. appl. Rad. Isot.* 36: 323-324

Wahid, P.A., Kamalam, N.V. and Sankar, S.J. 1988. A device for soil injection of ^{32}P solution in root activity studies of tree crops. *J. Plantation Crops.* 16: 62-64

Wahid, P.A., Kamalam, N.V., Ashokan, P.K. and Vidyadharan, K.K. 1989a. Root activity pattern of cashew (*Anacardium oxidentale* L.) in laterite soil. *J.Plantation crops:*17:85-89

Wahid, P.A., Kamalam, N.V., Ashokan, P.K. and Vikraman Nair, R.V. 1989b. Root activity pattern of cocoa (*Theobroma cacao*). *J. Nuclear agric. Biol.* 18: 153-156

Wahid, P. A. and Nair.1993.Cocoa.*Rooting patterns of tropical crops*. (eds. Salam, M. A. and Wahid,P.A.).Tata Mc Graw Hill Publishing Co.Ltd.,New Delhi

Walmsly, D. and Twyford, I.T. 1968. The uptake of ^{32}P by the robusta banana. *Trop. Agric. Trin.*, 45(3): 222-228

Weaver, J.E. 1926. *Root development of field crops*. Mc Graw Hill Book Company, INC, New York, p.473

* Originals not seen

ROOT ACTIVITY IN PINEAPPLE
(*Ananas comosus* (L.) Merr.)

By

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ABSTRACT OF THE THESIS

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ABSTRACT

An investigation was undertaken during 1999-2001 in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara, Thrissur to study the root activity in pineapple. The main objective was to know the most active root zone of pineapple and also to study the uptake of ^{32}P by pineapple grown under different systems of planting. The root activity of pineapple varieties Kew and Mauritius grown in trenches and on surface was studied employing ^{32}P soil injection technique. Activity was applied at varying lateral distances and depth of 15, 30, 45 and 60 cm. The uptake and sharing of ^{32}P by Kew and Mauritius grown under high density and low density system of planting, in trenches and on surface was also evaluated.

The results revealed that the most active root zone of pineapple irrespective of variety and method of planting was L_1D_1 (15 cm lateral distance and 15 cm depth) in ^{32}P absorption. The least active root zone was L_4D_4 (60 cm lateral distance and 60 cm depth). When lateral distance alone was considered irrespective of depth, variety and method of planting, the highest absorption of ^{32}P was obtained from 15 cm distance at all sampling intervals. Depth also showed the same trend.

There was no significant difference between the two varieties Kew and Mauritius and also between the two methods of planting (surface and trench method).

When the percentage distribution of active roots of pineapple irrespective of variety and method of planting was observed it was seen that about 45.9 per cent of the root activity was concentrated in a soil zone constituting 15 cm lateral distance and 15 cm depth which was the active root zone. The least active root zone (L_4D_4) contributed only 0.49 per cent of the active roots.

When lateral distance alone was considered, a lateral distance of 15 cm accommodated 61.38 per cent of the active roots followed by 30 cm and the least from 60 cm lateral distance (3.16%). When depth was considered 73.2 per cent of the root activity was seen at the surface 15 cm soil layer followed by 30 cm

(17.40%). The soil zone within 30 cm of lateral distance and 30 cm depth accommodate 80 per cent of the active roots.

The root excavation studies revealed that Mauritius grown under surface method produced more number of roots. Regarding length an average of 24 cm was noticed. When fresh weight and dry weight were observed Mauritius grown under surface method produced the highest value.

The plant height and leaf number were not influenced by variety and planting method. However trench method of planting produced more number of leaves than surface method. Significant difference was noticed between the two varieties when the flowering characters were taken into consideration.

The studies carried out to know the uptake of ^{32}P by the treated and surrounding plants revealed that there was no significant difference between the two varieties Kew and Mauritius when the uptake by the treated plant was considered. Planting densities also did not show any significant difference. However regarding the method of planting, trench planting was found to be significantly superior to surface planting in the absorption of ^{32}P.

Under high density and low density system of planting, Mauritius grown under trench planting recorded highest absorption of ^{32}P by the treated plant.

It was also found that the applied activity was absorbed not only by the treated plant but also by the contact and neighbouring plants, which indicated the sharing of activity by the surrounding non treated plants. But the absorption by the treated plant was found to be more followed by the contact plants irrespective of variety, planting method and density of planting system.